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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

*Direct all correspondence to: Thomas E. Pinelli, NASA Langley Research Center, MS 180A, Hampton, Virginia 23665-5225.

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).

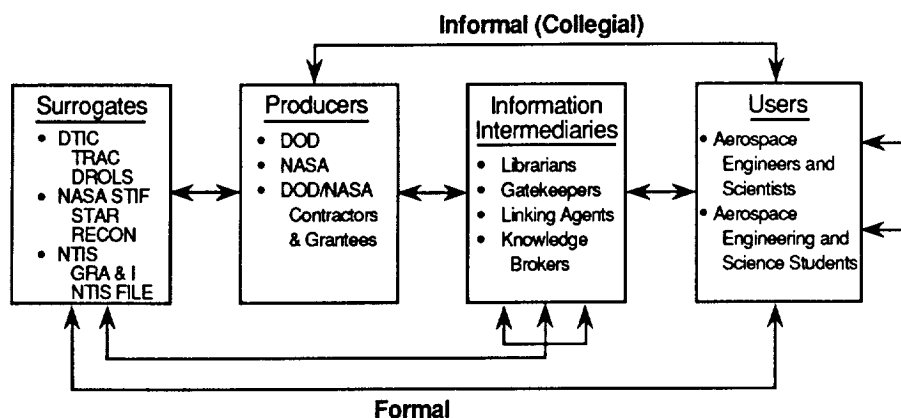


Figure 1. A Model Depicting the Transfer of Federally Funded Aerospace R&D

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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Contributors

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. Wentz 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. Wentz 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.