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Maximizing the Results of Federally-funded Research
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A Strategic Imperative for Improving U.S. Competitiveness

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Maximizing the Results of Federally-funded Research and Development through Knowledge Management: A Strategic Imperative for Improving U.S. Competitiveness

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Federally-funded research and development (R&D) represents a significant annual investment (approximately $79 billion in fiscal year 1996) on the part of U.S. taxpayers. Based on the results of a 10-year study of knowledge diffusion in the U.S. aerospace industry, the authors take the position that U.S. competitiveness will be enhanced if knowledge management strategies, employed within a capability-enhancing U.S. technology policy framework, are applied to diffusing the results of federally-funded R&D. In making their case, the authors stress the importance of knowledge as *the* source of competitive advantage in today's global economy. Next, they offer a practice-based definition of knowledge management and discuss three current approaches to knowledge management implementation—mechanistic, "the learning organization," and systemic. The authors then examine three weaknesses in existing U.S. public policy and policy implementation—the dominance of knowledge creation, the need for diffusion-oriented technology policy, and the prevalence of a dissemination model—that affect diffusion of the results of federally-funded R&D. To address these shortcomings, they propose the development of a knowledge management framework for diffusing the results of federally-funded R&D. The article closes with a discussion of some issues and challenges associated with implementing a knowledge management framework for diffusing the results of federally-funded R&D.

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Economists, management theorists, and business strategists alike recognize knowledge as *the* single most important resource in today's global economy. Information and knowledge have replaced financial capital as the main producers of wealth. A new "information capitalism" now dominates the world economy; industries that have moved into the center of the economy in the last 40 years have as their business the production and distribution of knowledge and information.[1] Knowledge *qua* capital represents a new and vital factor that must be added to the three factors of production—land, labor, and financial capital—traditionally studied by economists.[2] However, knowledge *qua* capital, or production asset, defies easy definition; therefore, existing economic theories cannot be applied to explain its behavior.[3] Schmookler[4] points out that knowledge may be valued for its own sake, as a "public good," or for its application, through which it becomes a "private" or "capital good." Theorists posit a positive relationship between knowledge accumulation/utilization and economic growth.[5] To develop a theory of the economics of knowledge, Romer,[6] Schwartz,[7] Scott,[8] and others have begun to investigate the economic behavior of knowledge and its role in innovation.

The international business community has come to view knowledge, particularly specialized knowledge, as an essential ingredient for competitive success.[9] Management theorists expect improvements in knowledge-based work to contribute significantly to industrial growth and gains in productivity in the United States and abroad. Furthermore, they anticipate that "[m]ore of an organization's core competencies will center around managing knowledge and knowledge workers."[10] Thus, effectively managing the creation, transfer, and use of knowledge resources is becoming a critical factor for the survival and success of organizations and societies alike.[11] Firms in such diverse industries as chemicals, pharmaceuticals, financial services, and telecommunications already consider the strategic management of knowledge—the "intellectual assets" of an organization[12]—a key corporate activity and have implemented knowledge management programs. These programs emphasize the critical nature of knowledge as a competitive asset and seek to maximize the ability of an organization to integrate and use various kinds of knowledge. Many firms have appointed individuals at the executive level to manage and direct the utilization of the organization's intellectual assets. These individuals are known by a variety of titles—chief knowledge officer (CKO), chief learning officer (CLO), director of intellectual capital, and other labels that describe the scope and direction of an organization's knowledge management initiatives.[13]

The federal government is perhaps the single largest investor in knowledge production in the United States, having spent approximately $79 billion on research and development (R&D) in fiscal year 1996. With knowledge considered the single most important contributor to technological innovation, economic growth, and international competitiveness, is the United States reaping the benefits of its significant annual investment in knowledge creation? The results of our 10-year investigation of the diffusion of federally-funded knowledge to the U.S. aerospace industry suggest not.[14] We believe that the return on investment in knowledge production can be improved if U.S. policymakers recognize the value of knowledge as a competitive resource in today's global economy, and replace or modify existing mission-oriented technology policy with a diffusion-oriented, capability-enhancing technology policy, and if the federal government adopts a system and methods for effectively and strategically managing knowledge.

KNOWLEDGE MANAGEMENT—AN OPERATIONAL DEFINITION

Recognition of the importance of knowledge as an asset and a source of competitive advantage is driving organizations to find ways of optimizing and managing this resource. Under the general rubric of "knowledge management," organizations in the private and public sectors have begun exploring methods for creating and deriving value from existing explicit and tacit organizational knowledge resources. Although there is no single, agreed-upon approach to the practice, knowledge management, in general, encompasses a variety of strategies, methods, and technologies for leveraging the intellectual capital and know-how of organizations for competitive advantage. In brief, the practices associated with knowledge management include identifying and mapping both the tacit (unarticulated and informal) and explicit (articulated and formal) knowledge of organizations; importing potentially useful knowledge from the external environment; making relevant knowledge available to users in forms that best meet their knowledge requirements; winnowing and filtering out unnecessary or irrelevant information; creating new knowledge that can provide competitive advantage; sharing the best methods and practices for completing knowledge-based work; and applying strategies, techniques, and tools that support the foregoing activities.[15]

Three approaches to knowledge management—a mechanistic focus, "the learning organization," and a systemic focus—currently dominate. The *first*, a mechanistic approach, relies almost exclusively on information technology for managing explicit knowledge. Tools like computerized knowledge bases and internal and external (technology-based) networks that enable the use of e-mail and groupware applications figure prominently in improving access to knowledge within an organization. Closely related to a dissemination model, this approach assumes that increased availability and access will improve the use of organizational knowledge resources. This approach largely ignores tacit knowledge. A *second* approach, which has roots in process reengineering and change management, deals with managing knowledge from the perspective of altering organizational culture and behavior. The "learning organization" approach, derived from the systems-theory work of Senge,[16] attempts to change rigidified and frequently dysfunctional behaviors and cultures that may result in knowledge hoarding. A "people-oriented" approach, it stresses collaboration and the sharing of knowledge through what Badaracco[17] terms developing "knowledge links." A learning organization encourages creative approaches to problem-solving; computer and information technology play only a secondary role in managing existing explicit knowledge. A *third*, systemic approach draws on theories and practices from a variety of disciplines (e.g., library and information science, organization science, and computer-supported collaborative work) and technologies (e.g., decision support systems, relational and object databases, and semantic networks) to examine the nature of knowledge-based work and model, elucidate, and manage both explicit and tacit knowledge resources. This approach acknowledges the importance of cultural and behavioral factors while seeking to maximize the value of internal (explicit and tacit) knowledge resources through the application of computer and information technology. The systemic approach also has a "competitive intelligence" element in that it recognizes the value of and seeks out the best sources of external knowledge.[18]

Because the practices associated with managing knowledge have their roots in a variety of disciplines, an all-encompassing theory of knowledge management has yet to emerge. Regardless of the approach taken, the goal of knowledge management is to leverage knowledge to maximize competitive advantage. The objectives of knowledge management call for making a direct connection between the intellectual assets of an organization, both tacit and explicit, and positive business results.[19] The objectives include (1) creating a knowledge base by identifying and capturing internal knowledge assets, importing external knowledge, and fostering the creation of new knowledge; (2) compiling and transforming existing knowledge for application and re-use through methods that reconstruct, validate, and inventory both tacit and explicit forms of knowledge; (3) diffusing knowledge among individuals and teams who can put it to use; and (4) applying knowledge that has been diffused to add value to products and services.[20] The wise use of computer and information technology coupled with an organizational culture that supports and rewards knowledge-creating and knowledge-sharing activities is fundamental for meeting these objectives.

KNOWLEDGE, U.S. SCIENCE AND TECHNOLOGY POLICY, AND COMPETITIVENESS

The U.S. government has played an important role in determining the direction and rate of technological innovation.[21] Although the policy focus and emphasis have shifted over the past 50 years, the assumptions underlying the model that dominates U.S. science (and technology) policy have not changed. The model derives from Vannevar Bush's *Science, the Endless Frontier*,[22] which was interpreted to mean that the support of basic scientific research would yield new technological ideas that would simply move from R&D to commercial products. In effect, this model takes a "pipeline" view of the innovation process.[23] Critics find several flaws in this model: (1) it takes an unrealistic view of the process of technological innovation; (2) it favors science and the creation of (new) knowledge over technology and the use of existing knowledge; and (3) it ignores the importance and the process of diffusing knowledge.

In the immediate post-World War II period, science and technology became strategic components of national security and foreign policies. During the Cold War era, U.S. national security and foreign policies focused on rebuilding the economies of allies and former enemies alike in an effort to establish successful free market democracies and counter the threat of Soviet expansion. As an element of these policies, the United States routinely encouraged the transfer of knowledge and technology to "friendly" nations engaged in economic reconstruction. Because defense needs dominated science and technology-related policies, little attention was given to the transfer and use of knowledge and technology for civilian commercial purposes.

As U.S. firms began to seek investment opportunities abroad, many foreign governments, as part of their domestic economic policies, made the transfer of highly regarded U.S. technology a condition of foreign investment. In many instances, U.S. national security and foreign policies actively encouraged and promoted such transfers, particularly to nations that served as a buffer against communist expansion. In the short term, these policies proved successful in helping to rebuild the economies of post-war Europe and Japan and ultimately in winning the Cold War. However, with the collapse of the former Soviet Union and the end of the Cold War, the United States found itself engaged in a different kind of conflict—a global economic one that is, at least in large part, an unintended consequence of the success of Cold War era security and foreign policies. In helping to rebuild the economic and technological infrastructures of allies and former enemies through the deliberate transfer of knowledge and technology, the United States has enabled these nations to become economic competitors on an equal footing with the United States in several industries.[24]

The International Competitive Landscape

The economic strength of the United States relative to the rest of the world has changed dramatically in the past 45 years. In 1950, the United States contributed nearly 40% of the developed world's gross domestic product (GDP); by 1994, the United States contribution had fallen to just over 24% of the world's GDP.[25] With respect to R&D, the shift is even greater. In 1950, the United States conducted more than twice as much R&D as the rest of the world; by 1994, the rest of the world was conducting almost twice as much R&D as the United States.[26] In the 25 years immediately following World War II, most of the significant technological developments occurred in U.S research establishments and laboratories. Since 1970, the balance has shifted considerably, with the result that knowledge and technology created outside the United States are increasingly important to the growth and competitiveness of U.S. industry. Other nations have developed sophisticated technical infrastructures, alliances, and partnerships that enable them to use the results of domestic and foreign R&D. A number of foreign nations now have the capability for rapid commercialization of new and emerging knowledge and technology and "prosper in an environment of shorter product, process, and service life cycles."[27] U.S. technological superiority during the immediate post-World War II era was gradually replaced during the 1970s and 1980s by a dominant triad composed of the United States, Europe, and Japan. The triad is now giving way to a global economy that includes a range of rapidly industrializing nations that offer potentially powerful economic competition as well as markets for U.S.-developed products and services. Many economic rivals consider knowledge and technology the weapons of choice in a global economic war.[28]

Other nations, particularly those of Western Europe and Japan, now enjoy technological parity with the United States and have become highly competitive rivals. Given the development of such competition, the emergence of a global economy, and the importance of knowledge and technology as key economic drivers, the United States needs to reevaluate its science and technology policies as they affect innovation and economic competitiveness. Since 1945, U.S. science and technology policies have focused on basic research as the primary vehicle for stimulating innovation,[29] with science policy emphasizing university-conducted research performed without thought of practical ends, and technology policy focusing on Department of Defense "mission-oriented," dual-use, spin-off applications. These policies reflect the dominant political-social view that (1) the route to successful innovation is through basic research, (2) the knowledge necessary for successful innovation comes from basic research, (3) technology is little more than applied science, and (4) apart from basic research, the remaining components of product and process innovation (e.g., design, development, and production) are not the purview of government and, therefore, should be left to the private sector. Increasingly, the importance of the linkage between the knowledge generated by basic research and commercial innovation has come under challenge. In fact, critics have begun to question the existence of a linkage. Study results indicate that economically successful innovation is frequently the product of incremental improvements in existing technologies[30] and that many breakthrough innovations stem from invention or trial and error learning, rather than basic research.[31] Critics generally agree that the linear research model, which assumes that basic research automatically leads to product development, is essentially a myth.[32] As Kealey[33] points out, "some 90 percent of new technology arises from the industrial development of pre-existing technology—not from academic science." Although we do not advocate ignoring the value of basic research (particularly in such fields as biomedicine and pharmaceuticals), the focus of current U.S. science and technology policies seems misdirected and simply inappropriate for a nation struggling to maintain its ability to compete in the global economy.

The Dominance of Knowledge Creation

From the end of World War II—when the United States emerged as the world's undisputed leader in science and technology—until the early 1980s, U.S. public policy focused on creating knowledge as a source of military advantage and a hedge against uncertainty.[34] Conventional wisdom held that the United States would continue to lead the world in major discoveries, inventions, and innovations. The prevailing philosophy underlying the "product-cycle theory" was that technological innovation in the United States would always remain a step ahead of would-be imitators.[35] However, the process of innovation is complicated, and the generation of knowledge represents only 5–10% of the effort required to introduce a new product.[36] Furthermore, technological innovation has less to do with generating new knowledge than with using existing knowledge because product development is an incremental process in which success comes from "patient, across-the-board efforts to improve product processes and to develop moderately innovative products that meet genuine consumer needs."[37] Federal science and technology policy continues to emphasize *knowledge creation*, which cannot, in and of itself, ensure U.S. technological superiority. As Alic points out, "innovation depends heavily on existing knowledge, often more so than on new knowledge .... New knowledge, at least in the sense of research results, rarely has direct bearing on competitive outcomes"[38] and does not provide an adequate foundation for competitiveness.

The Need for Diffusion-Oriented Technology Policy

Innovation is an inherently uncertain undertaking that involves the use of human and financial resources coupled with knowledge and technology to create new or improve existing products, processes, and services. As a system, innovation interacts with government at two basic levels. The first relates to harnessing knowledge and technology for public purposes. The second arises from the reliance of innovation on social context; that is, education and training to create a skilled workforce; a legal framework for defining and enforcing intellectual property rights, laws and regulations conducive to innovation as an essential engine of growth: and a variety of public policies that support the production, transfer, and use of knowledge and technology.[39] U.S. technology policy is considered "mission-oriented" because it focuses on radical innovation to achieve clearly established goals (e.g., military) of national importance. Ergas states that "the provision of innovated-related public goods is only a secondary concern of U.S. technology policy." In contrast, "diffusion-oriented" technology policy, utilized by such countries as Germany, Switzerland, Sweden, and, to a great extent, Japan, is bound up in the provision of public goods, and "has as its principal purpose the diffusion of technological capabilities throughout the industrial structure, and facilitates the ongoing and mainly incremental adaptation to change."[40]

With its emphasis on mission-oriented R&D, current U.S. science and technology policy emphasizes the supply or the creation of knowledge rather than its transfer and use. Mission-oriented science and technology policy may have been effective when the United States enjoyed undisputed economic hegemony, but it may not be advantageous in today's environment in which U.S. firms are challenged by foreign competitors in some fields, and are struggling to regain their former positions in others.[41] Indeed, Branscomb[42] posits that the U.S. loss of competitiveness in various industries and technologies has rendered obsolete many of the assumptions that drive existing U.S. science and technology policy. According to Branscomb,[43] the U.S. needs a diffusion-oriented or capability-enhancing technology policy that includes, among other things, managing the transfer and use of knowledge and technology. Alic[44] notes that the process of diffusion, which results in individuals and organizations learning from each other and thereby extending knowledge, is less effective in the United States than in countries like Japan that have diffusion-oriented science and technology policies. Although federal policy touches on many of the elements required for successful innovation (e.g., availability of capital, antitrust regulations, and intellectual property protection), the diffusion of existing knowledge "has yet to be invited to the technology policy ball."[45]

The Prevailing Dissemination Model

The dissemination model recognizes that the results of federally-funded R&D will not necessarily be sought after, the supply (production) of data, information, and knowledge is not sufficient to ensure its utilization, and intervention at the producer level is required to provide potential users with the access linkages. (Linkage mechanisms include various information products and services, as well as intermediaries.) This *one-way, producer-to-user* approach assumes that these linkage mechanisms, in and of themselves, are sufficient to ensure that the results of federally-funded science and technology will be utilized because they provide opportunities for users to determine what knowledge is available, acquire it, and apply it to their needs. The strength of this model rests on the recognition that transfer and use (in addition to production) are critical elements of the process of technological innovation. Its weakness lies in the fact that the one-way, producer-to-user approach is passive in that users are considered only when they interact with or contact the system for assistance. The existing federal system is based on a dissemination model and employs one-way, producer-to-user procedures that are seldom responsive in the user context. User requirements and behaviors are not known or considered in the design of linkage mechanisms. This model does not take into account the process of technological innovation at the level of the firm, nor does it acknowledge that small, medium, and large firms interact differently with the external environment. Lastly, this model fails to recognize that the willingness and ability of firms to absorb extramurally produced research results vary from industry to industry.

Effective knowledge transfer is hindered because the federal government "has no coherent or systematically designed approach to transferring the results of federally-funded research to the user."[46] The system for disseminating the results of federally-funded R&D is "passive, fragmented, and unfocused."[47] Approaches to transferring knowledge vary from agency to agency and have changed significantly over time. They reflect differences between agencies (i.e., legislative mandates), how agencies interpret their missions, and, most important, budgetary opportunities and constraints. In their study of federal scientific and technical information activities, Bikson, Quint, and Johnson found that many of the individuals they interviewed believed that "dissemination activities were afterthoughts, undertaken without serious commitment by federal agencies whose primary concerns were with [knowledge] production and not with knowledge transfer and use;" therefore, "much of what has been learned about knowledge diffusion has not been incorporated into activities designed to transfer the results of federally-funded R&D from producers to users."[48]

By and large, the programs undertaken by the federal R&D agencies to disseminate the results of government-funded R&D have been ineffective in stimulating technological innovation and in transferring technology.[49] According to Roberts and Frohman, these programs are the "highest in frequency and expense yet lowest in impact;" they "have led to few documented successes;" furthermore, they "start to encourage knowledge utilization only after the research results have been generated,"[50] rather than during the idea development phase of the innovation process. David,[51] Mowery,[52] and Mowery and Rosenberg[53] conclude that successful technological innovation rests more with the transfer and utilization of data, information, and knowledge than with their production.

The federal agencies' systems for disseminating the results of government-funded R&D have a formal and an informal component. The informal component relies on collegial contacts, and the formal component relies on surrogates, information producers, and information intermediaries to effect the transfer of the results of government-funded R&D from producer to user. Problematic to 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 or her area(s) of interest. Like other members of the scientific community, engineers and scientists are faced with the problem of too much data, information, and knowledge to know about, to keep up with, and to screen. Furthermore, information is becoming more interdisciplinary in nature and more international in scope. Two problems exist with the *formal* part of the system. First, the formal part of the system employs one-way, source-to-user transmission. The problem with this approach is that such formal one-way, "supply side" transfer procedures do not seem to be responsive to the users' contexts.[54] Rather, these efforts appear to start with a system into which the users' requirements are retrofitted.[55] The consensus of the findings from empirical research is that interactive, two-way communications are required to transfer data, information, and knowledge effectively from producers to users.[56]

Second, the formal part of the system relies heavily on information intermediaries to complete the producer-to-user process. However, a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking.[57] In addition, empirical data on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive. The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context.[58] In the case of the NASA system, information intermediaries report that (1) they do not view NASA as a proactive partner in diffusing the results of federally-funded R&D, (2) NASA lacks a good understanding of the user community and the needs of users, (3) little communication occurs between the intermediaries and NASA, and (4) NASA devotes little effort to involving information intermediaries in the knowledge transfer process.[59]

A KNOWLEDGE MANAGEMENT FRAMEWORK FOR THE FEDERAL SYSTEM

A knowledge management program for the federal R&D agencies presumes a proactive, collaborative relationship (partnership) between U.S. industry and the federal government with respect to knowledge diffusion. It also presupposes that U.S. industry and the federal R&D agencies recognize the value of knowledge as a competitive asset and possess a capacity to absorb external knowledge. To enhance their core capabilities, both will actively seek to identify, import, and integrate external knowledge and technology into their internal organizational and agency knowledgebases.[60] U.S. industry will then focus on channeling knowledge and technology resulting from federally-funded R&D to individuals and teams that can make the best use of them. Developing a knowledge management framework requires that the federal R&D agencies do the following: [61]

1. Design a plan that identifies agency objectives and needs for managing knowledge;
2. Audit agency knowledge bases to ascertain what knowledge currently exists, where it resides, if duplication or redundancy is warranted, and what additional knowledge may be needed;
3. Identify and assign responsibilities for knowledge management activities;
4. Design and implement specific policies and methods that include measurement (of effectiveness) criteria;
5. Create a technological infrastructure that provides a repository of explicit knowledge and pointers to tacit knowledge, permits collaboration and sharing, and facilitates the diffusion of new and existing knowledge; and
6. Promulgate standards, practices, and rules of interaction.

Establishing such a framework requires a shared vision, effective leadership that champions such a program, and a collaborative approach to development that relies heavily on input from users and prospective users.[62]

In light of today's global economy, the new mission of the federal R&D agencies should be to promote and improve U.S. competitiveness. The existing federal system for disseminating the results of federally-funded R&D should be reconfigured to support and enable knowledge management to maximize the "return on investment" in federally-funded R&D by meeting industry needs for external knowledge, technology, and expertise. An effective knowledge management framework would stimulate the diffusion and utilization of the results of federally-funded R&D by speeding flows of "user-friendly" knowledge to consumers in U.S. industry.[63] Creating such a framework will require crafting a coherent U.S. technology and information policy that recognizes, values, and leverages the knowledge resulting from federally-funded R&D.

A knowledge management framework for the federal R&D agencies would provide the strategies, methods, and tools to advance and cultivate the production, transfer, and use of knowledge throughout U.S. industry. To remain competitive, successful firms have had to become highly flexible and adaptive, forging strategic alliances with customers, suppliers, and distributors, and offering customized products and services that represent customer participation in design, manufacture, and distribution. A knowledge management structure at the level of the federal R&D agencies would also have to recognize and heed the implications of the changed nature of business relationships among U.S. firms. Developing a basic knowledge management structure to optimize diffusion of the results of federally-funded R&D would require taking the following actions:[64]

1. Model (i.e., categorize and represent) knowledge in a problem-solution context that not only promotes the diffusion of explicit knowledge but also supports the elicitation of tacit knowledge. The knowledge model should be based on user-specified needs and should represent knowledge in standard, non-proprietary formats to ensure its reusability and longevity.
2. Array consistently (according to agreed upon standards and formats) the knowledge resulting from such R&D activities so that users can easily identify, acquire, evaluate, interpret, and integrate it into their internal knowledge bases.
3. Monitor (i.e., acquire), screen, evaluate, interpret, and integrate relevant published (explicit) knowledge originating outside the United States into the agencies' knowledge bases for diffusion to industries that can integrate and apply it for competitive advantage.
4. Optimize the two-way flow of explicit and tacit knowledge by sponsoring and supporting informal technical discussions; conferences, symposia, and workshops; contracts with industry; non-contract cooperative programs; technology demonstration programs; and government-academia-industry personnel exchange programs.
5. Develop mechanisms that help knowledge seekers identify and locate relevant sources of tacit knowledge and expertise (i.e., subject-matter experts) through the creation of such information technology-enabled products as online yellow pages.
6. Develop mechanisms that facilitate awareness among members of industry sectors of explicit knowledge and that include announcements and updates of recently initiated and on-going federally-funded R&D activities (e.g., research and technology operating plans) and federally-sponsored research (e.g., grants and research contracts).
7. Establish guidelines and mechanisms for knowledge diffusion to ensure that foreign competitors do not benefit unduly from receiving the results of U.S. federally-funded R&D.
8. Evaluate the knowledge exchanged as a result of bilateral agreements with foreign governments and institutions to ensure *quid pro quo* on the basis of quantity and quality.

9. Develop mechanisms for identifying and tracking the activities and expertise of foreign research and R&D programs, facilities, and personnel (i.e., competitive intelligence) and diffuse it to interested parties within U.S. industry.
10. Develop evaluation components with metrics that rely on user input and feedback for determining the knowledge needs of U.S. industry sectors and assessing the efficacy of the federal agencies' knowledge management programs.
11. Recognize knowledge management as a legitimate element of the research process, and identify and assign responsibilities for managing knowledge at all levels of federal R&D agencies.
12. Budget and allocate funding for knowledge management activities through the federal R&D budget and programs to ensure that knowledge diffusion becomes an integral part of the R&D process.

ISSUES AND CHALLENGES FOR KNOWLEDGE MANAGEMENT

Knowledge management programs at both the industry and federal levels should focus on the management of knowledge as an intellectual asset. Whatever focus and techniques are used (e.g., best practices, decision-making, learning organization, accounting, or technology),[65] the critical nature of knowledge and of managing it effectively should be demonstrated in the organization's mission and vision, and knowledge management practices should be implemented and rewarded at all levels of an organization. Programs for managing knowledge must be adequately funded and staffed, lest we find ourselves paying the price for ignorance. Components of the existing information infrastructure, such as libraries, must rethink their purpose and refocus their activities to support knowledge management. The theoretical bases underlying knowledge management programs should also incorporate what is known about technological innovation, including how knowledge and technology diffuse at the individual, organizational, national, and international levels. Knowledge voids (i.e., what is not known about technological innovation) should inspire further investigation, the results of which can be applied to managing knowledge for competitive advantage.

For knowledge management to be successful at both industry and federal levels, certain challenges must be addressed. Some priority tasks are discussed below.

At the federal level, within the federal system, and at the agency level, knowledge diffusion must become part of the R&D process in both word and deed. Federal information policy, where absent, must be formulated and directly tied (linked) to technology policy. In today's competitive environment, diffusing the results of federally-funded R&D cannot continue to be considered an overhead (burden) expense. Adequate funding must be provided and such federal agencies as the Office of Science and Technology Policy (OSTP) that have a legislative mandate to (1) promote the transfer and utilization of federal scientific and technical information (STI) for civilian needs; (2) consider the potential role of information technology in the transfer process; and (3) coordinate federal STI policy and practices, must be held accountable by the Congress for apparently having abdicated their responsibilities. Finally, a coherent, systematically-designed approach to knowledge diffusion is needed at the federal level. The largely passive, one-way, producer-to-user distribution model must be replaced with a proactive, two-way, collaborative "enterprise" knowledge diffusion model.[66]

Although information technology (IT) will play an important role in knowledge diffusion, IT in and of itself cannot guarantee the success of any knowledge management initiative. Diffusing knowledge effectively has far more to do with the human side of the equation. Research concerned with technological innovation points out the importance of human interaction, human behavior, and information use and exchange. Clearly, an understanding of the user in a behavioral and organizational context is needed. However, the results of numerous information-seeking behavior and use studies conducted over the past 30 years are fragmented and ambiguous. The results have not accumulated to form a significant body of knowledge that can be used by information professionals, and they offer little in the way of guidance or "rules of thumb" for R&D managers. On the other hand, there is ample evidence that what has been learned about the information-seeking behaviors and uses of engineers engaged in R&D and technological innovation has not been incorporated into the information systems designed to service this population. As Pinelli[67] notes, two actions are required: development of a research agenda and creation of a method of linking research results with the individuals concerned with the design and provision of information systems, policy, products, and services.

Of all the organizational units within a firm, the library is well suited to help manage knowledge as an intellectual asset and to play a major role in knowledge diffusion. Davenport and Prusak[68] claim that libraries, while uniquely positioned within the organization to understand information requirements and to distribute information, have largely been left behind by the information revolution, most likely because they are based on an obsolete model of information provision. Libraries are poorly understood, usually not well integrated with either the business they serve or other information-oriented functions. As a result, the value they deliver is often unclear and often less than what is possible. Consequently, libraries and library services remain vulnerable to cost-cutting efforts by both managers and R&D organizations. To play a major role in knowledge management, libraries should emphasize the following: (1) proactivity over passivity; (2) the provision of information rather than documents; and (3) the provision of information in a problem-solution context.[69] Both libraries and librarians must look at ways of adding value that go beyond the information acquisition, classification, and storage model. Lastly, there is a great need to understand how people use and value information. Librarians are better positioned than many other groups within the firm to contribute to and build upon this understanding to help manage knowledge for competitive advantage.

Studies concerned with technological innovation at the firm level demonstrate the criticality of information to innovation, the importance of smooth information flows within the firm, and the value of importing information that resides external to the firm for maintaining competitive advantage. The need to manage data, information, and knowledge effectively is of paramount importance; in fact, managing these resources is increasingly considered the responsibility of every member of a firm. Within R&D, engineers are obvious candidates for knowledge management responsibilities, given the information-intensive nature of their work and the time they devote to working with information—up to 80% of their work weeks.[70] Thus, engineers should be proficient in the skills required for the effective production, transfer, and use of data, information, and knowledge. Such skills include (1) the ability to communicate effectively in writing, orally, and visually; (2) a knowledge and understanding of the nature and use of engineering and science resources and materials; (3) competence in using a library and a variety of other information repositories and resources; (4) computer, communication, and information technology use capabilities; (5) the ability to work collaboratively and to share and elicit information; and (6) competence in one or more foreign languages.

Knowledge is becoming a key resource in the global economy. It has replaced financial capital as the main producer of wealth. If nations and firms are to compete on the basis of knowledge, they must learn to treat knowledge as a capital asset, not as the by-product of a process, design, service, or product development. To ensure the competitiveness of the nation and the firm, traditional approaches to management have concentrated on minimizing overhead, cutting staff, and decreasing material costs as a means of maximizing sales and increasing market share. However, these measures are largely ineffective for a knowledge-based economy. To compete in a global, knowledge-based economy, the nation and firms have to learn to value and manage intellectual capital, which requires a different approach from the one used to manage financial capital. Today's global economy is characterized by (1) the rapid internationalization of markets and technology, (2) the spread of innovative activity, (3) fierce competition among firms and nations for markets and market share, (4) multiple numbers of strategic alliances and partnerships among firms to improve competitive position, and (5) the consequent transfer of knowledge and technology among allied firms and nations. Maintaining competitiveness in such an environment makes the astute management of knowledge by the nation and the firm not only desirable but also imperative. Failure to manage knowledge and technology, considered by some to be the weapons of choice in a global economic war, could spell disaster for the nation and U.S. firms.

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