EFFECTIVE PARTNERING:

A REPORT TO CONGRESS ON FEDERAL TECHNOLOGY PARTNERSHIPS

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FOREWORD

During the past 15 years, successive Congresses and Presidents have introduced a range of policies and programs designed to increase the effectiveness of government mission research and development and enhance U.S. technology-based economic growth. These policies and programs include the following:

- Licensing of federal patents;
- Cooperative research and development agreements;
- The Small Business Innovation Research program;
- The Advanced Technology Program; and
- The Manufacturing Extension Partnership.

Taken as a whole, these policies and programs represent a gradual evolution from the historic model—in which government is the principal **customer** for federally supported technology—to inclusion of a new paradigm appropriate to this era of dynamic commercial markets and global competition. In this paradigm, government is a **partner** with the private sector in developing and deploying new commercial technologies that fulfill mission objectives and enhance U.S. industry's market strength.

Extensive consultation with the private sector confirms that these partnership policies and programs, in combination with incentives for capital formation and regulatory reforms that reduce risk, are important in stimulating technological innovation and improving U.S. competitiveness.

This report analyzes this historic transition and describes best practices of the new paradigm across the range of programs. It also offers recommendations for further improving the effectiveness of present and future public-private partnerships.

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Chapter 1: Executive Summary

Since 1980, successive Congresses and Presidents have established a set of policies and programs designed to improve the effectiveness of government mission research and enhance U.S. technology-based economic growth. These efforts began with mechanisms designed to maximize the commercial impact of federal investments in research and development. Over time, however, the policy focus shifted to include new programs that seek to enhance directly the competitiveness of U.S. industry. This shift represents a fundamental change in the philosophy underlying U.S. technology policy.

We began, in the years following World War II, with informal processes of technology diffusion, based on the assumption that technologies developed in the course of federal missions would more or less automatically find use in the private sector. In the early 1980s, in an effort to meet mission objectives more cost-effectively and to leverage more fully the economic impact of mission Research & Development (R&D), the government introduced new programs, based on a model of actively encouraging commercialization of valuable federal technologies. The newest technology partnerships, introduced in the late 1980s, are based on a new paradigm in which the government is a partner with the private sector in developing and deploying new technologies in a global economy.

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This report analyzes this historic transition, explores the effectiveness of federal technology partnership programs in meeting their goals, and offers recommendations for further improving the effectiveness of public-private technology partnerships.

A comprehensive review of all federal technology partnership programs is beyond the scope of this report. Rather, the report focuses on the history and development of several key mechanisms for public-private R&D partnerships.

U.S. Technology Policy After World War II

Throughout much of the post–World War II period, the U.S. government added significantly to the world's science and technology base through a two-part strategy of supporting basic scientific research and pursuing the science and technology missions of federal agencies and departments. Fueled by the cold war and the space race, federal R&D spending rose dramatically. By 1964, U.S. government R&D investments exceeded the

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civilian, defense, and industrial R&D investments of all other developed countries combined.

U.S.–based corporations, by virtue of their global commercial dominance in technology-based industries, benefited especially from the enormous amount of federally sponsored basic research and mission R&D. The American economy benefited from federal R&D through an informal process referred to as "spin-off," in which the results of federally funded research were diffused and applied in the private sector.

U.S. industry continues to reap the commercial benefits of these investments in federal R&D. The present technical and competitive strength of the U.S. aerospace, information, computing, and biotechnology industries is due to a significant degree to sustained government support for science and technology research over several postwar decades.

Impact of Foreign Competition

During the 1970s and 1980s, however, many foreign competitors increased their technical capabilities and challenged U.S. commercial dominance in both foreign and domestic markets, which led to enormous U.S. job losses and economic dislocation. In this new environment, the U.S. economy benefited less from traditional processes of public-private technology development and diffusion.

There were at least three reasons for this phenomenon. First, as the technical sophistication of our major competitors grew, they too were able to appropriate the output of U.S. government basic and mission research, which reduced the relative impact of these public investments on American economic competitiveness. Second, traditional mechanisms of technology transfer, development, and diffusion took too long in an era of accelerating private sector product development. And third, as foreign R&D increased, U.S. government R&D represented a declining world share. For all these reasons, U.S.–based corporations and the U.S. economy benefited less than they had previously from federally supported basic research and from technologies resulting from government mission investments.

Changing Environment for Defense R&D

During the 1970s and 1980s, the federal government's traditional approach to R&D also became less effective in meeting government's own needs. Postwar military R&D and procurement had spawned technologies such as computers, semiconductors, and jet engines. However, because of expanding military specifications and the crush of an increasingly cumbersome federal procurement system, more and more commercial firms walled off their defense production or refused to do business with the Department of Defense (DoD) altogether. As a result, DoD came to rely on an increasingly isolated defense industrial base.

This segregation of defense and commercial firms occurred at a time when the defense industry was gradually losing its unchallenged position of technological leadership. The new technologies most critical to America's military advantage—software, computers, semiconductors, telecommunications, advanced materials, and manufacturing technologies—were increasingly being driven by fast-growing commercial demand, not by military demand. To preserve U.S. military superiority, DoD had to find a way to exploit the advanced technologies and efficient production capabilities of commercial industry.

Rise of Local and State Partnership Programs

Faced with economic decline and job losses, some state and local governments, together with numerous private sector and academic organizations, began to build diverse partnerships and programs to promote economic growth and job creation. Over time, these programs increasingly focused on the economic potential of technology. In the 1960s, some governments promoted technology-based economic growth through mechanisms such as North Carolina's Research Triangle complex. Ohio's Thomas Edison Program and Pennsylvania's Ben Franklin Partnership Program were introduced in the 1980s. Through these programs and others, states created networks of technical training and academic programs, fostered new businesses through "incubators," supported new technologies through grants, and diffused information about manufacturing technologies through extension programs. States also integrated federal laboratories, universities, industry consortia, and test centers into state economic development strategies. These new partnerships and programs brought together sources of new technology, insights about new markets, and the funding and management needed to bring success in those markets.

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Rise of Federal Partnership Programs

By 1980, there was widespread concern about the effectiveness of government mission research and declining U.S. technology-based competitiveness. These concerns were the impetus for new approaches to federal technology policy in the 1980s and 1990s.

Legislation and executive orders granted firms and universities irreversible and exclusive patent rights to federally developed technologies, promoted small business involvement in technology development and diffusion, and coordinated technology policies across agencies.

The initial federal technology legislation of the 1980s was responsive to the same concerns about competitiveness that drove state programs. The new legislation was also motivated by the belief that traditional federal policies—investment in basic and mission research without direct regard for commercial impact and with reliance on informal mechanisms of spinning off technologies to the private sector—were not maximizing the commercial potential of the results of federally sponsored research. Many public and private sector officials believed that federal laboratories and agencies had developed many technologies and processes that had commercial value but were languishing on the shelf, which reduced the value of these technologies for achieving agency mission goals.

In addition, through this and subsequent legislation, policymakers began to address the ways in which increased emphasis on commercializing federal technologies and the establishment of R&D partnerships with the private sector could improve the efficiency of mission-related research. This new approach to R&D partnerships had particular application in the defense sector, where R&D critical to national security was being driven increasingly by commercial market forces. In this environment, partnerships could help both civilian and military agencies better meet technology needs by exploiting commercial technologies and markets to meet the government's own needs.

In the 1980s, legislation and executive orders granted firms and universities irreversible and exclusive patent rights to federally developed technologies, promoted small business involvement in technology development and diffusion, and coordinated technology policies across agencies, among other provisions. Licensing of federal patents and public-private technology partnerships offered agencies a way to accomplish their mission objectives more efficiently. In addition, through these laws and policies, Congress and successive presidents sought to leverage fully the value to society of tax dollars invested in mission-related R&D.

While these policies were an improvement, they did not maximize the government's potential for fostering technology-based economic growth. Merely encouraging the commercialization of government mission R&D did not fully meet the needs of the private sector in responding to global competition.

In the late 1980s and early 1990s, Congress created two programs designed to enhance U.S. competitiveness directly—the Advanced Technology Program (ATP) and the Manufacturing Extension Partnership (MEP), described below. These initiatives are private sector–led technology development and deployment programs to speed technology diffusion and develop longer term, high-risk technologies that will provide widespread benefits to the U.S. economy but that would not otherwise be developed in a competitive time frame, if at all. These direct competitiveness programs are governed by a new paradigm for public-private technology partnerships in which the government and private sector are partners in developing and deploying new technologies. For example, in ATP, the private sector joins in cost-shared partnerships with the government to improve American technological competitiveness.

The federal government now administers the following partnership policies and programs to increase the effectiveness of mission research and promote technology-based economic growth and U.S. competitiveness:

- Licensing of federal patents;
- Cooperative research and development agreements (CRADAs);
- The Small Business Innovation Research program (SBIR);
- The Advanced Technology Program (ATP); and
- The Manufacturing Extension Partnership (MEP).

Licensing and SBIR are active spin-off programs designed to leverage the commercial impact of federal R&D investments. CRADAs join the government and industry in mutually beneficial joint civilian research. An additional program, Technology Reinvestment Project (TRP), launched to make defense products cheaper to buy, supported defense efforts through the development of dual-use technologies that exploit the rapid rate of innovation and the market-driven efficiencies of commercial industry.

ATP and MEP are direct competitiveness programs in which the government and private sector work jointly to raise the level of technology used by U.S. firms and to develop cutting-edge technologies and processes. Through these two programs, the federal government facilitates the development of promising yet unproved technologies that would not otherwise be developed in a competitive time frame, if at all.

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Although these programs represent only a small fraction of the federal R&D budget, they leverage money in the public and private sectors, causing an economic impact far larger than that suggested by the program budgets alone. Moreover, they are the only mechanisms focused specifically on providing a bridge between the federal R&D investment and the efforts of the private sector to remain globally competitive. These relatively small investments in federal partnerships play a central role in increasing the efficiency of government mission research and safeguarding the country's prosperity.

Findings

This study, conducted with the support of an interagency working group, began with a series of roundtable discussions with private sector and academic participants in federal technology programs. The study suggests the following:

Technology partnerships play an important role in fostering U.S. competitiveness.

Although the primary responsibility for maintaining U.S. competitiveness lies with the private sector, public R&D investments have long had a large impact on the private sector's ability to innovate and market new technologies. The past several decades of experience with public-private technology development and diffusion policies have taught us that federal technology programs contribute to U.S. competitiveness by

- maximizing the commercial impact and value to society of public investments in government-funded basic research and mission-related R&D, and
- working in partnership with the private sector to develop high-risk enabling technologies and speed their diffusion.

Technology partnerships enhance the effectiveness of government mission-related R&D.

With the explosive growth of cutting-edge R&D performed by commercial firms, U.S. agencies can no longer depend solely on internal mechanisms for meeting government mission requirements. By joining strategically with the private sector, U.S. agencies gain access to and leverage advanced commercial technologies, private sector production efficiencies, and larger markets, enabling the government to fulfill its mission requirements more effectively and at a lower cost.

Both large and small companies and a wide range of industries support an array of federal programs.

The U.S. private sector strongly supports federal technology partnership programs.

Private sector support is broad-based. Both large and small companies and a wide range of industries support an array of federal programs. Private sector partners perceive partnership programs to be a small but critical part of the U.S. science and technology infrastructure. This support has been clearly documented through surveys, academic studies, roundtable discussions with private sector representatives, and private sector appeals for expansion of these programs.

Federal technology partnerships are part of a larger set of private sector priorities for stimulating innovation and competitiveness.

In addition to leveraging federal R&D and catalyzing long-term, high-risk research, the U.S. private sector has called for other government actions to improve the business climate, especially through reform of federal tax and regulatory policies. The goal of these technology policy–related proposals is to reduce the high costs and technical risks that can impede innovation, through changes in federal regulations and product liability laws, new incentives for capital formation, and other initiatives. The Clinton administration strongly supports policy measures to make the business climate more conducive to innovation, provided these changes balance other important policy goals, including environmental protection, public health and safety, and the interests of consumers, manufacturers, and sellers, and respect the important role of the states in the federal system.

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Technology partnership programs benefit the U.S. economy in a variety of ways.

Some benefits of these partnerships accrue immediately in terms of profits, jobs, and new products, while others (such as catalyzing important long-term R&D areas) may require years to develop. Moreover, some benefits are easily measured while others, such as the promotion of business and R&D synergies, are more difficult to quantify. The active spin-off and defense dual-use programs offer significant benefits, in increasing the efficiency of government mission research and contributing to U.S. commercial growth. In contrast, ATP and MEP focus exclusively on and have the greatest potential for promoting technological innovation, economic growth, and U.S. competitiveness. Interim data for all types of programs are quite positive, showing significant short-term impacts for active spin-off programs and demonstrating that defense dual-use and direct technology programs are fulfilling their milestones and remain on track for long-term success. While the measurement of program results presents a difficult challenge, the administration has emphasized the need for greater accountability in the operation of these programs and is designing new systems to measure program inputs and outputs.

Government agencies are adopting a new paradigm for technology partnerships.

Government agencies are experimenting with and adopting a new model of public-private partnership in which the private sector is recognized as the government's partner in cost-shared technology development and diffusion programs. This paradigm enables agencies to fulfill their missions more effectively and enhances the impact of federal R&D partnerships on the U.S. economy. Direct competitiveness programs, such as ATP and MEP and the defense dual-use TRP program, which were designed according to the principles of the new paradigm, are drawing strength and support through their interactions with the private sector. In addition, new paradigm principles of service and improved accountability have improved the operations of the older programs that enhance the efficiency and commercial impact of government mission R&D.

Recommendations

Although individual federal agencies have already made significant progress in improving the effectiveness of programs and incorporating many features of the new paradigm, an opportunity exists to learn from the best practices across all agencies. To the extent permitted by agency missions, the agencies should take the following actions:

Make partnership opportunities more accessible and easier to identify.

- Disseminate information on federal research projects, expertise, and intellectual property through both public and private means.
- Serve as a catalyst to promote matching of new technologies developed in programs with sources of capital and other support.
- Increase public-private exchanges of scientific and technical personnel.
- Use participation in and support of industry consortia and other umbrella organizations as a means of ensuring broad private sector access to partnership opportunities.

Ensure effective protection of intellectual property.

- Use panels of industry representatives to help identify the commercial potential of agency research and inventions as early as possible.

- Use procedural options under the patent laws to secure additional time to collect private sector advice and ensure that appropriate protection is sought.

Be a better partner: improve speed, flexibility, and predictability.

Make administration of partnership agreements more responsive to industry needs.

- Use whatever form of funding agreement provides the agency with maximum flexibility to adopt commercial practices in structuring the agreement.

- Direct agencies to use, where available, "other transactions" or comparable authority permitting the greatest possible flexibility in the terms of collaborative research agreements.

- Increase the speed with which the agencies fund partnerships once they are agreed to.

- Where appropriate, use the "exceptional circumstances" authority of the Bayh-Dole Act to permit industry to own or control the rights to inventions resulting from federal funding, including inventions of subcontractors.

Make partnership agreements easier to negotiate.

- Use state and local economic development organizations, industry associations, and other intermediary organizations as partners, providing an umbrella under which individual businesses can perform collaborative research.

Make partnership agreements more predictable.

- Seek public-private agreement on the basic principles for partnership agreements.

- Build on these principles to give uniform agreement terms, where possible, and to make negotiations faster and outcomes more predictable.

- In the case of CRADAs, agree to give private sector partners the option of an exclusive license to inventions developed by federal agency employees in connection with the partnership.

Help small businesses secure necessary business and financial advice from state programs and private sector sources.

- Work with state and federal agencies to increase the support available to small businesses and others who need to improve their competence in the commercialization of new technologies.

Further increase the private sector role in project definition and selection.

- Seek private sector views on the portions of the mission research agenda with greatest commercial potential.

- Use this continuing source of guidance as a basis for selecting technology areas in which partnership opportunities will be offered under the partnership programs.

Shift to commercial financial management practices.

- Wherever possible, eliminate Federal Acquisitions Regulations Part 31 accounting requirements for private sector participants in research partnerships in favor of commercial practices.

- Review accounting procedures in all other programs with the objective of minimizing special standards imposed on private sector participants and following commercial practices more closely.

Continue developing systems to measure program results.

- Work in collaboration with other agencies and with interested private sector parties to identify appropriate measures of effectiveness for the types of research partnerships in which the agency participates.

- Ask the National Science and Technology Council or other appropriate organization to lead an interagency effort to coordinate agency measurement systems into a comprehensive measurement system for all federal partnership efforts.

Chapter 2: Federal Technology Policy, 1950–1980

Dual Thrusts: Basic Research and Mission R&D

During the two decades following World War II, federal science and technology policy had two strategic thrusts. The first was support for basic science: research without immediate practical application, but which expands our understanding of the basic principles of nature. The funding provided by the National Science Foundation (NSF) to scientists and universities is a good example of such support.

The second strategic thrust was the support of science and technology to fill public needs as articulated by Congress and carried out by U.S. government agencies and departments. Often called "mission research" because it was performed to further the various agency missions, this research, both basic and applied, focused on producing knowledge, products, or services of direct use to the agency funding it. The development of advanced weapons technologies for the Department of Defense (DoD) and tools used by the National Weather Service are two examples of mission research.

Magnifying and often intertwined with basic and mission research were the procurement activities of the federal government. With its large purchasing ability and often cutting-edge needs, the federal government could play the role of the valued "first customer" in buying new technology. By procuring these products, the federal government supported the development of technologies that were at first expensive but would ultimately provide important products and services at affordable prices.

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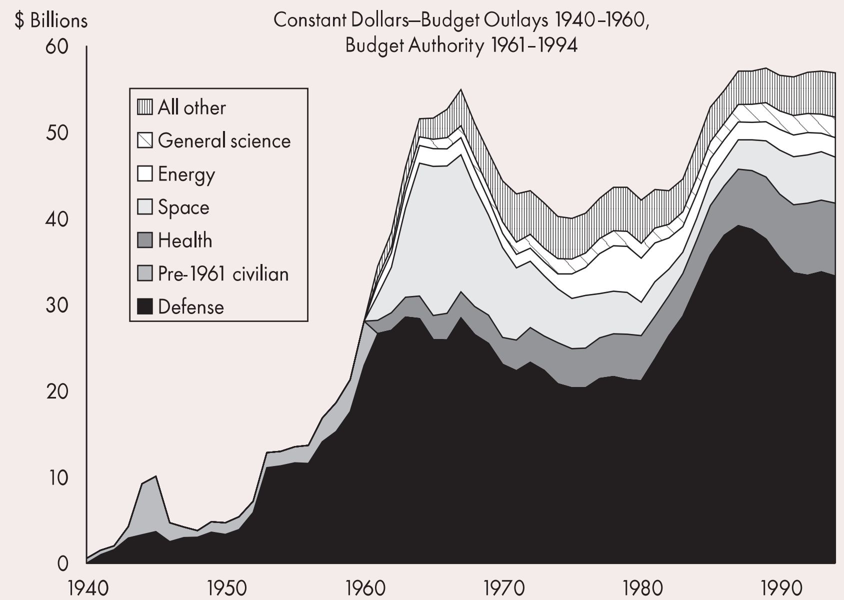
As illustrated in figure 1, government research and development (R&D) funding patterns have changed to reflect emphasis on different missions. Until 1960, the government's primary objective for R&D was defense. The space budget expanded rapidly in the 1960s but declined significantly in the 1970s. Energy R&D peaked in the late 1970s, and health R&D has grown steadily throughout the era to approximately one-third of total civilian R&D today. Moreover, although defense and civilian investments were roughly equal between 1965 and 1980, defense expenditures accelerated rapidly in the 1980s: in 1993, military R&D accounted for approximately 59 percent of total R&D investments.

Figure 1. Federal R&D Funding for Defense and Civilian Functions, 1940–1994



Notes: 1993 and 1994 are estimates. The steep rise in the civilian R&D portion of the graph for the 1943–1945 period is attributable to work performed under the Manhattan Project, which built the first atomic bombs. NSF is currently revising its R&D data to reflect the military nature of these expenditures.

Source: NSF, "Federal R&D Funding by Budget Function: FY 1991–93" and unpublished NSF data.

Commercial Impacts from Basic Research, Mission Research, and Procurements

Federal investments in basic and mission research advanced the state of knowledge in science as well as the missions of agencies and departments. These investments also contributed to U.S. competitiveness during the postwar decades through an informal spin-off process in which the results of federally funded research found uses in the private sector. Federal research flowed to the private sector along many paths, including published reports of research results, private sector performance of federally funded research, communications between federally funded and commercially oriented researchers, commercial hiring of persons formerly engaged in federally funded research, and government procurement of advanced equipment that met the technical requirements of DoD, the National Aeronautics and Space Administration (NASA), and the Department of Energy.

During the postwar period, private firms used federal technologies to create new industries. For example, federal R&D programs, particularly those in defense, supported important advances in fundamental knowledge of computer architecture, software languages, and design that found applications in both the civilian and defense sectors of the emerging industry (see box 1). In the aerospace industry, defense-related research supported the development and refinement of jet engines, aluminum airframes, civilian airliners such as the Boeing 707, and communications satellites.

During the postwar period, private firms used federal technologies to create new industries. For example, federal R&D programs supported important advances in fundamental knowledge of computers.

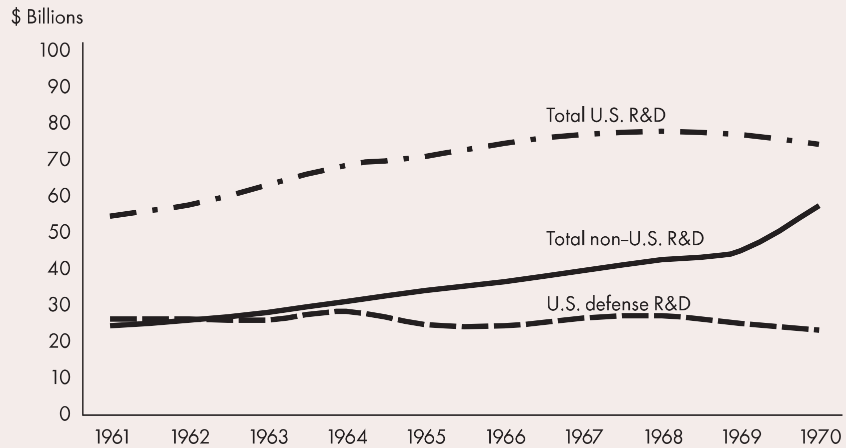
There were three primary reasons for the significant commercial impact of federal R&D investments during this period. First, defense research and development (and federal R&D generally) set the direction for world research by virtue of its large size and cutting-edge nature. In 1964, U.S. defense R&D alone was two-thirds as large as all government and industrial research and development, both civilian and military, performed by Germany, France, the United Kingdom, Italy, Sweden, and Japan combined. When the U.S. government's civilian R&D is added to that of defense, federal R&D investments exceeded those of all other developed countries (see figure 2).

Box 1. Technology Diffusion in Action

The field of semiconductors is an example of the significant commercial impact of government-sponsored R&D. The U.S. government played a primary role as the first customer for the semiconductor industry. The willingness and ability of the government—especially DoD and NASA—to become the first major customer for these new integrated circuit (IC) products allowed the U.S. semiconductor industry to improve production capabilities and equipment and reduce manufacturing costs. In fact, the federal government was the only customer for U.S.-made ICs until 1964. While this early support was born of agency mission research and procurement—primarily NASA's efforts to put a man on the moon—it ultimately led to the development of today's commercial semiconductor industry.

The software industry is another example. From the earliest years of the postwar era, private industry has been responsible for a great deal of innovation in software; but in the 1960s, industrial software innovation drew on research and manpower supported by federal government funds. Defense-related spending on software was aimed at creating a foundation for software R&D, training, and technology development. Of the 45 major advances in computer software that originated in the United States between 1950 and 1980, 18 were funded by the federal government. These advances later provided important benefits to the commercial software industry.

Figure 2. Total U.S. R&D Dominates Total Foreign R&D, 1961–1970 (1987 Dollars)



Source: NSF, *Science and Engineering Indicators,* 1993.

U.S. firms dominated domestic and world markets and were ideally positioned to capitalize on the fruits of federal R&D.

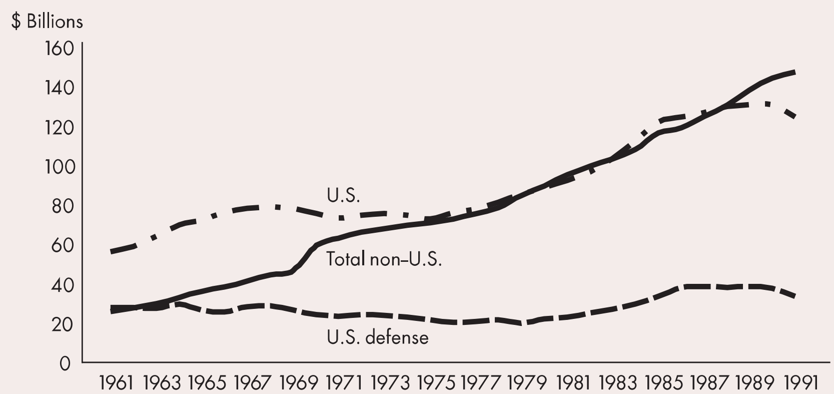
Second, lacking strong competitors, U.S. firms dominated domestic and world markets and were therefore ideally positioned to capitalize on the fruits of federal R&D. Although foreign firms had access to the same knowledge about federal research, through articles in scientific journals, conferences, and the like, most foreign companies were rebuilding after World War II and were unable to match the investments of U.S. firms in technology development, deployment, and manufacturing. Moreover, U.S. firms also benefited from contracts for the development of defense products that had both military and civilian uses. Under these circumstances, opportunities to commercialize mission R&D went to U.S.–based firms, giving them an added competitive advantage.

Third, the development times, diffusion process, and product life cycles in federal civilian mission research were comparable to the development times and product life cycles in commercial R&D, which facilitated diffusion of new technologies to the private sector and made it easier to transfer technologies from the public to the private sector.

The Rise of Global Competition and Its Implications for Federal Technology Policy

The relative size and impact of U.S. government R&D investments diminished in the 1970s (see figure 3). While U.S. research funding, and the federal dollars that constituted its single largest component, actually

Figure 3. Foreign R&D Surpasses U.S. R&D (1987 Dollars)



Source: NSF, *Science and Engineering Indicators,* 1993.

increased in constant dollars, an explosion of civilian research throughout the world resulted in the United States having a smaller share of the worldwide research effort in the 1990s than it had in the 1960s. Almost all of this foreign R&D was conducted in the private sector to create commercial products. Not only did the increased technological sophistication of foreign rivals begin to erode the competitive advantage enjoyed by U.S. firms, but their sophistication also allowed them to make use of the results of federally funded basic research, which were available to the entire world. When a new idea was described in a scientific journal or at a conference, it enhanced technology development globally, not just in the United States.

The commercial impact of federal R&D investments during this period was also diminished by another aspect of the new competitive environment: the gradual shortening of product development times. In the post–World War II years, both federal research and procurement and commercial R&D were characterized by fairly long development cycles. However, in the past few decades, commercial product development times have shrunk. By the 1980s, federal and private sector cycles had widely diverged, and the technology transfer process itself added time. The results of agency mission research were not reaching the commercial sector fast enough to have as large an impact on product development as they had before.

During the 1970s and 1980s, the federal government's traditional approach to R&D also became less effective in meeting government's own needs. Postwar military R&D and procurement had spawned technologies such as computers, semiconductors, and jet engines. However, because of expanding military specifications and the crush of an increasingly cumbersome federal procurement system, more and more commercial firms walled off their defense production or refused to do business with DoD altogether. As a result, DoD came to rely on an increasingly isolated defense industrial base.

This segregation of defense and commercial firms occurred at a time when the defense industry was gradually losing its unchallenged position of technological leadership. The new technologies most critical to America's military advantage—software, computers, semiconductors, telecommunications, advanced materials, and manufacturing technologies—were increasingly being driven by fast-growing commercial demand, not by military demand. To preserve U.S. military superiority, DoD had to find a way to exploit the advanced technologies and efficient production capabilities of commercial industry.

By 1980, there was widespread concern about the effectiveness of government mission research and declining U.S. technology-based competitiveness. These concerns were the impetus for new approaches to federal technology policy in the 1980s and 1990s, based on the conviction that America needed new government mechanisms and processes to enhance mission research and help improve U.S. competitiveness. The history and current status of these policies is the subject of the remainder of this report.

Chapter 3: Technology Partnerships and the Emergence of a New Paradigm for Economic Growth and Competition, 1980–1995

Since 1980, the federal government has developed more active policies and a new paradigm for the development and deployment of technology. Initially, the government developed programs to increase the efficiency and more fully leverage the commercial impact of mission research and development (R&D). Over time, however, Congress and the executive branch created new programs, based on a new paradigm in which the government and private sector are partners in developing and deploying new technologies. While these programs represent only a small fraction of America's total investment in R&D, they leverage money in the public and private sectors, causing an economic impact far larger than that suggested by the program budgets alone.

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The Role of States and Private Sector Groups

Federal technology partnerships grew in tandem with efforts at the state level to promote technological innovation through public-private partnerships. In fact, some of the first and most successful public sector efforts were undertaken at the state and local levels. The U.S. industrial downturn that resulted from the rise of global competition had a major impact on many local economies and quickly captured the attention of state governments. States whose economies were most dependent on manufacturing suffered the greatest declines in employment, wages, and tax revenues. Many states quickly perceived the importance of technology to their economies and began to develop new approaches to technology development and diffusion as part of their broader economic development policies.

For example, North Carolina's Research Triangle complex, formed in the late 1960s in partnership with the state's major universities, brought in billions of dollars in new investment and created thousands of jobs. Partly as a result of this success, North Carolina has an unemployment rate 2 percent below the national average. A more common use of technology as an element of economic development strategy is reflected in Ohio's Thomas Edison Program and Pennsylvania's Ben Franklin Partnership Program, both founded in 1983. To encourage research and development projects, these programs offer financing, technical assistance, and access to valuable assets such as supercomputers. Table 1 lists the states that spend the most to fund science and technology (S&T) programs, overall and per capita.

Some of the first and most successful public sector efforts were undertaken at the state and local levels.

Table 1. Top 15 States in Science and Technology Program Spending (Overall and per Capita), FY94

State	Overall Spending	State	Per Capita Spending
North Carolina	$37.5 million	Alaska	$15.45
Pennsylvania	34.1 million	Connecticut	8.37
Texas	30.0 million	Nebraska	5.69
Georgia	29.9 million	North Carolina	5.65
Connecticut	27.5 million	Delaware	5.39
Ohio	27.5 million	South Dakota	5.32
New York	22.9 million	Georgia	4.61
New Jersey	20.3 million	Kansas	4.48
Michigan	14.1 million	Hawaii	4.16
Maryland	12.7 million	Montana	3.72
Florida	12.6 million	Pennsylvania	2.87
Kansas	11.1 million	North Dakota	2.79
Virginia	10.4 million	Maryland	2.65
Nebraska	9.0 million	New Jersey	2.63
Alaska	8.5 million	Ohio	2.53

Source: Chris Coburn, editor, *Partnerships: A Compendium of State and Federal Cooperative Technology Programs,* Columbus: Battelle Press, 1995.

State programs sought to harness both local and federal resources with great creativity. States networked their training and academic programs into centers of excellence. They fostered new businesses by creating incubators and supported new technologies through grants. They diffused information about manufacturing technologies through extension programs and integrated existing technology resources such as federal laboratories, universities, industry consortia, and test centers into state economic development programs. These partnerships with economic development programs were particularly effective in reaching small business communities, providing a link between those businesses and the sources of new technology. The depth and breadth of state experience with these programs illustrates state support for public-private partnerships to enhance technology-based economic growth.

The success of these state programs provided important lessons on government technology policy. State and local projects demonstrated that new networks of partnerships and programs could supplement traditional methods of technology development and deployment. More important, these partnerships brought together sources of new technology, insights about new markets, and the funding and management needed to bring success in global markets.

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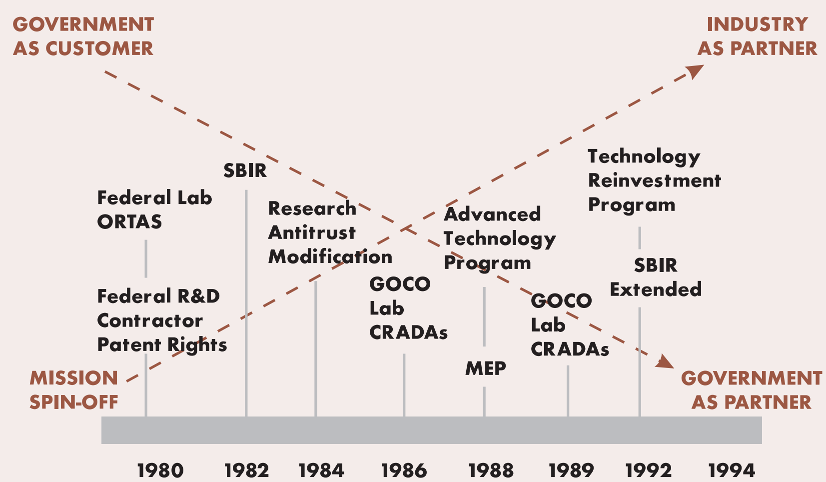
Federal Technology Legislation: Leveraging Mission R&D

The evolution of federal civilian technology policy has been a gradual process (see figure 4). As discussed above, in the first decades following the war, the federal government pursued a de facto technology policy of support for basic and mission research. This policy assumed that technologies developed by the government in the course of conducting basic and mission-related research would lead—as needed and more or less automatically—to commercial products and services. Federal research did not seek direct commercial impact and little attention was paid to changes in industry and in the world that were undermining the ability of U.S.–based firms to use federally developed technologies competitively. Consequently, despite some success in the 1960s and early 1970s, this spin-off model of innovation became less and less effective in meeting the technology demands of the commercial marketplace. The model also discounted the potential of employing or learning from commercial technologies and research methods to improve the effectiveness of government mission research.

By the late 1970s, there was dissatisfaction with federal policies on patenting the scientific and technical knowledge resulting from mission research. Many private and public officials believed that the federal

Figure 4. Evolution of Technology Partnerships, 1980–1995



Note: GOCO=government-owned, contractor-operated.

In 1980, Congress began a new era in federal technology policy with the enactment of legislation to bolster the commercial impact of federal R&D investments. Since then, several laws have addressed obstacles to increasing government R&D efficiency and commercializing federal technology. In the process, a new paradigm for public-private technology partnerships has emerged.

laboratories possessed valuable scientific and technical knowledge created in the pursuit of agency missions that could be quickly commercialized, benefiting both the agencies and the general economy. However, businesses wanted exclusive licenses to federal technology to protect their investments in commercialization, and many agencies granted only nonexclusive licenses. This arrangement discouraged technology diffusion to the private sector and jointly beneficial R&D projects.

The lack of a uniform policy among agencies for ownership of inventions was another major difficulty. The private sector faced a complex maze of patent policies that were often inconsistent from agency to agency, and sometimes even within the same agency. In 1980, at least 24 different patent policies were in effect in the federal agencies. The lack of a uniform federal patent policy presented a formidable barrier to public-private cooperation and was a particularly large obstacle to small businesses and universities, which lacked the legal staffs necessary to wend their way through the patent negotiation maze.

In 1980, Congress began a new era in federal technology policy with the enactment of legislation to bolster the commercial impact of federal R&D investments by more actively spinning off federal technologies to the private sector. Since then, several laws have addressed obstacles to increasing government R&D efficiency and commercializing federal technology (see box 2). In the process, a new paradigm for public-private technology partnerships has emerged.

The first piece of federal legislation designed to leverage the economic impact of federal R&D spending was the **Stevenson-Wydler Technology Innovation Act of 1980** (Stevenson-Wydler). Stevenson-Wydler granted broad authority to the Department of Commerce "to enhance technological innovation for commercial and public purposes . . . including a strong national policy supporting domestic technology transfer and utilization of the science and technology resources of the federal government." In addition to leveraging the economic impact of federal R&D investments, Stevenson-Wydler directed the federal government to conduct a wide range of research and cooperative activities to assess and improve American technological competitiveness.

Based on the premise that federal laboratories contained commercially valuable technology that would make U.S. firms more competitive, Stevenson-Wydler required each federal laboratory to establish an office to identify and transfer commercially viable technologies to the private sector. These Offices of Research and Technology Applications (ORTAs)

Box 2. Major Federal Technology Legislation, 1980–1992

- Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480)
- University and Small Business Patent Procedure Act of 1980 (P.L. 96-517)
- Small Business Innovation Development Act of 1982 (P.L. 97-219)
- National Cooperative Research Act of 1984 (P.L. 98-462)
- Japanese Technical Literature Act of 1986 (P.L. 99-382)
- Federal Technology Transfer Act of 1986 (P.L. 99-502)
- Omnibus Trade and Competitiveness Act of 1988 (P.L. 100-418)
- National Institute of Standards and Technology Authorization Act for FY 1989 (P.L. 100-519)
- National Competitiveness Technology Transfer Act of 1989 (P.L. 101-189)
- Defense Conversion, Reinvestment and Transition Assistance Act of 1992 (P.L. 101-510)
- Small Business Technology Transfer Act of 1992 (P.L. 102-564)

would assess the commercial potential of R&D under way at each laboratory and disseminate information on federally owned or originated technologies, products, processes, and services.

The **University and Small Business Patent Procedure Act of 1980** (known as Bayh-Dole, after its sponsors, Senators Birch Bayh [D-IN] and Bob Dole [R-KS]) was passed to reform government patent policy. Of the 28,000 federal patents sitting on the shelf at that time, fewer than 5 percent had been licensed. Another group of federal patents—those the federal government had permitted single companies to hold—had achieved a much higher rate of licensing (from 25 to 30 percent). The dual purpose of Bayh-Dole was to allow some federal contractors to patent their federally funded inventions and to allow federal agencies to grant exclusive licenses to their technology in order to make it more attractive to businesses. Preference in agency licensing was given to small businesses and universities, and the law required as well that products sold in the United States embodying the invention be manufactured substantially in the United States. Universities, which perform a large portion of federal research, have been particularly successful in licensing inventions pursuant to this authority. In the years since passage of the Bayh-Dole Act, research collaborations between universities and industry have increased substantially, and university research plays an important role in the development of new technologies in many sectors.

Stevenson-Wydler and Bayh-Dole were the result of the belief that federal laboratories hold valuable technological assets and that those assets should be used not only for pursuing an agency's mission but also to improve the competitive position of U.S. firms. This recognition of the government's role in competitiveness and its responsibility to help U.S. firms with user-friendly programs was a first step into the new paradigm of federal-private partnerships. As Senator Dole stated during floor debate on the bill, "The almost adversarial relationship that now exists between business and government must be replaced by a true and genuine partnership in which the government will act as impresario in bringing industry and universities together with new fields of knowledge and their practical implementation."

A second step into the new paradigm of public-private partnership was taken with the **Small Business Innovation Development Act of 1982**, the law that created the Small Business Innovation Research program (SBIR). Studies had concluded that small businesses in the United States were the engine of economic growth, but they received only a very small share of federal R&D funds. Congress hoped to ensure that more federal R&D funds went to small businesses by putting the SBIR program in place in government agencies and large federal laboratories.

Under SBIR, now reauthorized until the year 2000, each government agency and federal laboratory with more than $100 million in extramural research funds is required to set aside a percentage of those funds to be awarded competitively to small businesses. The percentage was initially set at 0.2 percent in 1983 and rose incrementally to 2 percent by 1995. In 1997 the rate is scheduled to rise to 2.5 percent.

SBIR is a three-phase program administered independently by each of the 11 participating agencies. Agencies invite eligible small businesses to propose innovative ideas that meet the specific research and development needs of the federal government. SBIR proposals are competitively selected and accepted only in response to specific solicitations of the participating agencies.

Phase I of the program provides funding to evaluate the scientific and technical merit and feasibility of an idea. Under Phase II, projects with the most potential are funded to further develop the proposed idea for one or two years. During Phase III the innovation is brought to market through private sector investment and support. Phase III is to be conducted with non-SBIR and usually non-federal funds. When appropriate, Phase III may involve follow-on production contracts with a federal agency.

Total annual awards of $693 million were allocated through SBIR in 1994; awards are anticipated to increase to $1 billion by 1997. While these awards are substantial, they place no additional burden on taxpayers, as they merely set aside a portion of agencies' R&D budgets appropriated to meet mission requirements. The benefits of the awards, however, have been substantial, as evidenced by the thousands of small firms that SBIR has enabled to undertake research projects, create new and innovative technologies, and sell competitive products to the world.

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Although still closely tied to agency missions, SBIR was a further step in the development of the new public-private paradigm. While Bayh-Dole and Stevenson-Wydler both sought to maximize the value of past R&D investments, SBIR was designed to encourage the agencies to make investments in mission research with the objective of enhancing U.S. commercial competitiveness.

The **Federal Technology Transfer Act of 1986** authorized cooperative research and development agreements (CRADAs) between federal laboratories and private firms, consortia, and state governments. This was the last major piece of legislation designed to leverage the economic impact of federal investments in mission R&D. CRADAs allow federal and private sector scientists and technologists to work closely together in developing a technology for government mission and commercial uses. A later amendment, the **National Competitiveness Technology Transfer Act of 1989**, expanded the definition of "federal laboratory" to include government-owned, contractor-operated facilities (GOCOs). Since most of the GOCOs are under Department of Energy (DOE) management and have tremendous capabilities, this change allowed DOE to greatly increase its cooperative work with the private sector.

CRADAs built in part on the experience of the National Aeronautics and Space Administration (NASA). The Space Act of 1958 authorized NASA to enter into and perform contracts, leases, cooperative agreements, and other transactions with the private sector when appropriate or necessary to agency work. Accordingly, since its inception, NASA has been partnering with industry for the development of new technologies with both commercial and mission applications. NASA currently enters into three major types of partnerships with industry: (1) unfunded cooperation and/or assistance; (2) public support involving the use of NASA funds; and (3) cost-sharing of goods or services for direct government benefit. NASA has used these flexible partnership agreements to focus on collaborative opportunities that enhance U.S. technological competitiveness by stimulating knowledge transfer, innovation, and understanding; leveraging U.S. R&D efforts and resources; and increasing the commercialization of NASA technology.

The development of CRADAs in the 1980s represented a further expansion of the use of federal research to bolster competitiveness. While SBIR authorized the use of some mission research funds for commercially promising projects by small businesses, CRADAs made more of the resources of the federal laboratories available to all U.S. firms. Although national security concerns prevent the opening of all federal S&T resources to private industry, CRADAs significantly expanded private sector access.

Federal Technology Legislation: Direct Competitiveness Programs

Thus, Congress created mechanisms for making research more efficient while maximizing the economic value to society of government funds already invested in pursuit of agency missions. However, throughout the 1980s, Congress and the executive branch remained concerned over the continuing erosion of U.S. technological and manufacturing prowess. By late in the decade it had become evident that the country's ability to commercialize new technology often fell short of competitive and market demands.

The U.S. private sector has been underinvesting in critical long-run R&D, in part because investments of this type often do not make good business sense for any individual company for several reasons:

- **Appropriability.** The generic nature of much necessary R&D makes it difficult for companies, especially those of small or moderate size with narrow product portfolios, to capture the benefits necessary to justify their investment. In the case of fast-growing knowledge-based technologies that have huge R&D investment requirements but relatively low production costs, it is particularly difficult for an individual company to protect its intellectual property rights.

- **Risk.** U.S. investors focus on high short-term returns and are reluctant to support longer term research programs with uncertain outcomes. In an environment in which R&D projects must compete for capital with shorter term, lower risk nontechnology ventures, the perceived downside risks of failure are often too great to support the necessary R&D investment, despite large expected benefits from the technology development.

- **Expense.** The systems integration and financial requirements of technology development are often beyond the resources of a single company or even a single industry.

In the **Omnibus Trade and Competitiveness Act of 1988**, Congress enacted two programs to help correct the national problem of underinvestment in important technologies. Separating themselves completely from mission research, the Advanced Technology Program (ATP) and the Manufacturing Extension Partnership (MEP) were designed solely to improve the competitive position of U.S. firms. The MEP does this by providing small manufacturers access to newer technologies, production methods, and manufacturing expertise. The ATP does this via shared funding to accelerate the development of high-risk enabling technologies.

ATP, the first program created by this law, is designed to act as a catalyst in the development of high-risk technologies that have broad application and the potential for large economic impact. A technology may be underfunded because the appropriable returns are too uncertain for private investors, the technical risk is too large, or the time to develop the technology is too long. ATP overcomes these obstacles by co-funding firms to develop technologies. ATP funding may not be used as a substitute for research investments that would otherwise be made by U.S. firms, nor is funding to be used to develop proprietary products. The purpose of the program is to encourage work on research that is in the country's long-term interest but that, for various reasons, the private sector is unable to support.

The second program, MEP, assists small and medium-sized manufacturers—who represent about 95 percent of all U.S. manufacturing establishments. This program is a nationwide network of affiliated, locally based manufacturing extension centers.

MEP was motivated by the recognition that most U.S. manufacturers are slow to adopt new technologies and approaches. To increase the speed with which manufacturers, especially small and medium-sized firms, adopt new technologies, a manufacturing extension network consisting of 60 centers in 42 states and Puerto Rico was established to provide a range of hands-on technical assistance to companies. These centers help manufacturers assess their current technology needs and competitive position, identify necessary changes in company operations, and define

ATP and MEP have gone farthest of any of the new partnership programs in exploring the dimensions of the new public-private paradigm.

and implement company-specific technology and business projects. The centers emphasize the use of appropriate technologies and rely on outreach by field agents to offer on-site advice and assistance.

ATP and MEP have gone farthest of any of the new partnership programs in exploring the dimensions of the new public-private paradigm. The purpose of these programs is to address directly, not as an offshoot of another federal mission, the technological challenges facing the U.S. private sector. Substantial private sector input is allowed. The mission of these programs *is* competitiveness.

Federal Technology Legislation: Dual-Use Partnerships for Defense

In 1990, Congress established a mechanism—the dual-use technology partnership—to enable the Department of Defense (DoD) to exploit advanced commercial technologies to meet military needs. The **Defense Conversion, Reinvestment, and Transition Assistance Act of 1992** and the resulting Technology Reinvestment Project (TRP) significantly expanded this approach. Unlike ATP and MEP, TRP's mission was *not* increased industrial competitiveness or economic growth, although the program contributed to both of those goals indirectly. Rather, TRP illustrated the application of partnership principles—cost-sharing, merit-based awards, and exclusive licensing—to achieve the federal government's own mission objectives.[1]

TRP partnerships allowed DoD to leverage the potential advantages of advanced commercial technologies—performance and affordability—to meet defense needs. DoD's aim was twofold: first, to speed the development of an emerging commercial technology so that a self-sustaining market develops sooner rather than later; and, second, to ensure that the technology develops in such a way as to simultaneously meet commercial needs and military requirements, e.g., for technological robustness or interoperability.

For example, one TRP partnership is presently blazing the trail in multichip module (MCM) technology. By replacing separate components with a single module, MCMs allow electronic systems to achieve faster performance, greater reliability, lower power consumption, and lower production costs. The military needs MCMs for activities ranging from

[1] *Second to None: Preserving America's Military Advantage Through Dual-Use Technology*, National Economic Council, National Security Council, and Office of Science and Technology Policy (February 1995).

precision guidance of advanced weaponry to real-time signal processing for intelligence applications. On the commercial side, MCMs open the door to a vast range of new and improved products, including global positioning systems, real-time engine controllers for automobiles, and digital signal processors for speech and images in telecommunications. A high-performance dual-use manufacturing base for MCMs can provide the foundation for U.S. military and commercial leadership in information technology well into the twenty-first century.

In some areas, dual-use partnerships help develop commercial applications for advanced military technologies as a way to lower the cost to DoD. To illustrate, a few years ago, DoD pursued microwave monolithic integrated circuit (MIMIC) technology as a strictly military development, but the high cost prohibited widespread use of the devices. MIMICs are advanced gallium arsenide semiconductors used for military radar. DoD now encourages MIMIC contractors to pursue commercial applications—in collision-avoidance systems for automobiles, satellite communications, and air traffic control signal processing. The payoff to defense is the world's best radar at a lower cost by leveraging commercial production.

DoD recently restructured TRP to increase the involvement of the military services and thereby encourage more rapid insertion of dual-use technologies into defense weapon systems. The new program is called the Dual-Use Application Program.

The TRP mechanism is yet another aspect of a new approach to technology partnership programs. This mechanism combined elements of the earlier public-private partnerships (such as exclusive licensing) with elements of the later federal partnerships (ATP-style cost-sharing). Where licensing and CRADAs aim to maximize the benefit to society of mission research and ATP and MEP focus solely on long-term U.S. competitiveness, TRP attempted to pursue an agency mission, the mission of DoD, via the market mechanism.

The New Paradigm for Improved U.S. Competitiveness

By the late 1980s, a new paradigm of technology policy had developed. In contrast to the enhanced spin-off programs—enhancements that made it easier for the private sector to commercialize the results of mission R&D—the government developed new public-private partnerships to develop and deploy advanced technologies. As described above, these new programs (which account for only a small fraction of federal investments in technology) incorporate features that reflect increased influence

These new programs incorporate features that reflect increased influence from the private sector over project selection, management, and intellectual property ownership.

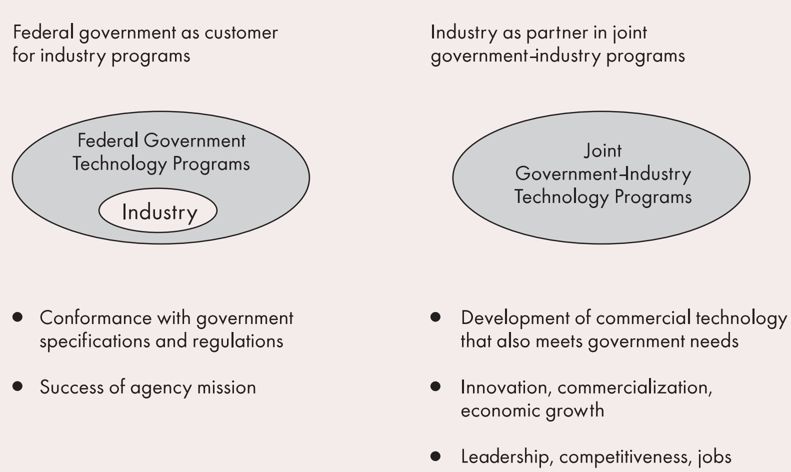
from the private sector over project selection, management, and intellectual property ownership. Along with increased input, private sector partners also absorb a greater share of the costs, in some cases paying over half of the project cost.

The new paradigm has several advantages for both government and the private sector (see figure 5). By treating the private sector as a partner in federal programs, government agencies can better incorporate feedback and focus programs. Moreover, the private-sector-as-partner approach allows the government to measure whether the programs are ultimately meeting their goals: increasing research efficiencies and effectiveness and developing and deploying new technologies. Finally, rather than relying on "technology-push" by the federal government, these programs use "market-pull" to promote innovation, increasing the probability that the targeted technologies will be successfully commercialized.

Key elements of the new paradigm include the following:

- **Maximizing the return on federal and private sector R&D investment.** Government should evaluate technology partnerships for their economic as well as technical merit, partnering with the private sector in areas of mutual technology needs. By focusing on projects with a high potential for economic growth, job creation, and improvements in the quality of life for Americans,

Figure 5. The New Paradigm: Federal Technology Partnerships



government can fulfill its responsibility to maximize societal good, and industry can maximize its return on investment.

- **Making government a better partner with the private sector.** Government should improve the speed, flexibility, and predictability of its programs. Faster, more flexible, and reliable programs will be better able to respond to technology development opportunities as they arise.

- **Increasing the private sector role in project definition, selection, and management.** Economic growth and jobs result from commercialization of R&D, which is the role of the private sector. Therefore, private sector needs must be met to the greatest extent possible when establishing research directions and selecting projects.

- **Conducting programs on a cost-shared basis.** Cost-sharing in public-private programs is critical, because it heightens the private sector partner's stake in the project, encouraging selection of projects with the best commercialization potential and promoting strong private-sector commitment to success. Cost-sharing ensures that the private sector partner has bought into the program.

- **Limiting the length of participation.** New paradigm programs should continue to limit project life to a short term (one to three years). Projects that cannot generate full private sector support by the end of this period fail, freeing government resources for use in other, more promising areas.

By focusing on projects with a high potential for economic growth, job creation, and improvements in the quality of life for Americans, government can fulfill its responsibility to maximize societal good, and industry can maximize its return on investment.

CHAPTER 4: FINDINGS

In the preparation of this report, the Office of Technology Policy (OTP) collected information from agencies, industry, and academia concerning the experience and lessons learned from federal technology partnership programs. This process provided broadly useful insights into the evolution and current operation of these programs. From this information, OTP has drawn findings, presented below, about the effectiveness of the partnerships in accomplishing their goals. OTP has also formulated recommendations for further refinement of federal technology partnerships. These recommendations are presented in chapter 5.

Partnership Programs and U.S. Competitiveness

Government plays an important role in fostering competitiveness and technology-based economic growth. Although the primary responsibility for maintaining U.S. competitiveness lies with the private sector, public research and development (R&D) investments have long had a large impact on the private sector's ability to innovate and market new technologies. The past several decades of experience with public-private technology diffusion policies have taught us that federal technology programs contribute to U.S. competitiveness by

Government plays an important role in fostering competitiveness and technology-based economic growth.

- maximizing the commercial impact and value to society of tax dollars invested in basic research and government mission-related R&D, and
- encouraging the government to work in partnership with the private sector to develop high-risk enabling technologies and speed their diffusion.[2]

Leveraging Mission R&D

In the course of pursuing mission-related R&D, the federal government generates new technologies and processes that offer both public and commercial applications. In order to maximize the economic benefit to society of the tax dollars invested in mission R&D, the government should ensure that the resulting technologies are effectively diffused to the private sector.

[2] The Competitiveness Policy Council recently published a report documenting and endorsing the federal role in promoting technology-based economic competitiveness. See: Robert M. White, *U.S. Technology Policy: The Federal Government's Role*, Competitiveness Policy Council, September 1995.

Maximizing the commercial impact of government mission research has been a major element of U.S. technology policy through the informal mechanisms of technology diffusion of the first postwar decades to the more active spin-off legislation of the 1980s. Licensing programs, cooperative research and development agreements (CRADAs), and, at least in part, the Small Business Innovation Research program (SBIR) are predicated on the idea that the government must maximize the economic impact of public sector R&D. Prudent public policy continues to dictate that the government take steps to ensure that technologies developed from mission-related R&D enhance America's economic growth and competitiveness to the greatest extent possible.[3]

Direct Competitiveness

Leveraging is not enough. Leveraging enhances the commercial impact of federal mission-related R&D, but it does not maximize the international competitiveness of U.S. firms because the nature of the marketplace, investment, and research itself have changed fundamentally over the past 50 years.

American companies enjoyed huge advantages in R&D and international trade in the first postwar decades, as described above. Now U.S. firms operate in a highly competitive global marketplace with increasingly capable foreign firms. The brutal competitiveness of a global economy has produced changes in the character of individual and corporate investment that have adversely affected U.S.–based R&D. Intense global competition requires a focus on providing competitive products with short lifetimes and generally lower profit margins. Rather than investing in a broad technology pool, as they did in the past, American firms are now devoting 90 percent or an even higher proportion of their available investment resources to shorter term product development and process improvement. Investments in broad-based R&D with long (sometimes 15-year) timelines no longer make good business sense for individual companies: the appropriable returns are too generic, distant, and uncertain; the technical risk is too large; and / or the time to develop the technology is too long to generate sufficient returns on investment. This

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[3] It is important to note that this strategy can work in both directions, enhancing the value of R&D performed by *both* government agencies and private firms. In studies of private sector interaction with federal laboratories, U.S. businesses cite leveraging corporate R&D among the most important payoffs from their work with federal laboratories. Firms have been especially complimentary of National Institute of Standards and Technology activities, citing the agency's combination of consultation services, laboratory visits, information dissemination activities, and highly trained personnel for establishing special relationships with the private sector.

hampers the ability of firms to perform the high-risk advanced research that sustains the long-term competitiveness of individual companies, creates high-wage jobs, and strengthens the nation's pool of knowledge for future innovation.

Foreign governments have been addressing this problem through the establishment of public-private R&D partnerships. European countries and Japan have established major cooperative efforts between government and business to develop and deploy advanced technology to raise their manufacturing productivity and improve the quality of their products while reducing costs and shortening the time to market. Until very recently, U.S.–based firms did not have access to these types of resources.

Finally, the way that research integrates into the economy has changed in some areas. While in the past it may have been possible to distinguish clearly between "basic" and "applied" research, the purpose behind the research no longer provides as useful a distinction. For example, while research undertaken to better understand cellular biology may be classified as basic, the same research undertaken with the purpose of developing a treatment for leukemia can be classified as applied or developmental. To the extent that we make distinctions in classifying research, it may be better in some contexts to use a time frame: research having short-term or long-term payoff potential. Or it may be useful to classify R&D as precompetitive or generic versus commercial product and process research. These distinctions may better reflect the current realities of R&D.

In 1988, Congress created two programs to promote U.S. competitiveness directly and counter the challenges to U.S. technological and manufacturing power: the Advanced Technology Program (ATP) and the Manufacturing Extension Partnership (MEP). These programs are as essential in 1995 as they were in 1988: the realities of the new global marketplace, foreign firms' access to public-private R&D partnerships, and the changing nature of research mandate a federal role in directly promoting technology development and deployment.

The realities of the new global marketplace, foreign firms' access to public-private R&D partnerships, and the changing nature of research mandate a federal role in directly promoting technology development and deployment.

Partnerships and Government Mission R&D

Technology partnerships enhance the effectiveness of government mission-related R&D. Strategic collaboration with commercial firms enables federal agencies to meet mission R&D objectives more efficiently.

Technology partnerships enhance the effectiveness of government mission-related R&D.

With the explosive growth of cutting-edge R&D performed by commercial firms, U.S. agencies can no longer depend solely on internal mechanisms for meeting government mission requirements. In several sectors (most notably defense) commercial markets are driving technologies that are critical to mission objectives. To gain access to these essential technologies, government agencies must increasingly join with private firms in joint development projects.

Even where government R&D is at the cutting edge, development of government-unique applications can be prohibitively expensive. In these cases, government agencies must join with private firms to develop wider commercial markets that make development of the technology affordable. Finally, in areas in which government agencies and private firms have complementary competencies and interests, joint development and deployment of technologies can generate synergies that advance the state of knowledge for both parties.

The recent Technology Reinvestment Project (TRP) mechanism is a good example of this relationship. By joining with the private sector to develop dual-use technologies for the military, this program enabled the Department of Defense (DoD) to tap critical expertise in the private sector and develop essential military technologies in a cost-effective manner. Older technology partnerships provide similar benefits. For example, CRADAs at both civilian and defense agencies are a prime vehicle for mutually beneficial research.

Thus, by joining strategically with the private sector, U.S. agencies gain access to and leverage advanced commercial technologies, private sector efficiencies and expertise, and larger markets, enabling the government to fulfill its mission requirements more effectively.

Support for Federal Programs

U.S. business strongly supports federal technology partnership programs.

U.S. business strongly supports federal technology partnership programs. Private sector support is broad-based, covering a wide range of industries and an array of federal programs. While some private sector groups and firms have made recommendations for improvements in program design and administration, the private sector has clearly articulated its enthusiasm for the programs and the public policies on which they are based through surveys, academic studies, roundtable discussions with industry, and private sector appeals for expansion of these programs.

Private sector support for federal technology programs is motivated by a widely shared perception of these programs as a small but critical part of the nation's science and technology infrastructure. It is also important to note that federal partnership programs are supported by the private sector's best experts in the development and deployment of technology, many of whom are not beneficiaries of the programs. These individuals, companies, and organizations support federal partnership programs because, as experts in the R&D field, they recognize the importance of federal programs for enhancing U.S. technological competitiveness.

This underlying consensus among U.S. businesses has been reflected in a history of bipartisan support for these federal programs in both the legislative and executive branches. Over the past decade and a half, through successive Congresses and presidents, both political parties have designed, enacted, implemented, and promoted technology partnership programs.

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Private Sector Support

Surveys of R&D managers in large research-intensive companies and smaller technology-oriented companies reveal strong support for federal partnership programs (see tables 2 and 3). The Industrial Research Institute (IRI) is an association of over 260 large research-intensive companies, employing over half a million scientists and engineers in R&D activities and accounting for over 80 percent of industrially performed R&D in the United States. In 1994, IRI conducted a survey of its members, asking them to rate the value of federal technology partnership programs. The survey showed strong support for technology development programs such as ATP and TRP. Almost two-thirds of the companies surveyed rated these two programs of "high" value, and another 28 percent rated them of at least "medium" value. Over 90 percent of those surveyed rated research consortia and CRADAs of high or medium value. Over half the IRI respondents rated SBIR as a high-value program, with an additional 29 percent rating this small business-oriented program of at least medium value. This last response is particularly significant, because IRI does not include small businesses, and thus it is highly unlikely that any members benefit directly from the SBIR program.

In fall 1994, Semiconductor Equipment and Materials International (SEMI), a 1,400-member association of generally small companies producing equipment and materials for semiconductor manufacturers, conducted a survey of its members. The SEMI results were similar to those of IRI. Moreover, the SEMI study showed particularly strong support among firms that had participated in these programs. Among

Even unsuccessful program applicants speak enthusiastically about technology partnerships. Applicants have praised TRP and ATP for bringing together disparate groups to pursue common technology development opportunities through the establishment of horizontal consortia, vertical product-supplier relationships, and linkages between large and small companies.

Table 2. Results of Industrial Research Institute Survey

"How do industry technology managers rate the value of these programs?"

Program	% "High"	% "Medium"	% "Low"
ATP, TRP	63	28	9
SBIR	56	29	15
Consortia	43	54	3
CRADAs	33	59	8

Source: Industrial Research Institute

those with experience in the programs in question, 100 percent rated ATP, consortia, and SBIR of high value. Among firms with experience in TRP and licensing programs, 80 percent gave them a high rating. And although a lower percentage of CRADA participants—69 percent—gave the program a high rating, this response still represents a high rate of satisfaction.[4]

The results of academic research and roundtable discussions demonstrate the depth of private sector support for technology partnerships, regardless of whether companies participate in the programs or benefit from a public-private partnership. For example, a study of private sector perspectives on commercial interactions with federal laboratories found a very high degree of satisfaction among industrial partners, with 89 percent of the respondents agreeing that the interaction was a good use of company resources.[5] Even in cases in which the costs exceeded the benefits of cooperation, many partners still expressed high levels of consumer satisfaction.

Even unsuccessful program applicants speak enthusiastically about technology partnerships. For example, applicants have praised TRP and ATP for bringing together disparate groups to pursue common technol-

4 In both the IRI and SEMI surveys, the results regarding MEP were ambiguous because of low levels of experience with this relatively new program. None of the SEMI respondents reported having had experience with MEP centers, and it is unlikely that the large member firms of IRI use MEP services.

5 Barry Bozeman and Maria Papadakis, *Industry Perspectives on Commercial Interactions with Federal Laboratories: Does the Cooperative Technology Paradigm Really Work?* Executive Summary, Report to the National Science Foundation, Research on Science and Technology Program, January 1995.

Table 3. Results of SEMI Survey

Program or Mechanism	High Evaluation	Medium Evaluation	Low Evaluation	Program or Mechanism Experience	High Evaluation by Those with Experience
ATP	67%	20%	13%	29%	100%
Consortia	66	17	17	32	100
SBIR	59	13	28	24	100
CRADAs	53	30	17	38	69
Licensing	50	34	16	18	80
TRP	38	45	17	16	80
MEP	33	30	37	0	N.A.

Source: Semiconductor Equipment and Materials International

ogy development opportunities through the establishment of horizontal consortia, vertical product-supplier relationships, and linkages between large and small companies. As a participant in an OTP roundtable with chief executive officers and chief technical officers noted, "These partnerships were some of the most beneficial aspects of federally funded consortia, and of the TRP and ATP, even if the partners didn't win awards." These roundtable groups recommended that the federal government further encourage the development of industry-to-industry partnerships. According to another participant, "Trying to make a bridge from innovation to production has been very difficult. Having access to resources—state, federal, etc.—could be a tremendous help. A network—large and small companies—could be a next step."

The high quality of the applications to participate in federal partnerships further demonstrates the tremendous level of private sector support for technology partnership programs, as well as the abundance of high-quality R&D projects that the private sector is failing to finance. For example, in its first competition, TRP received 2,800 proposals for its technology development, deployment, and training programs from all 50 states. Fewer than 10 percent of the applicants were selected, yet the number of proposals judged "highly meritorious" was so great that Congress authorized the use of fiscal year (FY) 1994 money to fund additional, meritorious FY 1993 proposals.

In addition to expressing enthusiasm about technology partnerships, many U.S. businesses and their trade associations have called for increased federal support for civilian R&D activities, including expansion of industrial extension programs, federal partnerships with the private sector, and technology diffusion activities. The National Association of Manufacturers (NAM) recently offered vigorous support for public-private partnerships in *NAM Policy on R&D Budget Cuts* (1995): "[B]oth industry and government can benefit from rapid development and deployment of new technologies by accessing expertise and capabilities that neither could cost-effectively duplicate alone. . . . [P]artnerships should be encouraged, not discouraged."

These sentiments reflect a widely shared private sector vision of government's role in encouraging economic growth through technology partnership programs. Common perceptions of the role of federal programs include leveraging both federal and private R&D investments, disseminating federal knowledge and expertise to boost the competitiveness of U.S. companies, and supporting high-risk, high-payoff research that is too expensive or too long term for individual firms to pursue. The survey results demonstrate independently that the private sector is particularly supportive of partnerships in areas with high technical risk, where industry efforts are highly fragmented, and where it is difficult for individual firms to isolate and profit from the benefits of high-risk research.

Bipartisan Support

Private sector consensus about the government's role in technology policy has been further reflected in bipartisan public sector support for federal programs. Bipartisan support for the current federal technology partnership programs dates from the first two pieces of legislation in 1980—the Stevenson-Wydler Technology Innovation Act and the Bayh-Dole University and Small Business Patent Procedure Act—and has continued through successive laws expanding and enhancing the effectiveness of public-private technology partnerships.

Technology partnership programs have been strongly supported by successive Republican and Democratic administrations.

Technology partnership programs have been strongly supported by successive Republican and Democratic administrations. All of the major technology legislation of the past 15 years was enacted by Democrat- or Republican-controlled Congresses and signed by Republican presidents. In 1985, the President's Commission on Industrial Competitiveness concluded in its report to President Reagan,

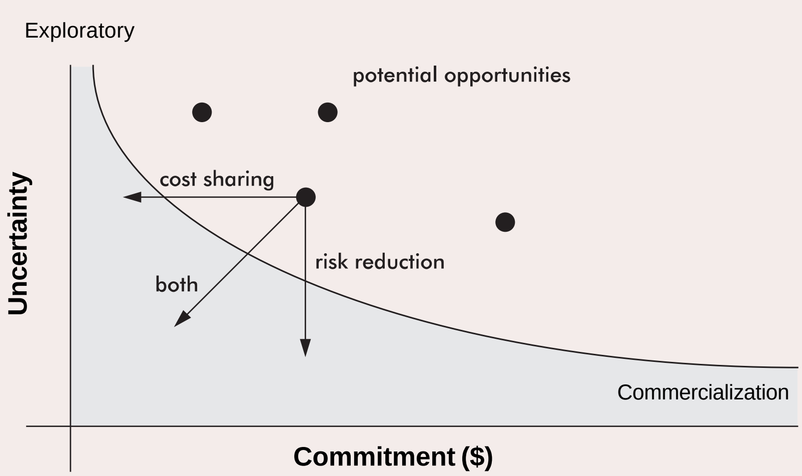
> Technological innovation, fueled by research and development, is a major force for improving the Nation's productivity, industrial competitiveness, and economic growth. It should be U.S. policy to strengthen our science and technology base and its application toward enhancing the technological capabilities of U.S. industry . . . . [Every] responsible approach should be pursued toward advancing R&D relevant to industrial processes and production, and to bringing them to bear on the improvement of U.S. manufacturing.

Partnership Programs, Public Policy, and the Business Climate for Innovation

Although federal technology partnerships are important to private industry, they are just one of several policy instruments that can significantly affect private sector innovation and competitiveness. Research conducted by OTP indicates that the private sector also would like the government to consider reforms in product liability laws, certain tax programs that affect capital formation, standard-setting regulations, and other regulatory policies that broadly shape the business climate for innovation. Careful policy reform in these areas may reduce the costs or uncertainties associated with investment in new technologies, thereby encouraging private firms to pursue a broader array of technological opportunities.

Firms invest in new technologies based on a complicated calculus that seeks to balance costs, risks, and potential rewards. In general, as figure 6 illustrates, the private sector manages risk by severely limiting invest-

Figure 6. Changing the Costs and Risks Associated with New Technologies



ment when the outcome is highly uncertain. All firms have different tolerances, but as economists have long noted, private industry in the aggregate often fails to invest in economically and socially desirable technologies because of the perceived costs and risks to individual firms.

Technology policy seeks to alter the private calculus of risk and reward in ways that move particular investment decisions under the curve in figure 6 within the bounds of acceptable cost and uncertainty. Some types of technology policy can accomplish this objective directly by providing matching funds, encouraging consortia and other cooperative business alliances, or facilitating the widespread diffusion of federal R&D. The partnerships discussed in this report all are designed to directly catalyze private sector investments in new technologies.

OTP has been working to enhance the business climate for innovation by eliciting ideas and proposals from the private sector and advocating appropriate policy changes. In 1994, OTP surveyed a wide range of industry representatives regarding areas in which policy reform could substantially improve their ability to invest in new technologies. Through this inquiry, we learned that business climate issues can significantly affect industrial innovation in general, and that individual sectors respond to particular policies in very different ways. For instance, representatives of the aerospace and biotechnology industries are particularly sensitive to capital formation issues and consequently advocate tax reforms that they believe will lower the cost of capital for R&D investments. Pharmaceutical companies emphasize product liability reform, as litigation costs have skyrocketed and substantially raised the investment uncertainty associated with new product technologies. Other industries advocate regulatory reform in areas particularly salient to their investment strategies: chemical firms, for example, advocate reforms in environmental regulation, while telecommunications enterprises expect industry-specific regulatory reforms to have an enormous impact on innovation and competitiveness in their industry.

The business climate policy concerns revealed by OTP's research are summarized in table 4. OTP advocates a full exploration of these proposals to determine whether changes are appropriate given other policy concerns, whether these reforms would stimulate innovation and raise competitiveness, how these changes would be structured, and how they would otherwise affect the economy. The Clinton administration strongly supports policy measures to make the business climate more conducive to innovation, providing that these changes balance other important policy goals, including environmental protection, public health and

Table 4. Business Climate for Innovation: Policy Concerns by Sector

Business Climate Policy Arena	Concerned Industries
Tax incentives for capital formation	Aerospace, air transport, electronics, biotechnology, chemical, information processing, machine tools, robotics
Product liability reform	Aerospace, air transport, electronics, construction, machine tools, pharmaceuticals
Regulatory reform	Air transport, chemical, medical equipment, machine tools, pharmaceuticals, telecommunications
Standards	Air transport, chemical, medical equipment, machine tools, pharmaceuticals
Procurement reform	Aerospace, electronics, construction, semiconductors
Strengthened intellectual property	Information processing, pharmaceuticals

safety, and the interests of consumers, manufacturers, and sellers; and respect the important role of the states in the federal system.

Measuring Success

Federal technology partnership programs benefit the U.S. economy in a variety of ways, and the Clinton administration has undertaken an unprecedented effort to quantify these benefits. Despite the difficulties of quantifying the diverse set of outputs from private or government-sponsored R&D projects, the administration has succeeded in documenting economic benefits from partnerships and has developed systems of measurement that represent a new level of accountability for these federal programs.

Federal technology partnership programs benefit the U.S. economy in a variety of ways.

Quantifying Program Results

Previous systems for measuring program success did not adequately document the most critical information about the results of federal partnership programs. As a result, it was often not possible to measure the economic impact of these programs.

In addition, the diverse nature of the outputs of any R&D project has made it difficult to measure the results of partnerships. The private sector has long grappled with the difficulties of measuring the outputs of R&D operations. The problems inherent in developing a system of measurements for private sector R&D—the diversity of outputs, changes over time, intangibles, etc.—have also affected efforts to measure the outputs of public-private R&D partnerships. For example, some benefits that accrue to the participating firms, their employees, and customers (in terms of profits, jobs, and new products) are readily quantifiable. However, other benefits may require years to develop. The development of new technologies and production processes sometimes occurs quickly and can be directly measured, but resulting changes in corporate (and industry) employment and profitability require a greater time to develop and a more sophisticated measurement system. Moreover, although some benefits are easily measurable, other benefits that lead to technical advances (such as the creation of business synergies or the facilitation of peer review) are less quantifiable. But they can be crucial in fostering innovation.

The licensing of federally funded inventions by universities under the provisions of the Bayh-Dole Act is an example of these difficulties. While some inventions produced licensing revenues immediately, 10 or more years of experience were required before the effort was truly successful in bringing forth new technologies and processes and in catalyzing new business activity.

As a result of the historical weakness of measurement systems for the partnership programs and the difficulty of quantifying results, varying amounts of information are available concerning the "outputs" of the older technology programs. Nevertheless, the administration has developed significant interim data demonstrating program successes in the older programs that leverage the economic impact of mission R&D (patent licensing, SBIR, and CRADAs). And ATP, MEP, and TRP, which have included measurement systems as an integral part of their operations, are meeting their milestones and remain on track for long-term success.

While the measurement of program results continues to present a difficult challenge, the Clinton administration has emphasized the need for greater accountability in the operation of these programs. In its first statement on technology policy, the administration stated, "[E]very federal technology program, including those of long-standing, will be regularly evaluated against pre-established criteria to determine if they should remain part of a national program." Since that statement, the administration has worked hard to develop rigorous and comprehensive measurements for all federal technology partnership programs.

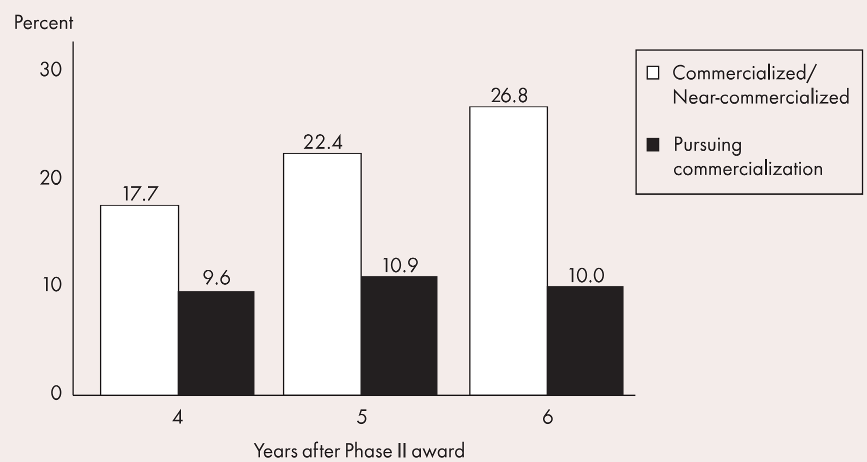
Interim Measures of Success

Preliminary output data for patent licensing and SBIR indicate some success, but these data also demonstrate the limitations of programs designed to maximize the potential for commercializing the results of government mission R&D. For example, since federal laboratories were given authority to license their technologies exclusively in 1986, the numbers of exclusive and nonexclusive licenses negotiated by federal laboratories and universities and the fees and royalties received from these laboratories have grown. Based on 1994 statistics from the Public Health Service and information compiled by the Association of University Technology Managers, the National Institutes of Health (NIH) ranks fourth, when grouped with universities, in royalty income generated and second in the number of licenses generating royalties.[6] However, the laboratories in general have been less successful in licensing than the universities, with about one-third the number of licenses that universities have generated. In addition, the growth in federal laboratory licensing has occurred primarily in nonexclusive licenses, which is counter to the Bayh-Dole Act's assumption that exclusive licenses were needed to encourage the private sector to commercialize federal technology.

SBIR historical data (see figure 7) show that 27 percent of the projects result in product sales to the private sector or a government agency within six years of the Phase II award. Sales to the government represent approximately 50 percent of total sales. Success rates vary widely by agency, with the Department of Health and Human Services (DHHS) having the highest percentage of SBIR projects in which a product has been sold as well as the greatest amount of product sales reported by SBIR companies. The varying rates of commercialization and sales among agencies appear to be the result of two factors: (1) the degree of alignment between the agency's mission research agenda and private sector interests, and (2) how the agency manages its SBIR program. The success of the DHHS program in generating high sales appears to be a result of the high degree of alignment between the research objectives of NIH and the pharmaceutical, biotechnology, and other health care sectors. High rates of commercialization at the National Science Foundation (NSF) and the Department of Energy (DOE) appear to result from their

[6] NIH reported $19.7 million in royalty income in FY 1994. This figure would rank NIH fourth among universities, based on figures published by the Association of University Technology Managers, Inc., in *The Chronicle of Higher Education* (January 26, 1996, p. A.24).

Figure 7. SBIR Results in Commercial Products



Source: SBA, Office of Technology.

The National Institute of Standards and Technology (NIST) reports that ATP grantees have successfully accelerated development of new technologies, enhanced their technical capabilities, and reduced the projected time to market ATP-supported technologies.

emphasis on the commercialization potential of projects they fund and the help they provide for the companies in learning how to finance and market their products.

Currently, the most reliable indicators of the economic impact of CRADAs and other cooperative agreements are academic studies of laboratory interactions with the private sector. The results show strong private sector support for CRADAs (see figure 8) and evidence of positive effects on participating companies, particularly in product development. In a broad sample of private sector partners reporting measurable benefits from an interaction with a federal laboratory, a survey by Bozeman and Papadakis[7] found a 3 to 1 return on private sector investment. There is little evidence, as yet, on job creation related to CRADAs.

Among the newer programs, ATP has met its interim goals. In 21 competitions since 1990, ATP received 2,180 applications and made 280 awards in 40 states and the District of Columbia. The government has invested $970 million, and industry has invested over $1 billion (see box 3).

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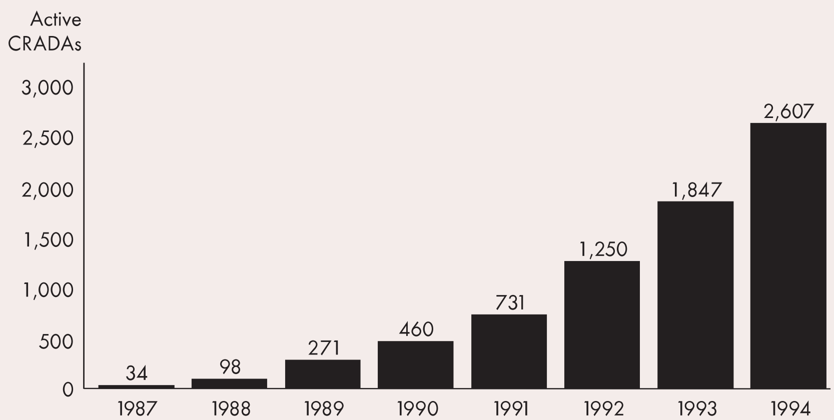
[7] Barry Bozeman and Maria Papadakis, *Industry Perspectives on Commercial Interactions with Federal Laboratories: Does the Cooperative Technology Paradigm Really Work?* Executive Summary, Report to the National Science Foundation, Research on Science and Technology Program, January 1995.

Figure 8. Increase in Number of Active CRADAs, 1987–1994*



*Excludes National Aeronautics and Space Administration and Social Security Administration.

Source: Data provided by the federal agencies.

The National Institute of Standards and Technology (NIST) reports that ATP grantees have successfully accelerated development of new technologies, enhanced their technical capabilities, and reduced the projected time to market ATP-supported technologies. In a survey of 1993 awardees, over half reported that the ATP had already accelerated R&D by one to three years. Respondents reported that most of the research—between 69 and 89 percent of the projects—would not have been pursued at all without ATP funding. Survey results also indicate that ATP has succeeded in increasing industry's R&D investment. There has also been

Box 3. ATP Competitions, 1990–1995

Number of applications	2,180
Number of awards	280
Single applicants	178
Joint ventures	102
Total participants	729
Small businesses	259
Total funds requested	$4,667 million
Total funds committed	$1,982 million
ATP share	$970 million
Industry share	$1,012 million

Among companies that made financial investments based on what they learned at the centers, 86 percent reported a positive result. Even among companies that made no investments, over half reported a positive impact.

early progress toward commercializing some ATP technologies: more than half of 1991 awardees have taken steps to commercialize products based on ATP-related technologies. And ATP firms are expanding and projecting future growth based on ATP-supported technologies.[8]

Because of its focus on shorter term technology deployment issues (rather than technology development), NIST's MEP is already having a significant impact. Like ATP, MEP was first funded as a pilot program. Since then, states, universities, and local economic development organizations have created centers for assisting their manufacturing firms, some co-funded by the federal government as manufacturing technology centers. Data are available from a few centers indicating the effects of the program (see table 5).[9]

Moreover, a recent General Accounting Office (GAO) study on manufacturing extension programs in general (not just the NIST MEP) reported very high levels of private sector satisfaction with federal, state, and university programs (see figure 9).[10] Almost three-fourths of the companies surveyed said that these programs had made a positive contribution to overall business performance—helping businesses work smarter, faster, and better. Among companies that made financial investments based on what they learned at the centers, 86 percent reported a positive result. Even among companies that made no investments, over half reported a positive impact (see figure 10).

Qualitative Indicators of Success

In addition to the economic benefits discussed in the preceding paragraphs, these programs have equally important but less tangible benefits for the private sector—benefits that are recognized and supported by U.S. business. As noted earlier, private sector surveys show strong general support for the partnerships, with a strong preference shown for programs with industry input into project selection (such as ATP), even though private sector participants must pay at least half of the costs.

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[8] NIST, Business Reporting System. June 30, 1995, First Anniversary Report, preliminary data. See also Dr. Bonnie Silber, *Survey of Advanced Technology Program, 1990–1992 Awardees: Company Opinion About the ATP and Its Early Effects*, Silber and Associates, 1996.

[9] NIST, *Delivering Results: A Progress Report from the National Institute of Standards and Technology*, 1995.

[10] United States GAO, *Manufacturing Extension Programs: Manufacturer's Views of Services*, Briefing Report, 1995.

Table 5. Effect of Manufacturing Extension Program Assistance on Sample Client Firms

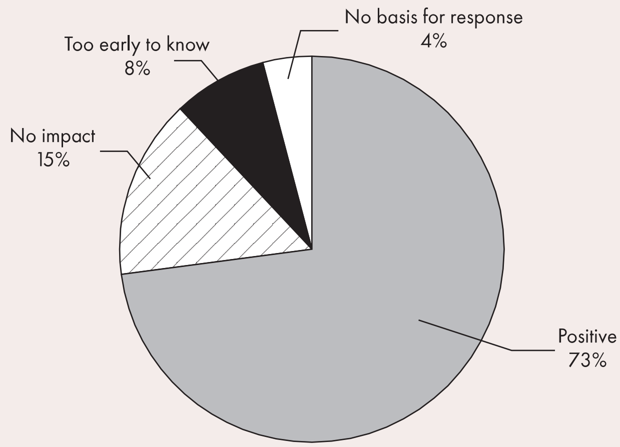
Business Category	Effect of MEP Assistance
Annual sales	49% increase
Exports	29% increase
Employment	15% increase
Sales per employee	17% increase
Payroll	17% increase
Average annual salary	4% increase
Manufacturing lead time	20% improvement
Scrap rates	28% reduction
Inventory turnover	43% increase
Computer usage	56% increase

Source: National Institute of Standards and Technology

R&D catalyst. In roundtable discussions with private sector representatives, the participants offered strong support for these programs because they removed barriers to public-private collaboration and, equally important, to collaboration between firms. Participants noted that the resulting pooling of expertise and resources enabled firms to master technological challenges that would have been beyond their individual technical and financial abilities. Participants said that newer technology

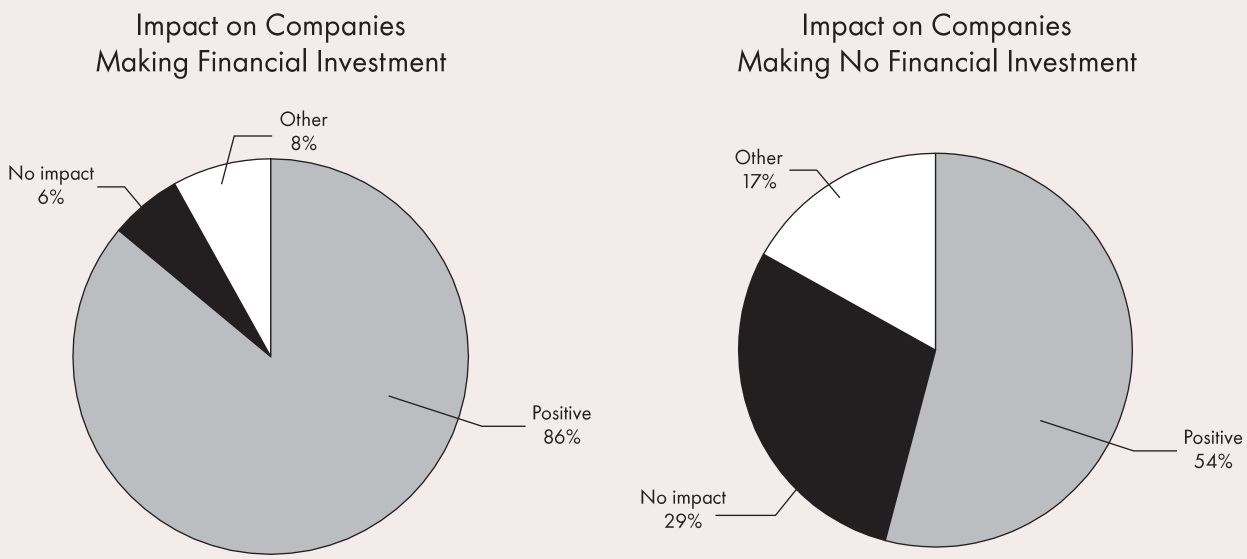
The resulting pooling of expertise and resources enabled firms to master technological challenges that would have been beyond their individual technical and financial abilities.

Figure 9. Client Views of Overall Impact of Federal, State, and University Manufacturing Extension Programs



Source: GAO.

Figure 10. Company Investment and Impact of Manufacturing Extension Programs



Source: GAO.

Companies report that the new partnerships and the synergies that result just from applying for federal programs are immensely valuable in and of themselves, whether or not the firms receive funding under the partnership programs.

partnerships provide a valuable service by bringing together firms that otherwise may not have made contact and fostering the creation of business and research synergies. For example, the National Coalition for Advanced Manufacturing (NACFAM) reports that the TRP process spawned a large number of new partnerships "in various combinations between large business, small business, state government, local government, technology centers, universities, community colleges, and associations." Companies report that the new partnerships and the synergies that result just from applying for federal programs are immensely valuable in and of themselves, whether or not the firms receive funding under the partnership programs.

Peer Review. Companies report that the peer review that is part of the application process is also of high value in developing new technologies, even if the company's application is not successful. And both participating and nonparticipating companies report that the review process often provides a technical "stamp of approval" that helps them raise capital in the private marketplace—one of the most formidable obstacles to technology development.

Technical consultation. Older programs that promote the commercialization of government mission R&D also provide important nonquantifiable benefits. A study of private sector participants in cooperative projects with federal laboratories concluded, "Perhaps the most significant result of the survey is that companies tend to interact with federal laboratories for reasons that have far more to do with long-term, less tangible payoffs than with expectations of business opportunities or technology commercialization." Companies reported that their major incentive for working with federal laboratories was access to technical resources. Firms also noted that informal types of interaction were the most frequent and effective and that the prime benefits of contracting and cooperating with federal laboratories were leveraging R&D, gaining access to federal expertise and facilities, and developing business opportunities—*in that order.* The study warned, "There is a danger that too much emphasis will be placed on evidence of tangible economic payoffs (CRADAs, licenses) as measures of success, with insufficient recognition of the value to companies of access to state-of-the-art knowledge and equipment."

Thus, through these less quantifiable benefits, federal technology partnerships are also meeting their goals for improving U.S. competitiveness by fostering the development and deployment of new technologies. Measuring the success of federal partnerships by long-term economic impact alone would unfairly discount the true value of the programs for the U.S. economy and in raising America's global competitiveness.

Developing a Federal Measurement System

In the past, monitoring focused on inputs: collecting information about the amount of funds spent, the number of agreements entered into by the agencies, the number of potential partners contacted, and related information. The focus of the Clinton administration with respect to these programs is on outcomes, which typically fall into two categories. The first is the more immediate effects of the partnership on its private sector partners. The second, longer term focus is the effect of the program on the economy in general. Short-term outcome measures might include partner satisfaction, invention disclosures, patent applications, new products and processes, changes in scrap rates, and changes in the ratio of sales per employee. Longer term measurements attempt to establish the programs' connection to and impact on economic growth. These efforts generally examine job creation, return on investment, productivity, and other broad measures.

Efforts to develop a systematic approach to measurement are under way throughout the executive branch. These initiatives focus on several different aspects of the challenge, ranging from the measurement of economic impacts of basic research to efforts to develop systems for measuring the outcomes of specific programs such as ATP and MEP. In addition, a subgroup of the Interagency Working Group on Federal Technology Transfer, led by OTP, has been working to develop a measurement system for both inputs and outcomes of federal laboratory collaborations with the private sector.

This subgroup has achieved its first objective of developing a set of common definitions for agency input data elements. The Office of Management and Budget has adopted these common definitions as a part of its system for tracking federal cooperative research. The second objective of the working group is to recommend methodologies for measuring outcomes—the economic impact of technology collaborations between federal laboratories and the private sector. The group is currently reviewing existing measurement methodologies and will recommend appropriate methodologies to the agencies for their use.

To address the critical need for reliable and comparable data concerning both inputs and outcomes of these programs, the administration will continue to work toward a system of measurement that is both comprehensive and systematic across the partnership programs. This effort must involve private sector representatives as well as academic and other subject matter experts. Such a system is a critical part of the administration's commitment to fostering economic growth by encouraging the development and deployment of new technologies.

Newer direct competitiveness and defense dual-use programs are drawing strength and support through their interactions with the private sector. New paradigm principles of service and accountability have improved the operations of the older programs that enhance the efficiency and commercial impact of government mission R&D. Changes in the broad spectrum of federal technology programs reflect the new paradigm in action.

A New Paradigm

Government agencies are adopting a new paradigm for technology partnerships. They are experimenting with and adopting a new model of public-private partnership, in which the private sector is recognized as the government's partner in cost-shared technology programs. These partnerships have enhanced the effectiveness of federal efforts to meet government mission objectives and promote technology diffusion and American competitiveness. Newer direct competitiveness and defense dual-use programs, which were designed solely according to the principles of the new paradigm, are drawing strength and support through their interactions with the private sector. In addition, new paradigm principles of service and accountability have improved the operations of the older programs that enhance the efficiency and commercial impact of government mission R&D. Changes in the broad spectrum of federal technology programs reflect the new paradigm in action.

The New Paradigm in Action—Programmatic Change

Maximizing Return on Investment

In their administration of both older and newer programs, agencies are more effectively maximizing the return on federal and private R&D investment (see table 6).

Commercialization potential. Some agencies now place greater emphasis on choosing SBIR projects with commercialization potential and are taking steps to increase the probability that firms take resulting products to market. The Navy requires a commercialization plan from a Phase II winner before it will release the last 20 percent of the award. NSF evaluates all of its SBIR projects based on commitments for follow-on funding; as a result, NSF's commercialization data show one of the highest rates of private sales and average sales per project.

Nonfinancial assistance. Agencies are providing valuable nonfinancial assistance to small firms. Since 1989, DOE has trained its SBIR Phase II winners in business practices, product marketing, and raising capital. DOE's early results indicate that 43 percent of the companies trained in 1991 had received follow-on funding as of July 1994. In a similar vein, DoD and NSF have sponsored major conferences to help SBIR companies market their products. Two such conferences have so far been held. The Small Business Administration provides a "matching" service, bringing together venture capitalists and SBIR winners. ATP and MEP also offer this type of assistance, having discovered that private sector partners often need this kind of support as much as they need technology-related assistance.

Agencies are providing valuable nonfinancial assistance to small firms.

Intellectual property rights. The government's newer technology programs are designed to maximize the return on R&D investment by strengthening the private sector's intellectual property rights. To maximize the commercial effectiveness of partnerships, private sector partners need both clear title and freedom from potential conflicts in product pricing and royalties. In the older programs, the federal government retains title to the intellectual property and licenses the firm to use the invention in exchange for a royalty. Most licenses are nonexclusive, and the agency retains the right to license other entities as well as rights to monitor the commercialization efforts of the licensee. In ATP, however, firms own any resulting intellectual property outright and do not need a federal license to use the technology. The intellectual property environ-

The government's newer technology programs are designed to maximize the return on R&D investment by strengthening the private sector's intellectual property rights.

Table 6. Federal Partnership Programs—Key Features

	Licensing	Cooperative Research and Development Agreement (CRADA)	Small Business Innovation Research Program (SBIR)	Advanced Technology Program (ATP)	Manufacturing Extension Partnership (MEP)	Technology Reinvestment Project (TRP)
Project selection basis	Industry chooses from available patents. Patents are generated by the agencies in the course of their mission research. Interested firms generally learn of the invention only after the patent has been applied for.	Nongovernment partners are free to propose a research collaboration in any area within the scope of the laboratory's research mission. The laboratory director, subject to varying degrees of review by agency headquarters, may decide whether to enter into such a partnership.	Government chooses mission topics on which it will consider proposals; applicants then propose specific projects. However, the law authorizes consideration of commercial potential by the agencies in selecting projects.	All research areas are open to industry proposals involving high-risk enabling technology. Selection of proposals for funding is made by National Institute of Standards and Technology on the basis of extensive peer review of technical and economic issues. Private sector consultants conduct economic evaluations.	Operating as an extension service, MEP centers provide help to all small and medium-sized manufacturers who seek it. A great variety of support services are provided to requesting firms.	Focuses on technology development and deployment issues of importance to the defense mission.
Project control accounting	The licensee agrees to be responsible for development of commercial applications. The government generally has little involvement in the commercialization process. However, royalty income received by the agency will be monitored.	The CRADA is a unique instrument not subject to procurement regulations nor to the rules for grants or other types of cooperative agreements. However, project controls consistent with the agreement's statement of work will be used.	Accounting rules may vary depending on the type of funding agreement used by the agency.	Generally accepted accounting principles are used by the parties.	Generally accepted accounting principles are used by the parties.	Varying mechanisms are used by the participating agencies, involving varying degrees of procurement, grant, and "other transactions" authority.
Intellectual property disposition	Industry generally secures a license, the terms of which are negotiated with the licensing agency. The terms are generally comparable to commercial licenses (e.g., exclusive, nonexclusive, or other forms). However, the government retains title, a license for government use, and march-in rights in the event the licensee fails to abide by its commercialization pledge.	The disposition of intellectual property is negotiated by the parties to each agreement. A laboratory may agree to license or assign inventions generated by the collaborative work. Licenses are negotiated in accordance with the general guidelines for agency licensing already discussed.	The small business contractor keeps title to any inventions arising from the work. The funding agency retains a license for government use and march-in rights, as in the case for most other government-funded inventions.	Intellectual property resulting from government funding is to be held by for-profit participants in the project.	MEP extension services are unlikely to produce intellectual property. Whatever technical data are produced by these services are retained by the client company.	The exact disposition of intellectual property may vary depending on the type of funding agreement used and the practices of the negotiating agency.

	Licensing	Cooperative Research and Development Agreement (CRADA)	Small Business Innovation Research Program (SBIR)	Advanced Technology Program (ATP)	Manufacturing Extension Partnership (MEP)	TRP
Government financial assistance	Agencies must fund the expenses of patenting and licensing efforts from their budgets. Royalties are sometimes used to cover some of these costs, but they are not significant in most agencies, and funding constraints therefore limit patenting and licensing activities.	Laboratories may contribute human and physical resources to the collaborative project but may not directly contribute any funds. As a general matter, the laboratory contributes no more than 50 percent of the total costs of the collaboration.	The funding agency pays the costs of the project, up to $100,000 for Phase I projects and up to $750,000 for Phase II projects.	Agency awards cooperative agreements with required cost-sharing.	The entire program consists of non-financial assistance services for small and medium-sized manufacturers.	Agency awards cooperative agreements with required cost-sharing.
Nonfinancial support	Technical support from the licensing agency or laboratory may be available.	Technical collaboration is the heart of the agreement.	Generally none (except for Department of Energy).	Agency provides value-added project oversight and technical support.	The entire program consists of non-financial assistance services for small and medium-sized manufacturers.	Project oversight and technical support may be provided by the agencies.
Speed and flexibility	Negotiations are comparable to private sector negotiations, but government procedures, including publication requirements relating to exclusive licenses, can cause delays in the completion of the negotiations.	Negotiations of the terms of a CRADA can be time consuming. Agencies and their laboratories have developed various “model” CRADAs to make negotiations simpler.	Government specifies the tasks, deliverables, and schedules in most agencies. The degree of flexibility in these areas varies from agency to agency.	The flexibility of the funding agreements used by National Institute of Standards and Technology provide it with a high degree of flexibility in meeting the legitimate needs of its industry customers.	Reimbursement for services is sought by the centers on a sliding scale set by each center.	The funding agreements used by the agencies embody a variety of approaches to partnership projects with varying degrees of flexibility to meet industry concerns.

Government agencies have improved the speed, flexibility, and predictability of their technology partnership programs.

ment of ATP was further improved when Congress eliminated a rule that required ATP participants to pay royalties to the federal government for product sales resulting from technology developed in whole or in part with ATP funding. This requirement ignored the often tenuous and ill-defined link between ATP-funded technology and an eventual product.

In a related example, NIH had imposed a so-called "reasonable pricing" clause in its exclusive licenses and CRADAs. This clause applied to all products later sold that incorporated the technology exclusively licensed from NIH. The refusal of many companies to engage in research projects with NIH and the agency's determination that the clause was detrimental to its research program without providing an offsetting benefit to the public led NIH to remove this clause from its model agreements in 1995.

Making Government a Better Partner

Government agencies have improved the speed, flexibility, and predictability of their technology partnership programs. These improvements and others make the partnerships more useful to the private sector without compromising government mission R&D objectives. In the past, the monitoring and control mechanisms used in these programs added to the risk and cost of partnering with the federal government. The imposition of excessive proposal, reporting, and accounting requirements deterred firms that do not customarily do business with the federal government from participation and added overhead costs for those firms that chose to participate. Many innovative improvements have been made by the agencies in these areas with the objective of lowering the risks and costs for private parties.

For example, the DOE SBIR program has eliminated the time gap between Phase I and Phase II by allowing firms to apply for early funding. This innovation, which enables small firms to retain key personnel on research projects, has been highly praised by firms participating in the SBIR program. In CRADAs, DOE has decreased its approval time by half since 1993 and expects to continue to reduce processing time through innovative use of model CRADAs and umbrella agreements with intermediaries. These mechanisms will allow the agency to initiate projects with a minimum of negotiation and paperwork. In FY95 NIH also significantly decreased its CRADA approval time, from a median of 69 days to 28 days.

TRP also reduced application and negotiation times for its agreements. In the first TRP competition in 1993, many firms found the time from proposal submission to completion of negotiations to be excessive.

A House Armed Services Committee survey of the winners showed an average of nine months from proposal due date to first receipt of funds, often too long for a firm to meet a brief market window. In response, TRP changed its requirements to allow firms to submit one-page white papers describing their proposed projects. TRP committed to reviewing the white papers and providing feedback on the potential of the project before the due date for full proposals. By using this opportunity, firms could test the waters without committing resources to a full proposal.

In some programs, especially the newer ones, agencies have simplified the management and control systems they use to monitor the project. For example, some agencies now use grants instead of contracts subject to the Federal Acquisition Regulations to disburse money for their SBIR programs. NSF has switched to a grants-only system; DOE uses a modified grant that incorporates deliverables and other requirements; and DoD uses the standard procurement contract to fund its SBIR recipients. In the newer TRP program, agencies require quarterly accounting reports on the progress of projects they co-fund, but they allow firms to use commercial accounting principles rather than federal accounting standards in making those reports.

Agencies have simplified the management and control systems they use to monitor the project.

Some innovations pioneered by state and local economic development groups make it easier for firms to apply for federal programs. Fully 30 states offer financial or technical assistance to SBIR applicants and winners. Financial assistance may be bridge grants or loans, commercialization grants or loans, or proposal preparation grants or loans. Technical assistance includes outreach and education, proposal review, proposal writing, and literature and topic searches.

Some innovations pioneered by state and local economic development groups make it easier for firms to apply for federal programs.

Enhancing the Private Sector's Role

In addition to maximizing the effectiveness of federal and private R&D investment and becoming better, more flexible partners, federal agencies have increased the private sector's role in project definition and selection. In their government mission-related R&D activities, agencies now place more emphasis on choosing projects with commercial potential. In general, the degree of private sector involvement in project definition and selection increases in the newer programs. For example, in many patent licensing programs, the technology has already been developed to the point where a patent is secured before industry interest is solicited. In the SBIR program, however, agencies propose research topics within the scope of their mission and then allow small businesses to propose specific research within these fields. Projects are selected on the basis of both mission benefit and commercial potential.

In contrast, the core concept of ATP is to involve the private sector in defining, selecting, and managing projects for public-private partnerships. Under ATP, firms propose projects in general and focused competitions, and proposals are selected on the basis of intensive peer review of both the technical and business aspects of the proposal.

Private Sector Support for the New Paradigm

Private sector analysts have noted and applauded these changes. A study by the Economic Strategy Institute found that two-thirds of the industrial managers it surveyed saw improvements in management initiative and flexibility of federal programs.[11]

The private sector is especially enthusiastic about the newest technology programs that fully reflect the new paradigm by giving the private sector a strong role in selecting, managing, and financing projects. Survey data, such as the IRI and SEMI studies, reveal high levels of support for ATP—the highest levels of support for any federal technology program. In particular, ATP has been praised for its flexibility and responsiveness. In a report on the progress of ATP, NIST quoted the vice president of a small company to demonstrate how this type of flexibility is critical:

> The personnel within the ATP have been the most responsive of any government organization that I have dealt with over the years. This is extremely critical. The commercial markets in technology-related fields move very fast, and a needless delay can kill a promising technology or leave it to be taken over by foreign competition.

In addition, the private sector has applauded these programs for their effective use of interagency coordination. According to NACFAM,

> [TRP incorporates an] unprecedented level of cooperation among six federal technology agencies, demonstrating that they can effectively pool their efforts on behalf of public-private partnership projects. . . . TRP has broken down several artificial barriers to pooling national resources on a pragmatic basis to address specific problems. This culture change is a major plus by itself.[12]

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[11] Michael Irish, ed., *Technology Exchange: A Guide to Successful Cooperative R&D Partnerships*, Washington, DC: Economic Strategy Institute, 1995; Michael Irish, Joint Efforts Crucial to Tech Base, *Aviation Week and Space Technology* 143:6, p. 66.

[12] National Coalition for Advanced Manufacturing, *NACFAM Analysis of the Technology Reinvestment Project (TRP)*, Washington, DC, 1994.

American business also supports the new paradigm because it recognizes the primary importance of the marketplace in driving technology research. In his study of private sector interactions with federal laboratories, J. David Roessner found preference for private sector–initiated, market-pull cooperative activities rather than government-initiated, technology-push programs.

American business also supports the new paradigm because it recognizes the primary importance of the marketplace in driving technology research.

Cost-sharing is an integral part of the newest technology programs. Both ATP and TRP require funding matches from all successful applicants, and the private sector also provides co-funding through consortia and CRADAs. In total, the private sector has invested $3 billion in co-financing for technology partnerships with the U.S. government. The potential pool of private sector funds is much larger. For example, each of the 2,800 proposals that TRP received in its first competition required a 50 percent funding match by the private sector applicant. This represented $8.5 billion in private sector funds in response to an offer of $472 million 1993 federal matching funds.

As noted earlier, at roundtables with industry, private sector representatives repeatedly expressed their preference for cost-shared partnerships over purely government-financed projects. Private sector firms and organizations prefer cost-sharing for the same reasons that make it an effective tool for government: cost-sharing encourages effective participation and influence for each of the participants, better ensuring that the partnership meets the goals of both the private and public sector participants.

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Chapter 5: Recommendations

Although federal agencies have made significant progress in improving the effectiveness of their technology partnership programs, there is room for improvement. Agencies should increase efforts to improve the commercial potential of federal technologies and increase the private sector's role in project definition, selection, and day-to-day management to ensure that technology partnerships are as effective as possible in meeting both public and private sector needs. And agencies should continue to make government a better partner—working quickly with new technologies, adjusting to changing conditions, and planning long-term relationships with the private sector.

Accordingly, the Office of Technology Policy makes the following recommendations for further improvement of federal technology partnership programs:

Make Partnership Opportunities More Accessible and Easier to Identify

Firms report difficulty finding appropriate partnership opportunities in the enhanced spin-off programs. They have difficulty finding which agencies (and which personnel within an agency) are performing research in areas of interest to them. They also find it difficult to locate intellectual property of potential interest to them. Firms that have not previously worked with the federal government (either in procurements or cooperative research) as well as small and medium-sized businesses appear to be at a special disadvantage in identifying such opportunities.

Disseminate Information

The decentralization of agency partnership efforts, which is so important to achieving speed and flexibility, has made it more difficult to meet this challenge. Because of the broad scope of the federal research effort and the decentralized nature of its management, comprehensive information concerning agency research agendas, staff expertise, and inventions available for licensing is not centrally available. The National Technology Transfer Center (NTTC), the Federal Laboratory Consortium (FLC), and the National Technical Information Service (NTIS) attempt to address this challenge. NTIS provides access to a broad array of information concerning agency research, and NTTC and FLC provide expert guidance and assistance to businesses seeking to identify relevant federal resources. In addition, some private firms have attempted to fill the void by providing lists of federal patents and collaborative research activities in easily

An ad hoc system of support is provided by both federal and state agencies to small businesses seeking to develop the business skills needed to bring their technologies to market.

accessible databases and reports. The positive response to these services from the private sector indicates that the information is valuable and needs to be provided even more broadly.

Match New Technologies with Sources of Capital and Other Support

As this report demonstrates, the development of new technologies is only the beginning of a complex commercialization process in which both capital and business acumen are required to achieve the goal of new products and services. While the federal government cannot be the source of the capital or the business expertise, it can be a catalyst enabling technology developers to find them. Almost all of the programs reviewed here have begun to address this need.

The Small Business Innovation Research (SBIR) program has made the most comprehensive effort to address this challenge. An ad hoc system of support is provided by both federal and state agencies to small businesses seeking to develop the business skills needed to bring their technologies to market. The Department of Defense (DoD) and the National Science Foundation (NSF) draw on private sector experts to provide business training conferences to program participants. The Department of Energy (DOE) operates an impressive commercialization assistance program that provides a spectrum of training and support to participants. The Small Business Administration (SBA) maintains a database of SBIR winners and of potential capital sources and provides matching services on request. Various state agencies provide support to local program participants, ranging from training to seed capital.

The Advanced Technology Program (ATP), agency cooperative research and development agreements (CRADA) programs, and Technology Reinvestment Project (TRP) have, to varying degrees, all attempted to provide technically competent firms access to private sector funding and other commercialization resources. In addition, as noted above, both public and private sector organizations have begun to assemble information concerning various facets of these programs. With this common purpose, consideration should be given to consolidating or coordinating these activities across programs and agencies.

For example, information concerning partnership projects in all of these programs might be consolidated in a central information bank, enabling potential investors to identify the full range of projects in their areas of interest. The same information bank might also identify investors interested in particular technologies, enabling program participants to identify potential funding sources. As noted, SBA has put together information of this nature for the SBIR program, and other state and federal agencies have similar compilations. What has been lacking is a determined effort to consolidate the information and improve its accessibility.

This consolidation and coordination need not take the form of a new program but could be constructed as a coordination of existing efforts comparable to that suggested earlier for general partnership information. One or more National Science and Technology Council (NSTC) committees could coordinate the efforts in partnership with state governments, which have played an important role in this area. Recent experience with the National Electronics Manufacturing Initiative project, initiated within NSTC in partnership with industry, indicates that such projects can be undertaken and are likely to be productive for both industry and government.

Promote Professional Interactions

One of the best ways to make these partnership opportunities better known and more accessible is to encourage greater contact among personnel in federal research agencies and industry. Such contacts can occur through fellowship programs, work details, procurement contracts, professional seminars, or joint research ventures. Many federal laboratories—especially defense-oriented laboratories—have worked at arms-length from the private sector. Although national security concerns will always limit interaction, there is room to reduce the cultural and geographic isolation of federal laboratories through a more active personnel exchange effort with the private sector. Personnel exchanges are an excellent and effective method of promoting collaborative activity, although such programs are likely to be used only by larger private sector firms. Sandia National Laboratories has initiated a novel program, the New Ventures Initiative, which might serve as a model for other agency research organizations. The program permits Sandia personnel to take entrepreneurial leave to encourage the transfer of new technologies to industry. As of January 1996, fourteen Sandia scientists had been granted unpaid leave under the new policy to help 12 companies apply lab-developed innovations.

Leverage Increased Interagency Coordination of Research

Increasing interagency coordination is another way to improve dissemination of information about technology partnership opportunities. As the executive branch, through NSTC, increases its efforts to coordinate research at the agency and interagency level, an information base will be created that will be of great value to industry. In particular, the work of

Broader groupings of companies may be represented by various types of umbrella organizations. By partnering with such organizations, agencies can multiply the impact of their efforts, offering several firms equal opportunities to participate in research.

the Civilian Industrial Technology Committee of NSTC is likely to produce information concerning federal agency research on topics with commercial potential that is not readily available from other sources. Information resulting from these interagency efforts should be provided to the public and private sector organizations already attempting to improve private sector access to federal research so they can deliver it to industry customers.

Use Consortia and Other Umbrella Organizations

The private sector has increased its use of research consortia as a means of addressing issues of common interest to different firms. These consortia may be horizontal in nature, including an array of firms in a single sector, or they may represent a vertical chain of suppliers, manufacturers, and customers of a particular product line. In addition, broader groupings of companies may be represented by various types of umbrella organizations, ranging from broad associations of companies interested in particular research issues to quasi-governmental organizations seeking to promote economic development in a specific locale. By partnering with such organizations, agencies can multiply the impact of their efforts, offering several firms equal opportunities to participate in research.

Ensure Effective Protection of Intellectual Property

Private sector representatives have expressed concerns about the patents obtained by the federal laboratories. They questioned what was being patented and the scope of some of the patents. The representatives recommended that the laboratories work more closely with industry to determine which inventions should be patented and in which countries to ensure that the patents interest industry. The private sector could advise the laboratories on which embodiment or commercial application of the invention should be included in the patent application. However, expanding the scope of the invention may require an agency to do further research to provide support for additional embodiments or applications.

Obtaining and maintaining patents is costly, and agencies must be very selective in what they patent. To minimize their patent expenses, laboratories can postpone some of their costs while they are looking for licensees to pay most, if not all, of the patent expenses. For example, laboratories can use the Patent Cooperation Treaty, which can give them up to 30 additional months for filing both foreign and U.S. applications. In addition, U.S. law was recently changed to permit the filing of provisional patent applications at one-fifth the cost of a conventional patent application while preserving the date of invention. Since the provisional application expires after one year, the laboratories would have an additional year to file a conventional application while looking for licensees.

Be a Better Partner: Improve Speed, Flexibility, and Predictability

Make Administration of Agreements More Responsive to Private Sector Needs

The private sector continues to be concerned about the speed with which partnership agreements are carried out and the flexibility with which they are administered. The goal of the negotiations of the partnership agreement should be to enable the parties to reach agreement on mutually beneficial terms in the least possible time while spending the least possible resources. Agencies have available to them a variety of funding instruments, and they should select the instrument most appropriate for the achievement of each goal. Possible funding instruments include contracts, grants, cooperative agreements, and a more general authority possessed by some agencies referred to as "other transactions" authority.

Contracts are the traditional means of federal procurement and are governed by the Federal Acquisitions Regulations (FAR). FAR imposes very specific rules on administering agencies and contractors, including competitive bidding processes and special accounting requirements. The contractual mechanism, while giving the government significant control over its purchases, is a very inflexible mechanism when used in collaborative research programs.

Grants are a more flexible mechanism for funding and require a lesser degree of administrative control by the federal government. Grants are, in essence, awards to third parties to support projects the agency wishes to support. Once a grant is offered, the administering agency retains less control over the direction of the project than in the case of a procurement, and there may be few requirements for deliverables, reporting, or accounting. Cooperative agreements also allow a greater degree of flexibility than contracts under FAR.

Finally, some agencies have available a fourth category of authority, the "other transactions" authority. This category falls outside the rules for contracts, grants, and cooperative agreements and consequently permits the agencies a greater degree of discretion concerning the terms to which they agree. It is an especially appropriate basis for research collaborations with private sector firms, because it permits agencies to follow standard

"Other transactions" authority falls outside the rules for contracts, grants, and cooperative agreements and consequently permits the agencies a greater degree of discretion concerning the terms to which they agree.

commercial practices and to adapt to the individual circumstances of each partnership. For example, an agency could more readily agree to changes in schedules and deliverables during the research process. Agencies using such authority would also find it easier to permit the use of commercial accounting principles as a contract management device, eliminating a major burden to private sector participants in these programs. The other transactions authority is available to and has been frequently used by both the National Aeronautics and Space Agency (NASA) and the Advanced Research Projects Agency (ARPA) to secure additional administrative flexibility in their collaborative research agreements with industry. Other agencies should be directed to determine whether they have a legal basis for such flexible authority. Where such authority exists, they should be directed to use it as a means of structuring research partnership agreements. If they do not have it, they should seek appropriate additional statutory authority to permit entry into such agreements.

Another private sector concern relating to agency responsiveness has been delay in providing funding once an agreement has been reached. Industry partners frequently assemble special personnel and equipment to carry out the agreement and must produce commercially meaningful results within a short period of time. For that reason, delays in receiving funding can have extremely serious repercussions. Several agencies have taken innovative steps to address this issue. For example, DOE has reduced gaps in funding SBIR projects through a novel early application process for Phase II projects. It accepts applications for Phase II awards from Phase I awardees even before their Phase I work is completed. As a result, many Phase II winners are able to begin their work immediately after completing Phase I.

Companies have also expressed concern about the need for control of intellectual property arising from partnerships with the government. Companies providing substantial funds to such a project may wish to own or control all rights in inventions arising from the work, including those made by subcontractors. Under existing laws and regulations, however, it is generally only the inventing company that can claim title to an invention resulting from federally funded research. It is possible for a funding agency to determine that "exceptional circumstances" require a different disposition of rights (e.g., all rights going to the private sector partners and not the subcontractor generating the invention), but this authority has been used only rarely. To address industry concerns in this area, the Department of Commerce could provide regulatory criteria for the appropriate exercise of the exceptional circumstances authority by the funding agencies, making it easier to control the dispersion of intellectual property in appropriate circumstances.

Make Partnership Agreements Easier to Negotiate

One promising approach to the problem of simplifying the negotiation of agreements involves the use of intermediary organizations when federal agencies and their laboratories deal with the business community. These organizations, by their nature, may provide a better interface for potential private sector partners than the research agencies and their laboratories and may also provide other types of support (e.g., business counseling and financial support) that the agencies and laboratories do not provide.

Intermediary organizations may provide a better interface for potential private sector partners than the research agencies and their laboratories and may also provide other types of support (e.g., business counseling and financial support) that the agencies and laboratories do not provide.

A variety of organizations may participate in such efforts. State and local economic development organizations may enter into CRADAs with laboratories, providing an umbrella under which their constituent businesses may establish research projects. The businesses are relieved of the need to negotiate an individual agreement and the state organization can help its constituents find relevant laboratory resources.

One example of such an agreement involves the Oak Ridge National Laboratories (ORNL), which negotiated a CRADA in 1994 with the state of Tennessee to provide manufacturing assistance to Tennessee manufacturers. The state's CRADA with ORNL allows small and medium-sized firms with manufacturing problems to tap the laboratory's impressive resources. In another example, "master" CRADAs were signed in December 1993 between DOE's national laboratories and Army's laboratories on one hand and the Big Three auto manufacturers on the other, as part of the Partnership for a New Generation of Vehicles (PNGV). These CRADAs will provide a framework for firms to work with the laboratories on PNGV projects, with each new project resulting in an approved joint work statement under the CRADA "shell." In this way the administrative costs of the work will be reduced and uniform terms and conditions will be applicable to all phases of the project.

CRADAs between laboratories and industry consortia may also provide a useful way of dealing with the complexities of consortia members' research objectives. A consortium may plan a long-term project with a federal laboratory or group of laboratories under such a CRADA, allowing its individual member firms to bring their work under that CRADA and avoid the costs and delays of negotiating separate agreements. The laboratories and industry have already shown a great deal of ingenuity in using the flexible CRADA authority to minimize administrative burdens for private sector partners, and, with further effort, additional successes are likely to emerge.

Make Partnership Agreements More Predictable

The private sector has also expressed concern about various approaches to the terms of partnership agreements among agencies and laboratories. The fundamental purpose of these agreements is to enhance private firm access to federal scientific and technical resources for the benefit of the U.S. economy. However, the negotiation of agreements sometimes becomes delayed by collateral legal issues relating to the terms of the agreement. Private sector partners, especially small and medium-sized businesses, find negotiation of agreements with federal agencies and laboratories to be both time-consuming and costly in legal, administrative, management, and technical resources.

While it is desirable to increase the predictability of the terms of these agreements, this should not be accomplished by sacrificing the discretion needed to make them responsive to the partners' needs. One approach to this challenge is to seek agreement on the basic principles to be embodied in the agreements without imposing on the parties any "boilerplate" contract terms. The negotiations could take place in a number of fora (e.g., under the NSTC umbrella) and should involve a broad cross-section of both industry and agency representatives. Once such principles are agreed to in each of the areas addressed by the agreements, both agencies and private partners will have a template for their negotiations that will make negotiations faster and outcomes more predictable. Using such an approach, differences between agreements in a particular program would reflect different work objectives rather than different legal interpretations of the programs, and the parties would be free to focus on the real purpose of the agreements—collaborative research.

One specific area in which greater certainty should be provided to private sector partners relates to the intellectual property rights transferred in connection with CRADAs. Two bills were recently introduced in the House of Representatives and the Senate that would amend the Federal Technology Transfer Act to give private partners in CRADAs ownership of their own inventions and an option for an exclusive license to inventions made by the federal laboratory employees.

Help Small Businesses Secure Necessary Business and Financial Advice from State Programs and Private Sector Sources

Many of the most successful partnerships under these programs have involved small businesses with a strong research capability. Unfortunately, many such firms have lacked the skills in market analysis, management, finance, and manufacturing necessary to commercialize the results of their research.

At present, a variety of federal and state agencies provide an ad-hoc system of support to small businesses seeking to develop the business skills needed to bring their technologies to market. In their SBIR programs, DoD and NSF draw on private sector experts to provide business training conferences for small business participants. DOE operates a commercialization assistance program directly focused on these needs, and SBA provides a matching service, bringing together venture capitalists and SBIR winners. A stronger, more comprehensive effort to help small businesses find the resources to improve their commercial competence could increase their ability to commercialize their technologies.

Further Increase the Private Sector Role in Project Definition and Selection

Although many of the partnership programs discussed here are closely tied to government mission research agendas, there is flexibility in several areas to give the private sector a larger role in defining the scope of the public-private partnership. A larger role for the private sector in this respect is not inconsistent with either the integrity of the agency's mission research or the concept of leveraging the economic impact of government mission R&D. What is needed is a willingness on the part of the agencies to solicit private sector views as to what portion of their mission research agenda is of interest. This information can then be used to select potential topics for these partnerships.

The consequences of failing to give the private sector such a role are reflected in recent research with partners of the federal laboratories. Research by J. David Roessner and Anne Wise indicates that intellectual property licensing has been one of the least successful and least popular approaches to public-private partnerships.[13] The private sector prefers approaches that involve market-pull rather than technology-push. The effectiveness of licensing is also limited by the "over-the-transom"

The private sector prefers approaches that involve market-pull rather than technology-push.

[13] David Roessner and Ann Wise, *Patterns of Industry Interaction with Federal Laboratories*, 1993.

Advisory groups might be asked to provide more specific advice concerning the areas in which a laboratory should pursue intellectual property protection for its work, with the objective of licensing technology to the private sector.

character of the transactions. Private firms generally become aware of licensing opportunities only after the agency has defined the invention and begun efforts to secure intellectual property protection.

A similar situation occurs in the process for defining the areas for partnering in the SBIR program. The research topics on which an agency will consider an SBIR proposal are defined by the agency according to its mission-related needs but often without any structured effort to consider the commercial potential of or private sector interest in these topics.

While most agencies consider commercial potential at a later point, when they are selecting proposals for funding, the failure to consider private sector interests in the initial framing of the research topics on which proposals are solicited is likely to result in the exclusion of some technical areas that are within the agency mission *and* have commercial relevance. Once again, the point is not to take the agency beyond its legitimate research mission but to ensure that, within the scope of that mission, the agency considers the private sector's interests in defining the areas in which it will solicit funding proposals.

To address this challenge, federal agencies need to find ways to involve the private sector in reviewing the commercial potential of their government mission work on an ongoing basis. This interchange could take place in several ways. To the extent that federal laboratories are involved, many have created industry advisory boards that are familiar with and can provide comments concerning the nature of the work carried out at the laboratory. These advisory groups might be asked to provide more specific advice concerning the areas in which a laboratory should pursue intellectual property protection for its work, with the objective of licensing technology to the private sector. They might also help an agency to develop an inventory of the most commercially attractive aspects of a laboratory's research portfolio. More generally, the issue might be addressed through the efforts of NSTC, which is working with the private sector in several areas to identify and manage federal research efforts having significant commercial potential.

Shift to Commercial Financial Management Practices

One of the principal headaches for private sector partners in these programs is the often perceived need to use federal cost accounting principles. Shifting from commercial methods of ensuring the proper use of funds to the use of government cost principles is both expensive and confusing for participants. Requiring the use of principles designed for monitoring government cost-based contracts and grants in the context of technology partnerships gives rise to potential disputes concerning the minutiae of projects and shifts the parties' attention and resources away from the research that was the reason for the partnership arrangement. In fact, private sector representatives participating in Office of Technology Policy outreach efforts ranked government administrative requirements—for proposals, accounting, audit, and reporting—as one of the top three barriers to involvement in federal technology partnerships. Similar results have been obtained in other surveys of industry.

As agencies recognize the unique character of these partnerships, they should use whatever flexibility is available to them to move toward commercial financial management practices. More recent programs have specifically addressed this issue. TRP, for example, permits nontraditional private sector partners to use their existing commercial financial management and project tracking systems. In addition, as noted earlier, other transactions authority, where available, enables agencies to collaborate better with their industrial partners by shifting to the use of commercial practices.

Even under more traditional forms of agreements such as contracts and grants, however, it should be possible for the agencies to provide some relief to private sector partners on this point. The original ATP legislation (the Omnibus Trade and Competitiveness Act of 1988) required ATP funding recipients to account for their expenditures of both internal and federal funds in their projects using Office of Management and Budget Circular A-122 (Cost Principles for Non-Profit Organizations) or FAR Part 31 (Contract Cost Principles and Procedures). Participants in the program, however, have questioned the need for these requirements, pointing out that FAR requirements force them to set up cost tracking systems for their firms that are at variance with their standard commercial systems. ATP has recognized the legitimacy of these concerns and is in the process of shifting, where appropriate, from principles designed for cost-based arrangements toward the use of commercial practices better suited to partnership arrangements.

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The experience of ATP and the other partnership programs with their private sector partners indicates that corporate fraud or misuse of funds is extremely unusual. In fact, ATP has encountered no such problems to date. Therefore, extensive costing requirements under partnerships may provide little value to the government and add large burdens to private sector participants. The federal cost principles are a product of the government-as-customer perspective embodied in federal procurement

The executive branch is taking steps to improve the management and coordination of the research conducted by its agencies and to assess the value of that research.

rather than of the partnership concepts embodied in these programs. Financial management and reporting practices should be tailored, as appropriate, to the different goals of the government procurement / contracting process and federal–private sector technology partnerships.

Continue Developing an Integrated System of Measuring Program Results

Both the administration and Congress have emphasized the need for greater accountability in the operation of government programs. The administration should continue to develop systems to measure program outputs, including the immediate effects of the agency action on private sector partners, as well as information concerning the longer term and broader economic effects of the activities.

To address the critical need for reliable and comparable data concerning both inputs and outputs of federal programs, a comprehensive system of measurement needs to be developed by the agencies, led by NSTC or another appropriate organization. The executive branch is taking steps to improve the management and coordination of the research conducted by its agencies and to assess the value of that research. An important part of any comprehensive assessment system is an effort to determine the commercial impact of the research. Such assessments are complicated and demanding and require the cooperation of private sector partners as well as a range of economic expertise that may not reside within the research organizations.

To ensure the effectiveness of any such system, both private sector representatives and academic experts must be involved in its development and implementation. Efforts are already under way in individual programs and individual research agencies to create local measurement systems. A broader effort must be built on these initiatives that spans the various types of partnerships described in this report and provides the basis for assessment of their effectiveness in promoting technological competitiveness and economic growth.