NASA/DoD Aerospace Knowledge Diffusion Research Project

IN-82-TM
150791
24P

Paper Twenty Seven

Knowledge Diffusion and U.S. Government Technology Policy: Issues and Opportunities for Sci/Tech Librarians

Reprinted from Science & Technology Libraries
Volume 13, Number 1 (1992): 33-55.

Thomas E. Pinelli
NASA Langley Research Center
Hampton, Virginia

Rebecca O. Barclay
Rensselaer Polytechnic Institute
Troy, New York

Stan Hannah
University of Kentucky
Lexington, Kentucky

Barbara Lawrence
American Institute of Aeronautics and Astronautics
New York, New York

John M. Kennedy
Indiana University
Bloomington, Indiana

KNOWLEDGE DIFFUSION INNOVATION
NASA DoD AEROSPACE

NASA
National Aeronautics and Space Administration

Department of Defense

INDIANA UNIVERSITY

Knowledge Diffusion and U.S. Government Technology Policy: Issues and Opportunities for Sci/Tech Librarians

Thomas E. Pinelli
Rebecca O. Barclay
Stan Hannah
Barbara Lawrence
John M. Kennedy

Thomas E. Pinelli serves as Assistant to the Chief, Research Information and Applications Division, Mail Stop 180A, NASA Langley Research Center, Hampton, VA 23665-5225. He received his PhD in Library and Information Science from Indiana University, Bloomington, IN.

Rebecca O. Barclay is Research Associate with the NASA/DoD Aerospace Knowledge Diffusion Research Project. She is pursuing a PhD in Communication and Rhetoric from Rensselaer Polytechnic Institute in the Department of Language, Literature, and Communication, RPI, Troy, NY 12180.

Stan Hannah is Assistant Professor in the College of Library and Information Science at the University of Kentucky, Lexington, KY 40506-0039. He is pursuing a PhD in Library and Information Science from Indiana University, Bloomington, IN.

Barbara Lawrence is Director of the Technical Information Division of the American Institute of Aeronautics and Astronautics (AIAA), New York, NY 10019.

John M. Kennedy is Principal Investigator of the NASA/DoD Aerospace Knowledge Diffusion Research Project and Director of the Indiana University Center for Survey Research, 1022 East Third Street, Bloomington, IN 47405. He received his PhD in Sociology from the Pennsylvania State University.

This paper is an intellectual product of the NASA/DoD Aerospace Knowledge Diffusion Research Project and was funded under NASA Grant NAGW-1682. The views expressed are the authors' and may not represent those of their respective institutions or the funding agencies.

/

pt-2

SUMMARY. Federal involvement in stimulating economic growth through the development and application of technology policy is currently the subject of serious debate. A recession and the recognition that an internationally competitive economy is a prerequisite for the attainment of national goals have fostered a number of technology policy initiatives aimed at improving the economic competitiveness of American industry. This paper suggests that the successful implementation of U.S. technology policy will require the adoption of a knowledge diffusion model, the development of user oriented information products and services, and a more "activist" approach on the part of sci/tech librarians in the provision of scientific and technical information (STI). These changes will have a dramatic impact on the sci/tech library of the future and the preparation of sci/tech librarians.

INTRODUCTION

Traditionally, the Federal government has limited itself to activities either directly or explicitly tied to an existing responsibility of a specific government agency. Since the early 1960s, however, government has taken an increasingly active role in stimulating technological change and innovation in the civilian economy. Federal attempts at stimulating and nurturing technological innovation represent a dramatic departure from earlier policy positions which were based on a strict interpretation of the "general welfare" clause of the U.S. Constitution.[1] Economic vulnerability, lagging productivity, unfavorable trade balances, loss of traditional markets, and unemployment are the primary reasons for government intervention.

Federal Involvement in Applied Research and Development (R&D)

The Federal government has successfully stimulated aerospace, agriculture, and biomedical R&D, as well as broader generic applied R&D in the National Institute of Standards and Technology (NIST). Scholars cite Federal intervention in aerospace and agriculture as models for government involvement in civilian R&D and precommercial research cooperation between industry and government. In fact, Vannevar Bush's[2] proposed model for the creation of his National Research Foundation was based on the land-grant colleges and the National Advisory Committee for Aeronautics (NACA). "Both offered science, applied science, technology, and a system for coupling knowledge with people who would use it in the field."[3]

By and large, Federal programs designed to stimulate civilian R&D have been unsuccessful. (This is not to say, however, that these programs did not contribute substantially to stimulating technological innovation.) Averch[4] suggests that these programs represent political rather than technical failures. Mowery[5] believes that the failure is both political and technical and attributes it to the application of an inappropriate theoretical economic framework, one that ignores or does not account for the effective transmission and utilization of complex research results and technological information. In particular, these programs overlook the abilities and limitations of organizations engaged in innovation to exploit extramural research, thus ignoring the relationship between knowledge production, transfer, and utilization as equally important components of the innovation process.

Unlike Japan, which has a managed and centralized approach to R&D, the U.S. funds R&D using various methods through numerous agencies of the executive branch. Federal R&D activities are undertaken by thousands of engineers and scientists in academia, government, and industry, and receive oversight, but not coordination, from many committees and subcommittees in both the executive and legislative branches of government.[6] Although considerable research into technological innovation and policy analysis has been conducted by various disciplines and from numerous perspectives, policy implications from the results of this research and investigation are inconsistent and contradictory, and are simply not used for policy development. In fact, Tornatzky and Fleischer[7] suggest that the "United States has no coherent innovation or technology policy. The United States does, however, have many programs and numerous policies which cut across political jurisdictions and the idiosyncratic missions and mandates of single agencies which are more or less responsive to a series of shifting political alliances and imperatives."

There is general consensus that current conceptual and empirical knowledge regarding both the process of technological innovation and U.S. government intervention is lacking. According to Curlee and Goel,[8] recognition is growing that technology transfer and diffusion is the "key" to the success of technological innovation. Consequently, understanding the influences that motivate innovation and channel its direction is necessary if government intervention is to successfully increase the production of useful innovation. Nelson[9] and Pavitt and Walker,[10] in their review and analysis of government policies and programs toward technological innovation, state that Federal innovation policy and prescription encourage innovation, not its adoption; knowledge transfer and utilization [diffusion] are "very inadequately served by market forces and the incentives of the market place." They conclude government would better serve public policy by assuming a more active role in the knowledge diffusion process and formulating policies and programs that encourage and improve communications between users and producers of knowledge.

Implications for Successful Federal R&D Intervention

An examination of aerospace and agriculture as successful Federal intervention programs suggests several points that should be considered by those involved in formulating Federal technology policy. Although primarily technical, these points have an obvious political component. *First*, any attempt at intervention and stimulation of civilian R&D must take into account the unique characteristics of the various industries, their previous experiences with the Federal government, and their abilities and limitations to exploit the results of extramural research. The market system specific to aerospace and agriculture exerts substantial pressure to innovate in order to maintain economic competitiveness. Consequently both industries devote considerable effort to experimenting, screening, and adapting new technology to their own specific needs. Few, if any, aerospace companies can afford to invest in long term, high risk R&D, thus making them ideal clients for a federally funded R&D program which produces new technology, works on specific-discipline related problems, and makes the results available to the companies.

Second, the character of the industry which is the presumed beneficiary of the R&D program is central to its potential for success. The structure of the industry must lend itself to taking advantage of the programs' results, the leaders of the industry must be interested in and not opposed to the programs, and the government/industry relationship needs to be based on long standing trust and the perception of mutual benefit. Both aerospace and agriculture have established relationships with the Federal government dating back to 1917 with the creation of the NACA and its first research laboratory and the Hatch Act of 1887 which created the agricultural experiment stations. Industry leaders support government involvement and perceive Federal research programs to be mutually beneficial.

Third, careful attention needs to be given to the balance between user (industry) needs and the institutional/technical capabilities of the R&D institutions in designing the programs. The conduct of research in and of itself is not sufficient to assure that it will be used productively and put to use in commercial applications. Both aerospace and agriculture use mechanisms such as committees and peer review to ensure that the federally funded research undertaken is relevant, desirable, and needed.

Fourth, there must be a system for coupling knowledge with people who would use it in the field. Both aerospace and agriculture have established programs for collecting, controlling, and disseminating the results of federally funded R&D. Within both programs the U.S. government technical report is used as a primary means of transferring the results of this research to the user community. Additionally, both systems have components that include collecting, translating, evaluating, and disseminating the results of foreign R&D to U.S. academic, government, and industry users. This point has particular relevance for the implementation of a knowledge diffusion model and a more activist role for the sci/tech librarian in knowledge diffusion.

Fifth, successful technology policy includes both "supply-push" and "demand-pull" elements. In the case of aerospace, the use of Federal policy to supply and push aerospace knowledge began with the creation of the NACA by Congress to "supervise and direct the scientific study of the problems of flight with a view to their practical solutions and to give advice to the military air services and other aviation services of government." In its wind tunnels and laboratories, the NACA worked on problems of aerodynamics and aeronautics common to both military and commercial aviation, guided by committees composed of representatives from the aviation industry, the military services, and academia.

The demand-pull was accomplished through the passage of various legislation including the Kelly Air Mail Act of 1925, the McNary-Watres Act of 1930, and the creation of the Civil Aeronautics Board in 1938. This legislation had the combined effect of furthering the demand for state-of-the-art aircraft and fostering the rapid diffusion and adoption of innovations that drew upon federally funded research results.

DIFFUSING THE RESULTS OF FEDERALLY FUNDED R&D

There is general agreement among policymakers that STI derived from federally funded R&D can be used to enhance technological innovation and economic competitiveness. Studies show a positive relationship between federally funded STI and successful innovation, technical performance, and increased productivity. What is unknown, however, is how STI is linked to the various components of the R&D process. Obtaining this knowledge is critical for formulating U.S. government technology policy. Such policy would, of course, recognize the inherent relationship between technological innovation and STI resulting from federally funded R&D.

Three models or approaches have dominated the "transfer" of federally funded R&D.[11,12] While variations of the models or approaches have been tried, Federal R&D transfer and diffusion activities continue to be driven by a "supply-side" model.

The Appropriability Model

The *appropriability model* emphasizes the production of knowledge by the Federal government that would not otherwise be produced by the private sector and competitive market pressures to promote the use of that knowledge. This model emphasizes the production of basic research as the driving force behind technological development and economic growth and assumes that the Federal provision of R&D will be rapidly assimilated by the private sector. Deliberate transfer mechanisms and intervention by information intermediaries are viewed as unnecessary. Appropriability emphasizes the supply (production) of knowledge in sufficient quantity to attract potential users. Good technologies, according to this model, sell themselves and offer clear policy recommendations regarding Federal priorities for improving technological development and economic growth. This model incorrectly assumes that the results of federally funded R&D will be acquired and used by the private sector, ignores the fact that most basic research is irrelevant to technological innovation, and dismisses the process of technological innovation within the firm.

The Dissemination Model

The *dissemination model* emphasizes the need to transfer information to potential users and embraces the belief that the production of quality knowledge is not sufficient to ensure its fullest use. Linkage mechanisms, such as information intermediaries, are needed to identify useful knowledge and to transfer it to potential users. This model assumes that if these mechanisms are available to link potential users with knowledge producers, then better opportunities exist for users to determine what knowledge is available, acquire it, and apply it to their needs. This model, which is used in aerospace, grew from recommendations of several "blue ribbon" committees such as those documented in the Weinberg Report (1963) and led to the creation of the Federal "clearinghouses" including the National Technical Information Service (NTIS). The strength of this model rests with the recognition that STI transfer and use are critical elements of the process of technological innovation. Its weakness lies with the fact that it is passive, for it does not take users into consideration except when they enter the system and request assistance; however, user requirements are seldom known or considered in the design of information products and services. This model employs one-way, source-to-user transfer procedures that are seldom responsive in the user context.

The Knowledge Diffusion Model

The *knowledge diffusion model* is grounded in theory and practice associated with the diffusion of innovation and planned change research and the clinical models of social research and mental health. In terms of Federal support for applied R&D, the Agricultural Extension Service, with its network of extension agents who work directly with farmers, closely approximates this model. Knowledge diffusion emphasizes "active" intervention as opposed to dissemination and access; stresses intervention and reliance on interpersonal communications as a means of identifying and removing interpersonal barriers between users and producers; and assumes that knowledge production, transfer, and use are equally important components of the R&D process. This approach also emphasizes the link between producers, transfer agents, and users and seeks to develop user-oriented mechanisms (e.g., products and services) specifically tailored to the needs and circumstances of the user. It makes the assumption that the results of federally funded R&D will be under utilized unless they are relevant to users and ongoing relationships are developed among users and producers. The problem with the knowledge diffusion model is that (1) it requires a large Federal role and presence and (2) it runs contrary to the dominant assumptions of the established Federal R&D policy system.

U.S. GOVERNMENT TECHNOLOGY POLICY AND KNOWLEDGE DIFFUSION

It is accepted *a priori* that STI resulting from federally funded research in science and technology can nurture and stimulate technological innovation. Therefore, it must be included as a component of U.S. government technology policy. Federal policymakers have expressed concern that STI may be underutilized and have suggested that the linkages between technology and STI be closely examined as part of the policy formulation process. In fact, a body of knowledge exists to support the claim that the existing model and mechanism used to transfer STI may contribute to its under utilization.[13] Finally, there are those who believe that the existing structure and organization of STI as manifested in present day libraries and technical information centers may actually impede its transfer.[14]

STI and Technology Policy

By and large, the relationship between STI and the process of technological innovation is not well understood by policy and lawmakers. The U.S. has no overall strategy regarding the use of STI to stimulate technological innovation and currently lacks a focal point for developing one.[13] At the Federal level, the transfer and utilization of STI goes uncoordinated; there is no centrality concerning issue identification and resolution. Although the Office of Science and Technology Policy (OSTP) has 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," in general, OSTP has not fulfilled this legislative directive.[6]

At present, the U.S. lacks a coherent or systematically designed approach to transferring the results of federally funded R&D to the user.[13] The very low level of support for knowledge transfer in comparison to knowledge production suggests that transfer efforts are not regarded as an important component of the R&D process.[14] Roberts and Frohman[15] claim that most Federal approaches to "transfer" are simply ineffective in stimulating technological innovation because they "start to encourage the utilization of STI only after the R&D results have been generated" rather than during the idea development phase of the innovation process.

Scholars such as Branscomb[16] argue that the current "supply-side" approach to knowledge production and the "trickle down" benefits associated with the funding of basic research and mission-oriented R&D are inadequate for developing a U.S. technology policy. They will simply not restore the U.S. to a more competitive footing with other industrialized countries such as Germany and Japan. These industrialized nations are adopting "diffusion-oriented" or "capability-enhancing" policies which increase the power to absorb and employ new technologies productively. U.S. technology policy efforts, on the other hand, continue to encourage innovation, not its adaption; remain product, not process oriented; and rely on a "dissemination-oriented" approach to the transfer of STI.

A strong technology policy would commit the U.S. to building a technology infrastructure that includes an STI transfer component based on a knowledge diffusion model. This model should have an "activist" component that emphasizes both domestic and imported STI, and it should be responsive in a "user" context. In short, this policy would be committed to "Total Quality Information Management." In addition to performing data and information evaluation, it would be coordinated across Federal agencies by the OSTP using a mechanism similar to the now defunct Committee on Scientific and Technical Information (COSATI).[16]

Limitations of the Existing Federal STI Transfer Mechanism

The existing Federal STI transfer mechanism is composed of two parts–the *informal* that relies on collegial contacts and the *formal* that relies on surrogates, information products, and information intermediaries to complete the "producer to user" transfer process. The producers are the Federal R&D "mission" agencies and their contractors and grantees. Producers depend upon surrogates and information intermediaries to operate the formal transfer component.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Center for Aero Space Information (CASI), and the National Technical Information Service (NTIS). Information intermediaries are, in large part, librarians and technical information specialists in academia, government, and industry. Those representing the producers serve as what McGowan and Loveless[17] call "knowledge brokers" or "linking agents." Information intermediaries connected with users act, according to Allen,[18] as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process.[19] Active intermediaries take information from one place and move it to another, often face-to-face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed."[20]

The major problem with the total Federal STI system is "that the present system for transferring the results of federally funded STI is passive, fragmented, and unfocused." Effective knowledge transfer is hindered by the fact the Federal government "has no coherent or systemmatically designed approach to transferring the results of federally funded R&D to the user."[13] Approaches to STI transfer vary considerably from agency to agency and, with any given agency, have changed significantly over time. These variations reflect differences between agencies (i.e., legislative mandates), the interpretation of their missions, and budgetary opportunities and constraints. In their study of issues and options in Federal STI, Bikson and her colleagues[14] found that many interviewees considered dissemination activities "afterthoughts, undertaken without serious commitment by Federal agencies whose primary concerns were with [knowledge] production and not with knowledge transfer"; therefore, "much of what has been learned about knowledge transfer has not been incorporated into federally supported STI transfer activities."

The specific problem with the *informal* part of the system is that knowledge users can learn from collegial contacts only what those contacts happen to know. Ample evidence supports the claim that no one researcher can know about or keep up with all the research in his/her area(s) of interest. Two problems exist with the *formal* part of the system. First, it employs one-way, source-to-user transmission. The problem with this kind of transmission is that one-way, "supply-side" transfer procedures do not seem to be responsive to the user context.[14] Rather, these efforts appear to start with an information system into which the users' requirements are retrofit.[21] The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer.[14]

Second, the *formal* part relies heavily on information intermediaries to complete the knowledge transfer process, but a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking.[22] The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context. To date, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive.[23]

The *formal* part of the transfer mechanism is particularly ineffective because STI is not organized and structured according to problem relevance. More to the point, putting STI to use frequently requires transferring it in a use context that is quite different from the context in which it was produced or originally packaged. This problem is complicated by the fact that STI is organized along traditional disciplinary lines as are subject matter indexes, abstracts, and key words. This organizational scheme makes multidisciplinary retrieval extremely difficult for users and (typically non-technical) information intermediaries alike. The *formal* part of the transfer mechanism becomes even less effective when the user's environment is not well aligned with the standard disciplinary taxonomies.[14]

The Existing Structure, Organization, and Management of STI

The existing structure, organization, and management of STI may restrict or inhibit the process of technological innovation. Consequently, changes must be made as part of any effort, national or otherwise, to nurture technological innovation and to stimulate economic growth through the development of technology policy.

Passivity of libraries. Traditionally, libraries and technical information centers that house STI are passive structures that require the user to initiate a request for information. They employ one-way, source-to-user transfer procedures that are seldom responsive to the user context. The consensus of findings from empirical research is that interactive, two-way communications are required for effective STI transfer.[14] Complaints from STI users indicate that these findings have not been incorporated into the design of STI products and services and the operations of most libraries and technical information centers that house STI.

Passivity may be attributable to two historical causes. *First,* for the most part, libraries and technical information centers that house STI are funded as cost centers: their cost is charged to the overhead of the organization. Constant attempts by organizations to reduce overhead result in passively structured and staffed operations. Such a low level of support for knowledge transfer prohibits interactive, two-way communications. In the new structure, organization, and management, STI must become more of a strategic resource and less of an overhead burden. *Second*, the paradigm governing library and information science education is based on a dissemination model which stipulates that libraries provide documents instead of supplying information; thus, library and information science graduates remain tied to information artifacts and do not learn to take active roles in the STI transfer process. Simply stated, libraries and technical information centers that house STI manage information resources (those things which carry information) rather than manage information.[24]

In the new structure, organization, and management of STI, passivity must become activism. The need for more frequent and more effective use of STI characterizes the strategic version of today's competitive marketplace. There are several reasons for this. Information technology is making the same STI available at the same time to all competitors. The marketplace is increasingly characterized by a growing number of stakeholders that are constantly changing. This implies that a broader array of STI will be needed for decision making and that simply providing retrieval and access without providing interpretation and analysis is meaningless. The need to provide STI interpretation and analysis is critical because there is less time available for making decisions and the half-life of information is getting shorter.[25] Finally, increasing U.S. collaboration with foreign producers will result in a more international manufacturing environment. These alliances will result in a more rapid diffusion of technology, increasing pressure on U.S. companies to push forward with new technological developments and to take steps designed to maximize the inclusion of recent technological developments into the (R&D) process.

Lack of user responsiveness. STI is just not organized, structured, and delivered in ways that take into account the characteristics of individuals involved in the process of technological innovation, the majority of whom are engineers. Technological innovation implies a knowledge-producing activity embedded within a larger problem-solving activity.[26] Throughout the innovation process, ideas and knowledge are pursued and transferred. The fact that these ideas and knowledge may be "physically or hardware encoded" does not alter the fact that the process of innovation is fundamentally an information processing activity.[18] To facilitate information processing, STI transfer mechanisms should be user-responsive, giving users greater control over and involvement in the knowledge diffusion process.[14]

STI is currently structured and organized around a (basic) science rather than an (applied) technology model that consequently better serves scientists, not engineers. Fundamental differences between science (scientists) and technology (engineers) have significant implications for planning information services for these two groups. Typically, the goal of the scientist is to build theory and advance knowledge by making original contributions to the literature. The goal of the engineer is to produce or (re)design a product, process, or system. Engineers, unlike scientists, work within time constraints; they are seldom interested in theory, source data, and guides to the literature so much as they are in reliable answers to specific questions.[27]

Engineers tend to read less than scientists, consult literature and libraries less frequently, and seldom use the information products and services which are directly oriented to them. What engineers usually want is a specific answer, in terms and format that are intelligible to them, not a collection of documents that they must sift, evaluate, and translate before they can apply them. Their search for information seems to be based more on the need for a specific problem solution than around a search for general opportunity.[27]

Limitations of STI retrieval systems. Contemporary STI retrieval systems may exacerbate the problems of the existing structure, organization, and management of knowledge and its lack of user responsiveness. In fact, STI retrieval systems may now be contributing to the very problems they were designed to solve. Few would argue with Lancaster[28] that "while technological advances have undoubtedly increased physical access to sources of information, it is very doubtful that intellectual access has increased significantly, if at all." Although advances in computer hardware may provide greater access to available STI, they do not provide an effective means of filtering the STI in terms of quality or problem relevance.

The rapid growth in the volume of STI that must be stored and retrieved is not the only problem confronting users of STI retrieval systems, however. There is a growing awareness that contemporary STI retrieval systems " . . . are primitive and prevent the full utilization of the information . . . "[29] The traditional STI retrieval system " . . . does not inform (i.e., change the knowledge of) users on the subject of their inquiry. It merely informs them on the existence (or nonexistence) and whereabouts of information packages relating to their request."[30] In other words, current STI retrieval systems are misnamed. They do not retrieve STI; rather they retrieve citations. The bibliographic citations, of course, do not reflect the rich network of inter-relationships that exist in any scientific discipline. In fact, the resulting citations are so devoid of structure that they are usually arranged chronologically by year or by authors' last names.

Researchers involved in technological innovation see their work in terms of STI that is problem-oriented and organized according to products, procedures, and processes. To meet their STI needs, they want a source that exhibits an understanding of the major topics and paradigms in their field. What they do not need is a bibliography produced by a librarian who typically has little, if any, education or experience in the subject being searched.

Librarians and information scientists usually discount the preceding criticisms by noting that most users cannot accurately or adequately define their information needs. Moreover, they assert that these individuals are information "illiterate." The fact is, however, that users of STI do not approach information searching in the same way that librarians do. Whereas a librarian might begin a search by consulting the appropriate index or guide to the literature, card catalog, or electronic database, STI users consult colleagues and personal collections of information.

The Promise of Intelligent Databases

The pressing need is to develop a new paradigm for structuring, organizing, and managing STI that will allow researchers to retrieve ideas–not bibliographic citations. Conceptually, the next step is to develop databases that will store not only facts about individual documents but also the linkages that exist among the documents. These "intelligent" databases would provide an abstract model of the subject specialty that would closely resemble the researcher's working model. In a very real sense such a database could be correctly termed an intelligent database. Such databases would equip sci/tech libraries with a retrieval tool that would equal the power of Vannevar Bush's famed Memex, the individualized, private file organizer and personal library that would act as "an enlarged intimate supplement" to the researcher's memory.[31] Most importantly, Memex would, like the human mind, be able to retrieve information by associating ideas and not by matching index terms.[31]

Intelligent databases are quite real. They are the outgrowth of the confluence of two key technologies. The first is the traditional online retrieval system with its processing and mass storage capabilities. The second is a subset of artificial intelligence: expert systems. Expert systems are now sufficiently developed to allow the construction of online retrieval systems that can represent documents in terms of concepts rather than keywords; in short, the technological tools needed to build databases that can truly represent the intellectual framework of a discipline are now available.[29]

The design of the complex knowledge representation schemes needed to construct intelligent databases will be a difficult and costly task. However, the availability of "shells," a software package that facilitates the building of knowledge-based systems (also called expert systems), by providing a built-in knowledge representation schema and inference engine, means that the builders of intelligent databases no longer need the advanced programming skills required for developing artificial intelligence applications.[32] In effect, the shells put the expertise needed to construct a knowledge-based system into a software package, thus reducing " . . . the levels of skill required by developers."[33] Advances in shells have so dramatically reduced the cost and risks of developing an intelligent database that Klein and Methlie state that the technology is now both practical and available.[34] The advent of intelligent databases will dramatically change " . . . how we do research, how we look for ideas, how we make decisions, and how knowledge is transmitted."[29] For Feigenbaum, McCorduck, and Nii, the benefits of intelligent knowledge databases are so compelling that there is no question that such systems will be built in next decade; " . . . the only open question is when."[35]

The Need for a New Paradigm

For practicing sci/tech librarians there is another "open question" that is important to answer: who will build and manage the new intelligent information retrieval systems? Hopefully, the information science component of the sci/tech library profession will play a central role in their design, construction, and management. However, there are several important and fundamental impediments that the profession must overcome before they can be important players in the development of intelligent databases. Information scientists must rethink many of their current practices and change many of their procedures. But, what is most urgently needed in the profession, as Dougherty notes, is "a dramatic break with the past" coupled with " . . . new initiatives that will enable [sci/tech] librarians to make fuller use of information technologies and the talents of library professionals."[36]

The need for breaking with the past is not mere rhetoric. This break with the past requires a new paradigm for structuring, organizing, and managing STI that allows for the retrieval of ideas; emphasizes sci/tech librarians interpreting and analyzing information rather than accessing and retrieving documents; and enables information scientists to play an active and central role in the design, construction, and management of intelligent STI knowledge-based databases using expert systems. Breaking with the past is never easy, however. The new paradigm may necessitate a complete restructuring of library and information science education, "support of basic information science, including research leadership in the field, and constant self-renewal through some drastic form of continuing education, e.g., joint commitment by school and student to lifelong cyclic return to the school, following the first degree."[37] To do less, according to Heilprin, will "probably lead to [the] absorption of functions and personnel of the [sci/tech] library by other, more competitively adaptive information communities." [37]

Sci/tech librarians have been educated and socialized to maintain, care for, and love the library and its enormous collection of documents. Since so much of the daily operation and activity of today's sci/tech libraries revolve around inventorying, housing, and maintaining the collection of documents, these libraries have inevitably been more concerned about preserving the collection than in accessing the collection. As Heaps has stated, the needs of the traditional library " . . . led to the development of standard procedures for manual cataloguing, use of card indexes, bibliographies, and the circulation and ordering of books, journals, and reports."[38] As a natural result, " . . . the traditional library was oriented more to managing the things which carry information than managing information as if it were a resource."[38]

While it is easy to point out obstacles that will prevent information scientists from participating in the development of intelligent STI retrieval systems, it is important to note that they also possess the type of skills that would qualify them to work as knowledge engineers. The term "knowledge engineer" was first coined by Edward Feigenbaum in 1977 to describe the person who would be responsible for identifying pertinent information, developing a knowledge framework through a combination of representation and inference, and implementing this framework using software tools.[35] The skills needed by the knowledge engineer include a solid working knowledge of systems design and "a fairly high degree of computer literacy;" in addition, the future knowledge engineer must possess " . . . a fairly wide range of skills, many of which are behavioral in nature."[39]

Clearly, many information scientists already have most of the skills that would be needed by a knowledge engineer. One fact is certain: intelligent databases will be developed in the near future, and they will offer the kind of context sensitive access that will transform Bush's visionary Memex into a practical research tool. What is less clear, however, is the role that information scientists will play in the development of intelligent databases. Hopefully, they will seize the opportunity and adapt their professional and educational institutions so that they can take full advantage of the enormous opportunities offered by intelligent database technology.

Unfortunately, library and information science education reflects the same uneasy mixture of traditional values overlaid with a soupçon of information technology that characterizes so much of the professional life of information scientists. A large part of the curriculum is designed to turn out students qualified to operate document warehouses, while a set of specialized courses that are usually introductory in nature, attempt to turn out information professionals equipped with the skills needed to take advantage of the new information technologies. In a very real sense, library and information science education is struggling, perhaps unsuccessfully, with an attempt to amalgamate two incompatible and competing paradigms.[40]

CONCLUDING REMARKS

In a *Wall Street Journal* editorial,[41] Peter Drucker stated that to be competitive and successful in the global marketplace requires a strategy that includes a commitment to change, leadership in the management of technology, and the wise use of knowledge. He further states that the Japanese are "willing to pay large sums to gain access to the knowledge their foreign partners will produce and control over it–or at least priority in using it."[41] In doing so, the Japanese have adopted a "diffusion-oriented" approach to technology policy. Every major Japanese industrial group has its own research institute, whose main function is to bring to the group awareness of any important new knowledge in technology developed world-wide.

U.S. technology policy must be based on the belief that the production, transfer, and use of STI is inextricably linked to successful technological innovation; that the process of technological innovation is best served by a "knowledge diffusion" based model; and that an STI transfer infrastructure, funded and coordinated as a partnership between American industry and the Federal government, is required for the nation to become competitive in the global marketplace in the 1990s and beyond.

For years land, labor, and capital were perceived to be the forces propelling the economic growth of industrialized nations. With the advent of a global economy, information has been added to the traditional sources of wealth.[42] In international industries, the successful firms will be those that produce, transfer, and utilize STI for marketplace and strategic advantages. "Comparative advantages of organizations are to be found more in knowing the *how* and *when* to use information rather than in simply having it."[25] Given that the *how* of information use is "inadequately developed and poorly applied in nearly all private and public organizations,"[42] American industry must reexamine its approach to the management and utilization of STI as part of a strategic version directed toward successful participation in the global economy.

A commitment by the sci/tech library community to change and to a new paradigm is required. While the exact shape of the new sci/tech library paradigm cannot be seen in minute detail, its major features are clear. The paradigm will embrace many of the same principles of success that have been identified in successful firms in the private sector. *First*, the paradigm must recognize that the sci/tech library's clients are striving to meet the demands of a rapidly changing competitive scene. *Second*, to meet their clients' needs, sci/tech library services will take on many of the characteristics common to the most successful private sector firms, such as, a proactive stance that emphasizes value-added services that are tailored to meet the individual needs of each user or groups of users, innovative services that are the result of intensive listening to the customer, exceptional services and responsiveness to customers, and a love and appreciation for change . . . "at least as much love for change as we hated it in the past."[43]

REFERENCE NOTES

1. Tiech, Albert H. "Federal Support of Applied research: A Review of the United States Experience." Paper commissioned for a workshop on *The Federal Role in Research and Development*, November 21-22, 1985, held in Washington, DC and sponsored by the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine.

2. Bush, Vannevar. *Science: The Endless Frontier*. (Washington, DC: Government Printing Office, 1945.)

3. Shapley, Deborah and Rustom Roy. *Lost at the Frontier: U.S. Science and Technology Policy Adrift*. (Philadelphia: ISI Press, 1985.)

4. Averch, Harvey A. *A Strategic Analysis of Science & Technology Policy*. (Baltimore, MD: The Johns Hopkins University Press, 1985.)

5. Mowery, David C. "Economic Theory and Government Technology Policy." *Policy Sciences* 16 (1983): 27-43.

6. Pinelli, Thomas E. "Enhancing U.S. Competitiveness through Federal Scientific and Technical Information: Issues and Opportunities." *Government Information Quarterly* 7:2 1990: 219-228.

7. Tornatzky, Louis G. and Mitchell Fleischer. *The Process of Technological Innovation.* (Lexington, MA: D.C. Heath Company, 1990.)

8. Curlee, T.R. and R.K. Goel. *The Transfer and Diffusion of New Technologies: A Review of the Economic Literature.* ORNL/TM-11155. Oak Ridge, TN: U.S. Department of Energy, June 1989. (Available from NTIS, Springfield, VA; N90-11655.)

9. Nelson, Richard R. "Government Stimulus of Technological Progress: Lessons From American History." In *Government and Technical Progress: A Cross-Industry Analysis,* Richard R. Nelson, ed. (NY: Pergamon Press, 1982), 435-463.

10. Pavitt, K. and W. Walker. "Government Policies Toward Industrial Innovation: A Review." *Research Policy* 5:1 (January 1976): 11-97.

11. Ballard, Steven et al. *Innovation Through Technical and Scientific Information: Government and Industry Cooperation.* (NY: Quorum Books, 1989), 39-45.

12. Williams, Frederick and David V. Gibson, eds. *Technology Transfer: A Communication Perspective.* (Newbury Park, CA: Sage Publications, 1990), 14-15.

13. Ballard, Steve et al. *Improving the Transfer and Use of Scientific and Technical Information. The Federal Role: Volume 2–Problems and Issues in the Transfer and Use of STI.* Washington, DC: National Science Foundation, 1986. (Available from NTIS, Springfield, VA; PB-87-142923.)

14. Bikson, Tora K.; Barbara E. Quint; and Leland L. Johnson. *Scientific and Technical Information Transfer: Issues and Options.* Washington, DC: National Science Foundation, March 1984. (Available from NTIS, Springfield, VA; PB-85-150357; also available as Rand Note 2131.)

15. Roberts, Edward B. and Alan L. Frohman. "Strategies for Improving Research Utilization." *Technology Review* 80 (March/April 1978): 32-39.

16. Branscomb, Lewis G. "Toward a U.S. Technology Policy." *Issues in Science and Technology* 7:4 (Summer 1991): 50-55.

17. McGowan, Robert P. and Stephen Loveless. "Strategies for Information Management: The Administrator's Perspective." *Public Administration Review* 41:3 (May/June 1981): 331-339.

18. Allen, Thomas J. *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization.* (Cambridge, MA: MIT Press, 1977.)

19. Goldhor, Richard S. and Robert T. Lund. "University-to-Industry Advanced Technology Transfer: A Case Study." *Research Policy* 12 (1983): 121-152.

20. Eveland, J. D. *Scientific and Technical Information Exchange: Issues and*

Findings. Washington, DC: National Science Foundation, March 1987. (Not available from NTIS.)

21. Adam, Ralph. "Pulling the Minds of Social Scientists Together: Towards a World Social Science Information System." *International Social Science Jcurnal* 27:3 (1975): 519-531.

22. Kitchen, Paul and Associates. *A Review of the Feasibility of Developing a Methodology to Demonstrate the Value of Canadian Federal Libraries in Economic Terms*. Canada: Paul Kitchen and Associates, March 1989.

23. Beyer, Janice M. and Harrison M. Trice. "The Utilization Process: A Conceptual Framework and Synthesis of Empirical Findings." *Administrative Science Quarterly* 27 (December 1982): 591-622.

24. Diener, AV Richard. "A Tale of Two Paradigms, or Whatever Happened to IRM?" *Bulletin of the American Society for Information Science* 18:2 (December/January 1992): 26-27.

25. Barabba, Vincent P. and Gerald Zaltman. *Hearing the Voice of the Market: Competitive Advantage through Creative Use of Market Information*. (Boston, MA: Harvard Business School Press, 1991), 23-25.

26. Vincenti, Walter G. *What Engineers Know and How They Know It: Analytical Studies From Aeronautical History*. (Baltimore, MD: Johns Hopkins University Press, 1990.)

27. Pinelli, Thomas E. "The Information-Seeking Habits and Practices of Engineers." *Science & Technology Libraries* 11:3 (Spring 1991): 5-25.

28. Lancaster, Frederick W. "Has Technology Failed Us?" *Information Technology and Library Management: Festschrift in Honour of Margaret Beckman*. 13th International Essen Symposium, 22-25 October 1989, ed. by Ahmed H. Helal and Joachim W. Weiss. (Essen: Essen University Library, 1991.)

29. Parsaye, Kamran et al. *Intelligent Databases: Object-Oriented, Deductive, Hypermedia Technologies*. (New York: John Wiley, 1989,) 256.

30. Lancaster, Frederick W. *Information Retrieval*. (New York: John Wiley, 1968), 1.

31. Bush, Vannevar. "As We May Think." *Atlantic Monthly* 176:1 (July 1945): 107.

32. Edwards, John S. *Building Knowledge-Based Systems: Towards a Methodology*. (NY: Halsted Press, 1991), 242.

33. Beynon-Davies, P. *Expert Database System: A Gentle Introduction*. (London: McGraw-Hill, 1991), 39.

34. Klein, Michael and Leif B. Methlie. *Expert Systems: A Decision Support Approach*. (Wokingham, England: Addison-Wesley, 1990), 2.

35. Feigenbaum, Edward; Pamela McCorduck; and H. Penny Nii. *The Rise of the Expert Company*. (NY: Vintage Books, 1988), 266.

36. Dougherty, Richard M. "Needed: User-Responsive Research Libraries." *Library Journal*. 116:1 (January 1990): 59-62.

37. Heilprin, Laurence B. "The Library Community at a Technological and Philosophical Crossroads: Necessary and Sufficient Conditions for Survival."

Journal of the American Society for Information Science 42:8 (September 1991): 566-573.

38. Heaps, H.S. *Information Retrieval: Computational and Theoretical Aspects.* (NY: Academic Press, 1978), 1.

39. Beerel, Annabel. *Expert Systems: Strategic Implications and Applications.* (Chichester: Ellis Horwood, 1987), 129.

40. Blaise Cronin observed that library and information science programs are, like the human brain, split into two hemispheres that have different functions; *Vibrations.* "Cronin Urges Technological Upgrade." 30:1 (Fall 1991): 1.

41. Drucker, Peter F. "Japan: New Strategies for a New Reality" *The Wall Street Journal.* October 2, 1991.

42. Badaracco, J.L., Jr. *The Knowledge Link: How Firms Compete Through Strategic Alliances.* (Boston, MA: Harvard Business Press, 1991), 1-2.

43. Peters, Tom. *Thriving on Chaos: Handbook for a Management Revolution.* (NY: Knopf, 1987), 45.