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SPECIAL ISSUE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION SCIENTIFIC AND TECHNICAL INFORMATION PROGRAMS

Guest Editor
THOMAS E. PINELLI

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Volume 7 Number 2 1990

GOVERNMENT INFORMATION QUARTERLY

An International Journal of Resources, Services, Policies, and Practices

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Government Information Quarterly
Symposium Issue on NASA

Volume 7, Number 2, 1990

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In Memoriam

George Mandel

This issue is dedicated to the memory of George Mandel, Chief of the Technical Information Services Division of the NASA Lewis Research Center. George died July 16, 1989, from injuries sustained in an automobile accident. For 34 years from his base at the Lewis Research Center in Cleveland, Ohio, he gave outstanding service and leadership to NASA's scientific and technical information program as well as to the nation's aerospace community. He served as national chairman of the Engineering Division of the Special Libraries Association and as national chairman of the Aerospace Division. He also lectured at Case Western Reserve University, School of Library Science, where he taught chemical literature. In 1984 he received the NASA Exceptional Service Medal. George Mandel was highly respected and known as a man of integrity among his peers. He will be greatly missed.

Foreword

Last July, President Bush issued Proclamation 5999, designating Space Exploration Day. In part, the proclamation stated:

> Three decades into our great adventure into space, we have learned more about our planet, the solar system, and the universe than was once imaginable. We have entered space for peaceful and scientific purposes; and, in the process, we have demonstrated what Americans can do when we put our will and our resources to work in pursuit of a worthy national goal. . . . As a nation, we have traveled hundreds of millions of miles in space, but we have only begun our journey. In the coming decades, we will continue to forge ahead, transforming dreams into reality.

We at NASA are especially fortunate to be facilitators in this journey—partners with the American people and our foreign allies. Fundamental to the development of new knowledge through science and engineering is the transfer of that knowledge to academia, our research community, and others within the public and private sectors.

This issue of the *Government Information Quarterly* deals with NASA's informational and educational programs, including the principal mechanism for knowledge transfer—its Scientific and Technical Information (STI) Program. Based in the seminal research in aeronautics in the early 1900s, the NASA STI Program has evolved into one that supports existing exchange agreements with the European Space Agency, Israel, Australia, and Canada and provides U.S. researchers with translations from 22 languages.

NASA's literature base of aeronautical and space research experience and findings has been, and remains, a critical adjunct to understanding our own fragile environment and seizing new opportunities for ourselves and those who follow.

Richard H. Truly
Administrator
National Aeronautics and Space Administration

SYMPOSIUM ISSUE ON THE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

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Introduction

THOMAS E. PINELLI*

Throughout most of its history, the National Advisory Committee for Aeronautics (NACA) was known as the most important and productive aeronautical research establishment in the world. The task that NACA received from Congress was simple: to supervise and direct the scientific study of the problems of flight with a view to their practical solution (P.L. 63-271).[1] Between its creation in 1915 and its change to the National Aeronautics and Space Administration (NASA) in 1958, the NACA published more than 16,000 technical reports which were sought out by aeronautical engineers both in the United States and abroad. Many of these reports are classics in the field of aeronautics and are still used and referenced; the data contained in these reports are essential to understanding the fundamentals of aeronautical research and design.

The NACA developed a reputation for efficiency and effectiveness that was so widespread that it came to be viewed as something of a model for research and later as a model for implementing a program for federally funded civilian research and development (R&D). The NACA offered science, technology, and a system for coupling knowledge with people who would use it in the field.

This system laid the foundation for the United States to dominate the world commercial transport sector. It is a part of the tradition that NASA inherited in 1958 from the NACA. Mindful of the importance of linking knowledge with the user, the National Aeronautics and Space Act of 1958 as passed by the 85th Congress specifically requires the NASA Administrator to "provide the widest practicable and appropriate dissemination of information concerning its activities and the results thereof" (P.L. 85-568).[2] This stipulation serves as the agency's charter to disseminate information.

During its 31-year existence, NASA has landed men on the Moon, placed a variety of satellites in orbit, sent probes to the far reaches of the solar system, helped keep the nation at the forefront of aeronautical research, collected untold amounts of data, and generated an incredible amount of information in the process. NASA has created a variety of programs to help manage its data and information and to comply with its congressional mandate.

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These programs and strategies are the focus of this symposium issue of *Government Information Quarterly.*

In the lead article, Wallace O. Keene, Assistant Associate Administrator for Information Resources Management, NASA Office of Management, discusses the complexity of managing information in a mission agency such as NASA by detailing the legal and regulatory complexities associated with the agency's primary product, scientific and technical information. Mindful that scientific and technical information (STI) is critical to the competitive position of the United States in the world community, Keene describes the infrastructure of information resources management: the organizational interfaces, the formal and informal mechanisms associated with the production, transfer, and utilization of knowledge within NASA, and some thoughts on the future.

For years, NASA has been conducting programs that have contributed to the expansion of human knowledge of phenomena in space and have helped us understand more about our home planet, Earth. In the process, more than 6,000 gigabytes of digital data have been collected from NASA science missions. James L. Green of the National Space Science Data Center (NSSDC), NASA Goddard Space Flight Center, Greenbelt, Md., provides a general overview of the agency's approach to the management of these data and focuses on the new NSSDC online interactive systems that are used extensively over international computer network to access these data.

The NASA STI Program is part of the NACA legacy. During the most active period of STI activities in the federal government, the NASA STI program came to represent some of the government's most creative thinking and planning for information dissemination and management. Van A. Wente, recently retired as Director of the NASA Scientific and Technical Information Division, NASA Office of Management, presents an abbreviated history of the program and its organization. Knowledge acquisition, production, processing, dissemination, and evaluation are the focus of his presentation. He concludes with a discussion of the major policy issues facing the program and some plans for the future.

The dissemination of NASA STI is being transformed by the ongoing revolution in electronic information and computer and information technologies. An overall strategy on the dissemination of NASA STI is needed if the potential of new electronic technologies is to be fully realized. Gladys A. Cotter, newly appointed Director, Scientific and Technical Information Division, NASA Office of Management, outlines the direction of the NASA STI Program for the 1990s and describes how these new technologies are and will be applied to make NASA STI more accessible and its dissemination more efficient and effective.

Congress has charged NASA with the task of stimulating the widest possible use of the vast storehouse of technology developed from its aeronautical and space activities and programs. NASA seeks to meet this responsibility through its technology utilization program. Lester J. Rose, recently retired as assistant head of the Technology Utilization and Applications Office, NASA Langley Research Center, Hampton, Va., describes the infrastructure, operation, management, and evaluation of the program. The aim is to broaden and accelerate the technology transfer process and to gain thereby a substantial dividend on the national investment in aerospace research in the form of new products, new business, and new jobs. In nearly three decades of operation, more than 30,000 secondary applications of NASA aerospace technology have emerged from this program.

Since its creation in 1958, NASA has developed and maintains a special relationship with the country's elementary, secondary, and postsecondary educational institutions. To preserve

the role of the United States as a leader in aeronautical and space science and technology, NASA continues to do its part to promote scientific and technological literacy and to train and otherwise help prepare the cadre of students who will become tomorrow's engineers and scientists. Science and engineering educators require specialized information, and Robert W. Brown, Director of the Educational Affairs Division, NASA Office of External Relations, lists the issues facing science and technology education; describes the content and diversity of the NASA educational programs that are designed to capture student's interest in science, mathematics, and technology at an early age, and to maintain their interest throughout higher learning; and continues with a discussion of proposed changes and program improvements. He concludes with a focus on how NASA intends to help the nation produce the 36 percent increase in engineers and scientists that will be needed by the year 2000.

Open access to the results of scientific inquiry and discovery, the recognition of these as intellectual property, government funded R&D, and the need for government to withhold or restrict the flow of STI for reasons of national security and economic well-being have combined to create a number of legal issues and precedents. Robert F. Kempf, Associate General Counsel for Intellectual Property, NASA Office of General Counsel, looks at the legal implications and issues surrounding intellectual property such as patent rights, copyrights, and trade secrets. He details the dramatic changes in the law and federal government policy relating to intellectual property rights and the transfer and commercial use of federally funded technology that have occurred during the past decade. His thoughts for the future are based on more than 30 years experience in dealing with the issues.

Ours is an open program. Since the early days of the U.S. space program, Americans and people from all nations have become fascinated by NASA's numerous launches, unprecedented achievements, and breath-taking photography from outer space. In the course of these events, NASA has developed a variety of programs for working with the media and hence with the public. James W. McCulla, Director of Media Services, and James F. Kukowski, Chief, Internal Communications, NASA Office of Communications, describe the various programs that are designed to communicate the results of NASA research, programs, and related activities to the NASA community, the media, and the public.

The growth of STI and federal STI systems is being guided by uncoordinated policies resulting in inefficiencies. Such being the case, the ability of STI systems to serve the needs of users would be questionable in spite of the fact that it is the responsibility of the federal government to promote prompt, effective, reliable, and systematic transfer of science and technology information. In the final paper, this writer looks at some of the key issues and options relating to the management of federal STI and the challenges facing federal STI programs.

In compliance with its congressional mandate of widest and most practicable dissemination of information, NASA has created a variety of programs to meet this requirement. To facilitate and supplement the information presented in this issue, an appendix has been added that contains a listing of the types of products and services available from NASA information programs. A second appendix is a list of acronyms and abbreviations used in these articles.

Two thoughts in closing: First, a publication such as this is an enormous undertaking that represents the untiring efforts of numerous individuals. We particularly thank the contributors; without their efforts there would be no publication. In addition, Wallace O. Keene

and Van A. Wente are recognized especially for their efforts in framing this issue. Second, if the readers of this issue finish with a better understanding of NASA and its approach to information management and dissemination, then we can take delight in knowing that our efforts have been put to good use and our mission has been accomplished. We hope this has been the case.

NOTES AND REFERENCES

1. *The Naval Appropriations Act*, 1916 (P.L. 63-271).
2. *The National Aeronautics and Space Act of 1958* (P.L. 85-568).

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Management of Information in a Research and Development Agency

WALLACE O. KEENE*

A healthy scientific and technical information (STI) program is the result of objective implementation of effective and efficient processes for the production, dissemination, and utilization of information.

Objectivity is often at odds with policies promoted by those who do not distinguish between primary and secondary source information. If the primary database is not created and managed objectively, the research aided or influenced by that database will be biased. Control of selected information limits access to it and indirectly controls the research based on it. At risk are billions of dollars worth of research and the postponement or nonrealization of benefits that might otherwise result.

Effective and efficient management can require an identification of needs before determining the method of obtaining them. In this framework, a feedback mechanism is needed to help assess whether we are fulfilling the needs identified. This is an incredibly difficult but necessary undertaking that is often overlooked.

This section of the *Government Information Quarterly* provides an overall introduction to NASA's management of scientific and technical information, and it introduces the larger technological, managerial, educational, and legal frameworks in which NASA, as a federal agency, must transfer and disseminate information. The way NASA manages administrative information in support of its mission programs will also be discussed.

The issues to be addressed in the information arena over the next few years are significant. The management of information will affect the technological position held by the United States among the nations of the world. In 1989 the Office of Technology Assessment (OTA) stated that the health of the U.S. scientific and technological enterprise is critical to economic growth, quality of life, environmental protection, international competitiveness, and other national goals.[1]

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WHAT IS SCIENTIFIC AND TECHNICAL INFORMATION?

Federal STI is information developed as a result of scientific, technical, and related engineering research conducted or supported (e.g., inhouse or through grants or contracts) by the federal government. STI includes information from both basic and applied research in the entire range of scientific disciplines—physical, social, medical, terrestrial, and biological. Responses to regulatory functions, e.g., monitoring environmental health and safety, result in the collection of other federal STI.

STI is generated by almost all federal agencies to some degree, although most comes from five agencies—NASA, the Department of Commerce, the Department of Health and Human Services' National Library of Medicine, the Department of Defense, and the Department of Energy. Often, the documentation produced is the only physical evidence that research was done in the first place, and significant opportunities are likely to be missed unless we put the research results into the hands of others in a timely fashion.

For the past several decades, information has become the principal product of the federal government in the midst of what can only be described as a technological revolution. As a consequence, numerous laws and regulations have been imposed that focus on information and information-related resources. The following list identifies principal legislation affecting the overall management of federal information resources.

- The National Aeronautics and Space Act of 1958, as amended, P.L. 85-568, which requires NASA to make its research findings available to the maximum extent practical;
- The Paperwork Reduction Act of 1980, as amended, P.L. 96-511, which sets into place the framework for the management of federal information resources;
- The Freedom of Information Act of 1967, as amended, P.L. 90-23, which provides public access to federal government information;
- The Competition in Contracting Act of 1984, P.L. 98-369, which requires full and open competition in the acquisition of hardware and software with few exceptions;
- The Technology Transfer Act of 1986, P.L. 99-502, which encourages greater use of federally funded technology;
- The Export Administration Act of 1979, as amended, P.L. 96-72, which controls exports of equipment and technology that have both commercial and military usefulness; and
- The Arms Export Control Act of 1968, as amended, P.L. 90-629, which controls the export of military weaponry and services.

These laws, combined with diverse agency needs and other competing interests, have not always worked to the public's advantage. In the absence of any broad study on the matter, it is not possible to quantify any resulting loss or gain. Nevertheless, it is relatively clear that hundreds of millions of dollars worth of effort are at risk.

Part of our research funding is accounted for in the federal government's Information Technology Systems (ITS) budget for computer and telecommunications hardware, software, and services needed to process, distribute, and use scientific, technical, and administrative information and data. The ITS budget amounts to more than $18 billion.

The U.S. aerospace industry dominates the world commercial aircraft market. As a result of the $17.7 billion trade surplus it produced in 1988, aerospace replaced agriculture as the leading positive indicator in the U.S. balance of trade. It matters then, in this nation's interest,

that research results and design information are properly released, released with a plan that provides new information first to U.S industry so that foreign interests cannot capitalize on the knowledge obtained at the expense of the U.S. taxpayers.

IS THE IMPORTANCE OF STI A NEW PHENOMENON?

Some believe that many of the STI issues are now emerging because of the evolution of information technology. Actually, the evolution of information-related technologies has only served to exacerbate the situation.

At a recent congressional hearing, Joseph Coyne noted that 25 years ago, the President's Science Advisory Committee (PSAC) recognized the importance of scientific and technical information and called for a review of the national STI structure.[2] Despite the interest, improvements were not made relative to the structure, and a deterioration was perceived. In 1987, Representative Douglas Walgren again raised the issue:

> Information with potential commercial value languishes inside [the] federal government because agencies do not aggressively seek a broader audience for its application. The Office of Science and Technology Policy, given a mandate by Congress to overcome these problems, has chosen not to exercise its authority. . . . The federal government has a unique role in the collection and dissemination of the best scientific and technical information from around the world, and our economy can ill afford further abdication of that responsibility.[3]

Robert B. Reich recently observed that Japanese firms regard global scanning for technological insights as an integral part of their business strategies, but that most U.S. firms do not systematically gather data on the results of government-funded research (U.S. or foreign); nor do they systematically review technical and scientific journals and newspapers published in other countries. The U.S. government does little to aid them in such efforts.[4]

What's going on? We know the problem and we know at least part of the solution. OTA testified at the October 1989 congressional hearings that the main reason that the government lacks a comprehensive STI strategy is the failure to recognize the important linkages between STI and several national goals. STI is a critical link between R&D and the achievement of other national goals such as improving the education of U.S. scientists, the strengthening of the U.S. civilian technology base, and fostering international cooperation on global problems. If left unattended, problems in managing and using STI will reach crisis proportions as the volume and complexity of STI continue to increase.[5]

The problem is not new and the fixes are not easy. Further, the implementation of solutions will have to take existing institutional mechanisms into account when winning strategies are being designed. The importance of the federal government's role in this enterprise, however, continues to be valid.

THE IDEAL STI ENVIRONMENT

The ideal STI environment would not be very complicated. Scientists and other researchers would have needed information available immediately. They could conduct further research and create new information. This new information would be immediately disseminated to peers and others for validation and then disseminated to the wider community.

Changes in this synergistic research and engineering environment would be accommodated immediately by changes in the tools needed to facilitate the work being undertaken. For example, higher-performance workstations and increased storage capacity at reduced cost would be available, as would the necessary revised processing algorithms embedded in the computer program code.

It would seem that if you can describe what you want, it should be possible to obtain it. Unfortunately, it does not always work that way, and the key to understanding and managing such a situation rests with the need to approach the problem systematically and comprehensively.

NASA'S STI-RELATED INFORMATION MANAGEMENT PROGRAMS

NASA and its contractors generate STI at many sites and on many levels throughout the organizations. As illustrated in Figure 1, the basic mission elements of NASA can be stratified into three categories:

- activities that develop new knowledge—the Office of Space Science and Applications and the Office of Aeronautics and Space Technology;
- activities that facilitate the development of new knowledge and develop new knowledge as a result of their work—the Office of Space Station, the Office of Space Flight Operations, and the Office of Space Operations; and
- activities that use this knowledge to design and carry out new programs—the Office of Exploration and the Office of Space Science and Application.

Figure 1 identifies several other Headquarters organizations that have a role in NASA's overall program of information resources management. Most notably, these include the Office of Procurement (Code H) and the Office of Safety, Reliability, Maintainability, and Quality Assurance (Code Q).

The NASA Office of Procurement governs how information resources are acquired contractually by NASA in line with the numerous regulations and policies imposed by external agencies such as the Office of Management and Budget (OMB) and General Services Administration (GSA). Often, it is the contract that brings together the diverse, and sometimes competing, technical, legal, and business interests of the government and the private sector. NASA technical managers rely on their procurement officials to assist them in acquiring and controlling contractor resources to implement NASA's scientific and engineering efforts. Given that the ratio of government to contractor staff at NASA is about 1:10 overall, procurement management is clearly an important factor in the management of NASA's scientific and technical information agenda.

The NASA Office of Safety, Reliability, Maintainability, and Quality Assurance is responsible for the independent assessment of these functions in all NASA's mission programs. Consequently, this office is the source of valuable engineering data about NASA's flight programs and the operation of the variety of telescopes, communications satellites, and other space orbiters deployed by NASA. Additionally, data elements on these efforts are germane to understanding the performance of the overall program in terms of national objectives, and therefore constitute a valuable input to executive information-related undertakings.

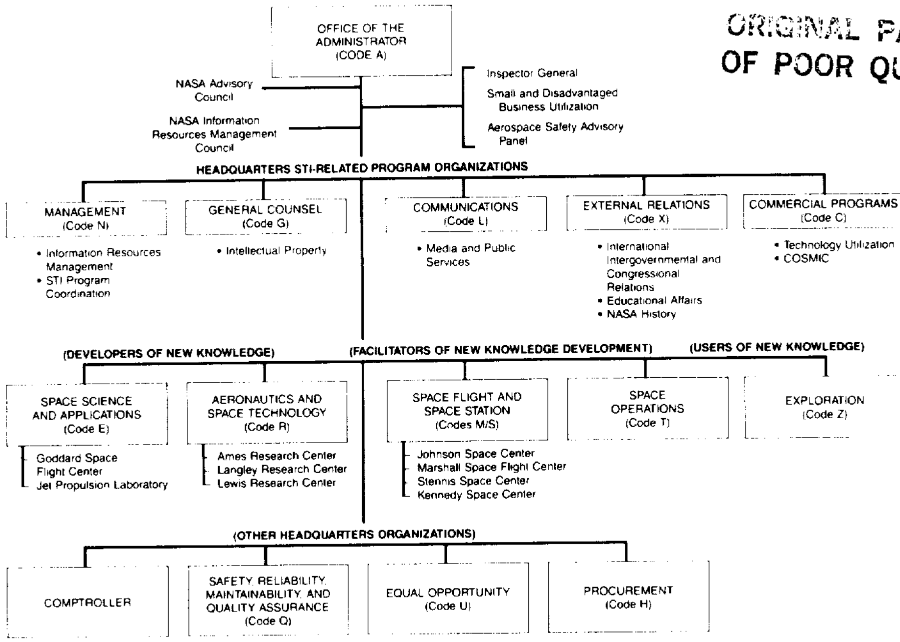


Figure 1. NASA Organization for STI.

It should be fairly clear that almost all NASA organizations can be viewed as involved in the production, dissemination, and management of STI, either directly or indirectly.

NASA STI program interfaces are shown in Figure 2.

RESEARCH EFFORTS SUPPORTING THE MANAGEMENT AND USE OF STI

As an integral part of its space science and aeronautics research efforts, NASA has undertaken a Computer Science Research Program using advanced concepts in system architectures, algorithms, and software. The program is improving the state of knowledge of fundamental aerospace computing principles and is advancing computing technology in space applications such as software engineering and information extraction from data collected by scientific instruments in space.

Emphasis is being placed on producing highly reliable software for critical space applications and for managing the enormous volume of space data we expect to collect. Computers for Space Station Freedom alone may employ 30 million lines of computer code. In addition, as shown in Figure 3, the projected growth rate for space science data through the mid-1990s is significant.

The program also includes the development of special algorithms and techniques to exploit the computing power provided by high performance parallel processors and special purpose

architectures. Critical areas needing these advancements are computational fluid dynamics, computational chemistry, structural analysis, signal processing, and image processing. Figure 4 provides an indication of the processing speeds attendant to the performance of specific types of scientific experiments. The computer architectures of interest include common and local memory multiprocessors, single-instruction-stream/multiple-data-stream processors, static data flow processors, systolic arrays, and heterogeneous multiprocessors with custom processors. Research is conducted in programming languages and environments, parallel and distributed operating systems, and performance measurements.

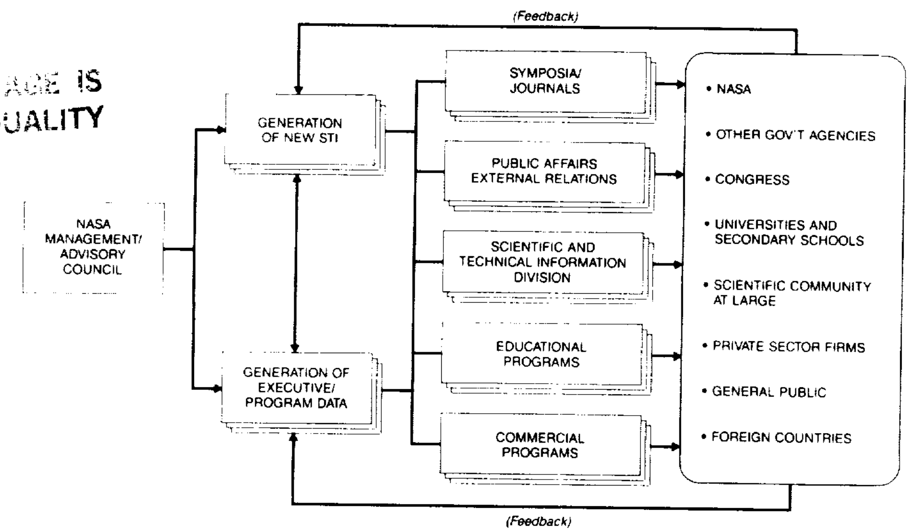
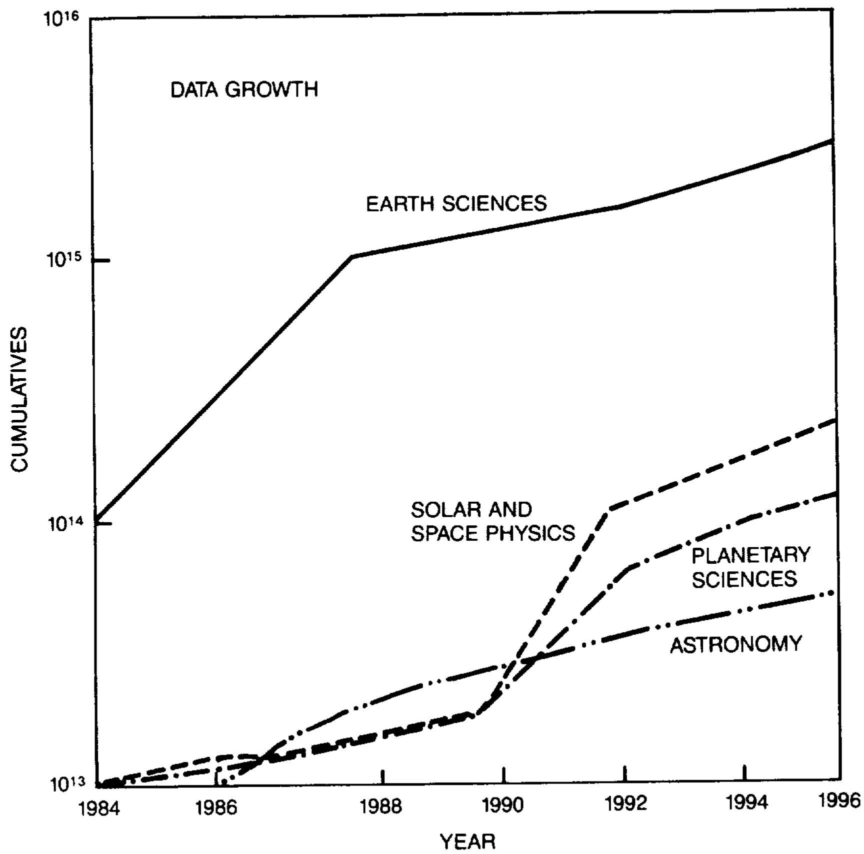


Figure 2. NASA's Scientific and Technical Information (STI) program interfaces.

NASA is conducting research in the fundamentals of database logic. This work has resulted in the development of a common user interface for accessing data from several databases with different structures. This work provides the foundation that will provide to NASA space data users access to multiple databases regardless of their physical distribution or structure. This work will reduce the cost of these information searches and will allow intensive research that would otherwise be unaffordable. Other work is under way to develop and test an expert system that can assist researchers to analyze data derived from space exploration.

NASA is conducting research to improve techniques for producing reliable computing systems. Its goals are to reduce the number of faults in software and to make fault-tolerant systems. New approaches and methods for software management and engineering have been devised and are now being evaluated under real working conditions. Future objectives for software engineering will include research on its theoretical foundation, and extending and evaluating approaches for developing reliable complex software.

This effort is coordinated within NASA through the Intercenter Planning Committee for Computer Science: representatives of all NASA installations and Space Station Freedom's Software Support Environment (SSE). It is coordinated externally with the Department of Defense (DOD) Software Engineering Institute, and by representation on the Federal



NOTE: Earth orbital missions assumed to last for 5 years, except for operational satellites and the space telescope, which are projected as continuing data producers

Figure 3. Projected Growth Rates for Space Science Data.

Coordinating Council for Science, Engineering, and Technology (FCCSET) under the auspices of the Office of Science and Technology Policy (OSTP).

NASA's High Performance Computing Initiative (HPCI) is a major topic of current legislation, which recognizes the tremendous importance of high performance to the United States' ability to maintain technical leadership in aeronautics, and to U.S. economic interests. In coordination with OSTP/FCCSET, the computation performance target for the HPCI program is a thousand-fold increase in performance within a 5-year period. The HPCI program will complement a variety of other NASA programs in the aerosciences, earth and space sciences, and exploration and experimentation. The program will directly complement the Numerical Aerodynamic Simulation Program.

HPCI's fundamental approach is to demonstrate to the aerospace industry the utility of advanced parallel computer systems capable of teraFLOPS performance. It develops and

demonstrates a multidisciplinary simulation and design methodology to design new generations of high-performance aircraft and propulsion systems. Current trends in aerospace vehicle design require even more highly integrated vehicles and engines in which traditional, single-disciplinary analysis and optimization (e.g., aerodynamics, structures, controls) are no longer sufficient to achieve required performance goals. Future systems falling in this category include the National Aerospace Plane (hypersonic aircraft), high-speed civil transport, and transatmospheric vehicles.

NASA'S ADMINISTRATIVE INFORMATION MANAGEMENT PROGRAM

In 1984 NASA established the Automated Information Management (AIM) Program to improve the management of NASA by eliminating redundant automation efforts across common administrative functions and installing compatible hardware and software. Some 17 information systems are affected, including finances, personnel, information, and facilities and equipment. By standardizing the administrative information-processing environment, scarce personnel and dollar resources can be used to greatest advantage. The overall responsibility for the AIM program rests with the NASA Office of Management. Oversight and advice are provided by the AIM Council, composed of senior NASA executives. Specific projects, undertaken in response to user requirements, are delegated to individual NASA installations, with one installation being designated as lead. For example, development work on NASA's personnel and payroll system (scheduled for implementation in fiscal year 1990) was done by the Johnson Space Center.

AIM program work is undertaken in response to user requirements. A complete methodology (based on the Software Management and Assurance Program) has been developed and is shown in Figure 5.

Overall, the goals of the program are to:

- implement a coordinated set of agencywide automated administrative information system capabilities for optimum productivity improvements consistent with sound management and technical practice;
- achieve acceptance throughout NASA that information is a valued strategic resource that can increase effectiveness and efficiency in performing administrative and management functions;
- optimize the interoperability of automated administrative information system resources, including the efficient exchange of information and transportability of software; and
- optimize the effectiveness and efficiency in the management of designing, developing, and sustaining new agencywide automated administrative information systems.

In fiscal year 1989, the AIM program completed the initial phases of a review of management information needs throughout NASA. The results of this review will be the cornerstone of an appropriate data administration program to create the necessary administrative information architecture.

COMMON INFRASTRUCTURE CONCERNS

The discussion of the management of NASA's information programs would not be

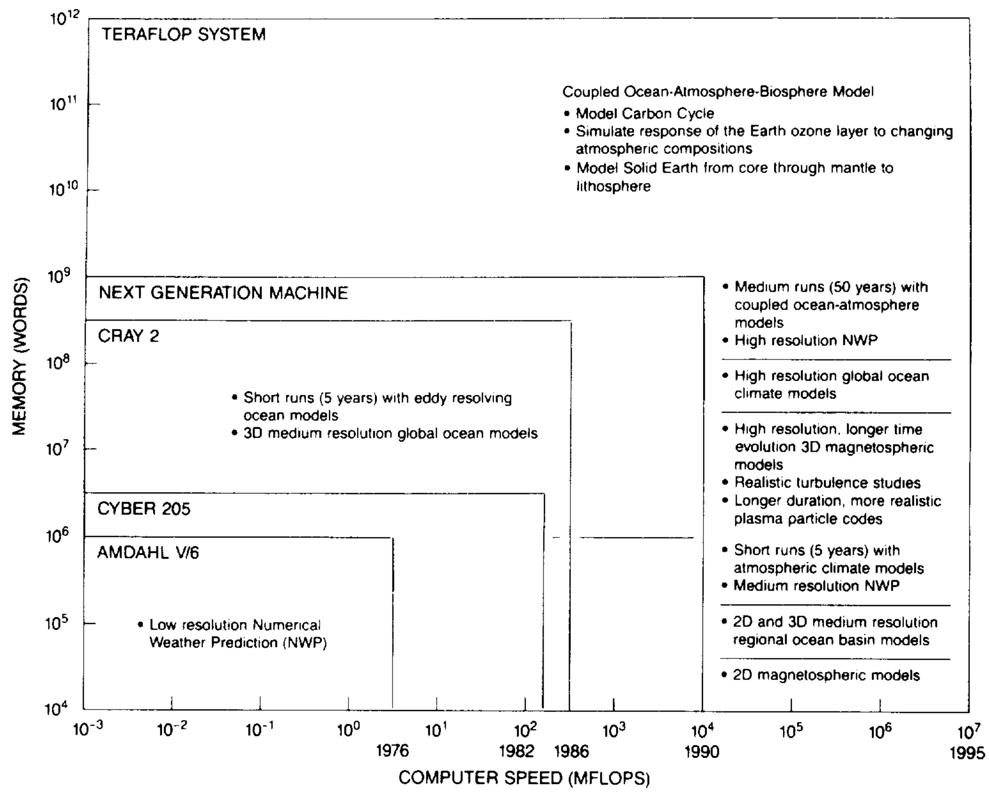


Figure 4. Modeling and Simulation of Space Science Processes Computer Speed and Memory Requirement.

complete without reference to the infrastructure necessary to manage the broad base of NASA information over its life cycle. The system often fails to respond effectively because the subject matter was not viewed systematically from the beginning. While the technological capabilities of individual NASA programs vary, a more broad-based, NASA wide approach is being formulated in line with evolving federal, national, and worldwide initiatives.

The principal technological factors affecting the management of information can be addressed at two levels. At the highest levels are architectures and standards that enable the components of the next level to interact appropriately. The next level consists of the computer- and telecommunications-related hardware and software necessary to move data between users and to manipulate and store data.

NASA is fortunate to have an excellent telecommunications network, a critical component of its day-to-day mission operations. NASA researchers at the various NASA installations will increasingly work on joint projects, and additional loads will be placed on the system to link to local area networks and to facilities managed by contractors, universities, and consultants. Issues to be addressed will include those dealing with the federal

PHASE	DOCUMENTATION	REVIEWS
• Predefinition	• Project Request Document • Feasibility and Cost/Benefit Analysis	• AIM Council/HQ Reviews
• Project Definition	• Project Initiation Agreement • System Concept Document • Project, Configuration Management, and Product Assurance Plan(s) • Functional Requirements Document • Procedures and Standard Manual	• AIM Council/HQ Reviews • System Requirements Review with IPUC
• System Development	• Plan(s) Updates • Requirements Specifications • Design Specifications • Test Plan and Procedures • User and Operations Guides • Training Plan	• HQ Reviews • Preliminary Design Review* • Critical Design Review* • Test Readiness Review* (*means all with IPUC)
• Implementation	• Certification and Product Assurance Reports • Site Installation Plan • Support Plan (for ongoing operations)	• HQ Reviews • Performance Demonstration with IPUC • Functional Configuration Audit • Physical Configuration Audit

IPUC = INTERINSTALLATION PROJECT USER COMMITTEE

Figure 5. Summary of AIM Project Management Requirements.

government's new telecommunications system, FTS2000, as it comes into service, network security, and interoperability of local area networks with the NASA-wide telecommunications network.

The question of security is paramount, and there are a number of equally important issues addressed under such terms as internal controls, risk management, and vulnerability analysis. From a security standpoint, NASA serves three communities that have distinctly different security concerns reflected in their data-processing and telecommunications operations.

- The research community in which NASA interacts operates in an open environment that fosters the free exchange of ideas. Care has to be taken not to institute controls at odds with the basic purposes of the program.
- The manned space shuttle mission operations that NASA operates are unique to NASA and are tightly controlled.
- Research information obtained from DOD is governed by the policies of DOD and are controlled as required.

Once all telecommunications concerns are addressed, the computers can acquire and process data. This presumes, of course, that some accommodations have been made to resolve the dissimilarities, among the operating systems of micro-, mini-, and mainframe computers throughout NASA. The evolving standards for Open Systems Interconnect (OSI) must be implemented to make computer software applications and files portable among data-processing environments. (NASA employs both versions of UNIX as well as several other operating systems.)

A further important consideration here may be the need to more closely integrate access to STI with the workstation environments of the researcher. This is both a technical issue and a human one. It is not clear that the researchers themselves would want to search and retrieve information. The Langley Research Center has implemented a pilot program that seems to work satisfactorily. Reference assistants are assigned to research organizations rather than having the researcher visit a reference library.

In some cases, the problem is not the dearth of information, but the oversupply. NASA's taxonomy of STI terms is an exhaustive three-volume thesaurus that forms the basis for its information retrieval process.[6] While some preliminary assessment has been made regarding the use of Boolean logic-based screening programs, such is not yet a reality. Training is required to fully exploit the database as it expands to include the increasing volume of space-related scientific and engineering reports.

Last but not least are storage considerations. There is widespread interest in the use of Compact Disk Read-Only Memory (CD-ROM) evolving as the most cost-effective mechanism to provide compact, high-resolution data storage. NASA's programs encompass plans for an enormous amount of data—thousands of terabits. Fortunately, plans are already under way to identify and sponsor research in areas of computer science that might not be expected to evolve without some encouragement from NASA. Nevertheless, the future is still challenging because of the lack of universal standards.

Years ago when STI was not computer-dependent, the sharing of information might have been labor-intensive, but it was not technically difficult. However, this sharing often occurred in a largely monolithic environment where projects were relatively independent. The technology that has evolved over the years can handle large volumes of data efficiently. As this technology evolved, researchers saw new ways of approaching problems and integrating solutions. With new opportunities often come new risks, and continued thoughtful development is necessary to establish the overall infrastructure of NASA's information management systems. A recent MIT study pointed out that putting the new technology in place can impede progress, if choices are not thought out carefully, because expensive conversion costs, hardware and software replacement costs, and retraining costs may be incurred.

How does one deal with such a diverse set of parameters? Part of the answer has to do with leadership. In 1988 NASA established an Information Resources Management Council comprising NASA's top management team. Because of competing priorities and the numerous demands on NASA's key executives, the Council chose to focus initially on specific issues of high importance rather than to attempt to undertake a much broader initiative.

The wisdom of this approach has proven itself. Significant near-term gains are evident and information resource management plans are meshing with the more sweeping NASA-wide strategic planning efforts. The Council has undertaken several important activities, including:

- reviewing NASA's software management practices and chartering the Ada and Software Management Assessment Group to provide a more comprehensive assessment;
- briefing Council members on selected NASA information resource-intensive projects that have the potential to affect other NASA areas, such as Space Station Freedom;
- briefing Council members on the direction being taken in this area by the U.S. Congress, GSA, and other central agencies, and the selected experiences of other agencies comparable to NASA in dealing with these organizations on information resource management issues, including system security;

- reviewing organizational, financial, and other impediments to effective use of information resources;
- recommending raising the delegations of procurement authority of all NASA organizations from $1 million to $2.5 million to expedite acquisitions; and
- conducting a survey of NASA program and installation officials regarding the utility of existing standards and the need for new standards.

As early as 1964, NASA had an Intercenter Committee on ADP to coordinate information-technology-related matters. This committee continues to function, addressing the changing nature of the issues as the technology began to mature.

EXTERNAL ORGANIZATIONAL INTERFACES

In addition to technological considerations affecting the information management program infrastructure, there are numerous organizational interfaces that directly affect the ability of any federal agency to effectively manage its STI. These interfaces include:

- the Office of Science and Technology Policy, which establishes and coordinates policy matters of great national importance for those issues under its purview;
- the Office of Management and Budget, which must approve the funding for individual projects and institutional operations;
- the General Services Administration, which must approve all procurement actions for computer and telecommunications hardware and software above $2.5 million (GSA will also control the implementation of FTS2000 and NASA's associated costs.);
- the National Archives and Records Administration, which is charged to collect information and make it available as a historic record;
- the Department of Commerce, National Institute of Standards and Technology (NIST), which must approve the use of new standards or variances from standards. NIST is also responsible for the security of sensitive (but unclassified) systems not under the purview of DOD;
- the National Security Agency, which is responsible for the security of classified systems and data under the purview of DOD;
- the congressional Joint Committee on Printing, which sets standards and control all contracts for printing of federal documents, including scientific and technical reports;
- the American Institute for Aeronautics and Astronautics (AIAA), which has been designated by the American National Standards Institute to establish the standards for space-science-related information; and
- the Advisory Group for Aerospace Research and Development (AGARD) of the North Atlantic Treaty Organization (NATO), which oversees the exchange and use of aerospace STI among NATO partners and between NATO members and non-NATO nations.

LOOKING TO THE FUTURE

The foregoing was designed to give visibility to the enormous administrative framework in which information managers must work to effect the transfer of knowledge resulting

from NASA's research efforts. Despite the complexity, the framework is workable and the job does get done. In many cases, what is perceived as bureaucratic is part of the system of checks and balances necessary to ensure that the objectives of both public policy and scientific merit are being met.

Since Apollo 11 landed on the Moon more than 20 years ago, NASA has undergone significant change. During this period, staffing levels dropped from 45,000 to 22,000. Comparable reductions in funding levels also occurred, although funding levels of the past few years have begun to increase in terms of constant dollars. Nevertheless, NASA is on an upswing and an important part of the rebuilding process is a new assessment of its STI Program to ensure that it responsibly meets the needs of the NASA community of scientists and engineers.

As mentioned earlier, evaluation is an important aspect of a well-managed program. Over the past several years, NASA has conducted a pilot survey of members of AIAA. While the findings are not conclusive (because AIAA is only one space science and engineering organization with membership from both the public and private sectors), 92 percent of the respondents indicated that NASA STI was important in terms of advancing the state of the art.[7] While the survey results show reasonably good acceptance of the finished product, NASA needs to move ahead to tailor its automated delivery of the information as effectively as possible.

The Technology Transfer Act of 1986 prompted a broad range of concerns as well as opportunities. The potential now exists for NASA scientists and engineers to receive royalties from their patented and copyrighted material. Increased opportunities in this area may help NASA and other federal agencies to retain skilled researchers. This also means, however, that new incentives will have an additional impact on how STI is managed by federal agencies.

In a very farsighted move, the U.S. Congress directed OTA to review U.S. policies for the control and dissemination of STI. Among other things, OTA's report recommends that Congress needs to consider strengthening the role of the Office of Science and Technology Policy (OSTP), which is directed by the Science Advisor to the President of the United States.

NASA is preparing for its future of increasingly complex and fascinating exploration and discovery. The participants in, and the beneficiaries of, these efforts will be the American people, and, to varying degrees, all nations on Earth. We believe that the management of NASA's STI will play an important role, and there is much work to do to ensure that NASA's program is objective, effective, and efficient.

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N90-28443

The New Space and Earth Science Information Systems at NASA's Archive

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The National Space Science Data Center (NSSDC), established in 1967, serves as a long-term archive and distribution center for data obtained on NASA space science flight investigations and provides a variety of services to enhance the overall scientific return from NASA's initial investment in these missions. NASA science data at the NSSDC cover the disciplines of astrophysics, Earth science, planetary physics, and space plasma physics.

Over 6,000 gigabytes of digital data (125,000 magnetic tapes) and 91 million feet of film products from NASA science missions have been acquired by the NSSDC since it was established in 1967[1]. To handle the requests for both digital and film products, the NSSDC has a variety of computer systems, both interactive and batch; dedicated photo laboratory facilities; large online database management machines; and optical mass storage devices. It also manages NASA's largest computer-to-computer wide area network.

Based on current agreements concerning future NASA missions, the NSSDC data holdings will increase dramatically, nearly doubling every 2 years, reaching nearly 40,000 gigabytes by 1995. Innovative ways of managing the information about such large volumes of data and implementation of large mass storage systems are necessary to provide users with better archive access while the NSSDC effectively manages the ever-increasing volumes of data that are coming into the archive[2].

With the ease of electronic access dramatically increasing over the last few years, the NSSDC has created a major new thrust by developing online computer information systems accessible to remote users 24 hours a day. Currently, not all the information about the NSSDC archive is accessible to remote users, and less than 2 percent of the NSSDC's total digital data archive is online[3], but these systems are already a major achievement in providing rapid access to NASA-acquired science data that is unprecedented in archive data management.

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This article focusses on the new NSSDC online interactive systems that are used extensively over international computer networks. These systems are typical of how NSSDC is responding to user demands for rapid access to archived data.

WORLDWIDE NETWORK CONNECTIONS

Many computer network connections have been made to provide remote access to the NSSDC by all its diverse users. Figure 1 shows a breakdown of the major network connections by communication protocol. The Bitnet connection supports only mail communication among many universities in the United States and NSSDC. Selected science computer network nodes worldwide and the general public primarily use the X.25 international packet networks to gain access to the data center. There are two major wide-area NASA networks that are used extensively by NSSDC: The Space Physics Analysis Network (SPAN)[4] and the NASA Science Network (NSN). SPAN contains more than 2,800 nodes in the United States and is internetworked with more than 10,000 nodes in the United States, Europe, Canada, and Japan (through other networks such as HEPNET). SPAN is managed by NSSDC and used exclusively by space and Earth scientists working primarily on NASA-related missions and projects.

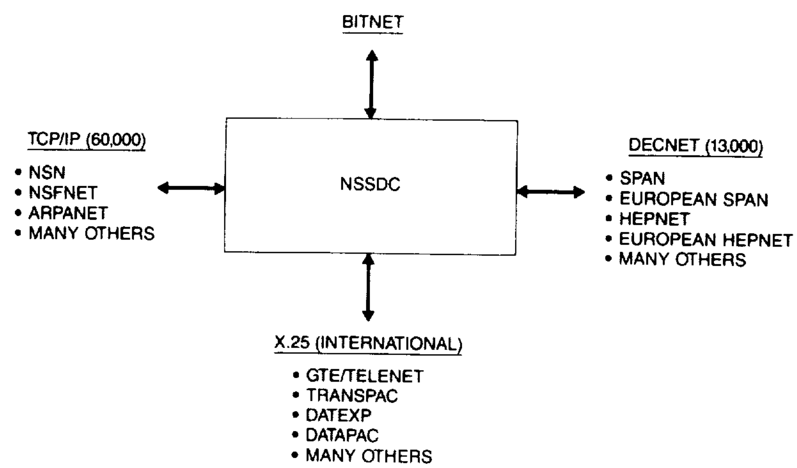

Figure 1. The wide-area network access to the NSSDC. NSSDC manages the SPAN computer network, which supports many connections to other wide-area DECnet networks such as HEPNET. Another major NASA network is the NSN, which provides TCP/IP connectivity to many other computer networks and the NSSDC. The Bitnet connection supports only mail communication between many universities in the United States and NSSDC. Selected science nodes throughout the world, in addition to the general public, use the X.25 international packet networks primarily to gain access to the data center.

NSN (which uses the TCP/IP protocol) is internetworked with other wide-area networks, such as ARPANET and the NSFnet, and can reach many thousands of computers, primarily at universities. In general, these wide-area networks are of relatively low speed but are providing a tremendously valuable service for remote users to gain access to NASA computer resources and to communicate with fellow researchers across the country.

The bulk of the wide-area network traffic is for informational purposes such as remote logon and mail; however, data transfer (in limited amount) is also supported. The wide-area networks provide the pathways for remote users to access the NSSDC facilities at any time, day or night[5].

"NEW TECHNOLOGY" DATA AND INFORMATION SYSTEMS

The NSSDC is responding to an ever-increasing number of user requests by putting more of the data and information about the data in its archive online for direct user access. With the ease of electronic access dramatically increasing over the last few years, the NSSDC's new online computer information systems can now be accessible to remote users 24 hours a day. This allows the NSSDC to "remain open" past normal working hours, providing scientists and students the ability to "browse" through the online information to look for an important data set.

The new online data and information systems currently operational at the NSSDC are shown in Table 1. These systems have been a tremendous success, handling more than 2,500 accesses by remote users annually and growing rapidly. The systems shown in Table 1 provide a variety of services, depending on the desires of the community of scientists they serve. The online systems provide information about data holdings, with several levels of complexity. For instance, the Master Directory (MD) contains a high-level overview of data held in the NSSDC and at a number of other NASA centers, established U.S. science research institutions, and other U.S. government agencies such as the National Oceanographic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS). The MD, therefore, is the first reference system to point to where the data are held[6]. More detailed information about data holdings, such as the processing history, quality, time resolution, etc., must be found in the other data systems, such as NASA Climate Data System (NCDS), to which the MD will refer a user.

The online information systems MD, personnel data base, Total Ozone Mapping Spectrometer (TOMS) data, Solar Wind data (OMNI), and the International Ultraviolet Explorer (IUE) request system are all accessible from one computer account called the NSSDC Online Data and Information System (NODIS). The interactive traffic to the NODIS account over the last year is shown in Figure 2. Since 1987, many new systems have been added to the NODIS account. Figure 2 shows the tremendous popularity of the NODIS system, with the average user accessing NODIS more than twice a month.

Another important example of the ready access to the data in the NSSDC archive is the IUE Interactive Request System. This system allows scientists to order observations taken by the IUE spacecraft.

The IUE Interactive Request System became operational in November 1987 through the NODIS account. The request system[7] consists of a large online mass storage device, menu-driven interactive information access software, a high-speed local-area network connecting the online storage with the interactive front ends, and the wide-area networks access to the system.

Rapid access to selected data has been frequently requested by scientists. Since it is not known ahead of time what sections of any one data set will be requested, the NSSDC loaded all the IUE data into the NASA Space and Earth Science Computer Center's IBM 3850 Mass Store in order to better accommodate the large user demand through faster request

Table 1. NSSDC New Technology Online Systems.

SCIENCE DISCIPLINE	SERVICE	INFORMATION	DATA*
All			
	Master Directory	X	
Astrophysics			
	IUE Request System	X	X†
	ROSAT Information Management System	X	
	Astronomy Catalog System	X	X
	STARCAT with SIMBAD access	X	X
Atmospheric Science			
	NASA Climate Data System	X	X
	Ozone TOMS Data	X	X
Land Sciences			
	Crustal Dynamics	X	X
	Pilot Land Data System	X	
Space Plasma Physics			
	Central Online Data Directory	X	
	Omni Solar Wind Data System	X	X
	Plasma and Field Models	X	X††
	Coordinated Data Analysis Workshop	X	X
General			
	SPAN-Network Information Center	X	
	Personnel database	X	

NOTES:
* Only partial data sets are available
† All available data is on line
†† Only software is being distributed

and delivery response. It is important to note that the NSSDC typically manages its archive offline. Storing all the IUE data online was done with full IUE Project cooperation to gain valuable experience with highly requested online data sets. The IUE data that are currently online consist of over 70,000 unique star images and spectra and total approximately 90 gigabytes in volume.

The IUE interactive request system software runs on the NSSDC VAX computers, which allow for a remote SPAN user to log on and order IUE data from the electronic IUE Merged Observer Log.

Once the exact data segment requested has been identified, the NSSDC request coordinator networks the IUE data from the Mass Store system. For requesters desiring a small number of spectra, the NSSDC request coordinator can network the data through SPAN to the target computer of the requesting individual within approximately 24 hours or create a magnetic tape to be mailed. Requests for IUE data sent on magnetic tape are handled easily by this system. Requests for IUE data also come to the NSSDC through letters and phone calls (not all users are on computer networks).

Figure 3 shows the yearly number of IUE images requested by individuals from 1979 to 1989. NSSDC also sends large amounts of IUE data to other archives; these requests are not included in this figure. The solid colored bars in Figure 3 show the number of images sent out on magnetic tape to individual requestors; the size of the cross-hatched bar represents the average monthly number of IUE images that have been networked to remote users using SPAN. From 1979 to nearly the end of 1987 the only service the NSSDC offered was an offline service in which a tape copy of the data was produced and sent to the requester. The bar graph also shows the yearly number of IUE images requested in 1988 and 1989.

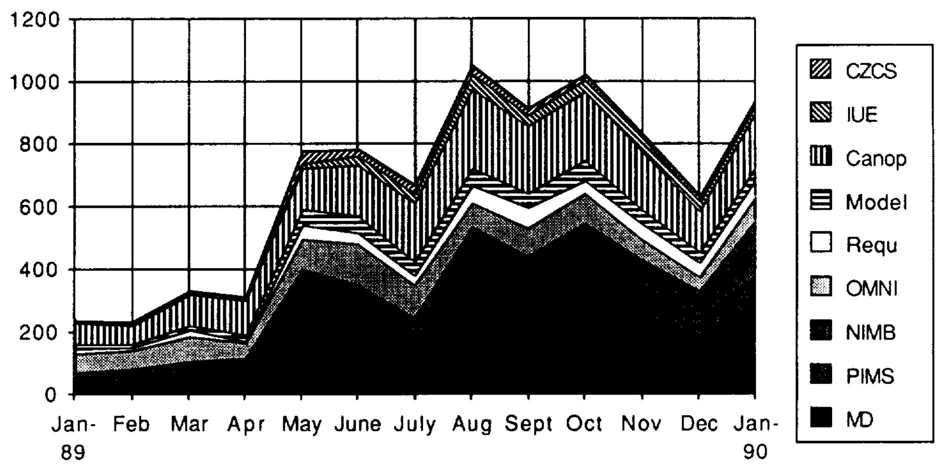

Figure 2. Interactive traffic from remote users, accessing several key NSSDC systems. Using the NODIS System, number of sessions (open circles) and users (filled-in points) is plotted against time. The dramatic increase seen after April 1989 results from several Information Systems becoming operational. It is important to note that the average number of accesses by scientists is more than twice per month.

Figure 3 also shows the dramatic increase in the amount of IUE data requested in 1988 and 1989, reaching approximately 3500 images and spectra a year. The computer networks were used to deliver, about 38 percent of the data, in 1988, and 60 percent of the data in 1989, while the remainder, are satisfied by sending magnetic tapes. Currently, the trend in the use of the IUE Interactive Request System, as well as all the other systems shown in Table 1, continues to climb.

The networked IUE images satisfied requests from many scientists at 15 institutions in the United States, Europe, and Canada (locations serviced by SPAN). In addition, care is taken to use SPAN for networking of the IUE data at times of non-peak network usage. Tests are currently under way in which some IUE data are compressed before being

networked to the user's remote computer and are then decompressed, therefore reducing the communication load on the wide-area network.

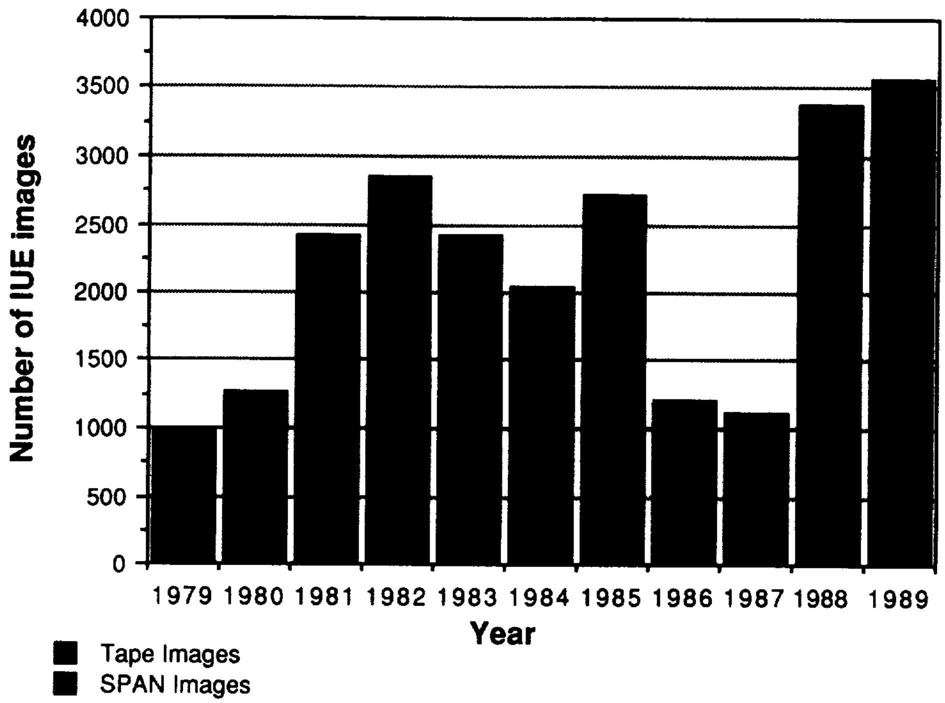

Figure 3. Number of IUE images requested (per year) since the archive was opened in 1979. Although the IUE Interactive Request System became operational in November 1987, it was not until January 1988 that remote users routinely accessed the new interactive system. The huge increase in the number of images distributed in 1988 and 1989 can be attributed to the better service that is now provided electronically. The cross-hatched bar in 1988 shows that nearly 40 percent of all images requested are delivered over computer networks. In 1989 it was 60 percent.

The request results for 1988 and 1989 (Figure 3) clearly show that the tremendous increase in requested data results from the convenience the interactive request system provides to the user. The following factors are a major part of the user convenience provided by the IUE Interactive Request System:

- immediate ordering of needed spectra/images;
- rapid turnaround providing the desired data while the scientists are interested;
- data loaded to the target system (no tape handling);
- data arriving in the desired format; and
- no need to send replacement tape to the NSSDC (currently the SPAN and NSN networks are a "free" service to users).

The IUE example is typical of all the interactive data and information systems that allow NSSDC to disseminate as much information as possible in a timely manner.

FUTURE INFORMATION SYSTEM ACTIVITIES

Based on current agreements concerning future NASA missions, the NSSDC data holdings will increase dramatically, approximately doubling every 2 years, reaching nearly 40,000 gigabytes by 1995. This is a staggering amount of data. Within the next year, the Hubble Space Telescope (HST) will be launched and will produce approximately 2,500 gigabytes (2.5 terabytes) of data per year. HST is a new type of mission for NASA; it is being designed as a "nearly permanent" observatory in space (lasting at least 15 years) and is one of NASA's several Great Observatories in space. Because of the huge amounts of data and the importance of the mission to the astrophysics community, the Space Telescope Institute in Baltimore, Md., has been created to be responsible for the science mission management and data archiving for the HST. It plans to make all HST data readily available through an online data archive.

The ability to electronically access and query the contents of a remote archive is of tremendous importance, greatly facilitating research in the space and Earth science fields. These online information systems must continue to grow in capability and complexity in order to accommodate the huge data volumes NSSDS expects to manage in the near future. It is clear, from examples like the Master Directory and IUE Interactive Request System, that online interactive information and data retrieval systems do provide a better service to the science research community than the offline letter requests for highly requested data sets.

Through the new online information systems, the NSSDC is striving to support active archive research on the individual scientist level at any time of day or night convenient to the researcher. The NSSDC will continue to aggressively pursue the "electronification" of its information about data and, to the extent reasonable, its archived data[8]. Much of the new data coming into NSSDC will be managed by the online interactive systems, but much more work remains to be done with the existing archived data.

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Scientific and Technical Information Management

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For more than 30 years scientific and technical information (STI) has meant to NASA the documented results of NASA research and development activities from all areas of NASA's comprehensive mission—plus available information from other sources around the world that are relevant to aeronautics and space activities. Substantial collections of such information and data exist at many NASA installations, some dating back to 1915 when the National Advisory Committee for Aeronautics (NACA) was formed.

As a subset of STI, scientific and technical data are defined as factual information which may be of many differing types: numeric, graphic, pictorial, and even computer programming. STI data do not normally include the electronic codes or electromagnetic transmissions that have not been "reduced" to referencable data. Unreduced data are usually of interest in telecommunications systems and as intermediate research products. (Research in communications science and technology is, of course, one of NASA's missions and is itself recorded as scientific and technical information.) The data most significant to NASA must be factual in the sense that they must also have all the labels needed to define and understand them.

When data are explained and interpreted they become information subject to permanent retention and dissemination. Such information becomes useful knowledge only when accompanied by understanding and it becomes most useful when followed by analyses and theories and even by plans for future work.

Scientific and technical information and data are essential ingredients in the expansion and dissemination of knowledge central to NASA's mission. But to become "knowledge" the information must be successfully presented to understanding individuals. This is the primary goal of the NASA Scientific and Technical Information Program—to present both new and old information relevant to people working in NASA's programs in such a readily

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useable way that it may, and will, be added to their store of knowledge. Of course, this store includes not only the content of their memories but also an awareness of, and an ability to access, large information resources that have no prohibitive barriers in terms of cost, timeliness, or ease of use.

BRIEF HISTORY OF THE NASA STI PROGRAM

The first published technical report from NASA's parent organization, NACA, was written in 1915 in the earliest stages of government-supported research and development. Even then a firm NACA policy required thorough reviews and approvals prior to release of any reports describing R&D results. Furthermore, the early library system made extensive efforts to acquire documents from worldwide sources that related to the NACA programs.

Such practices were continued in 1958 when NASA replaced the NACA. The new organization encompassed the NACA installations and was enlarged by additions of new and transferred installations. The principal addition to the STI Program occurred in 1961 when NASA started a new activity called the Scientific and Technical Information (STI) Facility. The STI Facility was located in the Washington, D.C., area and used contractors through successive competitive procurements to assure reasonable cost and the application of current technology. This 1961 startup and a number of other significant milestones are shown in Table 1. The most important technological events were the first use of a computer system to produce an index-abstract journal with companion automated search and retrieval capability, an integrated document distribution system using both paper and microfiche formats, and the first large-scale online retrieval system whose prototype was developed in 1966 by contractors other than those at the STI Facility. Online retrieval was tested then at a total of 23 workstations located at 6 different installations. Online retrieval became fully available throughout NASA in 1969.

One of NASA's most significant external arrangements in its early years was with the American Institute of Aeronautics and Astronautics (AIAA). Under a contract with NASA in 1963, AIAA began cooperative processing of new aerospace documentation into a single NASA database having standard terminology and no duplication in coverage. AIAA brought to this arrangement its close ties with aerospace corporations as well as its ties with similar societies in other countries. It also brought the combined foreign language and technical backgrounds that had already proved necessary to its staff in conducting AIAA information activities. Today, AIAA translates NASA input material from 22 languages.

Another significant agreement was established in 1964 with the organization now known as the European Space Agency (ESA). While NACA and NASA had already created document exchanges with foreign laboratories, universities, and other institutions numbering some 200 in over 40 countries, a new opportunity presented itself. In exchange for selected bibliographic data tapes and computer programs, the European Space Research Organization (ESA's predecessor) began sending NASA tapes and microfiche covering aerospace reports originating from European sources, all in a form suitable for direct entry to the NASA database. This concept of information exchange has now been extended to other nations that have committed themselves to providing NASA the same kind of reports in compatible formats. Australia, Canada, and Israel have all made such commitments. NASA attempts to balance the exchanges by requesting at least one processed aerospace report for each computerized connect hour to the NASA bibliographic data.

Table 1. Significant Milestones in NASA's Scientific and Technical Information Program.

1961	Established Scientific and Technical Information Facility.
1962	Produced first computer-generated abstract/index journal (Technical Publications Announcements) with associated computer search and retrieval system.
1963	Established contract with American Institute of Aeronautics and Astronautics.
1964	Established exchange agreement with European Space Research Organization (now European Space Agency).
1966	Tested prototypes of first large-scale online information retrieval system (NASA/RECON; fully implemented in 1969).
1971	Added current R&D project and contract descriptions to database.
1974	Added NASA library holdings to database.
1979	Extended online RECON access to contractor organizations.
1983	Added directory of numerical data to database.
1983	Made Aerospace Database available in U.S. through AIAA and private sector.
1985	Private sector (Dialog) instituted online availability of Aerospace Database.
1987	Made first of new series of national-level exchanges with Israel, followed by Australia (1988) and Canada (1989).
1987	Added 1915-1958 NACA collection to online database.
1988	Made NASA library network operational.

Of course, no historical brief of NASA's STI Program should omit the important contributions of the U.S. Departments of Defense and Energy. Through almost continuous exchanges of reports and bibliographic data, the three agencies have fostered mutually beneficial awareness of their respective programs and shared in the agencies' research results through adoption of bibliographic standards and sharing of retrieval software. In addition, the National Technical Information Service (NTIS) of the Department of Commerce has served as a valuable outlet to members of the public who use NASA STI. Thus, through varied contracts and numerous exchanges, NASA has consolidated worldwide aerospace information in a coordinated resource for its mission scientists and engineers.[1]

ORGANIZATION OF NASA FOR STI MANAGEMENT

Varied organizational locations of STI Program management in NASA reflect in microcosm many of the organizing problems that NASA faced in approaching the tasks assigned by the Space Act of 1958. Overall management of NASA's STI Program moved from its original 1959 placement in the administrative office of NASA Headquarters through four other office combinations, finally settling in the Office of Management in 1978. In between it existed

in the offices of technical information and educational programs, public affairs, policy planning, technology utilization, and industry affairs. The current structure is shown in Figure 1.

The STI Program ties with NASA installations should be particularly noted in Figure 1 and, through them, the ties to NASA contractors where much scientific and technical information is generated. The installations are responsible for research contracts and hence for assuring that the resulting contractor reports are properly reviewed and entered into the STI system. The installations are similarly responsible for their own employees' reports and papers. They also take an important user's role in managing the STI Program's direct contractors.

The NASA STI Facility is the principal source of documented information to users throughout the aerospace community. Its primary responsibilities are to NASA installations, contractors, and universities having aerospace curricula, but it also serves to consolidate input to the system from numerous domestic and foreign sources and to organize, store, and redistribute it to other information intermediaries as well as end users.

International information-exchange agreements are negotiated by the Scientific and Technical Information Division. The agreements are subject to approval as appropriate by the International Relations Division which, in turn, coordinates appropriately with the Department of State.

Figure 1 indicates a direct working relationship between NASA and AIAA. This is accomplished through a cooperative arrangement that allows AIAA to serve both its membership and the public while also meeting NASA's needs. AIAA provides NASA with abstracting and indexing services and with requested copies of meeting papers and journal articles (making appropriate copyright payments to their private-sector sources) while continuing to operate its open library.

Although NASA experienced some difficulty in organizationally positioning the agency-wide STI management on its organization charts, it had no trouble in establishing the fundamental need for the program nor in defining its scope of responsibilities. Approximately 90 percent of NASA's funds are directed toward contract research and engineering. Because a diverse group of field installations was expected to control both those contracts and their own internal research, NASA's information program was felt to require a close-knit combination of centralization and decentralization. Without a strong central resource, the costs of independent or separate systems and the lack of standardization would have slowed and inhibited NASA's research to an unacceptable degree. Without expert local management of the system producer and user interfaces, the central system alone would likely have been seriously impaired. The basic policy statements for the STI Program are presented in a NASA management instruction[2] and are summarized in Table 2 in their current forms, which are nearly identical to those first produced in 1961 and 1962.

PRODUCTION OF DOCUMENTED KNOWLEDGE

Documentation of aeronautics and space research, which starts when researchers become authors, has kept pace with the research itself. Within NASA and among its contractors and grantees, normal personal incentives for documenting one's professional efforts have combined with presentation requirements for attendance at meetings and have been augmented by NASA's strong pro-publication policies. Figure 2 illustrates the growth in the number of NASA STI documents between 1962 and 1989. The numbers reflect both

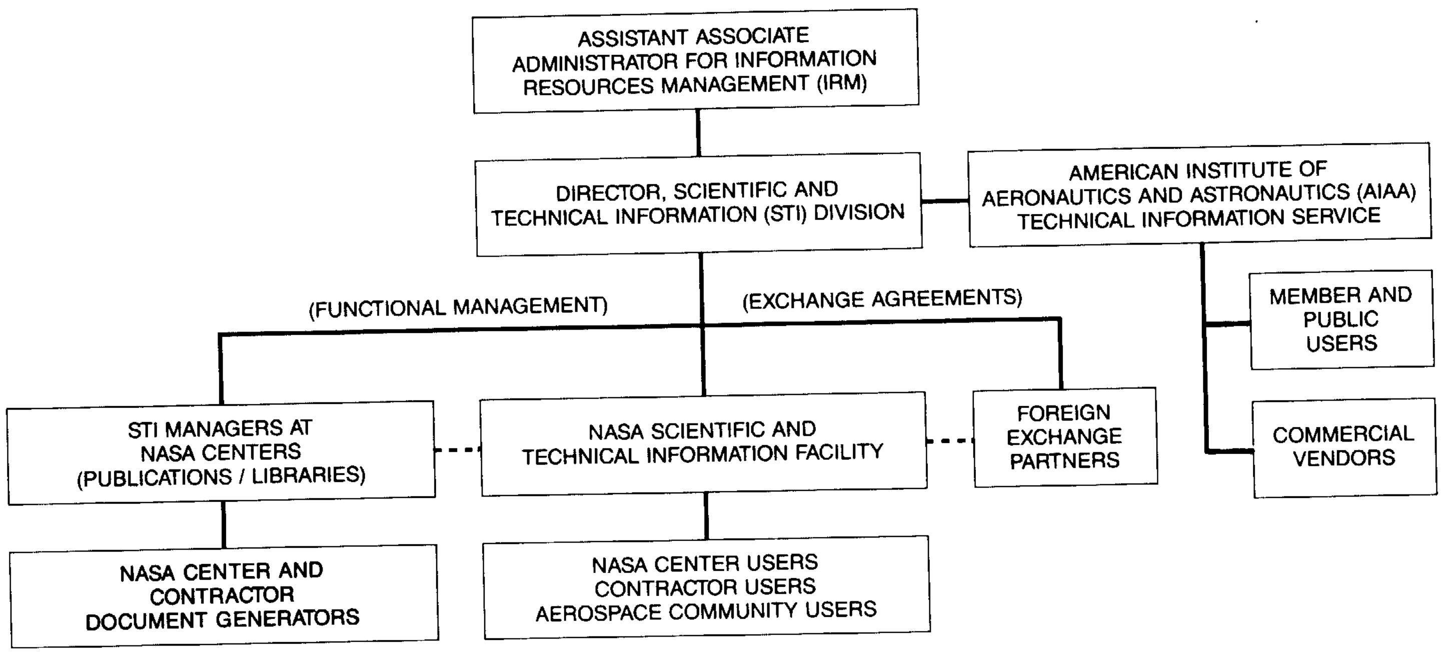

Figure 1. Organizational Relationships of STI Program. AIAA receives direct financial support under a NASA contract which provides for commercial vendor agreements having international restrictions.

Table 2. NASA Scientific and Technical Information Policy. These statements from Management Instruction 2220.5 set the tone for NASA's STI Program.

Scientific and Technical Information (STI) is an intrinsic element of every NASA scientific and technical endeavor and as such is subject to supervision and control of program management. Accordingly, NASA operates and maintains STI activities on a comprehensive basis in order to:

(1) Provide for the widest practicable and appropriate dissemination of its activities and the results thereof.

(2) Provide for interchange of STI within NASA and between NASA, its contractors and grantees, other Federal agencies (including their contractors and grantees), and the scientific and technical community, both national and international.

(3) Meet NASA's scientific and technical and related program requirements.

(4) Document all appropriate scientific and technical work using high standards and make such available promptly for publication and announcement in NASA scientific and technical publications, in contractor or grantee reports, in other scientific and technical publications, in learned journals, in proceedings of professional meetings, and/or in books and any other suitable media.

(5) Maintain a formal NASA publication series.

(6) Review NASA employee-authored information for technical accuracy, conformance to policy, and reporting standards before publication.

(7) Make the widest practicable and appropriate dissemination of NASA STI subject to U.S. laws and overall national policy to prevent adverse transfer of aeronautical and space technology. The dissemination may provide for early domestic availability or may be limited by Federal export laws or national security reasons. Such restrictions will not normally be placed on work done for NASA by an academic institution.

(8) Review for technical accuracy, conformance to policy, and reporting standards any contractor or grantee reports published by NASA.

(9) Start no new information facilities without formal determination by the NASA Associate Administrator for Management and the Official-in-Charge of the appropriate Headquarters Office that existing activities are unable to provide the requisite services.

(10) Conduct STI activities as a centrally coordinated agencywide network.

(11) Design specialized STI activities for compatibility with the NASA-wide network and, as practicable, with the systems of other Federal agencies and the scientific and technical community.

(12) Develop new or improved systems and techniques for the handling and dissemination of STI to yield improved services, greater efficiency, and reduced costs.

(13) Release STI in conformance with NASA regulations on the availability of agency records to members of the public and the NASA information security program.

separately bound documents and the unique papers or chapters documents contain whenever their authors are credited individually by receiving discrete entries in NASA's bibliographic database. There are three principal features of these data: the drop in NASA and contractor output between 1971 and 1980; the comparative steadiness of NASA publication through the private sector; and a pronounced NASA report upsurge in 1984 and onward. The steady fall-off until 1980 resulted directly from reductions in the agency budget and civil service employment, shown in Figure 3. However, the 1983 and 1984 increases in NASA report

output resulted from new agency policies that called for more complete monitoring and accounting of the information presented at NASA-sponsored conferences and in program descriptions.

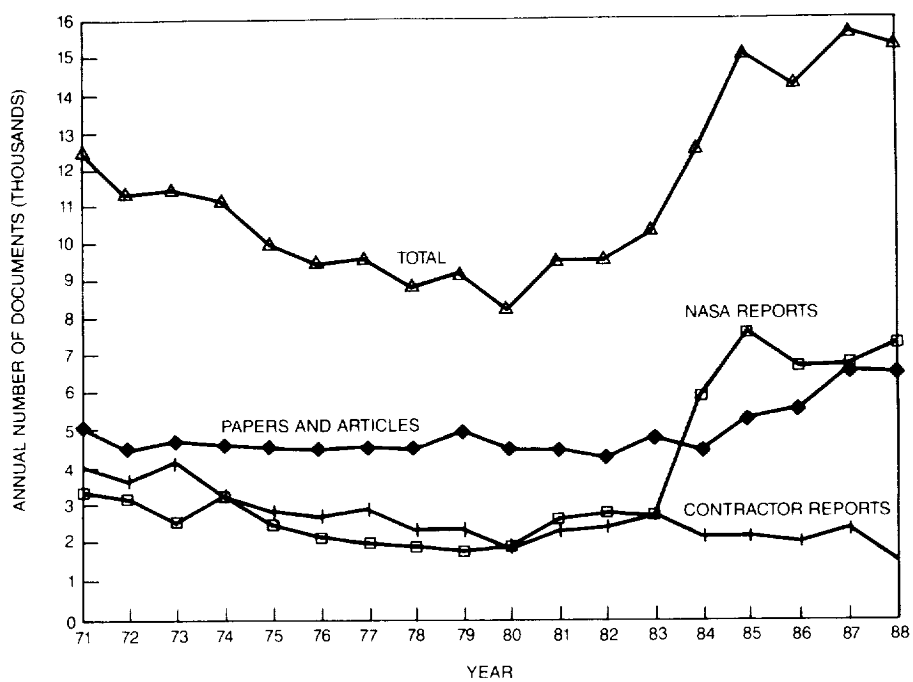

Figure 2. Annual Output of NASA STI Documents. These figures include meeting papers and journal articles published through the private sector as well as chapters and papers printed in books and conference proceedings when they are individually indexed and recorded in the NASA database. The increase in report output in 1983–84 results from improvements in monitoring and collection procedures.

As required by the longstanding publication policies cited in Table 2 and amplified in a procedural handbook,[3] NASA authors, contractors and grantees may publish in a wide variety of publications including reports, meeting papers, learned journals, proceedings of professional meetings, and books and other suitable media. The reports must take form in one of the seven NASA publication series listed in Table 3. Although not shown separately in this table nor in Figures 2 and 3, NASA publications that bear restrictions on their availability are included in both. Their proportion of the total NASA publications has remained reasonably constant at less than 10 percent.

The most significant policy that guides NASA STI managers is that all publications regardless of type must have prior reviews for technical accuracy, NASA policies (including those involving intellectual property), reporting standards, and possible dissemination restrictions. The most recent review instituted was in 1984 to assure conformance with national policies on adverse technology transfer, although an "early domestic dissemination" review

was being applied to selected programs as early as 1973. Unless a limited delegation of approval authority is given to NASA installations, all NASA-originated reports, papers, and articles must receive approval for their release from the appropriate Headquarters program office.

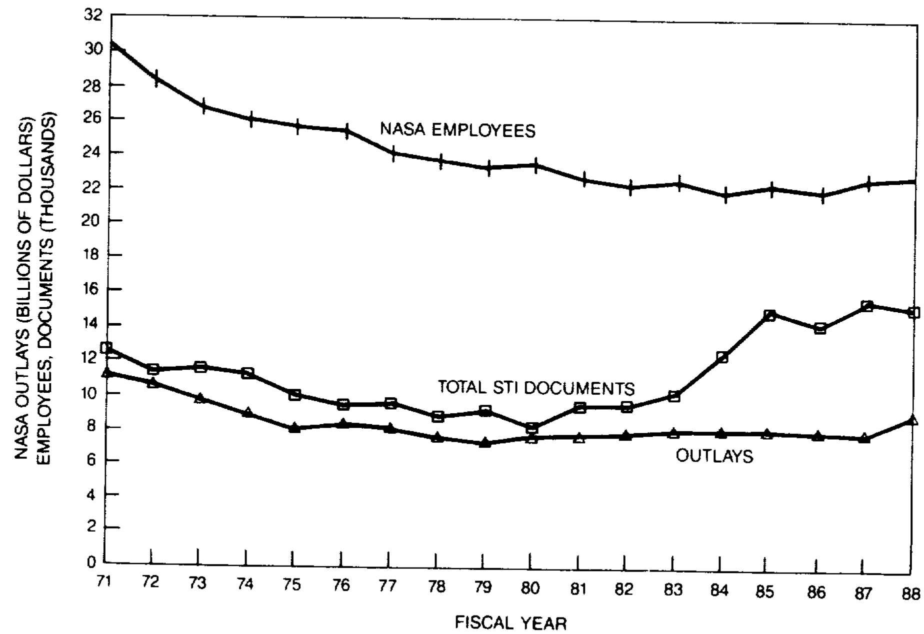

Figure 3. NASA Outlays, Number of Employees, and Total STI Document Output. Outlays are shown in 1988 dollars.

Other important publication policies state that (1) academic institutions are exempt, unless contractually required, from any publication restriction; (2) authorship will be reserved to persons who participate in the performance of the work from which the scientific and technical information results; and (3) joint authorship between a NASA employee and a contractor or grantee requires that publications follow policies that apply to NASA-authored work.

DISSEMINATION OF NASA STI

NASA exhibits a natural bias toward open communication with the scientific community and with the large and small private organizations that power the nation's aerospace industry. This bias stems from the Space Act, which requires the "widest practicable and appropriate" dissemination; it also reflects the human nature of the government employees whose responsibilities are to the U.S. taxpayer and to their own commitment to science and engineering. These factors, as well as those described in the preceding section, push the NASA scientists and engineers toward publishing their work and promoting the advancement of science

Table 3. NASA Scientific and Technical Report Series. All NASA-published scientific and technical reports and books must appear in one of these seven series.

SPECIAL PUBLICATION (SP)

Records scientific and technical information particular to NASA programs, projects, and missions for presentation to audiences of diverse technical backgrounds. SPs are often concerned with subjects of substantial public interest produced as books containing summaries of mission results, atlases, studies, program descriptions, retrospective assessments, histories, chronologies, bibliographies, and information guides and thesauri.

CONFERENCE PUBLICATION (CP)

Contains the records of scientific and technical conferences, symposia, special lecture series and seminars, and other professional meetings sponsored or cosponsored by NASA.

REFERENCE PUBLICATION (RP)

Contains compilations of significant scientific and technical data and information deemed to be of continuing reference value.

TECHNICAL PAPER (TP)

Records the findings of significant work conducted by NASA scientific and technical personnel. It is a report of completed research, or a major phase of research, presenting the findings and including extensive data analysis and/or theoretical analysis so that the significance of the results can be assessed. TPs receive prepublication professional review, but have fewer limitations on length and graphic presentation than journal articles.

TECHNICAL MEMORANDUM (TM)

Records scientific and technical findings that are not given broad dissemination because of the preliminary or otherwise limited nature of the information. TMs provide the most timely release medium.

CONTRACTOR REPORT (CR)

Records scientific and technical findings generated by contractors and grantees involved in NASA-sponsored research and development and related findings.

TECHNICAL TRANSLATION (TT)

Consists of English-language translations of foreign-language scientific and technical material pertinent to agency work.

and engineering. Any "political" restraint placed upon such motivations must be well developed and thoroughly justified. Contractor workers have similar motivations and restrictions, plus the constraints of possible proprietary content. The Space Act mandated openness to the fullest possible extent, but new intellectual property considerations are changing NASA policies in this area. Since 1915, NACA and NASA reports have been given public distribution or availability as a normal course.[4] Only for a specific reason such as national security or exceptional commercial value would a report or paper be given a limited distribution. Figure 4 is a flow diagram of NASA's research results moving from their place of origin, typically a NASA installation or laboratory, through various dissemination channels to destinations ranging from other NASA installations to the general public. A key aspect of this flow is that much of it is through the private sector, including professional society

meeting papers and journals made available by their publishers and by the library services of the AIAA in New York. Government organizations also provide direct channels to the public, but these are for the reports and books published by NASA. Generally, it is the U.S. Government Printing Office (GPO) that sells NASA books to the public and the National Technical Information Service (NTIS) of the Department of Commerce that sells NASA reports. NTIS handles the NASA books also as well as bibliographic data from the abstract journal, *Scientific and Technical Aerospace Reports (STAR).* All are available also through the GPO's depository library system. The abstract journal, *International Aerospace Abstracts (IAA),* is available from AIAA. Online access to bibliographic data is successfully provided in two ways. Access to *STAR* and *IAA*, which together are called the Aerospace Database,[5] is provided through AIAA acting as an agent to U.S. commercial vendors of services such as Dialog. The NASA STI Facility provides the NASA community with direct access to the entire NASA STI database via its NASA/RECON online system[6] and supports the access with all the specialized services described in the Processing section of this article.

Figure 4 attempts to condense this flow, concentrating on information to the public and to members of the aerospace community including NASA contractors, other government agencies and their contractors, universities with aerospace curricula, and NASA's foreign exchange partners. The exact volume of documents disseminated each year is difficult to measure because of numerous secondary points existing in the system. These include GPO with its large depository library system, NTIS with its huge permanent report collection, foreign exchanges, and especially all the recipients of the microfiche that are readily stored and used locally for either direct reading or blowback. Direct NASA distribution totals around 1,350,000 document copies annually of which approximately 1,000,000 are microfiche.

ACQUIRING INFORMATION FOR NASA RESEARCH AND DEVELOPMENT

The Space Act of 1958 charges NASA with preserving United States leadership in aeronautical and space science and technology. To assure this result, NASA has actively pursued both domestic and international acquisitions to support the highest competence and performance in its research and development endeavors. This continuing acquisition of new information serves also to minimize duplication of effort and unnecessary use of NASA resources.

International acquisitions for the NASA mission began in 1959 with establishment of bilateral exchanges between NASA and organizations having similar interests, primarily governmental research institutes and laboratories, universities, and professional societies.[7] The exchanges usually started with a simple interchange of letters, often at the library level, and involved only paper copies of reports and bibliographic products. There are currently 220 of these bilateral exchanges in 43 countries, and they contribute up to 2500 items annually to the NASA STI database.

The starting of an exchange in 1964 with the European Space Research Organization (ESRO), which later became the European Space Agency (ESA), embodied two substantial departures from the earlier exchanges. First, it was an STI exchange with an international organization, and second, it was an agreement to an exchange of electronic products. ESRO agreed to provide NASA with abstracts of scientific and technical reports originating

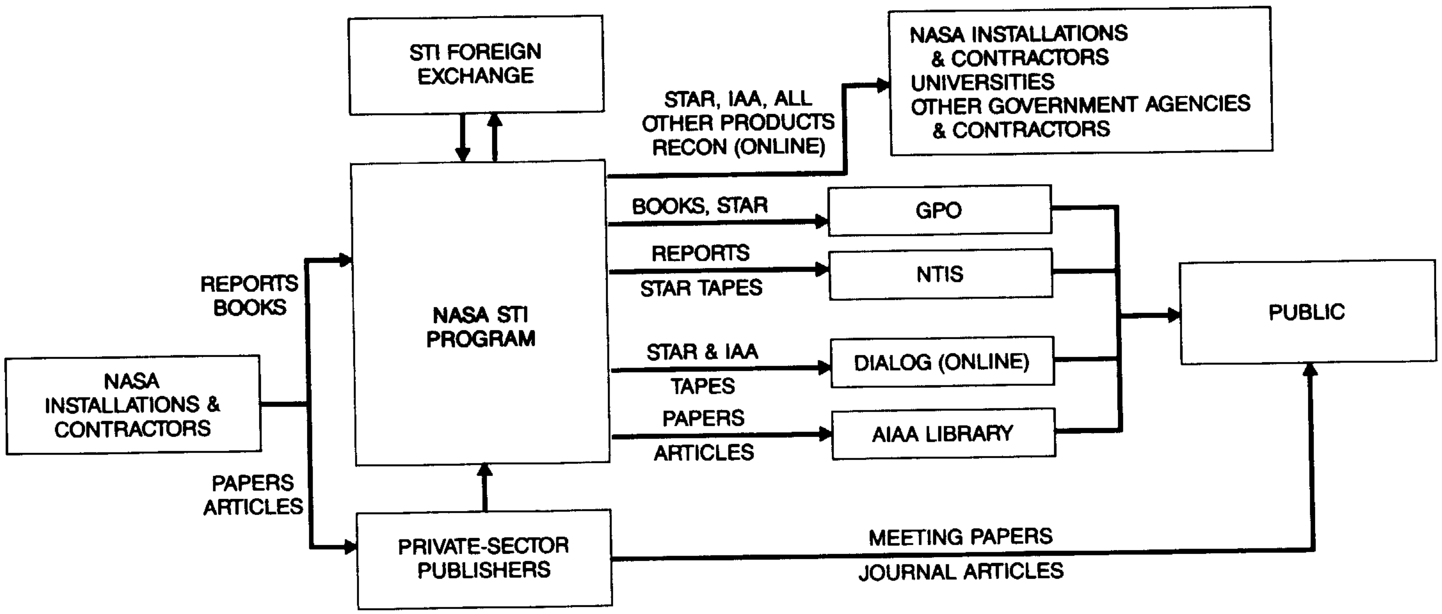

Figure 4. Dissemination of NASA Research and Development Results. Abstract journals and online databases contain descriptions of both NASA and non-NASA aerospace documents.

from European sources and to process them into an electronic form suitable for inclusion in NASA's bibliographic database. NASA, in turn, agreed to provide ESRO with copies of *STAR* and single copies of the documents it covered. ESRO was to service European requests for NASA reports announced in *STAR* if NASA had no bilateral relationship with the requesting organization. Both parties agreed in principle to exchanging microforms and tapes for computer searches as soon as ESRO established facilities for processing the European input and utilizing the tapes. In 1965, these arrangements were completed: NASA would send to ESRO tapes covering documents announced in *STAR* and *IAA* including backfiles; ESRO would send NASA machine-readable citations, with indexing by NASA terminology, and abstracts of the reports sent to NASA in a form suitable for immediate input. Later, in 1972, a NASA/ESRO Tripartite Exchange Program began when the two organizations agreed to extend access for searching of the NASA database to other organizations and individuals in ESRO-member states provided that a satisfactory tripartite exchange agreement was approved for each by the organization, by ESRO, and by NASA. ESRO also agreed to process input for those organizations in member states that were *bilateral* exchange partners with NASA, and to provide selected documents translated into English. In 1978, the two parties agreed on the establishment of national centers in appropriate ESA-member states to identify sources and assure proper input of aerospace documentation. Input requirements were changed from "best efforts" to "at least one in-scope report per each connect-hour" to the NASA file. The tripartite program now has more than 500 participants and sends 4000 relevant technical reports annually suitable for direct entry in the NASA file.

A third type of international exchange evolved in 1986 with the first "national level" STI exchange. Designed to streamline the bilateral exchanges, these agreements concentrated responsibility in a single government organization in each nation to replace the numerous partners that existed under the old bilateral system. The government organizations are responsible for insuring that all appropriate reports are collected and processed for direct input to the NASA system in much the same way that ESA now collects and processes information from member states in Europe. Access to the NASA *STAR* and *IAA* files is available either by tape shipment or by special arrangement with U.S. commercial online-service vendors of the Aerospace Database available through AIAA (e.g., Dialog). Agreements for national-level exchanges were started with Israel in 1986, with Australia in 1988, and with Canada in 1989, and one is being negotiated with Japan.

Figure 5 illustrates the wide diversity of information sources in the current NASA STI database. Foreign exchange agreements account for about 6,000 government-published reports annually, most of which are announced in the NASA abstract journal, *STAR*, and would not otherwise be available to NASA researchers. These exchanges also account for many articles, theses, meeting papers, and preprints that supplement the private sector publications and exchanges acquired by the AIAA for the abstract journal, *IAA*. The total foreign acquisitions comprise 41 percent of the 1988 database, with the leading foreign sources (the intellectual origin of each document) being the Soviet Union, the United Kingdom, West Germany, France, Japan, and Canada in that order. All documents selected for the exchange programs or for general acquisition to the database must meet a strict test of relevancy to NASA as described in a mission statement developed for this purpose.[8]

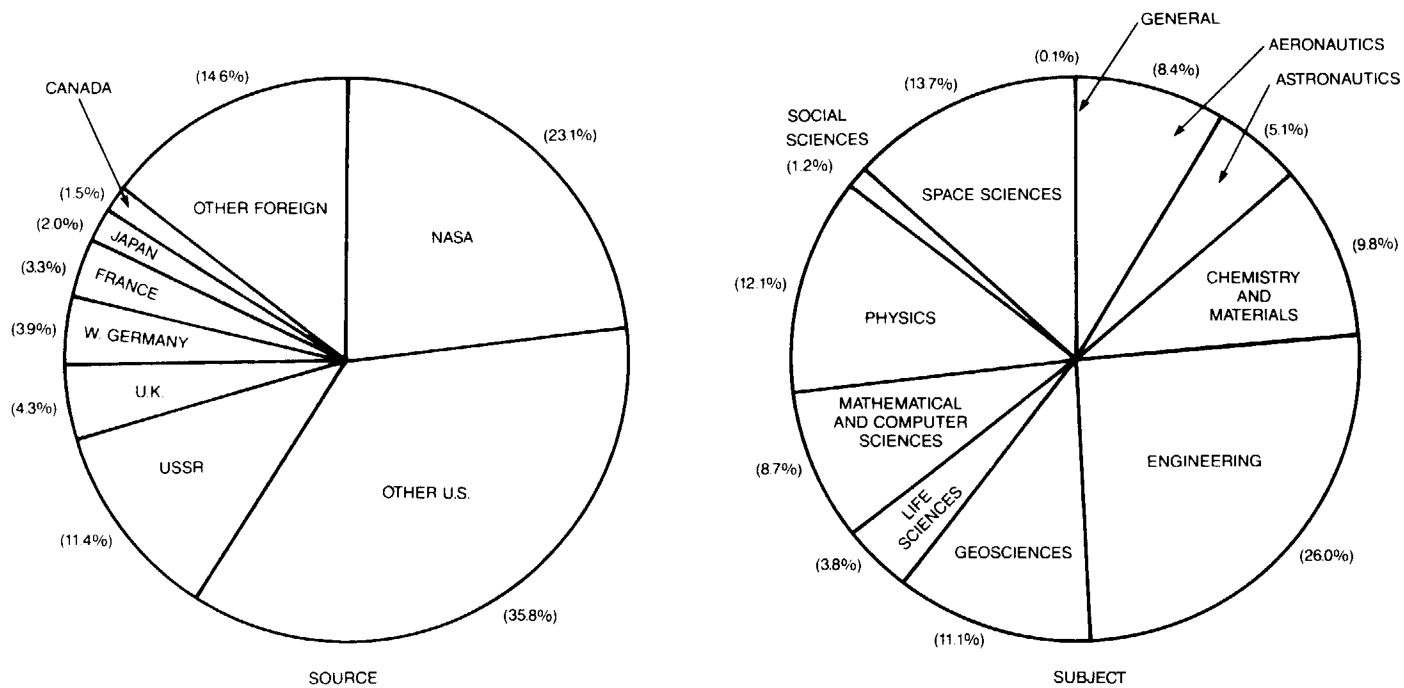

Figure 5. Sources and Subjects of NASA's STI Database Additions in 1988. The sources represent domestic financial support and foreign intellectual origin. All documents are directly related to NASA's research and development missions.

PROCESSING INFORMATION FOR UTILIZATION

On average, 85,000 aerospace documents are processed into the NASA STI system each year and added to an ever increasing database that in 1989 reached 3,000,000 separate documents or descriptions of unique aerospace related items. In addition to the microfilming described previously, new documents are placed into one of 75 subject categories for announcement in the two semimonthly abstract journals (*STAR* and *IAA*). They are then indexed according to the NASA Thesaurus,[9] a standard taxonomy or structured hierarchical vocabularly consisting of 21,000 terms and 160,000 codified interrelationships. Index terms from other systems are converted automatically and the computer assists in many ways to provide the best possible indexing.[10,11] As added weekly to the online database, the resulting bibliographic data become accessible to the NASA community via NASA/RECON. It provides an extremely powerful retrieval capability based on any combination of thesaurus indexing and descriptive cataloging supplemented by a rich text-searching capability based on unlimited combinations of document titles and abstracts. This initial document processing includes complete cataloging on each item for all authors with their full names and affiliations, corporate sponsors of documents, report numbers, contract numbers, names of journals, and a host of related information. All become points of retrieval in NASA/RECON where they can be used separately or combined in unlimited ways. NASA/RECON receives an average of 15,000 commands (requests for information or processing) a day including online document orders for copies of identified documents from the central storage points which are the NASA STI Facility for reports and AIAA for journal articles.

To make the processing and dissemination as efficient as possible, NASA divides its STI database into different categories reflecting not only the public-sector/private-sector document sources that distinguish *STAR* and *IAA*, but other groupings such as documents of limited availability or limited relevance and those that are two or more years old when processed. By such distinctions only the prime current material needs to be given full-cost treatment and announced in *STAR* and *IAA*. Others can receive progressively less expensive processing. One of the most important categories is that for local NASA library holdings of books, monographs, and journals, all of which receive special treatment in an integrated library network for totally sharing resources. Table 4 summarizes the principal functional categories and indicates the degree of processing each receives.

Processing new input for the database also includes producing current awareness services, which select only the new information acquired that would likely be useful to specific users of the system. These services are listed in Table 5 along with the frequency of each. In addition to the two abstract journals, which categorize and index the new documents added four times a month and which are often used for current awareness purposes, seven continuing bibliographies cover major areas such as aeronautical engineering and space station systems. *Selected Current Aerospace Notices (SCAN)* divides the new information into 190 different subject areas reflecting common standardized interests or profiles of users. *Updates* are individual profiles used to develop monthly personalized printouts of new information. These printouts are clearly the most useful, not only because of the explicitly tailored subject interest, but because they routinely include the relevant new contracts and projects established by NASA as well as notifications based on authors names, current contract numbers, and corporate sources. However, the most timely and flexible current awareness system offered is that provided through local NASA/RECON access.

NASA/RECON stored searches allow the user to store personal or group interest profiles that reflect his or her own interests and then to exercise them frequently online to produce descriptions of new documents added to the database since the previous interrogation. In all cases, documents identified as having special interest can be viewed at the local library or ordered from the two sources (STI Facililty and AIAA) for delivery by regular or express mail or by facsimile transmission.

Table 4. STI Database Processing Categories. Information is organized and processed to differing degrees reflecting its function and potential value. STAR and IAA documents are also filmed when possible and reproduced as microfiche. Retrieval from all document categories is available online through RECON.

TYPE OF DOCUMENT	Cataloged	Indexed	Abstracted	Announced
Primary scope, current reports and government publications	X	X	X	STAR
Primary scope, current papers, articles, and books	X	X	X	IAA
Primary scope, limited availability reports	X	X	X	
Current project descriptions	X	X	X	
Numerical dataset descriptions	X	X	X	
Computer program descriptions	X	X	X	
R&D contract descriptions	X	X		
Peripheral scope or older reports	X	X		
Non-NASA limited-availability reports	X	X		
R&D administrative reports	X			

Processing information into the database can be complete only when the resulting information about information or the full text of the recorded information, be it in the form of reports, papers, project and contract descriptions, numerical data, or other media, is available in convenient form and examined by a user. Thus, the systematic organization (processing) of STI needs to be followed by eliminating or reducing common convenience and economic barriers to its use and by active promotion of its use.

EVALUATION OF THE MANAGEMENT SYSTEM

The management of any information program as large and complex as NASA's scientific and technical information program justifies serious efforts at evaluating its effectiveness.

Table 6 lists eight of the principal evaluations conducted by or for NASA in this area. Results of these studies were invariably useful, although specific changes made to the program in consequence are typically difficult to identify. However, the 1967 study on the 1966 testing of an online retrieval prototype clearly occupied a major role in issuance of the new NASA specification for an improved NASA/RECON system in 1968.

Table 5. NASA Current Awareness Products and Services. These services provide users with descriptions of new information selected and organized for their individual needs.

PRODUCT OR SERVICE	FREQUENCY
Scientific and Technical Aerospace Reports (STAR)	Semimonthly
International Aerospace Abstracts (IAA)	Semimonthly
Selected Current Aerospace Notices (SCAN)	Semimonthly
Continuing Bibliographies:	
Aeronautical Engineering	Monthly
Aerospace Medicine and Biology	Monthly
Technology for Large Space Systems	Semiannual
Space Station Systems	Semiannual
NASA Patent Abstract Bibliography	Semiannual
Management	Annual
Update Profiles	Monthly
RECON Stored Searches	User-chosen

The most recent study,[12] reported in 1989, is a pilot investigation for a much larger undertaking which, when completed, will surely have a major impact on future NASA STI products and services. The study sampled 353 members of the AIAA and found that 78 percent of this community use NASA-authored technical reports and that the percentages of the same community who either use or are familiar with the principal NASA bibliograhic tools are: *STAR* 67 percent, *SCAN* 41 percent, *IAA* 36 percent, and NASA/RECON 32 percent The latter numbers are significantly different among the sample's NASA employees: *STAR* 91 percent, NASA/RECON 80 percent, and *SCAN* 37 percent. The sample to be used in the complete study will be expanded to include other members of AIAA as well as members of the Society of Automotive Engineers and others who may not have joined these societies.

POLICY ISSUES

What was good for NASA in the 1960s and 1970s is not necessarily as effective in the 1980s and 1990s, and new opportunities have clearly arisen. New approaches obviously are required to accommodate the proliferation of microcomputers (also referred to as personal computers) and new storage technologies, including both compact optical discs and centralized systems accompanied by high-speed communication. These advances could readily serve to take full-text documented information almost instantaneously to working scientists and engineers. The role of the traditional library and information specialists or intermediaries becomes a policy issue, especially when the personal assistance of information specialists is well known as a source of substantial enhancement to the quality of any given knowledge transfer. Even application of artificial intelligence to computer systems could not replace proper human assistance until well into the next century.

Table 6. Principal Evaluations of NASA STI programs.

YEAR	PRINCIPAL SUBJECT	PRINCIPAL AUTHOR	REFERENCE
1967	Prototype online system	D. Meister	NASA CR-918
1973	User requirements/staff location	J. Duberg	Unpublished
1975	Program in NASA Centers	H. Pryor	*Spec Lib* 66:11
1978	Program in NASA Centers	R. Burr	N89-70333
1979	Program in aeronautics industry	P. Monge	NASA CR-181367
1981	Program in academia and industry	T. Pinelli	NASA TM-81934
1982	Formats of NASA reports	T. Pinelli	NASA TM-84502
1989	Program in AIAA membership	T. Pinelli	NASA TM-101533

A policy issue that requires more immediate attention is the degree of integration of the information producer and the researcher with the dissemination and retrieval system. As aerospace scientists and engineers become more automated and network-oriented they clearly will become less attuned to using traditional documents for communication. Yet the NASA mission is to expand knowledge of aeronautics and space, which means that all data and factual information in the electronic hopper must still be thoroughly analyzed and recorded if it is to be used by new generations of workers or transferred to those not in the immediate circle of the originator. The policy problem is the extent that new-age researchers will continue to be authors as well as workers and how to assure proper recording of their analyses, theories, and plans.

The final major policy issue involves the changing rights to intellectual property and how a research and development agency of the federal government should approach it. This factor can be used to enhance the quality of research and development obtained by tax dollars only if the newly permissible or legally mandated incentives to contractors and

government employees are carefully planned and monitored so as not to yield inadequate reporting and an eventual reduction in application of the results. The legal aspects of this subject are discussed fully in a separate article in this issue.

PLANS FOR THE 1990s

If one considers an information system only for aeronautics and space documents, as NASA first began to develop at the dawn of the computer age in 1961, the current NASA STI system is a dream come true. The planners are left with improvements such as providing for online editing and peer review of new documents, quicker and cheaper delivery of full-text documents, artificial intelligence to improve retrieval, and possibly online translation of non-English languages to speed their delivery in usable form. A communications link between NASA/RECON and the Science Network of NASA's National Space Science Data Center (NSSDC) is being developed and is to be tested in the spring of 1990. This new link will far surpass the existing Numerical Database Directory on NASA/RECON that refers NASA/RECON users to data sets such as are held by the NSSDC. Users of either NSSDC or NASA/RECON systems would become able to switch from science data to science documents and vice versa.

SUMMARY AND CONCLUSIONS

The NASA mission is so scientifically and technically advanced that it would be inappropriate to leave the internal and external communication of its results to traditional means. Consequently, NASA has built upon an active STI Program already established by its principal predecessor organization and enlarged it as a centralized system while maintaining local laboratory controls on report generation and library use. The agency automated the dissemination, processing, and retrieval of both old and new information using the existing information industry competitively as operating and development contractors. NASA has created a cooperative arrangement with the largest professional society in aeronautics and space, developed worldwide sources of STI in information exchange partnerships, and implemented a broad range of STI databases and informational products and services. As a result, NASA has largely met the diversity of STI needs of its aeronautics and space scientists, engineers, and research managers.

New information technologies, combined with evaluations of the existing program, now require new directions for NASA's STI Program. Direct interactions with aerospace professionals—NASA, university, and contractor alike—must increase and become fully integrated into the flow of electronic results from creator to user. Creation of new scientific and technical knowledge must take place in concert with rapid and easy transfer from primary investigators to users and to potential users who exist within other disciplinary boundaries. Investigators must always remember their obligations to be analysts, theoreticians, and authors as the distinction between documented and undocumented information becomes less clear. Only by effectively transferring such knowledge will NASA be able to meet the world challenges in aerospace and fulfill its mission to maintain the leadership role.

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NASA Scientific and Technical Information for the 1990s

GLADYS A. COTTER*

In this article, we outline our projections for NASA scientific and technical information (STI) in the 1990s. NASA STI for the 1990s will maintain a quality bibliographic and full-text database, emphasizing electronic input and products supplemented by networked access to a wide variety of sources, particularly numeric databases.

STI for the 1990s will build on the accomplishments of the 1980s. Although budgetary realities are a constraint, there is much we can accomplish by applying new technology creatively. The changes now in process will provide a springboard for further change.

CHANGING REQUIREMENTS FOR MANAGING NASA STI

NASA is by concept and by practice an advanced-technology agency. The thrust of the 1990s will be toward a more comprehensive, systematic use of computer and communications technology for all phases of NASA STI.

Computers for STI use in the 1960s and 1970s and continuing into the 1980s were tools to assist and, where possible, replace manual operations. STI managers hoped that computerization would prove cost-effective; this was not always so. However, many new capabilities were realized. NASA will strive in the 1990s to use technology to meet new demands of users in a more cost-effective manner. The reconditioned Scientific and Technical Information Modular System (STIMS) and reconditioned RECON command and access structure are expected to be completely installed and operational at the NASA STI Facility by June 1990. This will position NASA to take advantage of state-of-the-art technology for several years into the 1990s, to handle the expected volume of electronic input and output, and to network effectively.

CURRENT AND FUTURE TECHNOLOGY

As the 1980s closed, neither scientist, engineer, nor STI professional had to be convinced

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that menu-driven systems, common command languages, gateways, and networking were hard realities. We all use them; available hardware and software determine our methods of working. Anticipated technology influences the systems we install: a well-designed system is developed and implemented to interface with and evolve into the next generation system. Available technology controls STI use to a degree most of us never anticipated, and to an extent as yet undetermined. Most of us still think and act as though we were still in a non-computerized environment, and don't know well enough yet what we can reasonably expect from our personal computer or workstation, our local area network (LAN), our mainframe, our search and retrieval software, or our database management system. Workstation technology as pioneered for the Space Station may become the prototype for what the efficient workplace will become: more comfortable, less stressful, encouraging relaxed but alert attentiveness. STI access will be an integral part of this workstation development.

Artificial intelligence (AI), expert systems, and knowledge-based systems will be used in the development of future STI systems and to focus design and engineering of new and modified STI subsystems. These technologies are workable for narrowly defined activities. They are largely simulation routines, but they frequently try to simulate the wrong thing: manual performance of an activity or too broad-based an application. As we become more comfortable in our computerized environment, we will be better able to develop and use systems that will increase the efficiency of STI input, processing, search, and retrieval.

Electronic Output

To a large extent, new NASA STI technology has been determined and defined in the 1980s and the groundwork laid for implementation and expansion in the 1990s. Quality of the NASA STI database should be improved in both content and timeliness to receive electronic input from those whose input is now on paper. STI professionals will be working with the NASA installations to receive electronic input, first of the bibliographic entry of their publications, then the full text. While the NASA installations have indicated interest in this NASA-wide system, they will have to agree on common elements and convert to compatible hardware, software, and formats. The next step will be to obtain electronic input from NASA contractors. NASA installations and contractors already process their documents electronically; given standard formats and instructions, they will be able to transmit their documents electronically, thus moving toward a tightly-knit agency-wide STI activity.

CHANGING USER NEEDS FOR STI SEARCH AND RETRIEVAL

As part of their daily research and development (R&D) activities, scientists and engineers at NASA installations and with NASA contractors acquire and use STI from NASA's database. Often the act of acquisition is performed by an information specialist rather than by the scientist or engineer; sometimes it is a joint effort of both. Use of the information specialist for information retrieval is frequently a chargeback service.

NASA STI professionals are themselves major users of NASA STI. They use it in order to keep up with the activities of the scientists and engineers. The traditional services they provide to the scientists and engineers are necessary but not sufficient; NASA scientists and engineers need to have access to more than one information retrieval system. To assist

these researchers in developing a comprehensive perspective, the STI professional must be familiar with and able to use many other information retrieval systems: federal and commercial, bibliographical, full-text, or numerical. The amount and type of assistance needed varies from client to client and occasion to occasion.

NETWORKING

The NASA STI professionals must be at home with different computer hardware and software and with a variety of networks. Nearly every researcher in the NASA community has his or her own personal computer or workstation and is on at least one LAN. Pointers to data provided by traditional STI tools are becoming less and less useful and effective for the NASA scientist or engineer. Documents retrieved can be as often frustrating as useful. Searches resulting in a long printout of NASA/RECON entries, or a series of entries viewed on the screen, may be baffling to the untrained user. Documents or substantial abstracts may supply facts, but the researcher's immediate need is for data that can be manipulated on the computer. Receiving a tape in the mail may be helpful, but more helpful is the ability to target and access the necessary data within minutes via a network the researcher hadn't known existed, using protocols that were previously unfamiliar.

NASA STI networking will make use of the approach already developed for scientific networks within NASA to link researchers to networks outside NASA. This methodology investigates, defines, and implements a unified approach to developing and interconnecting data systems so that users may rapidly obtain information about data of interest to them, and to enable efficient distribution of up-to-date information about data throughout the systems. In an effort coordinated by the STI Division, representatives from participating data systems will work together to:

- determine, document, and implement as fully as possible a set of guidelines or recommendations on the concepts and capabilities of an interoperable data system;
- determine, together with scientist and engineer users, requirements for interoperability;
- develop and implement interconnections so that a user may search for data sets or data systems of interest, starting with a directory, and then transfer through computer networks to the places where further information is available, and then to the data for access and manipulation;
- develop a common directory interchange format for sharing information among the data systems for input and update of directory-level information; and
- assist a user in searches among the data systems by automated transfer of information describing the user's requests.

An initial step to networking is linking NASA/RECON with the National Space Science Data Center (NSSDC) and the Space Physics Analysis Network (SPAN) to allow mutual access by users. Hardware and software interface at the NASA STI Facility will permit direct connection to the LAN at NASA Goddard Space Flight Center (GSFC). Thus users of NASA/RECON who find references to a particular database may "hotkey" to the NSSDC Master Directory and be led via the network to access that database. Similarly, a NSSDC user of a database on the SPAN network may switch to NASA/RECON and search for references to documents about that database.

Initial STI networking efforts will emphasize coordination of existing networks and clearinghouses, either within the aerospace community or related to it. The NASA Office of Space Flight (the Space Shuttle program) and the Office of Space Station operate information systems that can be accessed via links similar to the NASA/RECON-NSSDC link. Systems for accessing materials data and wind tunnel data are candidates for networking. A clearinghouse for applied and engineering data to complement NSSDC's activities for space science will be explored. Although only 2 percent of NSSDC's data are available online, it is a useful 2 percent.

INTERAGENCY AND INTERNATIONAL COOPERATION

Networking provides the basis for input to the NASA STI Facility from the NASA installations and also for information processing links with other federal agency large-scale STI operations such as the National Technical Information Service (NTIS), Defense Technical Information Center (DTIC), and the Department of Energy Office of Scientific and Technical Information (DOE/OSTI). These are represented in the interagency group of the departments of Commerce, Energy, NASA, and Defense Information (CENDI). The NASA STI Facility currently processes computer tape input from these agencies using its computer-aided indexing capability; networked input will allow direct transmission of this information, or distributed access.

The current open political climate presents a challenge to develop interoperability between U.S. government STI and the STI of the U.S.S.R. and Eastern Europe. NASA has a keen interest in this because of the active Soviet space program and existing U.S.S.R.-U.S. cooperation. The U.S.S.R.'s Institute for Scientific and Technical Information (VINITI) has indicated a willingness to share its burden of providing several hundred thousand abstracts a year of the world's scientific and technical literature. VINITI issues several dozen series of bibliographic journals. Most of these are in Russian, although some are abstracted in English. Translation is a mutual problem. VINITI's operations are already computerized, offering the possibility of networked access for searching and for inputting directly into the NASA STI database. Recent availability of desktop Russian-to-English translation software will assist in converting Russian language abstracts to English. NASA's computer-aided indexing capability can be adapted to translate the universal decimal code used by VINITI to NASA thesaurus terms.

A review of existing NASA STI commitments to the STI programs of the European Space Agency (ESA), the Advisory Group for Aerospace Research and Development (AGARD), and NATO, and the role each of these organizations might play in light of the new openness of the U.S.S.R. and Eastern Europe, will be undertaken in the 1990s.

ENTREPRENEURIAL STI AT NASA

NASA's STI services must be tailored to meet the needs of the NASA R&D activities. Instead of stating "these are the services we offer," we must ask the question "What are the services you need?" We must confirm that existing programs are needed and find innovative ways to implement new services. NASA STI managers and professionals have to play an aggressive role in working with the researchers to identify what services and information they need, and they must be flexible to implement unique services required by and paid

for by subsets of the R&D community. A big part of the cost of STI projects (as for any technical project) goes for developing software to support new approaches and to create network communications that work.

To provide STI services to researchers, NASA STI professionals must identify the services needed, determine development cost and time, and provide the appropriate program manager with the opportunity to fund the project so that the STI services they need can be developed in a timeframe that coincides with their programmatic requirements. Services developed in this manner will obviously have high usage because they will be developed to meet specific program-oriented goals. Integrating STI services into programmatic environments will ensure that STI services are an essential component of NASA R&D and that NASA receives the full benefit of being able to quickly identify relevant STI (past and present) and build that knowledge into current and planned R&D activities.

Analysis, planning, and management for such development projects must be formal, rigorous, and businesslike. Milestones must be projected for implementation and costs. Emphasis is on the bottom line: exactly what does the customer need and what is the most cost-effective strategy for meeting that need?

Program-oriented STI projects will bring NASA STI professionals in closer collaboration with NASA's R&D program managers because they will participate in the R&D process. The STI professional will become a partner in the program by devising information strategies tailored to assist programmatic success.

STI managers and professionals will continually improve their insight into the evolving needs, desires, and special characteristics of aerospace science and engineering. At the same time, the NASA scientists and engineers will become more and more attuned to what the NASA STI program can do for them. This partnership provides a foundation for accelerating the NASA R&D objectives.

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Technology Utilization: Managing the Transfer of NASA Aerospace Technology to Other Industries

LESTER J. ROSE*

In the legislation that established the National Aeronautics and Space Administration (NASA) in 1958, Congress directed that NASA provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof—for the benefit of all mankind. The objective of this language was to maximize the benefit of and realize a dividend on NASA's investment in aerospace research and technology and provide the most effective utilization of the scientific engineering resources of the United States.

NASA's response to this congressional mandate resides in the Technology Utilization (TU) Program, a multifaceted effort designed to facilitate the application of aerospace technology in both the public and private sectors. The program serves as a link between the innovators of technology and those who may be able to use it productively. Since 1962, NASA has stimulated the secondary applications of technologies developed initially for the agency's mainline programs through its TU program.

Impetus to NASA's technology transfer activities (and to that of other government research and development (R&D) labs as well) was provided in 1980 by passage of Public Law 96–480, often referred to as the Stevenson-Wydler Technology Innovation Act of 1980, and later amended to expand and further promote technology transfer by the Federal Technology Transfer Act of 1986 (Public Law 99-502) followed by Executive Order 12591, Facilitating Access to Science and Technology (April 10, 1987).

BACKGROUND

NASA (and its predecessor, the National Advisory Committee for Aeronautics (NACA)) has a long history of developing new aerospace-related technology and disseminating and transferring it to industrial customers. In the early agency days, the nation's aeronautical

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industry depended on NACA to supply research information and data to enable the industry to grow to a preeminent international position following World War II. In the late 1940s and 1950s, NACA continued its key role in the generation of new aircraft technologies by expanding its research activities to address problems of materials and propulsion and then to those in the transsonic, supersonic, and hypersonic flight regimes. There is little doubt that NACA-generated aircraft technology was a major contributor to the rapid growth of the U.S. aircraft industry and its subsequent economic impact.

The TU program has grown substantially in both content and scope since its inception. Initially organized as a means for disseminating NASA's new technology to the public and private sectors, its activities today include industrial outreach in the form of technology application centers and teams as well as applications engineering projects managed by NASA's installations. Figure 1 depicts basic attributes of the program.

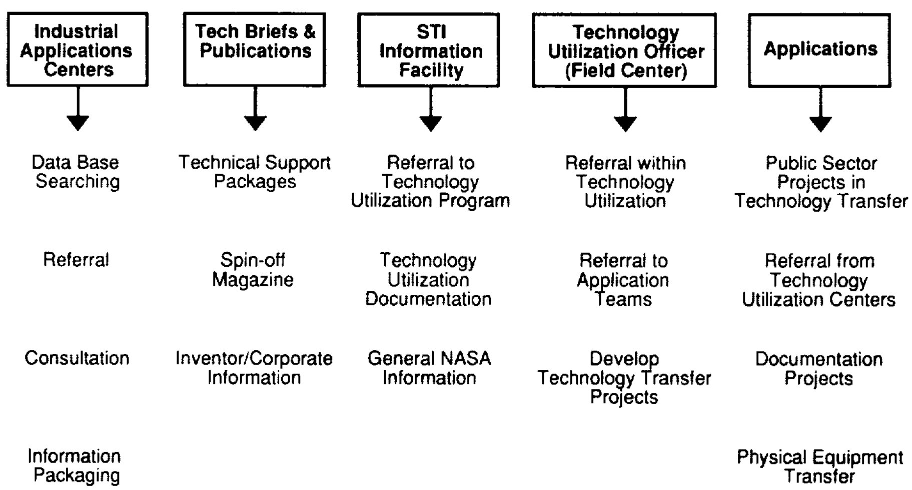

Figure 1. Attributes of the Technology Utilization System. (Adapted from McCarthy[1].)

Even with the right climate and the right organizational structure, the transfer of technology is far from effortless. It demands hard work on the part of both the purveyor and receiver for the transfer to be effective. It involves the use of technology developed for one purpose to satisfy a need elsewhere. It requires (1) the knowledge that an advance has occurred in one field; (2) the recognition of its significance and applicability in a different field; and (3) the capability to make the required adaptations.[2] The Weinberg report states that "transfer of information is an inseparable part of research and development. All those concerned with research and development—individual scientists and engineers, industrial and academic research establishments, technical societies, government agencies—must accept responsibility for the transfer of technology."[3]

NASA programs of the past three decades have created a vast repository of new technology that is available for use by industry to create new products and processes. It may be likened to a natural resource that can be mined and be put to work to enhance productivity and

competitiveness. Its importance is underscored by the more than 30,000 secondary applications of this technology—spinoffs—that have emerged to the benefit of the nation's economy and lifestyle.

PROGRAM DESCRIPTION

The TU program facilitates the transfer of this wealth of NASA technology. It encompasses the following four major activities:

1. Dissemination of new technology;
2. Industrial outreach;
3. Applications engineering projects; and
4. Repository services.

Dissemination of new technology. New technology information is broadcast via several elements of the program. One element, *NASA Tech Briefs,* is a monthly journal containing brief articles that describe innovative technology derived from research and technology activities in aeronautics and space science. *NASA Tech Briefs* articles are concise summaries of new NASA technologies written to inform a broad technical and management readership of possibilities for applications in the private sector. Approximately 700–800 new technology items are announced annually in *NASA Tech Briefs.* Current circulation is approximately 160,000 copies. The journal is published by a commercial house, with costs defrayed by advertising revenues. Subscription is free to qualified applicants.

Information supplementing that contained in an individual Tech Brief is often issued as a Technical Support Package (TSP); the TSP may be obtained from NASA upon request. The TSP is usually in report document format; where necessary, drawings, fiche, tapes, or film may serve as the medium. The report may be a standard NASA formal referenceable document or an informal report prepared to supplement a Tech Brief article. Requests for TSPs number more than 100,000 annually.

A listing of NASA's patented inventions available for licensing, more than 4,600 citations, is published semiannually in the *NASA Patents Abstracts Bibliography.* This compilation is published as a service to companies and individuals seeking new, licensable products for the commercial market. NASA inventions best serve the interests of the United States when their benefits are made available to the public. In many instances, the granting of nonexclusive or exclusive licenses for the practice of these inventions may assist in the accomplishment of this objective.

Hundreds of NASA software programs created for engineering and scientific design and analysis, which have potential for secondary uses, are maintained at NASA's Computer Software Management Information Center (COSMIC), operated by the University of Georgia at Athens, Ga. COSMIC is the central office established to distribute software developed with NASA funds. Its role as part of NASA's technology transfer network is to ensure that industry, other government agencies, and academic institutions will have access to NASA's advanced computer software technology. COSMIC operates as a business, making the programs available to the user community at a fraction of their original development cost.

Industrial outreach. The outreach segment of the TU program has developed over the years into an extensive network. The network encompasses the NASA installations sup-

ported by Industrial Applications Centers (IACs) and affiliates located in 34 contiguous states coast to coast, plus Alaska and Hawaii (Fig. 2). The system thus provides geographical coverage of the nation's primary industrial and public health concentrations as well as regional coverage of state and local governments engaged in technology transfer activities. The network's objectives are to uncover and delineate needs and problems within the industrial, biomedical, and public sectors and match them with NASA technology, and in certain cases to engage in cooperative projects with industry and other agencies to develop new products or processes derived from NASA innovations. The 10 NASA installations are supported in their outreach efforts by the IACs and affiliates, the Technology Application team, and COSMIC. Most of these IACs and teams are associated with or located at state universities.

Figure 2.

This combined network of NASA installations and applications groups offers public and private clients access to a vast storehouse of technical information drawn from the NASA databank and more than 400 other computerized databases, including the national research data bank of the Federal Laboratory Consortium (FLC) that links 500 federal R&D

laboratories. The technical expertise of staff engineers and scientists affiliated with each of the network organizations is also available.

Key elements of the technology transfer network are the TU Offices at the NASA installations. Their technical staffs keep abreast of new technology and innovations within NASA and actively pursue potential technology transfers to the private and public sectors. New technologies are documented, reported, and made available to the industrial and biomedical communities and to the public sector. The NASA installations conduct seminars, workshops, symposia, and conferences to disseminate aerospace technology to industry and actively support conferences for industry organized by the IACs.

Applications engineering projects. An important activity of the technology transfer function is the management and conduct of applications engineering projects. Such projects usually stem from requests for assistance with specific engineering problems that come from other government agencies or from industrial or biomedical consortia. The applications team and application centers maintain liaison with industrial and medical groups (e.g., National Institutes of Health, American Ceramic Society, Iron and Steel Institute) to seek out problems, particularly those which may be amenable to solution through the application of NASA technology. These projects are generally co-funded; NASA provides technical management as well.

An example of a recently completed applications project is a portable system for use in monitoring toxic wastes and water quality for the presence of pollutant elements of interest such as arsenic, lead, mercury, cadmium, and chromium. The system was developed for, and co-funded by, the Environmental Protection Agency (EPA) in a cooperative interagency project in response to an EPA requirement. The system is a spinoff from the technology used to characterize elements in the soil of the planet Mars on the Viking lander missions to the planet in 1976. The system was delivered to EPA in 1989.

Repository services. The entire technology utilization and dissemination process is supported by an enormous repository of information contained in NASA's scientific and technical information system (see paper by Wente, this issue). The system includes a computerized database of about 3 million documents covering a wide array of aerospace and related topics. It draws information from NASA, other government agencies, contractors, academia, and professional societies and organizations, as well as from more than 700 foreign organizations with whom the agency has exchange agreements.

Assessing the Program

A number of studies have been conducted in an attempt to quantify the program from a cost-benefit standpoint. A report that examined previous cost-benefit studies concluded that "the NASA Technology Utilization Program can be characterized as a public investment which creates growth by facilitating the secondary application of existing technology." Further, "Effective technology transfer, however, requires that potential users of technology must also invest in the process in order to realize the potential benefits that may result from its use."[4]

A recent study surveyed benefits from NASA-assisted technology transfer. Over 440 separate instances of the application of NASA-sponsored or NASA-provided technology were reviewed; 83 percent showed a contribution toward either savings or sales. There were 67 instances (18 percent of the 83 percent) in which a product, a process, or even an entire company was created from NASA-furnished technology.

The economical benefits of NASA's TU program are not easily quantifiable in monetary terms. More readily attributable benefits of the technology transfer process are that it

- provided knowledge or technology of a critical or valuable nature;
- created new opportunities;
- helped to meet competition;
- enhanced safety regulations and working conditions (i.e., quality of life); and
- helped avoid R&D "dead ends."

By themselves these latter benefits would indicate that NASA's TU program has been a valuable resource for the private and public sectors of the economy.

From Aerospace to Other Industries

The aerospace industry has reaped considerable benefits as a technological "borrower" in at least two specific ways.[6] Many of the significant innovations that have appeared in the commercial aerospace industry were originally developed for military application. The aerospace industry has also benefitted from technological developments in other industries, notably the metallurgical, materials, petroleum, and electronics industries. Often with support from NASA and the Department of Defense (DOD), the aerospace industry has helped create new industrial technologies that, in addition to their extensive use in aerospace, have ultimately strengthened many other U.S. industries. Examples of these technologies include turbochargers: devices for improving engine efficiency; fiber-reinforced plastics: a type of composite material with improved strength-to-weight and producibility characteristics; and computer-aided design and computer-aided manufacturing (CAD/CAM): a process for improving efficiency in design, analysis, and production. Cross-linkages among these three technologies have also emerged. CAD/CAM systems are being increasingly used to design and fabricate fiber-reinforced plastics (FRPs). FRPs are being used increasingly to make lighter, stronger turbocharger components, designed with CAD/CAM systems.

During the last quarter of a century, more than 30,000 spinoffs have emerged from NASA-developed and -sponsored aerospace technology. The spinoffs from the Apollo program alone are significant. Many of these secondary applications have been stimulated through the NASA technology transfer process to developments in various industries and numerous commercial applications in diverse areas such as health and medicine, public safety, consumer/home/recreation, agriculture, transportation, energy, and manufacturing technology. Two specific technologies are singled out for discussion.

In addition to the developments made in composites technology by American industry, NASA has stimulated developments in composites through its TU program that have led to further developments in other commercial applications. Following is a partial list of NASA "spinoffs" applications for composites, as identified by the Denver Research Institute by type of application:

Manufacturing Consumer Goods. Babcock and Wilcox Company used composite materials data compiled by NASA to design composite products used in golf club shafts and tennis rackets for Wilson Sporting Goods, and also to produce composite parts for business machines and computer manufacturers, such as Xerox.

Construction. Owens-Corning Fiberglass Corp., under contract to NASA, developed the first application for fiberglass fabric for the manufacture of nonflammable clothing and structures, including development of Teflon coating for fabric application experience used to develop commercial market; current uses include protective clothing and roofs and coated fabric used commercially in air structures developed by Bird-air Structures and Geiger-Berger & Associates.

Air Transportation. Friction characteristics of graphite and graphite-metal, developed for NASA, were used by B.F. Goodrich Company to develop new brake linings for commercial and military aircraft.

Health Services/Rehabilitation. Composite materials developed by NASA for aircraft and spacecraft applications are used to design lightweight leg braces that weigh 50 percent less than similar metal braces, provide improved mobility, are more attractive, and cost less to manufacture than metal braces.

The proliferation of different kinds of software for dynamic structural analysis among various design and engineering groups prompted NASA to fund the development of a standardized package to be used to obtain reliable and consistent results in a wide range of aerospace applications. The result is NASA Structural Analysis (NASTRAN). The major components and related computer applications have been adapted by several non-aerospace industries to meet various design requirements. The Denver Research Institute documented the following cases of significant NASTRAN use:

Eastman Kodak used NASTRAN to design buildings and production equipment for chemicals, plastics, and fibers and to analyze stress in piping systems wind load on exhaust stacks and vibration of processing equipment.

Walt Disney World used NASTRAN to design the support structure for the Mountain and Big Thunder Railway roller coasters at Disneyland and Disney World.

The Ford Motor Company used NASTRAN for design analysis of car, truck, and farm tractor components and has reported substantial material and manpower savings.

The General Motors Corporation used NASTRAN as an analytical tool in its new-car program and reported significant average weight reduction and more efficient body structure for its front-wheel drive cars.

CONCLUDING REMARKS

Economic growth is thought to be highly correlated with spending for R&D. The expenditure of approximately $60 billion for R&D by the U.S. Government, rather than by private industry, has been viewed by some as a possible inhibitor to economic growth; however, there is general agreement that the results of federally funded R&D have the potential to increase the nation's competitive position in the world marketplace. The evidence of this inhibition is inconclusive, however, since the federal government often conducts long-term R&D in high risk areas where commercial enterprises fear to tread. Thus new technologies may develop more rapidly through federally funded R&D than if left to the private sector (which generally funds R&D that is not high risk and has a 3–5 year payoff). It then falls to the federal government to develop the appropriate transfer mechanisms to ensure that the results of federal R&D find their way to industry. Such a requirement, however, places technology transfer at the federal level in a larger context framed in the following manner:

1. Since the United States devotes a significant portion of its resources to federally funded science and technology, it has at least a de facto science and technology policy. Does the United States need, or should it have, a coordinated policy concerning the transfer of technology resulting from federally funded R&D?

2. If so, what should be the distribution of responsibilities between the public and private sectors in transferring the results of federally funded R&D?

3. What is known about the transfer of federally funded R&D? Can the transfer of technology from federally funded R&D programs be encouraged by a program designed to do precisely that?

4. If the answer to question 3 is yes, what pace of technology transfer can or should take place or should be encouraged?

This is not the proper forum to consider these questions. However, it is not unreasonable for those Federal agencies that spend R&D funds to devote some attention and portion of their R&D budget to knowledge transfer and utilization. At the Federal level, knowledge transfer and utilization should be viewed as an integral part of the agency's mission.

Finally, the transfer of aerospace technology to U.S. industry has been widely advertised as an integral and necessary result of the public's investment in aerospace R&D. By congressional mandate it is NASA's responsibility to promote the transfer of technology resulting from its R&D activities.

In the 27 years of the TU program, efforts to transfer this technology have resulted in tens of thousands of applications. Some offer only moderate increments of economic gain or lifestyle improvement; others have substantial economic value. Collectively, they represent a substantial return on the U.S. aerospace R&D investment in terms of economic competitiveness, industrial productivity, and the health and well-being of the nation.

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The naming of manufacturers in this article is for accurate reporting and does not constitute an official endorsement, either expressed or implied, of such manufacturers by NASA.

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NASA's Educational Programs

ROBERT W. BROWN*

NASA's role in aeronautics and space research and development has resulted in many referring to NASA as an education agency. They say this because of the mandates in the Space Act to expand human knowledge of space, to arrange for participation in space endeavors by the scientific community, and to disseminate information to the widest practicable audiences. Aeronautics and space topics have long been known to be a magnet for learning. Today, with the increased attention on educating our citizens, NASA hopes to assist the educational community in the use of this magnet through its educational programs.

To achieve this goal, the Educational Affairs Division has designed educational programs to capture students' interest in science, mathematics, and technology at an early age, and to maintain their interest throughout higher learning. At the high school and university levels, these educational programs seek to channel more students into engineering and science careers. For teachers and university faculty. NASA's educational programs recognize the importance of upgrading knowledge, skills, and experience.

Excellence in education becomes more important than ever as NASA continues Space Shuttle operations and begins construction of Space Station Freedom, a permanently manned space station.

The national goals that will extend U.S. leadership include a permanent lunar base, expeditions to Mars, and extensive exploration of our solar system. Meeting these goals, however, will require years of planning and preparation. Intensive research and technology development in robotics, automation, space sciences, life sciences, space transportation, and many other areas must take place. Such research and development depend on a well-educated workforce. A large pool of highly motivated, talented workers must be developed and available. Action must be taken now to ensure that our youth are equipped with the educational tools they will need. This effort will require the cooperation of government,

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industry, the educational community, and the public. NASA will continue to play a pivotal role in the development of this workforce through its Educational Affairs Division and its installations.

PIPELINE ISSUES

In the Educational Affairs Division, much of our attention is occupied by trying to keep the "pipeline" of science and engineering students filled. These same issues preoccupy other organizations throughout the country. Significantly, the United States is faced with:

- a decline in the number of students who choose science and engineering careers;
- a low level of literacy in science and mathematics for our middle- and high-school students compared with similar-level students in other industrialized countries;
- a declining proportion of 18- to 24-year-olds who represent the traditional college students;
- a projected 36 percent increase in scientists and engineers needed by the year 2000;
- a large increase expected in the early 21st century in under-represented minorities and women, a group not traditionally drawn to the physical sciences and engineering; and
- a decline in the proportion of U.S. citizens pursuing Ph.D.s in science and engineering, compared with an increase in foreign nationals pursuing these advanced degrees from American universities.

These issues are compounded when one takes a close look at the poor preparation our teachers receive. For example, the 1983 Yearbook of the National Science Teachers Association reports that nearly one half of all high-school science teachers have never had a course in computer science or calculus. It further states that only one-third of all elementary science teachers have taken a college chemistry course, and that only one-fifth have had a course in physics.

NASA AEROSPACE EDUCATION PROGRAMS

Covering fiscal years 1988 through 1992, the Educational Affairs Division's Five-Year Plan provides the framework for NASA's overall aerospace education program. It encompasses our developmental planning in elementary education, teacher education, university programs, educational partnerships, and emerging educational technologies. The five-year plan states critical objectives for increasing the teaching of space science and technology in elementary and secondary schools, development of educational partnerships, the new Space Grant College and Fellowship Program, ambitious goals for reaching increasing numbers of under-represented minorities, and strategies for improving the longstanding and immensely popular Aerospace Education Services Program, commonly known as the Spacemobile Program.

In August 1988 an agencywide inventory of NASA educational programs was completed. Using data from 1987, the inventory revealed that NASA administers 162 aerospace education programs and projects, which cover elementary, secondary, university, and post-graduate levels. These programs reached more than 6 million participants with the annual cost for all programs at almost $64 million.

Some of our educational programs are designed to address specific pipeline issues, such as how to capture a student's interest in science, mathematics, and technology at an early age and grade level. In the late 1950s, the United States was also concerned with increasing interest in mathematics and science education, but focused energies on students at the secondary level. Since then we have learned that if students do not develop a significant interest in these subjects by the third or fourth grade, their prospects of developing an enduring interest diminish over time.

Our aerospace education programs typically seek to channel more students at the junior and senior high and undergraduate levels into science, engineering, and related career paths. For university graduates and post-graduates, our focus is on attracting and retaining students in critically needed aerospace disciplines, and for teachers and university faculty, we strive to upgrade their knowledge, skills, and experiences.

Pre-College Student Programs

The Aerospace Education Services Program (AESP), or Spacemobile as it is better known, was initiated in 1961. The program gets its name from the fact that its corps of 26 aerospace education specialists drive specially equipped NASA vans to elementary and secondary schools around the country. At the schools, these specialists conduct school assemblies, give classroom lectures, conduct teacher inservice and preservice workshops, and hold community education enrichment programs. They use models of the Space Shuttle, rockets, and satellites, as well as actual spacesuits and space food. They also use interactive computers and laser disc players.

During fiscal year 1988, the Spacemobile Program reached 876,000 students and 27,700 teachers through 4,200 assembly programs. Specialists visited 3,000 classrooms in 1,900 schools, and conducted 1,600 teacher workshops. Unfortunately the extensive demand for Spacemobile visits and the current funding limit, which keeps us at 26 specialists, means that a school requesting a Spacemobile visit could have to wait anywhere between two and four years.

The Urban Community Enrichment Program (UCEP) is conducted by a small subset of the aerospace education specialists. By working collaboratively with up to 20 schools in an urban area for up to eight weeks (or a semester) at a time, these aerospace specialists conduct a program that reaches out to an entire community.

The Summer High School Apprenticeship Program (SHARP) is designed for academically superior under-represented minority students. The program provides selected students eight weeks of summer employment at NASA installations under the mentorship of a NASA scientist, engineer, or other technical specialist. Over the past eight years the program has averaged 150 students a year and has been one of NASA's most effective programs. Nearly all of the students graduate from high school, attend college, and major in science, engineering, or other disciplines germane to NASA's interests. Many who have since graduated from college are either working professionally in aerospace fields or attending graduate schools.

The Space Science Student Involvement Program (SSIP) is a partnership program administered through a contract with the National Science Teachers Association (NSTA). The program is designed to encourage students in grades 6 through 12 to develop aerospace-related experiments and to compete for an opportunity to have their experiments tested

by NASA. During the 1987–1988 program year, 1,945 students submitted entries, and many who reached the regionals were called upon to defend their proposals before a team of NASA scientists and engineers. The competition resulted in 11 national winners at the senior-high level and three national winners at the junior-high level.

SSIP also reaches thousands of students who do not submit formal entries. They are exposed to the program by the creative teachers, who incorporate aerospace concepts and materials into classroom activities. SSIP's Mars Settlement Illustration and Journalism competition also involve students in aerospace activities.

The program's immediate predecessor, the Space Shuttle Student Involvement Program, has permitted 19 student experiments to fly on the Shuttle. The final two Shuttle experiments were on board STS-29. They investigated animal bone healing in weightlessness, and the effects of space flight on the development of fertilized chicken embryos. President Bush invited those students, their faculty advisers, and commercial underwriters to the White House for special recognition, along with the STS-29 astronauts.

The NASA Orbiter Naming Program was initially sponsored by Congressman Tom Lewis (R-Florida) in March 1986 and authorized by Congress in October 1987. The legislation called for the name of NASA's replacement orbiter to be selected from suggestions submitted by students in elementary and secondary schools. Its purpose was to increase students' interest and enthusiasm for space exploration, research, and discovery.

NASA consulted other federal agencies and educational associations in designing the clear educational content of this program. Over 71,000 students representing 6,100 teams, each led by a school faculty member, entered the national competition. They prepared and submitted interdisciplinary classroom projects to justify the name they proposed. The winning name, selected by President Bush, was Endeavour, the name of the ship James Cook sailed to explore the South Pacific and the Antarctic in the 18th century. It was the name entered by both the winning elementary and secondary teams. The winning teams were from Senatobia, Miss., and Tallulah Falls, Ga. They were honored, along with their faculty team coordinators, by President Bush in a White House ceremony on May 16, 1989, along with the STS-30 astronauts.

The Space Exposed Experiment Developed for Students (SEEDS) will allow students from grade 5 through the university level to determine what effects the weightless environment of space has had on tomato seeds orbiting Earth since April 1984. The 12 million Rutgers tomato seeds aboard the Long Duration Exposure Facility (LDEF) are the crucial components of the program. The Space Shuttle has now retrieved LDEF, and the seeds will be distributed to the more than 116,000 teachers who have registered for the program. Participants will also receive a set of control seeds that have not been in space. Students will compare the two sets of seeds when studying germination and plant growth rates, the number and size of tomatoes produced, the effect of soil types on plant growth, and more advanced experiments involving chromosome mapping and enzyme and hormone tests. This program represents an educational partnership between NASA and the Park Seed Company of Greenwood, S.C.

Teacher Education Programs

NASA conducts workshops and programs designed to increase the knowledge, skills, and experience of teachers. For example, the Spacemobile Program, besides its student

workshops, supports a number of teacher education programs. During the 1988 school year more than 1,600 workshops were conducted involving 27,700 teachers.

The NASA Education Workshops for Mathematics, Science, and Pre-college Technology Teachers (NEWMAST) and the NASA Education Workshops for Elementary School Teachers (NEWEST) are specialized aerospace education programs for teachers. Designed for high school and elementary teachers, respectively, these honors workshops provide a two-week structured experience for 215 teachers under the tutelage of NASA scientists, engineers, and education specialists.

Drawing upon the science and technology resources of these facilities, teachers develop classroom curriculum materials to use at their schools when they return. Some lesson plans have used information about the Apollo landing sites to enable students to read polar coordinate systems and to identify locations by latitude and longitude. Other lesson plans have taught mapping skills and grid coordinate systems by helping students correlate Landsat images with conventional road maps. The Space Station Freedom mock-up at Marshall Space Flight Center was used by some teachers to help their students design and construct a habitation module for a space station.

NASA's Teacher Resource Center Network provides teachers access to a variety of aerospace materials such as videotapes, slides, audiotapes, publications, lesson plans, and activity plans. Resource rooms were first developed at each of NASA's nine field installations, and their success led to the development of a series of Regional Teacher Resource Centers across the country, usually located at universities. Regional centers are coordinated by the Central Operation of Resources for Educators Center (CORE), and in fiscal year 1988 they served over 60,000 teachers.

The Teacher in Space Program is another extremely important and active element in our teacher education programs. Barbara Morgan, NASA's Teacher in Space Designee, remains under contract to the Educational Affairs Division while teaching part-time at McCall-Donnelly Elementary School in McCall, Id. Since the Challenger accident, this intelligent, dedicated, and energetic teacher has made over 200 educational appearances to schools, universities, professional societies, civic organizations, and other groups. We hear from teachers around the world, who feel that their status as teachers has been enhanced through identification with the pioneering images of Christa McAuliffe and Barbara Morgan.

NASA remains committed to long-term opportunities for persons outside the professional categories of Astronaut or Payload Specialists to experience space flight, especially when it contributes to our approved objectives or is in the national interest. When the time comes that NASA determines a flight opportunity is available, first priority will be given to a Teacher in Space in fulfillment of space education plans.

In the meantime, Barbara Morgan and many of the 113 Teacher in Space Ambassadors actively conduct a variety of aerospace activities, which is what the program is really about. For example, Barbara Morgan is involved in a nationwide effort with the National Congress of Parents and Teachers (National PTA) to promote mathematics education. Some of the ambassadors are engaged in developing classroom activities that promote space science and technology. Still other ambassadors conduct public television programs that use aerospace topics.

NASA Educational Publications represent the primary resource for teachers who seek current, accurate information about aeronautics and space research and development. These publications bring aeronautics and space activities to the teacher for use in the classroom.

An average textbook takes from 5 to 7 years to produce, whereas a NASA educational publication is usually available in 5 to 7 months. Teacher and student demand for NASA educational publications is intense. Many titles are quickly exhausted and must be reprinted to keep pace with demand. The most popular titles include *A Meeting with the Universe, What's New on the Moon, How We Get Pictures from Space, Space Mathematics, This Is NASA, Aerospace Careers, Space Station: The Next Logical Step,* and educational wallsheets on Space Shuttle and Spacelab.

We distribute our publications to mailing lists that include more than 80,000 educators. Most of our educational publications are also sold by the Superintendent of Documents, U.S. Government Printing Office. Sometimes commercial publishers produce and distribute our publications at no cost to NASA. We are continually seeking new avenues to reach the widest possible audiences for our books and other materials. We actively seek and develop partnerships with other government agencies and commercial publishers.

Educational Technology promises new methods to deliver aerospace services and information. For the past 2 years, for example, we have conducted eight interactive satellite videoconferences for elementary and secondary teachers. These 1-hour videoconferences covered such topics as the Hubble Space Telescope, Space Station Freedom, Aeronautics, Living in Space, Future Exploration, Launch Vehicle Preparation, and Technology for Your Classroom. Receiving sites ranged from a one-room elementary school in Alaska with a receiving dish, to a state satellite network in Missouri. PBS stations in Los Angeles, Calif., and Norfolk, Va., also received the transmissions and rebroadcast them. At a videoconference, aerospace educators present demonstrations and lectures on a particular topic and teachers call in with questions. The events are downlinked to more than 400 sites and have so far reached about 2,000 schools and 20,000 teachers.

NASA Spacelink, an electronic information system for educators, is another of our educational technology programs. NASA information and educational materials are stored in a computer file at the Marshall Space Flight Center in Huntsville, Ala. Spacelink can be accessed over a regular telephone line, and is designed to communicate with a variety of modems and computers, especially those most commonly found in classrooms and homes. The only charge to the user is the cost of a telephone call to Huntsville. Established in February 1988, Spacelink received 14,200 calls during its first year of operation. Each call averaged 8 minutes.

The Aerospace Education Software Directory is an inventory of commercial and public domain computer software on aerospace education programs. The publication lists software intended for grade 3 through the university level. Topics include astronomy, aeronautics, aerospace physics, manned space exploration, rocketry, and satellites.

UNDERGRADUATE, GRADUATE, AND UNIVERSITY FACULTY PROGRAMS

The NASA Graduate Student Researchers Program, with its Minority Graduate Program component, and the NASA/NRC (National Research Council) Resident Research Associateship Program are two of NASA's larger programs administered for graduate students, postdoctoral researchers, and university faculty. Although these programs provide fellowship and research opportunities to approximately 600 graduate students and university faculty, they are exclusive of NASA's larger relationship to the university community.

The Baccalaureate Cooperative Education Program, which is NASA's single largest undergraduate program, is a partnership between NASA and many of the nation's colleges and universities. Cooperative education (co-op) integrates college-level study with periods of meaningful, full-time work. This is achieved through agreements between NASA installations and certain universities in which students enhance their academic knowledge, personal development, and professional preparation. Approximately 940 undergraduates participated in the fiscal year 1988 co-op program.

The NASA/USRA (Universities Space Research Association) University Advanced Design Program is a similarly large, but different, undergraduate program. It is directed primarily at undergraduate senior engineering students and intended to heighten enthusiasm for design within the engineering curriculum; to produce innovative advanced designs in aeronautics and space; and to encourage U.S. students to seek graduate study or employment within aerospace fields. Currently, 36 universities and 8 NASA installations participate. During the year, students work on 21st-century design problems such as a lunar storage and transfer system or long-term space habitats. Students present their design projects to each other and to NASA officials at a summer conference. After the conference, graduate teaching assistants spend a 10-week internship at a NASA center to plan the next semester's course.

The NASA/American Society for Engineering Education Summer Faculty Fellowship Program has a direct impact on undergraduate students although it is not an undergraduate program. Each summer, approximately 250 university faculty members spend 10 weeks at NASA installations conducting research on topics of mutual interest, with about 10 percent of their time spent at seminars. The program is designed to enhance career development of university faculty, particularly those from smaller institutions without extensive research facilities. Participating faculty return to their institutions with new knowledge to incorporate into coursework and additional research opportunities for students. A follow-up study conducted in 1987 on the program between 1981 and 1985 showed that participants were able to support more than 300 undergraduates with research grants and that almost 52,000 students benefited from participants' experience through new courses or course material.

University Programs also include the many small and specialized programs that NASA sponsors. For example, 17 students participate in the Ames Work Engagement Program for Scientific Technicians and 10 students take part in the Jet Propulsion Laboratory's Planetary Geology Undergraduate Researcher Program. Specialized programs, such as minority outreach, are designed to augment the nation's engineering and science work force by helping to eliminate under-representation of minorities, women, and the handicapped. An example is the Xavier University Engineering Bridge Program, in which 46 black students prepare for an engineering curriculum. Another program, the Recruitment and Retention for Excellence in Engineering, supports 17 Hispanic and 3 Native American students at the University of New Mexico. In addition, more than 200 undergraduate and graduate students through the Historically Black Colleges and Universities (HBCU) program are given opportunities to work in a research environment at NASA installations. Besides the obvious advantages to the students, the program increases the relationship and the involvement of HBCUs in NASA-sponsored research.

The Space Grant College and Fellowship Program is NASA's newest university program, and will eventually serve many undergraduate and graduate students. The program was mandated by Congress in 1987, which directed the program to:

- establish a national network of universities with interests and capabilities in aeronautics, space, and related fields;
- encourage cooperative programs among universities, aerospace industry, and federal, state, and local governments;
- encourage interdisciplinary training, research, and public service programs related to aerospace;
- recruit and train professionals, especially women and under-represented minorities, for careers in aerospace science, technology, and allied fields; and
- promote a strong science, mathematics, and technology education base from elementary school through university.

Up to 12 space grant colleges or consortia will be selected via a competitive, peer-reviewed process in 1989.

COORDINATION OF AEROSPACE EDUCATION ACTIVITIES

We realize that NASA does not have sufficient resources to enhance the teaching of science, mathematics, and technology in the nation's schools by itself. We believe that if aeronautics and space concepts are to have some presence in this country's 83,000 elementary and secondary schools, with 45 million students and 3 million teachers, and the 12 million students and faculty in higher education, we must form educational partnerships. This is one of our greatest challenges because successful partnerships do not magically materialize, and it is much easier to talk about them than to actually engage in the meaningful coordination that is required to develop them.

To date, our programs are best characterized by three types of coordination. The first type of cooperation is with organizations that operate aerospace programs for us through grants or contracts. Such arrangements include the National Science Teachers Association, Oklahoma State University, the Universities Space Research Association, TRESP Associates, American Society for Education Engineering, the National Research Council, and the Council of Chief State School Officers. These are our strongest coordination efforts.

Our second coordination effort is with other nonprofit education organizations. They include the Challenger Center for Space Science Education, the Young Astronaut Council, the Astronauts Memorial Foundation, the U.S. Space Foundation, the Alabama Space and Rocket Center (U.S. Space Camp), and the Science Service. Our relationships with these groups are relatively new, but we are increasing them.

Finally, coordination efforts are made with other federal agencies. One example is our strong partnership with the National Air and Space Museum. We have also worked closely with other Federal agencies such as the National Science Foundation, the U.S. Department of Education, the Department of Energy, the Department of Defense, and the Federal Aviation Administration.

Partnerships are also being established between corporate leaders and educators. NASA believes these efforts are vital, especially in science, mathematics, and technology. We are, therefore, beginning to work with the aerospace industry to replicate proven models.

The Industry Initiatives for Math and Science Education (IISME) is one such model.

This 5-year-old program results from a consortium of San Francisco area educators and employers, including the NASA Ames Research Center. IISME gives science and math teachers a chance to step into the business world each summer. More than 270 teachers have participated in the program, translating their research into schoolwork and influencing some 40,000 students each year.

By teaming with aerospace contractors, NASA has under review a plan to help replicate this industry initiative. A consortium, composed of a NASA installation and local businesses, would be established near each of the NASA installations. It would provide structured summer employment for teachers. We are discussing this effort as a partnership opportunity with the Triangle Coalition for Science and Technology Education. Costs would be funded by the National Science Foundation with some help from NASA.

In addition, we plan to encourage aerospace employees to consider second careers in science, mathematics, and technology teaching. This supports President Bush's program to encourage alternative certification, which would allow talented Americans from every field to teach in America's classrooms. As a result of recent orientation sessions at the NASA Goddard Space Flight Center, several federal and contract engineers are now taking education courses in preparation for certification and a retirement career in science and mathematics teaching.

However, there are some disincentives to participate in this program. First, such employees may not be given administrative leave to attend their certification courses, nor to meet the requirements for observation and practice teaching time. Annual leave or other personal leave must be taken for these periods. Tuition is another problem because certification courses are not related to current duties and personnel may not be compensated.

A third inhibitor is the federal tax law. It discourages those engineers and scientists who might volunteer to become science, mathematics, and technology teachers. The tax law will not allow the deduction of tuition expenses because the required education courses are unrelated to current employment. The tax law also taxes stipends, should any of these employees decide to pursue graduate study and obtain fellowships after retirement.

It is clearly beyond NASA to recommend the resolution of these problems, and reasons not to make changes may exist. However, as long as these conditions do exist, efforts to encourage retiring scientists and engineers to prepare for second careers in teaching are unlikely to succeed.

Our experiences during the first 2 years of our five-year plan for aerospace education signal the need to accomplish a more strategic impact, rather than a greater volume impact on the nation's science, mathematics, and technology education system. The current constrained budget environment forces us to focus on activities that make the broadest and most effective impact.

Future Plans

As Lennard A. Fisk, NASA's Associate Administrator for Space Science and Applications, has testified, we will launch 36 science missions in the next five years. And if we are smart, we will use these missions to conduct the biggest and most public science and engineering lesson ever for the youth of this nation. Each mission will reveal a different and wondrous aspect of science—whether it is in planetary exploration, or in material and life science research. And each is an engineering marvel. Let the youth of our nation learn

from what we are doing and be inspired to do better in their generation.

President Bush best summed up our space goals in his July 20, 1989, address from the steps of the National Air and Space Museum to honor the 20th anniversary of the first lunar landing. He said, space is the inescapable challenge to all the advanced nations of the Earth. And there's little question that, in the 21st century, humans will again leave their home planet for voyages of discovery and exploration. What was once impossible is now inevitable.

The time has come to look beyond brief encounters. We must commit ourselves anew to a sustained program of manned exploration of the solar system—and yes—the permanent settlement of space. We must commit ourselves to a future where Americans and citizens of all nations will live and work in space. Our goal is nothing less than to establish the United States as the preeminent spacefaring nation.

To advance our aerospace education programs, we would like to:

- modify, but retain, the priorities of our five-year plan, namely, elementary education, teacher education, university programs, the Space Grant College and Fellowship Program, under-represented minorities, educational technology, Spacemobile Program, and educational partnerships;
- design and structure some of our pre-college programs as demonstrations to test different approaches, assess outcomes, document results, and disseminate findings for adoption by others;
- use NASA's newly emerging Space Grant College and Fellowship Program as a model to promote partnerships and cooperation among universities, federal, state, and local governments, and aerospace industry to encourage and facilitate the application of university resources to aerospace and related fields;
- seek opportunities for joint and coordinated funding and programs between NASA and the National Science Foundation, the Department of Education, and other federal agencies;
- expand the Spacemobile Program by establishing a spacemobile for each state with justifiable school population and distribution. Diversified approaches and experimental projects among the states will be used to assess the effectiveness of motivating more student and teacher interest in science, mathematics, and technology;
- target colleges of education to support a set of pilot projects to teach future educators how to infuse aeronautics and space concepts into the existing curriculum of any school system in which they may be employed;
- establish a wide talent pool of technical writers to produce, for NASA's dissemination, modular sets of supplementary curriculum materials featuring aeronautics and space. The materials will be drawn from NASA's aeronautics, space science, and technology missions and activities and tailored to specific school courses and subjects. The science and engineering expertise of the Astronaut Corps will be a key resource;
- implement the proposed National Scholars Program (NSP), which is designed to produce 320 Ph.D.s from under-represented minorities in science and engineering by the year 2000; and
- continue to demonstrate alternative uses of technology to deliver aerospace education services to teachers and students.

CONCLUSION

We are convinced that the aeronautics and space program represents a powerful magnet for learning. The range of aerospace education programs and activities that NASA has established for elementary through postgraduate school helps to expand students' interests in science, mathematics, and technology. Through our teacher education programs, NASA enriches other academic subject areas as well.

In anticipation of Space Station Freedom, a permanent lunar base, manned Martian expeditions, and the projected series of planetary missions and other aerospace developments, our students will be exposed to a rich set of incentives to help prepare them for key roles in this nation's future work force. NASA's educational efforts will be further strengthened by partnerships with other federal agencies and both public and private organizations.

NASA's relationship with the educational community has been a long and beneficial one. Our programs are many and diverse. In one dimension, certain programs contribute directly to NASA's research into problems of flight within and outside the Earth's atmosphere. In a second dimension, other programs integrate the knowledge derived from aerospace research and development into the educational system at all levels—elementary through postgraduate. What is significant, however, is not the size or number of individual programs or projects, but their diversity and how each contributes to the mission of the National Aeronautics and Space Administration and, therefore, to the United States civilian aerospace effort.

Legal Ramifications of Intellectual Property

ROBERT F. KEMPF*

The dissemination of federally funded scientific and technical information (STI) is an important function of all federal agencies. Because of its value, STI can be protected as intellectual property. Under this protection, constraints, controls, and exclusivity may be imposed on the use, reproduction, disclosure, and further dissemination of the information. While protection as intellectual property has always been possible and has been applied to some degree, government policies have changed drastically in recent years to encourage, if not actually require, more intellectual property rights protection of federally funded research and development (R&D) activities. This article discusses some of the reasons behind these changes and the effect of the changes on the more traditional approaches to the dissemination of federally funded STI; it includes predictions as to what may occur in the future.

THE DISSEMINATION CULTURE

The widespread dissemination of the results of R&D activities is an important function of many federal agencies and is authorized, if not actually mandated, in the organic statutes of many agencies. For example, section 203(a)(3) of the National Aeronautics and Space Act of 1958, as amended (42 U.S.C. 2473(a)(3)) directs NASA to "provide for the widest practicable and appropriate dissemination of its activities and the results thereof." The dissemination of STI is also influenced by the Freedom of Information Act (FOIA), which has been interpreted and applied to include such information within its ambit.[1] The rationale behind these dissemination statutes and their implementing policies and procedures stems from a combination of an historical openness-in-government society; an educational philosophy based on a free exchange of ideas, particularly in relation to basic and applied

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research; and straightforward populist attitudes to the effect that if the public pays for it, then the public owns it. In addition, many federal agencies, in carrying out their missions and program objectives, have developed strong relationships with their user constituencies to ensure that the results of research activities of mutual and beneficial interests are freely and openly exchanged.

Thus, an extensive infrastructure has evolved within the federal government for the documentation, reporting, evaluation, cataloging, and dissemination of scientific and technical information generated by, or under the support of, federal laboratories. Detailed descriptions of this infrastructure have appeared in this journal and elsewhere. For the purpose of this article, it is sufficient to note that the source of the scientific and technical information that is entered into this infrastructure may be a contractor or grantee whose R&D activities are funded by the federal government or a civil service employee conducting R&D activities in the course of her or his official duties. Consequently, the STI involved is the result of federal funding and therefore, if the free and open dissemination culture were carried to the limit, would automatically be placed in the public domain.

However, national priorities and policies with respect to the dissemination of federally funded STI from either source are in a state of flux and are changing at an accelerated pace in the direction of preventing (or delaying) certain categories of STI from being placed in the public domain. The reasons for the changes are derived largely from the reality, or perception, of the declining capabilities of the United States in international competition—and more specifically from an assessment that, although the United States has been and probably still is the world leader in basic and applied research, it is falling behind its serious international competitors in the practical application of research results to the actual products and processes necessary to compete in world markets. Since more than 50 percent of the R&D activity conducted in this country is federally funded, it is not surprising that funding policies should be modified to increase the potential for applying the research results to practical products and processes in an effort to increase our ability to compete internationally. In this context, it is important to note that the changes occurring are not to prevent the transfer of federally funded STI to the U.S. private sector or to unduly inhibit dissemination within the United States, but to limit or channel such transfer in a manner that will provide greater benefit to the U.S. economy in the face of accelerating foreign competition for high-technology markets. Also, these changes have been directed to the transfer of detailed technical information that may be applied to practical products and processes having commercial potential. The overall philosophy concerning the dissemination of basic scientific information funded by the federal government has not changed. While the ends of the spectrum may be readily identified, there is a band in the middle where the distinction between basic scientific information and detailed technical design information is not clear. There is, however, a point at which some STI may be considered "technology" or a "resource" suitable for transfer and application to practical products and processes of economic value in international competitive markets; as such it can be protected as intellectual property as an incentive for private investment in the transfer process. When this occurs, the technology may be subject to restrictions on further dissemination, reproduction, and use that are at odds with the more traditional open and free dissemination policies and practices. Consequently, there is an increasing need to integrate the government's policies and practices for the dissemination of its scientific and technical information with the technology transfer process in this changing environment.

Technology Transfer Considerations

The process of technology transfer has been, from its inception, a process that is often praised in the abstract, frequently encouraged by actual conduct, and sometimes mandated by statute, executive order, or regulation. Its purpose and the government's role are often misunderstood. This has resulted in two divergent philosophies regarding technology transfer, sometimes referred to as technology transfer "plus," and technology transfer "minus." The former focuses on making federally funded technology available to the private sector for commercial use; the latter is directed to restricting availability under the export control laws and regulations or for national security reasons. We address here some of the issues involved in the relationship of intellectual property rights to technology transfer "plus."

While the term technology transfer still has no universally accepted definition, it is generally understood by its practitioners and advocates (or even detractors) to mean the process of making the results of federally funded R&D activities available for the beneficial use of a specific user constituency, to solve a specific problem by any recipient, or to produce some practical and marketable commercial product or process. Beyond this broad meaning, most operative definitions are limited in terms of the general effect of the transfer (i.e., detrimental to national security, useful in international competition or in furtherance of agency mission objectives, or having the potential for secondary or "spinoff" application); the specific purpose of the transfer (i.e., for the beneficial use of a particular user constituency, to solve a specifically identified problem, or to improve an existing product or process); or by the transfer mechanism.

It is the consideration of the transfer mechanism, in the context of the type of technology involved and the purpose of the transfer, that has had the greatest effect on federal agency policies, procedures, and practices relating to the acquisition, evaluation, and dissemination of STI. While the transfer mechanisms may be multifaceted and overlapping, typical among them are formal publication and distribution programs; informal contacts and exchanges between agency personnel and specific user groups; formally structured cooperative research and development activities; and the allocation, protection, and licensing of intellectual property rights.[2] The changes that have occurred during the last decade to address international competitiveness issues have resulted in definite shifts in the direction of greater emphasis on cooperative R&D activities, and on the protection and licensing of intellectual property rights. At the same time there has been somewhat less emphasis on the more traditional publication and dissemination mechanisms. In any event, the increased emphasis on cooperative R&D, coupled with greater protection and licensing of intellectual property rights, if not understood and coordinated, could in some instances be in conflict with the established and traditional agency policies, procedures, and practices under formal publication and distribution programs. It could also inhibit some of the informal contacts between agency personnel and specific user groups.

This need not be so; if the interrelations of all transfer mechanisms are better appreciated and coordinated, all transfer mechanisms can coexist and can mutually foster beneficial use of federally funded technology by the U.S. private sector, while at the same time not inhibit the dissemination of the results of basic or applied research. Coordination and flexibility are key elements, since selectivity, timing, feedback, and mutually agreed-upon actions can avoid conflicts between cooperative research and development activities or the protection of intellectual property rights on one hand, and an agency's more traditional policies and procedures for the publication of STI on the other.

The Intellectual Property Nexus

Two laws (including rather significant amendments) enacted during the past decade and an Executive Order directly relating to them have been primarily responsible for the shift in emphasis to cooperative R&D activities, as well as to the allocation, protection, and licensing of intellectual property rights as important technology transfer mechanisms.

The first law is Chapter 18 of Title 35, United States Code, enacted as Public Law (P.L.) 96–517 in 1980. It is commonly known as the Bayh-Dole Act. The second is Chapter 63 of Title 15, United States Code, enacted as P.L. 96–480, also in 1980. It is commonly known as the Stevenson-Wydler Technology Innovation Act of 1980, or simply the Stevenson-Wydler Act. The Stevenson-Wydler Act was amended in several significant ways by the Federal Technology Transfer Act of 1986 (P.L. 99–502), now usually referred to as the Technology Transfer Act.

The Bayh-Dole Act ensured that contractors and grantees that are small business firms or nonprofit organizations shall have the first option to acquire exclusive commercial patent rights to inventions made in the performance of federally funded contracts and grants. It also provided to all agencies clear authority to license for royalties, on an exclusive, partially exclusive, or nonexclusive basis, patents on inventions they own. An important feature is that it eliminated any bias in favor of nonexclusive licensing over partially exclusive or exclusive licensing that previously existed in many agencies. The purpose in both cases was to increase the opportunity for commercial use of federally funded technology. While exclusivity may enhance commercialization and royalty income, it also presupposes valid, enforceable patents. This in turn has created a greater need for close coordination between the patent process and an agency's dissemination and publication procedures to ensure that premature disclosure will not prejudice the patent rights of either the contractor or the agency.

The Stevenson-Wydler Act of 1980 established the first positive requirements and infrastructure for government technology transfer activities. Its legislative history acknowledged, and in some instances the act itself adopted, some of the features of NASA's Technology Utilization Program. These requirements and infrastructure, however, focused primarily on the identification, documentation, acquisition, and subsequent dissemination through publication (or by placing in the public domain) new technology developed by federal laboratories or their contractors. This was sometimes referred to, particularly by critics, as a passive transfer mechanism. There was little, if any, consideration of intellectual property rights that may be associated with technology, of any need for the exclusivity possible under such rights, or of the prospect of an agency entering into cooperative arrangements with the private sector to achieve technology transfer. In other words, there was no recognition of the synergism that could exist between the original Stevenson-Wydler Act and the possible exclusivity under the Bayh-Dole Act, even though both were enacted in the same year. Consequently, the Stevenson-Wydler Act was amended by the Technology Transfer Act to provide for more active transfer mechanisms by authorizing and encouraging cooperative activities and by producing a stronger link with intellectual property rights and the exclusivity provided thereby.

An important feature of the Technology Transfer Act was that it gave agencies clear authority to enter into cooperative research and development agreements with the private sector. This included the ability to permit the private sector to acquire exclusive commercial rights to inventions made under such agreements, including inventions made by federal employees.

NASA had preexisting authority under sections 203(c)(5) and (6) of the Space Act to enter into substantially the same types of agreements as those authorized by the Technology Transfer Act. However, the enactment of the Technology Transfer Act produced greater visibility for, and interest in, such agreements. As a result, an increasing number of such agreements have been implemented or are under consideration, granting greater patent exclusivity to the private participant to thereby make it more important that the premature publication of the resulting STI does not prejudice such exclusivity.

Another feature of the Technology Transfer Act that had a significant effect on in-house R&D activities at federal laboratories is a requirement that whenever an agency receives any royalties or other income from the licensing of an invention, at least 15 percent must be shared with the employee inventor. Also, agencies have the authority to use the remaining income to support additional licensing and technology transfer activities. This includes all inventions made at federal laboratories, not only those made under a cooperative research and development agreement. This change is extremely important. Previously any such royalty income had to be deposited in the general receipts of the U.S. Treasury and not shared with the inventor nor used by that laboratory. As a result, the number of inventions reported to NASA and other agencies has increased noticeably. Most reported increases range from 20 to 30 percent. This in turn has produced increasing pressure to obtain patents on, and to actively pursue royalty-sharing licenses for, these reported inventions. Also, of course, greater precautions are necessary to ensure that premature publication will not subvert the opportunity to patent, license, and obtain royalty income.

The Executive Branch also took steps to strengthen the ties between intellectual property rights and the technology transfer process by issuing Executive Order 12591, signed by the President on April 18, 1987. For example, section 1(a) requires agencies to take the steps that may be needed, including delegations of authority, to enter into the Cooperative Research and Development Agreements (CRDAs) authorized by the Technology Transfer Act of 1986. It was clear that the Executive Branch did not intend to leave this authority unimplemented.

Also, section 1(b)(4) of the Executive Order requires agencies to ensure, consistent with the Presidential Memorandum on Government Patent Policy of May 18, 1983, that contractors and grantees that are not small business firms or nonprofit organizations shall also be afforded first option to acquire exclusive commercial rights to inventions made in the performance of federally funded contracts and grants. Rights to inventions made under NASA contracts with other than small business firms and nonprofit organizations still remain subject to section 305 of the Space Act, which requires NASA to acquire title to such inventions unless waived under the NASA Patent Waiver Regulations (37 CFR 1245.1). These Waiver Regulations have been greatly liberalized to comply with the spirit and intent of the Presidential Memorandum and section 1(b)(4) of the Executive Order. Thus NASA has been able to adjust its statutory requirements to afford greater patent exclusivity for technology it funds, in order to be consistent with the changing environment in this area.

Another important aspect of the Executive Order is section 1(b)(5), which requires agencies to implement, as expeditiously as possible, royalty-sharing programs for inventions they license. It is clear here also that the Executive Branch did not intend to leave this authority unimplemented. NASA implemented its royalty-sharing program in NASA Management Instruction (NMI) 3450.2B. Under this NMI the first $2,000 received annually

from each license, as well as 20 percent of any royalties over $2,000, is paid to the inventors. The NMI also emphasizes the need for prompt reporting of inventions and assigns responsibilities to all those involved in the patent licensing and royalty distribution process. Since valid, enforceable patents must be acquired in order to have a "product" that can be licensed to create such royalty income, the ramifications of the requirement to establish a royalty-sharing program are clear and have been borne out by increased invention reporting, patent, and licensing activities, as previously mentioned.

Finally, section 1(b)(6) of Executive Order 12591 requires agencies to cooperate in developing, pursuant to guidelines to be provided by the Office of Federal Procurement Policy, regulations that will enable contractors and grantees to retain rights to computer software, engineering drawings, and other technical data "generated" in the performance of federally funded contracts and grants. The important point to note is that the technical data generated under contract are those data which, under present policies and practices, agencies normally require to be unrestricted and enter into their publication and dissemination infrastructure. Affording a contractor "rights" to such data will result in some degree of exclusivity under intellectual property law, of a type and to an extent yet to be determined. Whether such data can or should be entered into an agency's dissemination infrastructure for limited or restricted distribution is an issue that must be addressed once the extent and type of such exclusivity has been determined. Ultimately, implementation will be made by revisions to section 27.4 of the Federal Acquisition Regulation, and intense interagency activities are now in process to achieve that implementation.

SOME PRACTICAL EFFECTS ON AN AGENCY'S PUBLICATION AND DISSEMINATION ACTIVITIES

There are three basic forms of intellectual property rights protection that may affect an agency's policies and procedures relating to the publication or dissemination of the results of R&D activities: patent rights, copyrights, and trade secret (or the equivalent) rights. In general, and at the risk of oversimplification, a patent provides for the exclusive right to make, use, or sell the end-item product or process described and claimed in the patent. Copyright protects the specific expression or manifestation of the copyrighted "work" (but not the ideas or concepts that may be embodied therein) and provides for the exclusive right to perform certain acts in relation to the work, such as the reproduction, distribution, performance, or display of the work. In both cases, once certain legal requirements and formalities have been met to protect the right, the informational content or the ideas or concepts described or disclosed in the patent or the copyrighted works are publicly available; however, unlicensed individuals cannot make, use, or sell the patented product or process, or reproduce, distribute, perform, or display the copyrighted work for personal or economic gain.

The situation is markedly different for trade secret protection: for such protection to be established and maintained, the information divulging the trade secret must be held in confidence. While absolute secrecy is not necessary, the information must be subject to some safeguards against unauthorized disclosure and use, and any recipients of the information must be subject to legally binding nondisclosure agreements or commitments. The following is a discussion of the relationship between the publication and dissemina-

tion of technology and these three forms of intellectual property rights protection, as well as the effect of increased government emphasis on intellectual property rights on agencies' publication and dissemination policies.[3]

Patent Rights

Once a patent application has been filed in either the United States or a foreign patent office, information disclosing the invention (technical reports, journal articles, and the like) may be published or disseminated. However, the premature publication of information disclosing an invention may preclude obtaining a patent on that invention. Since, as a general rule, patents have no extraterritorial effect, the national laws of each country in which a patent is to be obtained must be checked to determine what may constitute premature publication in regard to the specificity of the information published in describing the invention, as well as to the timing of the publication in relation to the date a patent is applied for. In the United States there is a 1-year grace period between the publication date and the application date of a patent. In many foreign countries a patent must be applied for before any publication takes place. The degree of specificity in a publication that will bar a patent is often a highly subjective judgment call.

Because of international convention, many countries, including the United States, will recognize the filing date in another country that is a member of such convention if a patent application is filed in the second country within 1 year of the first. Thus, if worldwide patent protection is to be obtained, a patent application must first be filed in a convention country prior to any publication or public disclosure of information disclosing the invention.[4] If this rule is not followed, then the laws of each country in which patent protection is to be sought must be reviewed and a judgment made in each case as to whether a patent can be obtained. This process can be very time-consuming and risky because the matter may not be conclusively put to rest until a court ruling is made after protracted litigation. The same rule applies if only U.S. patent protection is sought, except that filing for the patent application must be within 1 year of any publication or public disclosure of information disclosing the invention, rather than prior to any subactivities. Accordingly, a decision on foreign filing should be made as soon as possible in order to ascertain whether the 1-year grace period is available. If these rules are not followed, the patent may be barred or declared invalid in one or more countries, resulting in the loss of royalty income. Thus coordination between the publication procedures and the patent filing process of an agency becomes very important. Doubt should be resolved by obtaining patent review and delaying publication until either patent protection is obtained or a decision is made not to file for a patent.

One complicating factor in delaying publication is the Freedom of Information Act, which could force unrestricted public release of information disclosing an invention.[5] However, in anticipation that that act could require premature release, the Bayh-Dole Act gave federal agencies the authority to withhold from public disclosure (including release under FOIA) information disclosing an invention for a reasonable time for patent applications to be filed.[6] This applies to inventions by government employees as well as to those by contractors and grantees; in either case this authority may be invoked so as not to force premature release of information disclosing an invention to a third party in response to a request made under FOIA. Again, coordination between the FOIA release process and the patent filing process of an agency is necessary to ensure that this authority is properly utilized.

In addition to the possibility of release under FOIA, the information involved may often be contained in scientific and technical reports prepared by contractors or by federal employees that an agency itself intends to publish or disseminate. In this event, care must be taken to ensure that the agency does not publish the reports prematurely so as to compromise patent rights. Government policies in this regard place the responsibility on the contractor submitting the report or the federal employee preparing the report to notify cognizant agency personnel that the report contains information disclosing an invention so that the agency may take appropriate steps to withhold the report from publication for an agreed-upon period.[7] When the agency is notified, the report will be withheld for at least 6 months, with flexibility for reasonable extensions. As an example of how this may be implemented, NASA procedures for entering scientific and technical reports into its dissemination process provide an opportunity to identify reports that may contain information disclosing an invention as a matter of course.[8] The report is withheld from publication for at least 6 months when the submitter notifies NASA and a reasonable extension may be needed to file a patent application. Regulations dealing with the policies and procedures for inventions made under a contract or grant also caution of the need to notify NASA that a report contains information disclosing an invention so that it can be withheld from publication.[9] Similarly NASA's management instruction dealing with such inventions informs the employees of the need to report an invention promptly and to take the necessary steps to time the publication of these reports so as not to prejudice patent rights.[10]

Copyrights

Under present law, works created by a federal employee cannot be copyrighted. However, copyright may be established for works created under a contract or grant unless prohibited in the contract or grant. Current government policy is to permit a contractor or grantee to establish claim to copyright for works produced when doing so is an incentive for distribution or dissemination of the work by the contractor or grantee and such permission is not in conflict with an agency's dissemination or distribution policies and procedures or not otherwise inconsistent with the government's purpose for having the work prepared.[11] The permission-granting procedures, as well as the specific contract terms and conditions implementing the right to establish claim to copyright, are set forth in the applicable data rights regulations for contracts and grants. For contracts, specific instructions and clauses are set forth in subpart 27.4 of the Federal Acquisition Regulation for the civilian agencies and in the Department of Defense Supplement thereto for contracts entered into by the Department of Defense (DOD).

It is standard practice, when an agency permits a contractor or grantee to copyright works (other than computer software) produced under contract or grant, for the agency to reserve a license for government purposes. This license normally enables the agency to distribute the work to the public when such distribution is considered proper. For the civilian agencies the contractor or grantee retains exclusive commercial rights for any further reproduction or distribution of the copyrighted work. Consequently, the recipient of such a work from a civilian agency does not have, or acquire, the right to further reproduce or distribute the copyrighted work for any nongovernmental purpose. This limitation preserves the commercial exclusivity afforded the contractor. Under DOD's policies and regulations, however, both the government and the recipient can reproduce and distribute the copyrighted work

for any purpose whatsoever. Thus the copyright holder has no commercial exclusivity. This discrepancy in DOD policy and regulations may need further review in today's changing environment.

In order to put all recipients on notice as to respective rights in copyrighted works, the contractor is required to place a copyright notice, as well as a notice of government sponsorship, on works delivered to the government. When NASA enters such a work into its distribution system—which it is permitted to do under the license mentioned above—an additional notice is affixed to the work that informs the recipient that the document is copyrighted, that it may be reproduced and redistributed only for government purposes, and that all other rights (i.e, commercial rights) are reserved by the copyright owner.[12]

Trade Secrets

Another recognized and commonly used form of intellectual property protection in the private sector is trade secret protection. Such protection, however, is intrinsically different from patent or copyright protection in that it requires that the information be maintained in confidence, with any recipient of the information bound by an express or implied non-disclosure agreement. Thus, by definition, any information protected as a trade secret, or the functional equivalent, is not suitable material for, and should be excluded from, an agency's normal or routine scientific and technical information dissemination activities.

This has been a non-issue in that most agencies' scientific and technical information dissemination activities have been based on information produced at government (i.e., taxpayer) expense in an environment that presumes that such information should be obtained by the government without restriction so that it may be freely disseminated or placed in the public domain. Consequently, to the extent exclusive commercial rights have been invoked to encourage technology transfer and commercialization for government-funded technology, it has been by patent or copyright protection only. While, as discussed, such protection does require some procedural burdens and cautions and may restrict the ultimate end use of the products and processes resulting from the information, or the reproduction and redistribution of specific expressions of the information, it does not detract from the basic function of the dissemination of the results in terms of the free exchange of ideas and concepts, or even the informational content, of scientific and technical information produced or sponsored by a federal agency. In fact, such dissemination functions and patent rights and copyrights have coexisted, often in supportive relationships, in meeting the mutual objectives of technology transfer and commercialization for some time.

This environment could change, however, depending on the extent and manner in which the requirements of section 1(b)(6) of Executive Order 12591 are implemented. As previously discussed, contractors and grantees are to be afforded "rights" (yet to be defined) to engineering drawings, computer software, and other technical data generated under contract or grant. Since the Executive Order was issued at a time when patent rights and copyrights, as discussed above, were routinely available to contractors and grantees, trade secret rights, or some functional equivalent requiring confidentiality for some period of time, appear to be what was intended. Practically speaking, the commercial interests of the proprietor of any such rights can be protected only if the recipient of the information is bound by an express nondisclosure agreement, or somehow an implied understanding of confidentiality can be imposed government-wide on recipients (an approach at odds with present common law prin-

ciples). In any event, some percentage of federally funded scientific and technical information may have to be excluded from an agency's dissemination and distribution activities, or such activities will have to be significantly revised to handle distribution under nondisclosure agreements or under some as yet unspecified implied understandings of confidentiality.

At present, such considerations are directed only to STI generated under contract or grant, and not to information generated at federal laboratories by civil service employees. However, questions are also being raised in relation to cooperative research and development agreements (of the type authorized under the Technology Transfer Act) regarding the ability of an agency to agree with the private participant to maintain technical information produced under the agreement in confidence for some reasonable period, even if the information is generated by a federal employee at a federal laboratory. At present, this ability is contrary to long-standing policies and is legally questionable because of FOIA. Further legislation will be needed if confidentiality is to be afforded to such information.

Questions are being raised as to whether there should be additional legislation to allow computer programs and similar technology generated by federal employees to be copyrighted. The purpose, apparently, is to allow computer software and related technology to be licensed for commercial use and royalty income generated and shared by the federal employee and the laboratory in a manner similar to that for royalties generated by the licensing of patented inventions under the Technology Transfer Act. These questions have precipitated ongoing reviews by the General Accounting Office, the results of which may produce recommendations for further legislation or the need for more definitive guidelines in these unsettled areas.

COMPUTER SOFTWARE ISSUES

Computer software is unique in that information describing or expressing the software, and the software as an end-item product or process, often merge and take on the dual characteristics of both information and an operating device or working tool. Thus computer software is the most obvious example of a case in which it is necessary to distinguish between "information" to be disseminated for explanatory or descriptive purposes and "technology" to be transferred for end-item commercial use. This distinction has been diluted because government policies and practices do not necessarily distinguish among computer programs (usually in machine-readable form) that cause a computer to execute operations, descriptive design material (in human readable form) that will allow a computer program to be recreated or reconstructed, and the database that contains or stores the information the computer and its program process or operate on.

If distinctions along the foregoing lines can be developed and maintained, then "computer software," as that term is often used generically, can be treated as discussed above. For example, computer databases, to the extent they comprise a collection of information converted to computer-recognizable form for the purposes of storage, manipulation, transmission, display, and the like, should be treated no differently from the same information in more human-recognizable form. In other words, the format in which the information exists, or the media on which it may be maintained, should not require any different treatment of the information for dissemination policy, technology transfer, or intellectual property rights purposes.

On the other hand, a computer program intended to operate in or in conjunction with a computer, should be treated as an operating tool or property, and not as information, in that it is an extension of the computer or computers with which it is intended to operate. However, such programs are also valuable "technology" that as end items should be transferred for commercial use—they are not information. NASA has established a separate infrastructure, the Computer Software Management and Information Center (COSMIC), operated by the University of Georgia, to make computer programs developed by or for NASA available for commercial and governmental use by purchase, lease, or license. The programs so distributed may include supporting documentation sufficient for the program to be operated and maintained, but not the databases (i.e., the information) on which the computer programs operate.

As to intellectual property rights considerations, the foregoing discussion of patents, copyrights, and trade secrets may be applied to the various subsets of computer software as appropriate. For example, although rather difficult, time-consuming, and expensive, a patent may under appropriate circumstances be obtained for a computer program as an end-item product or process. The situation is the same as that for a patent obtained on any other end-item product or process and the descriptive material relating thereto, including cautions against premature publication.

The most convenient and commonly used protection for computer software is copyright protection. Under the copyright laws both the computer program and the descriptive documentation from which a computer program may be recreated may be copyrighted. However, as previously discussed, copyright is not presently available for works authorized by Federal employees in carrying out their official duties. Thus, copyright for federally funded computer software is available only for software generated under contract or grant, to the extent that agency policies permit. Under the Federal Acquisition Regulation for civilian agencies, when copyright is permitted, the funding agency does not, under its license for government purposes, obtain the right to disseminate the software to the public (as an agency can do for non-computer software material). This is to maximize commercial rights to the software for the contractor as an incentive to make it commercially available. Thus NASA, in recognition of the COSMIC infrastructure set up to disseminate NASA-funded software, does not normally permit a contractor to copyright computer software generated under contract. However, on a case-by-case basis a contractor may be permitted to copyright the software where there is an intent and commitment to make the software available in a commercial product line. When this mission is granted, the software is not entered into the COSMIC infrastructure.

Documentation of a computer program of a nature that may allow the program to be recreated or reproduced (such as source code) is, as a practical matter, usually disseminated, in conjunction with the program it describes. Such documentation may also be subject to intellectual property protection. However, if the program is made subject to either patent or copyright protection, then the protection of the documentation will probably be no greater than that afforded the end-item program. For example, the informational content, or conceptual ideas, contained in such documentation could allow a similar (but legally distinguishable for patent or copyright purposes) program to be developed. Thus, it is often the practice in the private sector to maintain such documentation, particularly source code, in confidence as a trade secret, and this even though the end-item program may be subject to copyright or patent protection. However, for reasons previously discussed, such protection

is not now normally available for federally funded software, leaving patent or copyright protection for the end-item program the only choices. Whether or not trade-secret or some equivalent protection will be available in the future is contingent on the ultimate implementation of section 1(b)(6) of Executive Order 12591 and some of the other reviews that are being made in this area.

The Future

While there have been dramatic changes in the law and federal government policies relating to intellectual property rights and the transfer and commercial use of federally funded technology over the past decade, the environment should start to stabilize. In the main, the changes have been accommodated and adjusted to by NASA and other agencies. This has resulted in certain refinements in and a need for closer scrutiny of NASA's policies and procedures for the dissemination and distribution of STI, but no drastic restructuring of the basic approach to meet NASA's statutory obligation to provide for the widest practical and appropriate dissemination of information concerning NASA's activities and the results thereof. While there may be further changes in the process of implementing section 1(b)(6) of Executive Order 12591 or as the result of legislation that may be passed to permit certain technical data generated by federal employees at federal laboratories to be maintained in confidence for commercial purposes, or to allow computer software generated by the federal employee or contractor to be copyrighted, any prediction of what may occur, and its impact, is premature. There will be a need to balance dissemination needs and requirements with the exclusivity afforded to meet commercialization objectives. If this is done, however, there is no reason why any changes that may result cannot be accommodated as have those in the past decade. As long as there is understanding and agreement on the overall objective of transferring federally funded technology in a manner that is beneficial to the U.S. private sector in this era of escalating international competition, and there is also coordination of the transfer mechanisms involved, all transfer mechanisms can, and should, coexist, and even reinforce one another.

NOTES AND REFERENCES

1. 5 U.S.C. 552. There has always been some concern as to whether detailed technical data should be considered an "agency record," rather than a "resource" not subject to the FOIA. However, over the years case law has treated detailed technical data as agency records. The Department of Defense has obtained an exemption to such treatment (10 U.S.C. 140c) for technical data that are subject to the export control laws and regulations. Other agencies have been unsuccessful in obtaining a similar exemption. In a broader sense, the failure to differentiate between the dissemination of STI as an end process and as an integral part of an agency's R&D programs and technology transfer activities has obscured efforts to develop government policies in these areas.
2. For a more detailed discussion of various agency transfer mechanisms, see Richard L. Chapman, "The Federal Government and Technology Transfer." *Technology Transfer* (Winter, 1989).
3. An extensive discussion of the relationship between intellectual property rights and information policy may be found in a report by the U.S. Congress, Office of Technology Assessment, *Intellectual Property Rights in an Age of Electronics and Information*, OTA-CIT-302 (Washington, D.C.: U.S. Government Printing Office, April 1986).
4. The convention revising the Convention of the Union of Paris of March 20, 1883, as revised for the protection of industrial property, done at Stockholm July 14, 1967, entered into force for the United States September

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5, 1970, with the exception of Articles 1 through 12, which entered into force for the United States August 25, 1973. See 21 UST 1583; 24 UST 2140; TIAS 6293, 2727.

5. Supra, note 1.
6. 35 U.S.C. 205.
7. See, for example, the Federal Acquisition Regulation at 27.305-5; and 37 CFR 401.13(c).
8. NASA Scientific and Technical Information Handbook Documentation, Approval, and Dissemination. NHB 2200.2, (February 6, 1987), pp 2-6.
9. Supra, note 7.
10. NASA Management Instruction NMI-3450.2B, (October 13, 1987).
11. This approach for works produced under contract is recognized in the legislative history for 35 U.S.C. 105 (in House Report 94-1476).
12. Supra, note 8, pp 2-9.

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Communications and Media Services

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By virtue of the National Aeronautics and Space Act (1958), the National Aeronautics and Space Administration (NASA) is required to be open about its activities and to maximize communication with the public. The Office of Communications is responsible for a wide variety of programs to meet these requirements: issuing press releases in both paper and electronic forms, serving the television and other media with audiovisual products, responding to public inquiries, coordinating speakers and exhibits, and assuring compliance with the Freedom of Information Act.

These programs have been extraordinarily well developed throughout the years of NASA successes in aeronautical research and development, manned missions, Earth observations, and space exploration. The programs are divided into two broad areas of public affairs: media services and public services. Traditionally, NASA relies heavily on the capabilities of television, newspapers, and periodicals to disseminate information to the public. While these avenues of communication have been highly effective since 1959, service to the public via the media needs to be supplemented with direct communication in ways that only a NASA civil servant or contractor can manage (answering 25,000 pieces of correspondence annually, for example).

NASA boasts a significant internal communication program that dates from the agency's origin. It includes, of course, the communication of scientific and technical information that is inherent in its research and development missions, and, in an effort to go beyond the usual informal mechanisms and the obligatory administrative directives, it also includes a system of newsletters and employee briefings. These activities exist at both NASA-wide and installation levels. In addition to covering administrative matters and the general concerns of NASA personnel, the system includes occasional status reports on the

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accomplishments and plans associated with NASA's ever-evolving scientific and technical missions.

NASA's internal and external communication methods are summarized in the paragraphs that follow. The Appendix of this issue contains a listing of sources that may be called upon to obtain these services.

EXTERNAL COMMUNICATION

Information Services for the Media

Electronic Information Distribution

NASA news releases and other information, including Space Shuttle status reports, Shuttle manifests, current mission information, public affairs contacts, and a calendar of events, are available electronically through Dialcom.

NASA Select TV-Audio System

The NASA-wide TV-audio release system is a valuable tool for media covering the agency's activities. During Space Shuttle missions, the system provides real-time air-to- ground communications between the orbiter and mission control; public affairs launch, mission, and landing commentary; and many related news briefings. The system is also used for other NASA briefings and events. For most press briefings, the system is interactive (one-way video, two-way audio) among NASA installations so that media covering an event from one installation may ask questions at a briefing originating at another.

Television

NASA Headquarters produces a 14½-minute magazine-format videotape each quarter, called "Aeronautics and Space Report." The program is available to TV stations via satellite through the services of Medialink. It is also uplinked to NASA installations via the NASA Select TV system. As an aid to broadcasters wishing to excerpt portions of this videotape for news programming, both audio channels are used. Channel 1 audio carries a completely mixed track with narration, music, actualities, and effects. Channel 2 audio has effects and actualities only.

Audio

NASA produces a weekly 4½-minute program called "The Space Story" and a 90-second spot called "Frontiers." These topical radio programs feature astronauts, scientists, and other people involved in NASA's ongoing research efforts. These programs are distributed via satellite and on broadcast-quality cassettes to thousands of radio stations in the United States and abroad. Audio tapes of mission highlights and other space-age sound effects are also available from the NASA radio office.

NASA Broadcast News Service

Several NASA installations also provide up-to-date reports on aeronautics and space activities through automated telephone systems. Status reports during Space Shuttle missions

are available from the John F. Kennedy Space Center (prelaunch information), Lyndon B. Johnson Space Center (mission operations), and Dryden Flight Research Facility (landing operations). The Headquarters audio news service makes it possible for stations to receive material from interviews with the astronauts before Space Shuttle missions.

Motion Pictures

Films describing NASA research and development programs in space and aeronautics may be borrowed from one of seven regional film libraries. There is no charge, but borrowers must pay the cost of return postage and insurance. Regional film libraries are maintained at all NASA installations.

Still Photography

NASA installations maintain photo files on current projects and those of the recent past. Older files are purged periodically to make room for new material. The Broadcast and Audio Visual Branch, NASA Headquarters, has files covering projects and missions extending back to the agency's creation in 1958. Researchers seeking early or general material may save time by beginning their search at Headquarters.

Information Services for the Public

Astronaut Appearances

NASA responds to requests for astronaut appearances, both foreign and domestic. In 1988, NASA astronauts made 1,525 individual appearances in the United States and 435 in foreign countries. NASA also supports postflight appearances of individual astronauts and Space Shuttle mission crews.

Exhibits

The best of NASA technology is represented through the planning, design, and implementation of major NASA exhibits to be featured at expositions and air shows across the United States and in foreign countries. In addition to these exhibits, NASA maintains an overall exhibits program, supporting the requirements for Headquarters program office and installations.

Graphic Arts

To assure the standardized use of graphic designs throughout NASA, the agency developed a "Unified Visual Communications System." The successful application of this system was recognized in 1985, when NASA received the prestigious "Award for Design Excellence" from President Reagan.

Fine Arts

NASA's Fine Arts program commissions artists to document and depict significant NASA activities, events, and accomplishments through various media. These original works are displayed for public viewing at major NASA Visitor Centers. Most recently, a musician

was commissioned to portray the glory and pride of our country's return to space with the launch and landing of STS-26 (the Discovery mission) in 1988.

Artifacts

This program oversees the identification and disposition of NASA artifacts. If NASA determines that an artifact is no longer useful either technically or for exhibition purposes, then the artifact is, in most cases, transferred to the Smithsonian Institution's National Air and Space Museum for public display.

Guest Operations

Guest Operations is responsible for planning and managing an efficient and cost-effective operation for accommodating the public at Space Shuttle launches and landings. Guest invitations and protocol activities associated with certain special and public events conducted jointly by NASA and other organizations, both domestic and foreign, are also coordinated.

Public Inquiries

The vast majority of all NASA Headquarters public mail is screened and answered by NASA Public Services. Currently, this office is responding to approximately 25,000 pieces of correspondence annually.

Speaker Services

As a service to NASA public speakers and other recognized speakers outside the agency, NASA maintains and distributes a "Speaker Reference Book" on current NASA programs and activities, as well as significant speeches, congressional testimony, etc., delivered by the NASA Administrator and other senior agency officials.

EMPLOYEE COMMUNICATION

In the wake of the Challenger accident in 1986, NASA began to see the need for an intensified and more timely form of internal communication programs for its employees. All that existed was an agency-wide monthly publication and a variety of biweekly or monthly newsletters generated at individual installations.

In an agency-wide survey at that time, NASA employees indicated they generally received their news about NASA from their daily newspapers or local or national television news programs. Erroneous, controversial, or confusing media reports about the agency often angered and confused employees. Morale at the agency became a serious problem.

To help correct this problem, an Internal Communications Office was established within the Office of Management to develop a program of information specifically aimed at the employee and quickly delivered. The new internal communications system was patterned after NASA's successful public and news-media information activities. It is believed to be unique among government agencies, but is essential in high-visibility organizations such as NASA where employees must be kept fully aware of significant events that will attract public attention. Such awareness keeps morale up and effectiveness high.

Televised information programs, collectively called NASA Update, were transmitted over

the NASA satellite transponder to all agency facilities throughout the United States. NASA management, including the Administrator and astronauts, reported on Shuttle recovery progress and agency officials were asked to discuss new programs and the status of ongoing projects. Even members of the media, former members of Congress, and nationally recognized scientists and engineers appeared to discuss their views of the agency's recovery from the loss of Challenger and the impact of the Presidential Commission findings.

As the Internal Communications Branch began to take shape, it became evident that gathering of news and information even for employees was the responsibility of experienced public affairs specialists. The Internal Communications Office was transferred to the newly established Office of Communications. Under this office several new or revised information projects, specifically for NASA employees, were begun.

Information Efforts for Employees

NASA Headline News

NASA Headline News is a daily news report written and edited by the Internal Communications Branch. Headline News uses a 120-second, 1-page news format which usually fills a single 8″×11″ page and takes about 2 minutes to read. The information is gathered from NASA news releases, wire services, major newspapers, television news services, aerospace-related publications, and other independent news sources. The daily news report also contains the schedule of televised public affairs events available for viewing on the NASA satellite transponder. Headline News is filed daily, Monday through Friday at 12:00 pm Eastern time, on the NASAmail (GTE Telemail) electronic bulletin board. Agency employees and contractors who have access to the NASAmail system may avail themselves of the information. In addition, the news report is recorded on a digital voice repeater that may be dialled at 202/755–1788. Since its inception, aerospace media also avail themselves of this service because of its immediacy and brevity.

Daily News in Brief

Daily News in Brief is a summary of major news stories about NASA filed in major newspapers and aerospace publications, and broadcast on radio and television. Daily News in Brief is the most popular of the internal communications information publications. Each day an editor reads a wide variety of information sources and abstracts the most important articles. Even if information is found to be incorrect or negative to the agency it is summarized and filed. Gross errors found in the stories are generally noted by the editor and corrected if warranted. This procedure assures that NASA management and employees are aware of any negative or erroneous information about the agency. Daily News in Brief is filed at 12:00 pm each weekday on the NASAmail electronic service.

NASA Update

The initial biweekly televised discussion programs with agency and agency-related individuals underwent a major format change after its first year and emerged as a weekly 5-minute NASA news program. It is a fast-paced program of the latest agency news and it also presents a variety of video-taped features provided by NASA installations. The show

is produced in Washington, D.C., and relayed to other NASA installations every Thursday via the NASA satellite transponder. Installations tape the program and play it over their internal cable systems that day and again on Friday. The program is also shown on monitors located in agency credit unions, employee stores, hallways, and cafeterias. Because the program is transmitted by satellite transponder, non-NASA organizations can view the program as well.

NASA Activities

NASA Activities, the agency-wide employee publication, recently underwent a major format change. Higher quality newsprint, liberal use of photographs, and a variety of interesting features have improved its acceptance by employees. The editor works closely with his peers at the installations in an effort to showcase important center activities for readers. With a distribution of 35,000, the 16-page publication is sent to every civil service employee in NASA. Additional copies are sent to major NASA contractors and retirees, and may be purchased by the general public through the Government Printing Office.

Current News

Current News is an expanded version of a previously existing daily media reprint effort of the NASA newsroom. Current News is a limited-distribution compilation of major newspaper, wire service, and trade magazine articles and summaries of television news reports. Every morning the Newsroom clips up to 10 major newspapers and some trade papers. Same-day distribution is made to major program offices in Headquarters, selected congressional offices, and several offices serving the White House. Current News is also distributed to macro program and project offices throughout the agency.

Television Services

Another effort at NASA Headquarters is the production of special television and videotaped programs.

An offshoot of the regular television production efforts is special televised programs aimed specifically at NASA employees. The Internal Communications Branch produces special programs or assists in the production of special messages to employees by the Administrator or other management personnel.

In addition, NASA has produced a 12-minute "Welcome to NASA" video-tape that is shown to new employees. Also in production is a special 15-minute tape explaining the rudiments of the agency's proposed drug-testing program.

Installations Augment Headquarters Output

At NASA Headquarters and most of the installations, additional efforts are made to keep employees better informed. At Headquarters a biweekly bulletin board called HEADS UP is posted at all elevators in the major buildings occupied by the agency. HEADS UP features a variety of institutional news items that are of local interest only.

Installations expanded or improved their own methods of distributing information by combining the Headquarters-produced information sent by electronic mail with their own. Therefore, each installation is able to augment the agency-wide news with local information.

WORLDWIDE ELECTRONIC MAIL NETWORK

NASA's space efforts have worldwide interest and participation. NASAmail (a GTE Telemail system) is used extensively not only by NASA employees, but also by its contractors, to communicate among scientists, engineers, and professional and administrative personnel. NASAmail is the lifeblood of many projects that have international participants. The network literally stretches around the world. It also finds its way into scores of colleges and universities throughout the United States and Canada.

The NASAmail system affords NASA a vehicle to distribute its information. NASA Headline News and Daily News in Brief are read not only by NASA employees and contractors in Australia, Asia, and Europe, but also by foreign space scientists and engineers.

Further distribution of the news headline service and TV schedule occurs through NASA SPACELINK, the agency's electronic information system for the educational community. The computer-accessed services, provided by NASA's educational affairs activities and operated by the Marshall Space Flight Center's Public Services and Education Branch, includes Headline News as part of its service to teachers and students.

THE FUTURE

As the worldwide information explosion grows, particularly in scientific and technical areas, NASA is continually faced with providing greater and greater amount of information to the outside world. Therefore, it is increasingly important that information be distributed not only quickly and efficiently, but in a cost-effective manner.

As new technologies in information dissemination develop, they are looked at by the Office of Communications. Although no special office has been established to track new technologies, several employees are instrumental in evaluating and implementing new communications techniques.

One NASA program that will require special efforts is the information flow from the Hubble Space Telescope. The orbital observatory, scheduled to be launched in March 1990, is expected to create an avalanche of written and pictorial information in the field of astronomy. Other programs such as the Galileo mission to Jupiter and the mapping of Venus by the Magellan spacecraft also present a challenge to NASA's information efforts.

Farther down the road, but of extreme concern now, is the flow of information expected from Space Station Freedom. Once in orbit, the station will provide information not only to the United States but to a variety of international partners. Television will play a major part in passing along scientific and technical information.

CAN NASA MEET THE CHALLENGE?

As the agency plans for a return to the Moon, about the year 2000, and eventual manned exploration of Mars, communications to the scientific community and the public present a challenge of unprecedented proportions. Space missions will become more complex technically, scientifically, and administratively. NASA has been cooperating with foreign governments in a variety of international space projects over the past three decades, and such efforts are on the increase.

The public information program of NASA's Office of Communications has been highly

successful for the past 30 years. It will require continual upgrading in the years ahead. Through the use of new and improved communications methods and innovative planning, NASA will be able to keep the world abreast of new and exciting breakthroughs in space science and applications.

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Enhancing U.S. Competitiveness through Federal Scientific and Technical Information: Issues and Opportunities

THOMAS E. PINELLI*

The federal government funds a major portion of research and development (R&D) in the United States, and it is estimated that $61 billion will be spent on federal R&D in 1989.[1] The mounting intensity of global economic competition underscores the critical role played by the federal government in the funding of science and technology.

The justification for federally funded science and technology follows the arguments that government-funded research in science and technology serves to support a wide range of national goals: to improve health, defend the nation, fuel economic growth, and provide jobs in new industries. Events such as Sputnik and the increased use of science and technology by government at all levels to solve social problems in the late 1960s and 1970s, the energy crisis, and the growing sophistication of the U.S.S.R. technology account for the growth of federally funded research in science and technology.

Viewed as a process that includes basic science, applied science, and technology, R&D is the basis of U.S. improvements in health, strong national defense, and exciting and fundamental advances in knowledge. However, in terms of economic competitiveness, it is important to recognize that, unlike other countries such as Japan, federally funded R&D in the United States is carried out in a totally decentralized environment. Federally funded R&D takes place within numerous agencies of the Executive Branch; is undertaken by thousands of engineers and scientists in academia, government, and industry; and receives oversight and coordination from both the executive and legislative branches of government.

In recent years, two factors have combined to make certain individuals, groups of individuals, and organizations question the assumed benefits associated with federally funded

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R&D. Huge deficits and budget constraints are forcing lawmakers to reevaluate spending and to form spending priorities. Technology has become a critical component of economic competitiveness. The suggestion has been offered from various quarters that federally funded science and technology should be viewed as an investment that should produce a measurable economic return.

Discussions concerned with the role of the federal government in funded science and technology frequently result in heated debates giving rise to the following questions. Has the funding of science and technology by the federal government markedly contributed to accomplishing national goals such as improved health and the creation of new jobs and industries? Can the impact of federally funded science and technology be quantifiably assessed and compared with other programs concerned with, for example, housing and care for the elderly? Have the results of federally funded research increased the competitive position of U.S. industry? Are the results of federally funded research organized and managed in such a way that U.S. industry has clear and unobstructed access to these results or do barriers exist that prohibit its utilization? What role should the federal government assume in the production, collection, organization, and transfer of federally funded STI? These questions, while easily framed, cannot be answered in "yes" or "no" fashion. They do, however, form the basis for spirited public policy debate and scholarly investigation. This article will attempt to examine them by focusing on the issues and opportunities relative to STI and competitiveness in the United States.

BACKGROUND

Prior to World War II, the funding of science and technology by the federal government was limited and was concentrated in a handful of Federal agencies. The federal government funded between 12 and 20 percent of all U.S. R&D in the 1930s. All that changed with war in Europe. Today, the number is much closer to 50 percent.

The World War II era witnessed increased participation on the part of academia and industry in government-sponsored R&D. Their enhanced role set the stage for the revolution in federally funded R&D following the war.

Agriculture, aviation, defense, and health have enjoyed long histories of federal support and practical success. The success of these programs together with environmental concerns, the energy crisis, and various social issues prompted lawmakers and policy makers to consider the use of federal funds to stimulate innovation in other industries, but with little success. Why have these programs succeeded while other have failed? Two of these programs, agriculture and aviation, are discussed here.

Both are noteworthy for their practical success. Both serve as successful models for implementing targeted federally funded R&D and for understanding the diffusion of federally funded STI. Both models vary in their use of active information intermediaries and surrogates.

Agriculture. The assumption that the country derives economic benefit from federally funded science and technology has been fundamental to government policy since after the American Civil War. Agricultural science was the first federally funded science and technology program. It became so with the passage of the Hatch Act in 1887. The act provided federal funding for research at the agricultural research stations associated with the land-grant colleges which were created in 1862 by the first Morrill Act.

For nearly a century, since the passage of the Hatch Act, the federal government has had a program to support applied research related to improved agricultural productivity. Policy makers believed that a productive agricultural sector was essential to the country's well-being, and that farmers could not be expected to do their own research. Agricultural research remained the largest recipient of Federal support until after World War II.

There is general agreement among public policy makers that the agricultural model was successful in diffusing federally funded agricultural research to farmers (users), and thus in raising their level of agricultural productivity.

Aviation. Federal funding for aviation was the federal government's second venture in targeted R&D. The first consistent federal funding for aviation began with the passage of the Naval Appropriations Act of 1916 (P.L. 63-271) that created the National Advisory Committee for Aeronautics (NACA) which later became the National Aeronautics and Space Administration (NASA) in 1958. Fresh from the experiences of World War I and the European combatants' use of the airplane for tactical support, policy makers became convinced of the revolutionary importance of the aircraft to national defense. Further, they viewed aviation as a new technology that could change the world and create an entirely new U.S. industry.

The benefits of this investment to the U.S. aviation industry and the consuming public are substantial. In 1989, the aerospace industry continues to be the leading positive contributor to the U.S. balance of trade among all merchandise industries, including agriculture.

What factors are responsible for the relative success of this targeted federally funded science and technology program?

The U.S. government has played a critical role in the success of the aviation industry in two ways. First, the market side of the industry was helped by federal (public) policy in the form of the Kelly Air Mail Act of 1925, the McNary-Watres Act of 1930, and the institution of the Civil Aeronautics Board in 1938.

Second, the development side was helped by Federal (public) policy with the creation in 1917 of the NACA with its congressional mandate to supervise and direct the scientific study of flight with a view to practical solutions.

If agriculture and aviation stand as successes in terms of targeted federally funded science and technology programs, it seems appropriate to mention, at least in passing, some of the more notable failures. The success of federally funded science and technology in agriculture and aviation led the Kennedy administration to consider other federal programs to stimulate innovation in other industries. Why? The reason was simple. Administration officials were concerned about the continued growth and competitiveness of the U.S. economy and the role of technology in industrial progress. Selected industries (textiles, coal, and housing) were targeted for assistance under the Civilian Industrial Technology Program (CITP). The Carter administration proposed the Cooperative Automotive Research Program (CARP), which aimed at advancing knowledge that could contribute to improving automotive technology. By any appropriate standards of measurement, both programs were failures. Why? Why would similar public policies applied to different industries yield very different results?

Both agriculture and aviation recognized the fundamental importance of the knowledge derived from research. Both recognized the need to link producer and user with the knowledge derived from research. Both linked science and technology policy to STI policy. Both placed equal weight on innovation and knowledge utilization. Both invested heavily

in the support of utilization and diffusion of research results. Both employed active information dissemination programs.

The underutilization of technical knowledge rather than the utilization of technical knowledge constitutes the critical policy issue associated with federally funded science and technology programs. Other reasons notwithstanding, the common element associated with less than successful targeted federally funded science and technology appears to be the failure to include "knowledge diffusion" policy in the form of a program that links knowledge "production" with knowledge "utilization."

ISSUES AND OPPORTUNITIES CONCERNING COMPETITIVENESS

The thesis of this article is that federally funded STI has the potential to increase U.S. industrial innovation and productivity, and to maximize the economic competitiveness and vitality of the country. Our experience as a nation suggests that those federally targeted science and technology programs considered to be successful recognized the interdependence of knowledge production and knowledge transfer. There is, however, concern.

Over the past 30 years, more than 50 studies relative to federal STI have been conducted. These studies raise a number of specific issues and concerns. Recently the U.S. House of Representatives, Committee on Science, Space, and Technology, Subcommittee on Science, Research, and Technology held hearings on federal STI policy. Joseph G. Coyne, speaking on behalf of the federal interagency group CENDI (Commerce, Energy, NASA, and Defense Information), stated the following:

> The U.S. does not have an overall [STI] strategy, and it does not have a focal point to develop one. There are a number of laws, regulations, and standards now under consideration that could have a major impact on [federal] STI programs. However, at the federal level, there is no focal point for coordination, [STI] issue identification, and resolution."[3]

There are numerous issues and opportunities associated with Federal STI. Five of those considered to be most significant in terms of their impact on U.S. competitiveness have been selected for discussion here.

Issue 1: Knowledge Production and Knowledge Utilization

The U.S. government is the single largest source of STI in the world. The results of this research are considered by many to be an essential component of the Nation's economic competitiveness. However, Federal policy makers have been concerned that the information created through the billions of dollars spent annually by the federal government is not well utilized because the transfer process between the producer and user is inadequate.

Dissemination efforts are not viewed as an important component of the R&D process, and therefore there is a low level of support for knowledge transfer in comparison to knowledge production. This producer-user disconnect practically guarantees that much of the Federal investment in creating STI will not bear fruit in terms of tangible products and innovations. This disconnect stands in stark contrast to the agriculture and aviation programs.

The opportunity to enhance U.S. competitiveness exists with the recognition by federal policy makers and lawmakers that federal STI is a critical aspect of the R&D process and serves a variety of other national goals. Policy makers involved in federal science and technology programs need to understand the relationship of STI to the R&D process: knowledge transfer is an inseparable part of R&D, and knowledge transfer must be an integral part of federal science and technology programs.

Issue 2: federal STI Policy

The federal government has been involved in creating, supporting, and transferring STI for virtually 200 years. Major changes in that involvement have usually coincided with times of crisis and military conflict. World War II resulted in an expanded federal role in science and technology.

The National Science and Technology Policy, Organization, and Priorities Act of 1976 (P.L. 94–282) states that "it is the responsibility of the federal government to promote prompt, effective, reliable, and systematic transfer of science and technology information."[4] The act also states that the federal government has the responsibility not only to coordinate and unify its own science and technology information systems, but to facilitate the close coupling of institutional scientific research with commercial application of the useful findings of science.

Despite such lofty and noble goals, there is general agreement that the federal government has no coordinated STI policy, and the problem of coordinating federal STI policy is still unresolved.

The opportunity to enhance U.S. competitiveness begins with recognizing (1) the uniqueness of STI among other types of information, (2) the relationship between U.S. science policy and U.S. STI policy, and (3) the relationship of the parts of federal STI policy to the whole of federal STI policy.

Office of Management and Budget (OMB) A-130, "Management of Federal Information Resources," states that the open and efficient exchange of federal STI is important and fosters excellence. However, A-130 fails to distinguish among types of information (e.g., STI) on the grounds that the Paperwork Reduction Act of 1980 made no such distinction. Thus the question of who should perform or provide the service takes precedence over the service.

In a narrow sense, federal science policy has helped expand the frontiers of new knowledge and federal STI policy has promoted the application of new knowledge. A broader use of federal science and STI policy is to serve various other national goals such as economic competitiveness.

The National Science and Technology Policy, Organization, and Priorities Act of 1976 (P.L. 94–282) established the Office of Science and Technology Policy (OSTP). OSTP serves as a source of judgment for the President and shall advise him of scientific and technological issues that affect national policy and the economy. P.L. 94–282 gave OSTP a mandate to promote the transfer and utilization of STI for civilian needs, to consider the potential role of information technology in the information transfer process, and to coordinate federal STI policies and practices. It is generally agreed that OSTP has not fulfilled its legislative mandate.

The opportunity to enhance U.S. competitiveness exists if the Executive Branch assumes a leadership role for science and technology to enhance U.S. economic competitiveness. With the abolishment of the NSF Office of Science Communication and the demise of the Committee on Scientific and Technical Information (COSATI), OSTP could assume an institutional leadership position within the Executive Branch or at least provide a coordination function between the Executive Branch agencies and the OMB.

OSTP has provided staff attention to STI matters in the past and has supported activities of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). One effort to remedy the STI policy void has been the formation of CENDI, a group of STI managers working to develop STI standards and to solve common problems. However, while the efforts of CENDI are admirable, they fall far short of the coordinated federal STI policy and policy implementation and oversight needed to help ensure that federal STI is actively used to enhance U.S. economic competitiveness.

The opportunity to enhance U.S. economic competitiveness exists with a more clear delineation of roles and responsibilities in federal STI policy implementation. For years the federal government has played an active role in the transfer of federally funded STI. During the Reagan administration, this active role came under intense criticism and scrutiny, manifested itself in greater involvement on the part of the private sector in transferring the results of federally funded STI, and was exemplified by the desire of that administration to privatize many federal responsibilities and STI activities including the functions of the National Technical Information Service (NTIS).

Consequently, a significant element of federal STI policy should include the following:

- determination of the players and their respective roles;
- effective working relationships between the public and private sectors;
- a strong coordination function to ensure that the various players carry their respective roles and responsibilities with optimum efficiency and effectiveness;
- more interactive, user-guided involvement and the removal of "cultural" barriers between federal STI producers and users; and
- better understanding of users and their values, norms, and communications and information-seeking and -gathering behavior; knowledge of the users' institutional environment; and the way(s) in which users typically obtain and use knowledge, information, and data.

Issue 3: Knowledge Diffusion

There is ample reason for government policy makers to question how effectively and efficiently federal STI is transferred or diffused to U.S. industry. A large body of knowledge exists on the topic of knowledge diffusion in agriculture; however, little is known about the diffusion of knowledge derived from federally funded science and technology. Studies of federal STI programs and users of federal STI are limited and add little in terms of understanding the diffusion or transfer process associated with federally funded STI.

The opportunity to enhance U.S. competitiveness exists with a better understanding of the knowledge diffusion process as it relates to federal STI. Innovation is a complex process composed of multiple and interrelated systems. A better understanding of knowledge diffusion by federal policymakers, R&D managers, and federal information professionals

should result in more intelligently designed public policy and programs than could, in turn, enhance U.S. competitiveness.

Issue 4: Scientific and Technical Information

A model that depicts the transfer of scientific and technical information in federally funded aerospace R&D is composed of two parts: the informal, that relies on collegial contacts, and the formal, that relies on surrogates and information intermediaries to complete the producer-to-user knowledge transfer process (Figure 1).

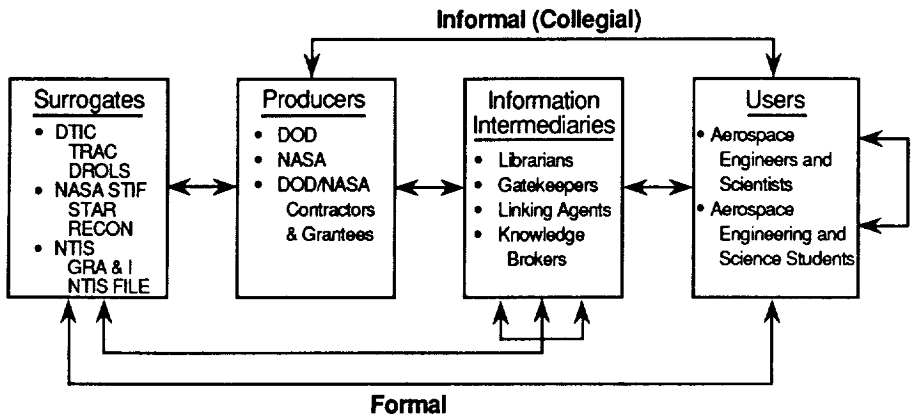

Figure 1. A Model Depicting the Transfer of Federally Funded Aerospace R&D

Framework. The producers are the federal agencies (e.g., NASA) and their contractors or grantees. The surrogates include the Defense Technical Information Center (DTIC), the NASA Scientific and Technical Information Facility (NASA STI Facility), and the NTIS. The information intermediaries are, in large part, librarians and technical information specialists in academia, government, and industry.

Information intermediaries who represent knowledge producers are expected to serve as knowledge brokers or linking agents. Information intermediaries connected with knowledge users act as technological entrepreneurs or gatekeepers. The effectiveness of the transfer process is increased if the information intermediaries are active: i.e., they take information from one place and move it to another, often face to face. The classic example of an active information intermediary is the agricultural extension agent. Passive information intermediaries, on the other hand, simply make the information available, relying on the initiative of the user to request or search out the information needed.

Assessment. A number of studies in recent years have been specifically concerned with STI, knowledge transfer, and U.S. industrial competitiveness. They find that knowledge transfer procedures have not been adopted by federally supported information transfer activities, and that dissemination activities are treated as afterthoughts.

Problems exist with the total system as well as with the two parts. The total federal system of information transfer is passive, fragmented, and unfocused, and has no coherent or systematically designed means of transferring the results of federally funded R&D to the user.

The problem with the informal part of the system is that from collegial contacts, engineers and scientists can learn only what their colleagues happen to know. In addition, ample evidence exists to support the claim that researchers cannot know about or keep up with all of the research in their specific areas of interest. Like other members of the scientific community, engineers and scientists are faced with the problem of too much information to know about, to keep up with, and to screen.

Two problems exist with the formal aspects of the system. First, the formal part of the system employs one-way source-to-user transmission, which is not responsive to the user context. Rather, these efforts appear to start with an information system into which they later try to retrofit the users' requirements. The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer.

Second, the formal part of the system relies heavily on the use of information intermediaries. The problem in evaluating this is that empirical findings on the effectiveness of these individuals and the role they play in information transfer are sparse and inconclusive. Their impact is likely to be strongly conditional and limited to a specific institutional context.

The opportunity to enhance U.S. competitiveness begins with an understanding of the federal STI system and component subsystems. Empirical investigations, using innovative methodologies and rigorous experimental designs, need to be undertaken. The present system uses one-way source-to-user transmission procedures that do not appear to be responsive to the user context. These procedures should be replaced by interactive, two-way communication. "Cultural differences," the often-cited impediment to the development of a two-way exchange between information producers and users, should be reduced wherever possible.

Issue 5: Open Versus Restricted Access to STI

In his congressional testimony in 1989, Joseph Coyne framed the issues in terms of opened communication versus restricted access, including the Freedom of Information Act (FOIA), sensitive but unclassified information, Export Administration Regulations (EAR), and the International Trade in Arms Regulations (ITAR). There are two schools of thought regarding the management and sharing of STI resulting from federally funded science and technology programs.

One school fosters and encourages the unrestricted, full exchange of such information. Proponents of this approach take the position that only unrestricted flow, complete freedom, and access to information can ensure vital cross-fertilization of research results among engineers and scientists, both nationally and internationally. These proponents also state that a free exchange is vital for the promotion of U.S. competitiveness and innovation. They emphasize that unrestricted, full exchange of information is a two-way street.

The other school of thought advocates the protection of information by restricting access. Proponents of this approach believe that the flow of information must be restricted to control military technology vital to U.S. technological superiority, to protect national defense, and to prevent technology drafting (following in the tailwind of U.S. technology advances). This philosophy also claims that protecting information by restricting access promotes U.S. competitiveness and innovation.

The opportunity to enhance U.S. competitiveness exists with the recognition that, in simple truth, no empirical evidence exists that warrants the total adoption of either school of thought. What is needed is a middle ground, a balanced approach that will protect U.S. national security and foster U.S. competitiveness in the international marketplace.

The opportunity to enhance U.S. competitiveness exists with an answer to the question "Does the classification of government-funded R&D, for reasons of national security, actually restrain the competitiveness and innovativeness of American industry?" The Elliott Report of 1964 recommended that a mechanism be developed and implemented that will ensure that classified or otherwise restricted STI, usually in the form of U.S. government technical reports, does not remain unavailable to American industry any longer than is essential to the national interest.[5] To this should be added the need for a program that will work actively to ensure that declassified and otherwise limited-distribution U.S. government technical reports are made available to American industry.

CONCLUSION

The federal government spends approximately $60 billion annually but virtually none of this is for research on how to best transfer the results of federally funded R&D or to assess the impact of federally funded R&D on U.S. innovation, productivity, and competitiveness. This low level of funding for knowledge transfer and utilization (compared to knowledge production) supports the conclusion that knowledge transfer and utilization are not components (or simply not important ones) of the R&D process. An alternative conclusion is that government-funded R&D is simply funded for the sake of R&D; that is, to lay the groundwork for future technological development and advancement but without any clear or immediate application or direction in mind.

The American public has the right to expect that the approximately $60 billion spent each year by the federal government for R&D should somehow support both short- and long-term national economic goals while increasing the country's competitive position in the world marketplace. There is general agreement that the results of this expenditure have the potential to do exactly that. There is also concern that a host of mitigating factors may be restricting the utilization of federally funded STI, thus limiting industrial productivity and innovation and inhibiting the economic competitiveness and vitality of the country. There is general agreement that coherent, systematically designed public policy is needed for transferring the results of federally funded STI to maximize U.S. economic competitiveness. Such a goal can be reached but it takes the will of a people; the formulation, implementation, and coordination of Executive Branch policies; and congressional leadership, oversight, and support for the required infrastructure through legislation and appropriations.

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Wallace O. Keene is currently the Assistant Associate Administrator for Information Resources Management at NASA. Before joining NASA, Mr. Keene held executive positions with the Department of Health and Human Services and the Department of Energy, following several years with the Army Security Agency and the private sector. He has been a member of the adjunct faculty of the American University since 1983. Mr. Keene received a B.A. in mathematics from Florida State University and an M.B.A. in management and operations research from American University. He is a member of the Operations Research Society of America, and the American Institute of Aeronautics and Astronautics.

James L. Green is the Director of the National Space Science Data Center (NSSDC) and associate chief of the Space Data and Computing Division at NASA Goddard Space Flight Center. He received a doctorate in physics from the University of Iowa in 1979 and has published more than 30 scientific articles. His major activities in space science research have involved various aspects of magnetospheric physics of Earth and Jupiter. Dr. Green has been involved in verifying the existence of Earth's polar wind, the discovery of nitrogen in Earth's magnetosphere, and finding the origin of many naturally occurring magnetospheric high frequency emissions. Before becoming director of the NSSDC, Dr. Green was a scientist at Marshall Space Flight Center from 1980 to 1985.

Van A. Wente directed the Scientific and Technical Information Division, NASA Office of Management, from 1981 until his retirement from government service in May 1989. He directed systems development in that office beginning in 1961. After receiving a B.S. in chemical engineering from Washington University and working in industry, he began his federal employment in naval research and later worked in atomic energy technical information. Mr. Wente attended the Industrial College of the Armed Forces and served as a director of the National Federation of Abstracting and Information Services.

Gladys A. Cotter is the Director of the Scientific and Technical Information Division, NASA Office of Management. She was formerly the Director of the Defense Applied Information Technology Center, a component of the Defense Technical Information Center, and has held other positions related to the development and management of technical information and its associated technology. Ms. Cotter received an M.B.A. in information systems management from the George Washington University and her M.L.S. in automated systems from the University of Maryland.

Lester J. Rose recently retired as Assistant Head of the Technology Utilization and Applications Office at NASA Langley Research Center. He received a B.S. in aeronautical engineering from the University of Minnesota in 1943. Before joining Langley Research Center in 1978, Mr. Rose was employed in the aerospace industry for 31 years in various engineering and marketing positions.

Robert W. Brown is the Director of the Educational Affairs Division of the NASA Office of External Relations. His Federal service has also included positions with the Department of Health, Education, and Welfare, the Office of Economic Opportunity, the Office of Personnel Management, and the Federal Executive Institute. In addition, he has been a Federal Executive Fellow at the Brookings Institute. Dr. Brown received a B.A. from Lincoln University, an M.A. from Atlanta University, and a doctorate in public administration from the University of Southern California.

Robert F. Kempf is the Associate General Counsel for Intellectual Property for the NASA Office of General Counsel. He received a B.S. from the University of Massachusetts and a J.D. from Chicago-Kent College of Law. He has held several patent attorney positions in NASA and has served as a patent examiner in the U.S. Patent and Trademark Office. He has also held various engineering positions in private industry and has served as President of the Government Patent Lawyers Association.

James W. McCulla is Director of the Media Services Division of the NASA Office of Communications. He joined NASA in 1980 as Chief of the Public Services Branch of the Office of Public Affairs. In 1983, he was named Deputy Director of the Public Affairs Division. He has held his current position since 1987. Before joining NASA, Mr. McCulla was with the Agency for International Development.

James F. Kukowski is the Chief of Internal Communications, NASA Office of Communications. He was responsible for establishing the office after the loss of the Space Shuttle Challenger. Mr. Kukowski is a veteran NASA public affairs officer. He has served with the Space Shuttle program, the Office of Space Science and Applications, and the Office of Tracking and Data Systems. During his tenure at NASA Headquarters, he has carried out a wide range of audio-visual activities, including radio and television production. Mr. Kukowski joined NASA in 1966 as an educational specialist.

Thomas E. Pinelli is Assistant to the Chief of Research Information and Applications Division at NASA Langley Research Center. He holds a B.S. and M.S. from Old Dominion University, an M.S. from Clemson University, an M.P.A. from Golden Gate University, an M.S.L.S. from Catholic University, and is a doctoral candidate at the School of Library and Information Science, Indiana University. He serves as associate editor for research of *Technical Communication, Journal of the Society for Technical Communication;* as a member of the Technical Information Panel of the American Institute of Aeronautics and Astronautics; and is a member of the American Society for Engineering Education. He is the director of the NASA/DOD Aerospace Knowledge Diffusion Project. Mr. Pinelli has authored or co-authored 54 technical reports, journal articles, and conference papers related to scientific and technical communication.

N90-28451

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Appendix A: NASA Information Services

This appendix provides a consolidated list of sources for NASA information products and services.

NASA INFORMATION PRODUCTS AND SERVICES

The STI Database

At the heart of the NASA Scientific and Technical Information system is a database of aerospace information comprising more than 3 million documents. The content of the collection is in keeping with NASA's mission. Subjects covered are aeronautics, astronautics, chemistry and materials, engineering geosciences, life sciences, mathematical and computer sciences, physics, social sciences, and space sciences.

Interactive searches of the STI Database are possible through the use of NASA/RECON, the government's first major online bibliographic retrieval system. The database contains a citation for each document and an abstract for most; full text copies of the documents are available in either paper copy or microfiche. Copies may be ordered either online or through your local technical library. In many cases, copies will already be available at the library.

Contributions to the STI Database

Information added to the database comes from a variety of sources, including NASA and its contractors, the Department of Defense and its contractors, the Department of Energy and its contractors, other domestic sources, exchanges, and foreign sources. Most of the documents collected are unclassified and unlimited in terms of availability, but a small percentage is either classified or limited for various reasons. The foreign material comes from more than 130 countries and more than 600 exchange agreements. Of the USSR and other foreign material, about 85 percent is in English and the remainder in foreign languages. The latter will be translated into English upon request to the NASA Translation Service (described below).

Three organizations are responsible for collecting and processing information to be included in the STI Database: the NASA Scientific and Technical Information (STI) Facility, the American Institute of Aeronautics and Astronautics (AIAA), and the European Space Agency (ESA).

The NASA STI Facility acquires NASA, NASA contractor, and NASA grantee reports; reports issued by other government agencies, domestic and foreign institutions, universities, and commercial firms; translations in report form; NASA-owned patents and patent applications; and dissertation and thesis material emphasizing aeronautics, space, and supporting disciplines. In addition to updating the database and operating the NASA/RECON system, the STI Facility produces a variety of current awareness service including the announcement journal, *Scientific and Technical Aerospace Reports (STAR)*, published twice each month.

AIAA acquires periodicals (including government-sponsored journals), books, meeting papers, and conference proceedings issued by professional societies and academic organizations, and translations of journals and journal articles. Also, AIAA publishes an announcement journal *International Aerospace Abstracts (IAA)* twice a month.

ESA provides access to European aerospace literature and plays a vital role in acquisitions, translations, and processing. A 1964 NASA-ESA agreement initiated exchange of reports and computerized data.

Users

The principal users of the NASA Scientific and Technical Information system are scientists and engineers who work for NASA and NASA contractors. However, other government agencies and their contractors use the NASA STI Database and its products. The system is available to the academic community and to U.S. industry, for which the NASA Technology Utilization Program provides access and value-added analysis via regional applications centers. The citations contained in *STAR* and *IAA* are available as the Aerospace Database to U.S. users through AIAA and commercial vendors of online retrieval services. In addition, selected foreign organizations are involved in information exchanges.

PRODUCTS AND SERVICES

Scientists and engineers working at NASA installations or for NASA contractors and subcontractors normally obtain products and services from the NASA Scientific and Technical Information system by making a request to their local technical library. Products and services are usually available to NASA employees at no charge; contractors pay a nominal fee. To register as a NASA contractor, call (301) 621–0153 or send requests to the NASA Scientific and Technical Information (STI) Facility:

NASA Scientific and Technical Information Facility
Attn: Registration Services
P.O. Box 8757
BWI Airport, MD 21240

If you are neither a NASA employee nor a contractor nor grantee of NASA, you may request any of the following services or searches through the National Technical Information Service (NTIS), Springfield, VA 22161, unless otherwise specified.

NASA/RECON

NASA's online retrieval system uses both high-speed communication lines and dial-up net-

works. It is the only system that allows comprehensive searching of the entire NASA database. Call (202) 755–1246 regarding availability.

Search Requests

Timely response is made to special requests for NASA/RECON searches from contractors and others.

STAR

Scientific and Technical Aerospace Reports (STAR), a semimonthly abstract and index journal, announces all unclassified and unlimited reports added to the STI Database. Subscriptions to *STAR* are available to NASA and NASA contractor employees without charge.

IAA

International Aerospace Abstracts (IAA), a semimonthly abstract and index journal, announces journal articles, papers, and conference presentations. Subscriptions to *IAA* are available from the American Institute of Aeronautics and Astronautics (AIAA), 555 West 57th Street, New York, NY 10019, (212) 247–6500, or through NTIS, Springfield, VA 22161.

SCAN

Selected Current Aerospace Notices (SCAN) is a semimonthly service that announces additions to the database selected from 191 subject topics.

Continuing Bibliographies

Bibliographies covering a variety of key subject areas and providing a current awareness service at frequencies that vary from monthly to annual are available. These include: *Aeronautical Engineering, Aerospace Medicine and Biology, Earth Resources* (publication discontinued in 1990, but back issues remain available), *Management, NASA Patents, Technology for Large Space Systems, Space Station Systems,* and *NASA Scientific and Technical Publications: A Catalog . . .*

Update

Update is a personalized monthly current-awareness service that may be tailored to the needs of technical monitors, principal investigators, scientists, or engineers working on NASA contracts. *Update* comprehensively covers all new additions to the database for the month relevant to the subscriber's contract, including the new Research and Technology Objectives and Plans (RTOP) and new contract descriptions.

ADDS and Standing Order

Copies of new NASA reports are available through the Automatic Document Distribution Service (ADDS) and the Standing Order Service, which distribute approximately 3500 NASA and NASA contractor documents annually. Documents are distributed automati-

cally in one or more of the subject areas included in the STI Database. Some are distributed in microfiche form only and a small number in printed form only. Standing Order Service offers NASA contractors a monthly invoice instead of the annual subscription fee billed under *ADDS*.

Document Requests

Full-text paper copies or microfiche of almost all reports and papers in the STI Database are available through registered technical libraries and online NASA/RECON requests. Registered libraries that do not have NASA/RECON passwords may request reports by telephoning the STI Facility, (301) 621–0147, and may request published papers, journal articles, and conference proceedings by telephoning the AIAA library, (212) 247–6500.

Translations

English translations of foreign-language documents may be requested by NASA technical libraries from the NASA central translation service. Telephone (202) 755–1074.

Microfiche Distribution

Almost all new reports are available in microfiche form to NASA installations and registered organizations. Send requests to the STI Facility. Automatic distribution of literature announced in *IAA* in microfiche form is available from AIAA.

Miscellaneous Databases

Various other databases are available for search and retrieval. These include *RTOPs*, *Research and Development Contract Search File*, a *Directory of Numerical Databases*, and the *NASA Historical File*. Send requests for information on these databases to the STI Facility. The *Aerospace Research Information Network (ARIN)* containing NASA-wide library book and journal holdings is available at your local technical library.

NATIONAL SPACE SCIENCE DATA CENTER (NSSDC)

NSSDC is located at the NASA Goddard Space Flight Center, Greenbelt, MD 20771. Various services are described as follows and additional information can be obtained from the contacts listed at the end of each entry.

NSSDC Online Services

The NSSDC has data sets (containing data from many different satellites) and services available online. An account on the NSSDC VAX is required in some cases. Some services are offered through the NODIS system (NSSDC Account) on the NSSDC VAX cluster. Such access is free.

Nathan James, Code 633
(301) 286–9789
(SPAN) NCF::JAMES
(internet)james@nssdc.gsfc.nasa.gov

NASA Master Directory

The NASA Master Directory (MD) is an online search providing brief overview information about NASA and important non-NASA space and Earth science data. The MD may be accessed via SPAN, dial-up, or Internet.

James R. Thieman, Code 633
(301) 286-9790
(SPAN)NCF::THIEMAN
(internet)thieman@nssdc.gsfc.nasa.gov

IUE Request Service

The International Ultraviolet Explorer (IUE) request service allows IUE archival data to be requested and transmitted via SPAN from the NSSDC to the requester's node. The Uniform Low Dispersion Archive (ULDA), a compacted subset of the IUE archive, allows users a quick look at selected data to determine their usefulness before they request the complete spectral image. The IUE request service can be accessed via the NSSDC account.

Charleen Perry, Code 633.4
(301) 286-2899
(SPAN)NCF::PERRY
(internet)perry@nssdc.gsfc.nasa.gov

ROSAT MIPS

The ROSAT Mission Information and Planning System (MIPS) was developed to assist scientists to prepare Roentgen Satellite (ROSAT) proposals for observing X-ray sources by the ROSAT satellite scheduled for launch in May 1990. It also provides necessary schedules and reports to NASA Headquarters, the U.S. ROSAT User Committee, and general observers, and will directly interface with the West German mission-planning software.

Jeanne Behnke, Code 634
(301) 286-8340
(SPAN)ROSAT::BEHNKE
(internet)behnke@rosat.gsfc.nasa.gov

Online Astronomy Catalog Ordering System

This ordering system provides interactive access to the Astronomical Data Center's Status Report on Machine-Readable Astronomical Catalogs for users of the NSSDC VAX 8650 computer. It is designed to allow users to locate catalogs by subject and keywords, and to submit requests for data directly over the SPAN network.

Wayne H. Warren, Jr., Code 633
(301) 286-8310
(SPAN)NCF::ADCMGR
(internet)adcmgr@nssdc.gsfc.nasa.gov

STARCAT/SIMBAD

NSSDC has access to major retrieval systems for astronomical data through the locally installed Space Telescope ARchive and CATalog (STARCAT) system developed at the Space Telescope/European Coordinating Facility and the European Southern Observatory. Access to the Set of Identification, Measurements and Bibiliography for Astronomical Data (SIMBAD) databank in France is achieved through STARCAT and by a direct connection to the French packet-switched network TRANSPAC via GTE Telenet. The STARCAT system is a collection of software and associated astronomical data, and the SIMBAD databank is an object-oriented system designed to provide the latest observational data and bibliographic information for individual astronomical objects.

Wayne H. Warren, Jr., Code 633
(301) 286-8310
(SPAN)NCF::WARREN
(internet)warren@nssdc.gsfc.nasa.gov

NCDS

The NASA Climate Data System (NCDS) is an integrated scientific data and information system that supports researchers in the atmospheric, ocean, and Earth sciences by allowing them to interactively locate, access, manipulate, and display climate-related date. It is available on the NSSDC DEC VAXCluster (VAX/VMS) to the international user community over a wide variety of networks, including SPAN and Internet.

Lola Olsen, Code 634
(301) 286-9760
(SPAN)NCF::OLSEN
(internet)olsen@nssdc.gsfc.nasa.gov

TOMS

Data retrieved from the Total Ozone Mapping Spectrometer (TOMS) currently flying on NASA's Nimbus-7 satellite is archived at NSSDC for the study of stratospheric ozone. That instrument produces daily global maps of the total ozone column, and NSSDC continually places the latest gridded TOMS ozone data online.

Carolyn Ng, Code 633
(301) 286-4088
(SPAN)NCF::NG
(internet)ng@nssdc.gsfc.nasa.gov

PLDS

The Pilot Land Data System (PLDS) is a distributed prototype information system being developed to support research by land scientists. A small-scale operational period will begin in mid-1990.

Blanche Meeson, Code 634
(301) 286-9282
(SPAN)NCF::MEESON
(internet)smpt% "meeson.nssdca.gsfc.nasa.gov

CDDIS

The Crustal Dynamics Data Information System (CDDIS) was designed and implemented as part of the data management for the Crustal Dynamics Project formed by NASA to advance the scientific understanding of Earth dynamics, tectonophysics, and earthquake mechanisms. It is operational on a dedicated DEC MicroVAXII computer and is accessible through SPAN, Internet, and GTE Telenet.

Carey Noll, Code 634
(301) 286-9283
(SPAN)CDDIS::Noll
(Internet)noll@cddis.gsfc.nasa.gov

Omni Data Set

This data set contains field and plasma data provided by some 12 different spacecraft and selected solar and geomagnetic activity indices. Access is gained through the NSSDC account. Data can also be provided on magnetic tape, DC-ROM, and floppy disk, and as both plots and listings in the *NSSDC Interplanetary Medium Data Book.*

Joseph King, Code 633
(301) 286-7355
(SPAN)NCF::KING
(internet)king@nssdc.gsfc.nasa.gov

ADC

The Astronomical Data Center (ADC) specializes in the acquisition, processing, documentation, archiving, and distribution of machine-readable astronomical catalogs and other specialized data sets in various astronomical disciplines.

Wayne H. Warren, Jr., Code 633
(301) 286-8310
(SPAN)NCF::WARREN
(internet)warren@nssdc.gsfc.nasa.gov

Request Activities

NSSDC completes about 2,500 requests for offline data and information each year, providing data on magnetic tape, computer printouts, microfilm, microfiche, hard copy, cut prints, cut film, and roll film.

Patricia Ross, Code 633
(301) 286-6695
(SPAN)NCF::PATROSS
(internet)patross@nssdc.gsfc.nasa.gov

TECHNOLOGY UTILIZATION

NASA's Industrial Applications Centers (IACs) form a nationwide network offering a broad range of technical services, including computerized access to more than 100 million documents internationally. IACs provide assistance in solving specific technical problems or simply provide information. User-friendly IACs are staffed by technology tranfer experts who provide computerized information retrieval from one of the world's largest banks of technical data. Nearly 500 computerized databases, from NASA's own database to Chemical Abstracts and INSPEC, are accessible through the 10 IACs. IACs also offer technical consultation services or linkage with other experts in the field. You can obtain more information about specific services by calling or writing the nearest IAC. User fees are charged.

Aerospace Research Applications Center (ARAC)
Indianapolis Center for Advanced Research
611 N. Capitol Avenue
Indianapolis, IN 46204
F. Timothy Janis, Director
(317) 262-5036

Rural Enterprises, Inc.
Central Industrial Applications Center/NASA (CIAC)
P.O. Box 1335
Durant, OK 74702
Steve R. Hardy, President
(405) 924-5094

North Carolina Science and Technology Research Center (NC/STRC)
P.O. Box 12235
Research Triangle Park, NC 27709
H. Lynn Reese, Director
(919) 549-0671

NASA Industrial Applications Center
823 William Pitt Union
University of Pittsburgh
Pittsburgh, PA 15260
Paul A. McWilliams, Exec. Director
(412) 648-7000

NASA/Southern Technology Applications Center
Box 24
Progress Center, One Progress Blvd.
Alachua, FL 32615
J. Ronald Thornton, Director
(904) 462-3913
(800) 225-0308 (toll-free U.S.)
(800) 354-4832 (Florida only)

NASA/UK Technology Applications Program
University of Kentucky
1009 Kinkead Hall
Lexington, KY 40506-0057
William R. Strong, Director
(606) 257-6322

NERAC, Inc.
One Technology Drive
Tolland, CT 06084
Daniel U. Wilde, President
(203) 872-7000

Technology Application Center (TAC)
University of New Mexico
Albuquerque, NM 87131
Stanley A. Morain, Director
(505) 277-3622

NASA Industrial Applications Center (WESRAC)
University of Southern California Research Annex
3716 South Hope Street, Room 200
Los Angeles, CA 90007-4344
Radford G. King, Exec. Director
(213) 743-8988
(800) 872-7477 (toll-free U.S.)
(800) 642-2872 (California only)

NASA/SU Industrial Applications Center
Southern University Department of Computer Science
P.O.Box 9737
Baton Rouge, LA 70813-9737
John Hubbell, Director
(504) 771-6272

If you represent a public sector organization that has a particular need, contact NASA's Application Team for technology matching and problem solving assistance. Staffed by professional engineers from a variety of disciplines, the Application Team works with public sector organizations to identify and solve critical problems with existing NASA technology.

Technology Application Team
Research Triangle Institute
P.O. Box 12194
Research Triangle Park, NC 27907
Doris Rouse, Director
(919) 541-6980

Technology Utilitization Officers (TUOs) and Patent Counsels at each NASA installation facilitate technology transfer between NASA and the private sector.

If you need further information about new technologies presented in *NASA Tech Briefs,* request the Technical Support Package (TSP). If a TSP is not available, contact the TUO at the NASA installation that sponsored the research. The TUO can arrange for assistance in applying the technology by putting you in touch with the people who developed it. If you want information about the patent status of a technology or if you are interested in licensing a NASA invention, contact the Patent Counsel at the appropriate NASA installation. Refer to the NASA reference number at the end of the Tech Brief.

Ames Research Center
Moffett Field, CA 94035
TUO: Geoffrey S. Lee
Mail Code 223-2
(415) 604-6406
Patent Counsel: Darrell G. Brekke
Mail Code 200-11
(415) 604-5104

Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
TUO: Daniel G. Soltis
Mail Stop 7-3
(216) 433-5567
Patent Counsel: Gene E. Shook
Mail Code 301-6
(216) 433-5753

John C. Stennis Space Center
Stennis Space Center, MS 39529
TUO: Robert M. Barlow
Code HA-00, Bldg. 1103
(601) 688-1929

John F. Kennedy Space Center
Kennedy Space Center, FL 32899
TUO: Thomas M. Hammond
Mail Stop PT-PMO-A
(407) 867-3017
Patent Counsel: James O. Harrell
Mail Code PT-PAT
(407) 867-2544

Langley Research Center
Hampton, VA 23665
TUO: John Samos
Mail Stop 139A
(804) 864-2484
Patent Counsel: George F. Helfrich
Mail Code 279
(804) 864-3523

Goddard Space Flight Center
Greenbelt, MD 20771
TUO: Donald S. Friedman
Mail Code 702.1
(301) 286-6242
Patent Counsel: R. Dennis Marchang
Mail Code 204
(301) 286-7351

Jet Propulsion Laboratory
NASA Resident Office
4800 Oak Grove Drive
Pasadena, CA 91109
TUO: Gordon S. Chapman
Mail Stop 180-801
(818) 354-4849
Patent Counsel: Paul F. McCaul
Mail Code 180-801
(818) 354-2734
TUO for JPL: Dr. Norman L. Chalfin
Mail Stop 156-211
(818) 354-2240

George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
TUO: Ismail Akbay
Code AT01
(205) 544-2223
Patent Counsel: Bill Sheehan
Mail code CC01
(205) 554-0021

Lyndon B. Johnson Space Center
Houston, TX 77058
TUO: Dean C. Glenn
Mail Code IC-4
(713) 483-3809
Patent Counsel: Edward K. Fein
Mail Code AL3
(713) 483-4871

NASA Headquarters
Washington, DC 20546
TUO: Leonard A. Ault
Code CU
(202) 453-2636
Assistant General Counsel for Patent Matters: Robert F. Kempf
Code GP
(202) 453-2424

NASA's Computer Software Management and Information Center (COSMIC) is the place to contact for information about software developed with NASA funding. COSMIC publishes an annual software catalog.

COSMIC
382 East Broad Street
Athens, GA 30602
John A. Gibson, Director
(404) 542-3265

The NASA Scientific and Technical Information Facility can answer questions about NASA's Technology Utilization Network and its services and documents. The STI Facility staff supplies documents and provides referrals.

NASA STI Facility
P.O. Box 8757
Baltimore, MD 21240-0757
Walter M. Heiland, Manager
(202) 621-0242 or -0243.

NEWS AND PUBLIC SERVICES

The NASA Public Affairs Office offers a variety of information services that you may find valuable for research work or for keeping abreast of developing news events.

Electronic Information Distribution

NASA news releases and other information (Space Shuttle status reports, Shuttle manifest, current mission information, public affairs contacts, calendar of events) are available electronically through ITT Dialcom. For access to NASA NEWS through this system, contact the NASA NEWS representative, ITT Dialcom, Inc., (202) 488-0550.

NASA Select TV-Audio System

The NASA-wide TV-audio release system is a valuable tool for media coverage of the agency's activities. During Space Shuttle missions, the system provides real-time air-to-ground communications between the orbiter and mission control; public affairs launch, mission, and landing commentary; and related news briefings. The system is also used

for other NASA briefings and events. For most press briefings, the system is interactive (one-way video, two-way audio) between installations.

NASA Select coverage of Shuttle flights and other major news events is carried on a full satellite transponder as follows: Satcom F-2R, transponder 13, C-band; Orbital Position: 72OW; Frequency: 3960.0

MHz; Vertical polarization; Audio monaural: 6.8 MHz.

NASA Select video is also available at the AT&T Switching Center, Television Operation Control, Washington, DC, and the following NASA installations: Headquarters, Ames Research Center, Dryden Flight Research Facility, Jet Propulsion Laboratory, Johnson Space Center, Kennedy Space Center, Langley Research Center, and Marshall Space Flight Center. For Space Shuttle missions, updated NASA Select TV schedules may be obtained by calling COMSTOR (713) 280-8711. COMSTOR is a computer database service requiring the use of a telephone modem.

For additional information concerning NASA Select programming, call NASA Headquarters (202) 453-8372.

Television

NASA Headquarters produces a 14½ minute magazine format videotape quarterly called "Aeronautics and Space Report," which is available to TV stations via satellite through the services of Medialink. It is also uplinked to NASA installations via the NASA Select TV system. As an aid to broadcasters wishing to excerpt portions of this videotape for news programming, both audio channels are used. Channel 1 audio carries a completely mixed track with narration, music, actualities, and effects. Channel 2 audio has effects and actualities only.

To downlink this program from Medialink, television stations may call NASA Headquarters (202) 453-8594. Stations are notified in advance by Medialink when to expect a satellite feed with information on the current topics. Scripts are mailed out approximately 1 day before the satellite uplink.

Audio

NASA produces a weekly 4½ minute program called "The Space Story" and a 90-second spot called "Frontiers." These topical radio programs feature people active in NASA's ongoing research efforts, and are distributed via satellite and on broadcast-quality cassettes to thousands of stations in the United States and abroad.

Mission highlight audio tapes and other space-age sound effects are also available from the NASA radio office, (202) 453-8596.

NASA Broadcast News Service

Several NASA installations provide up-to-date reports on aeronautics and space activities through automated telephone systems. The codaphone services are Dryden, (805) 258-4464; Goddard (301) 286-NEWS; Johnson (713) 483-8600; Kennedy (407) 867-2525; and Headquarters (202) 755-1788.

Status reports during Space Shuttle missions are available by calling the above numbers for Kennedy (prelaunch), Johnson (mission operations), and Dryden (landing operations).

The Headquarters audio news service makes it possible for stations to receive interview material from astronauts before Shuttle missions.

Motion Pictures

Films describing NASA research and development programs in space and aeronautics may be borrowed from one of seven regional film libraries. There is no rental charge, but borrowers must pay the cost of return postage and insurance. Regional film libraries are maintained at Ames Research Center, Goddard Space Flight Center, Johnson Space Center, Kennedy Space Center, Langley Research Center, Lewis Research Center, and Marshall Space Flight Center.

Still Photography

NASA installations maintain photo files on current projects and those of the recent past. The Broadcast and Audio Visual Branch, NASA Headquarters, has files covering projects and missions dating back to 1958. Researchers seeking early or general material may save time by beginning their search at Headquarters.

Appendix B: Acronyms and Abbreviations

ADC	Astronomical Data System
ADDS	Automatic Document Distribution Service
AESP	Aerospace Education Services Program (Spacemobile)
AGARD	Advisory Group for Aerospace Research and Development
AI	Artificial Intelligence
AIAA	American Institute of Aeronautics and Astronautics
AIM	Automated Information Management
ARIN	Aerospace Research Information Network
CAD/CAM	Computer-Aided Design/Computer-Aided Manufacturing
CARP	Cooperative Automotive Research Program
CDDIS	Crustal Dynamics Data Information System
CD-ROM	Compact Disk—Read-Only Memory
CENDI	Commerce, Energy, NASA, and Defense Information
CITP	Civilian Industrial Technology Program
CORE	Central Operation of Resources for Educators
COSATI	Committee on Scientific and Technical Information
COSMIC	Computer Software Management and Information Center
CRDA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
DTIC	Defense Technical Inormation Center
EAR	Export Administration Regulations
EEC	European Economic Community
EPA	Environmental Protection Agency
ESA	European Space Agency
ESRO	European Space Research Organization
FCCSET	Federal Coordinating Council for Science, Engineering, and Technology
FLC	Federal Laboratory Consortium

FOIA	Freedom of Information Act
FRP	Fiber Reinforced Plastic
GPO	United States Government Printing Office
GSA	General Services Administration
HBCU	Historically Black Colleges and Universities
HPCI	High-Performance Computing Initiative
HST	Hubble Space Telescope
IAA	*International Aerospace Abstracts*
IAC	Industrial Applications Center
IISME	Industry Initiatives for Mathematics and Science Education
ITAR	International Trade in Arms Regulations
ITS	Information Technology Systems
IUE	International Ultraviolet Explorer
LAN	Local Area Network
LDEF	Long Duration Exposure Facility
MD	Master Directory
MIPS	Mission Information and Planning System
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NASP	National Aerospace Plane
NASTRAN	NASA STructural ANalysis
NATO	North Atlantic Treaty Organization
NCDS	National Climate Data System
NEWEST	NASA Education Workshops for Elementary School Teachers
NEWMAST	NASA Education Workshops for Mathematics, Science, and Precollege Technology Teachers
NIST	National Institute of Standards and Technology
NMI	NASA Management Instruction
NOAA	National Oceanographic and Atmospheric Administration
NODIS	NSSDC Online Data and Information System
NRC	National Research Council
NSF	National Science Foundation
NSN	National Science Network
NSP	National Scholars Program
NSSDC	National Space Science Data Center
NSTA	National Science Teachers Association
NTIS	National Technical Information Service
NWP	Numerical Weather Prediction
OMB	Office of Management and Budget
OSI	Open Systems Interconnect

OSTI	Office of Scientific and Technical Information
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
PLDS	Pilot Land Data System
PSAC	President's Science Advisory Committee
R&D	Research and Development
RECON	REmote CONsole System
ROSAT	ROentgen SATellite
RTOP	Research and Technology Operating Plan/Objectives and Plans
SCAN	*Selected Current Aerospace Notices*
SEEDS	Space Exposed Experiment Developed for Students
SHARP	Summer High-school Apprenticeship Program
SIMBAD	Set of Identifications, Measurements, and Bibliography for Astronomical Data
SPAN	Space Physics Analysis Network
SSE	Software Support Environment
SSIP	Space Science (Shuttle) Student Involvement Program
STAR	*Scientific and Technical Aerospace Reports*
STARCAT	Space Telescope ARchive and CATalog
STI	Scientific and Technical Information
STIMS	Scientific and Technical Information Modular System
TOMS	Total Ozone Mapping Spectrometer
TSP	Technical Support Package
TU	Technology Utilization
TUO	Technology Utilization Officer/Office
UCEP	Urban Community Enrichment Program
ULDA	Uniform Low Dispersion Archive
USGS	United States Geological Survey
USRA	Universities Space Research Association
VINITI	U.S.S.R. Institute for Scientific and Technical Information

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