SCIENCE, TECHNOLOGY, AND THE STATES IN AMERICA'S THIRD CENTURY

SEPTEMBER 1992

A Report of the

CARNEGIE COMMISSION
ON SCIENCE, TECHNOLOGY, AND GOVERNMENT

The Carnegie Commission on Science, Technology, and Government was created in April 1988 by Carnegie Corporation of New York. It is committed to helping government institutions respond to the unprecedented advances in science and technology that are transforming the world. The Commission analyzes and assesses the factors that shape the relationship between science, technology, and government and is seeking ways to make this relationship more effective.

The Commission sponsors studies, conducts seminars, and establishes task forces to focus on specific issues. Through its reports, the Commission works to see that ideas for better use of science and technology in government are presented in a timely and intelligible manner.

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FOREWORD

State governments have long been users and generators of scientific and technological information. Since World War II, however, the states' involvement in science policy has been overshadowed by the rapid expansion of the federal role, first in defense and later in space and health research.

With the end of the Cold War, the economy, the environment, education, and health care will rise to the top of the American agenda. These are all areas in which states have traditionally played a major role. As the nation moves to address these issues, both the federal government and the states will have new roles to play, and their relationship will be redefined to meet the demands of a new era. In order to fulfill their responsibilities, the states must continue to increase their competence in science and technology. New kinds of partnerships, both between states and among states, the federal government, industry, and academia, will be necessary if the nation is to confront the problems and seize the opportunities that the future will bring.

This report examines the achievements of the states in managing science and technology and recommends ways in which they can join with industry and the federal government to address the domestic issues of the 1990s and beyond. The report focuses in depth in one area of policy that is well developed in many states: government–industry partnerships to support the development and diffusion of industrial technology. These programs may be models for cooperation between government and the private sector in other areas. They may also show the way for federal–state partnerships that best exploit the complementary strengths of the two levels of government.

To ensure the effectiveness of the new partnership with the federal government and industry, the report proposes the establishment of an interstate compact to help the states themselves decide what policies work best in a decentralized and variegated nation. This compact will enable states to work more easily with the federal government so that, together, they can help reshape the relationship between science, technology, and government in our rapidly changing world.

Science and technology are central to nearly every issue of government policy today, and governors and legislators need sources of impartial, expert, technical advice and analysis. The report recommends that states increase their own technological competence by availing themselves of the best possible S&T advice at the highest levels of government. In particular, governors should have easy access to S&T information. Governors need a designated science advisor who has access on a regular basis to the best scientists, engineers, and physicians in the state.

We wish to thank the members of the Task Force on Science and Technology and the States and particularly its chair, Governor Richard Celeste, for their outstanding work.

William T. Golden, Co-Chair
Joshua Lederberg, Co-Chair

PREFACE

This report of the Carnegie Commission on Science, Technology, and Government was prepared by the Task Force on Science and Technology and the States. The Commission was established in April 1988 to assess the mechanisms by which the federal government and the states incorporate scientific and technological knowledge into policymaking processes. The Commission formed the task force in 1991 to study a key level of this nation's government that, in earlier studies of the Commission, had been examined only tangentially.

The task force held its first meeting September 9–10, 1991, in Middleburg, Virginia. Subsequent meetings were held March 15–16, 1992, in Deerfield Beach, Florida, and May 14, 1992, in Washington, DC.

The task force was chaired by former governor and Advisory Council member Richard F. Celeste. The task force members were William O. Baker, Arden L. Bement, Erich Bloch, Lawton Chiles, Daniel J. Evans, B. R. Inman, H. Graham Jones, Frank E. Mosier, Walter H. Plosila, Donna Shalala, Luther

Williams, Linda S. Wilson, and Charles E. Young. Christopher M. Coburn was the staff director for the task force. Commission staff members who worked with the task force and contributed to the development of the report were David Z. Robinson, Maxine L. Rockoff, Jonathan Bender, and David M. Kirsch. Thomas H. Moss also assisted the task force. The task force is grateful to Harvey Brooks for his interest and invaluable insight. The final report was drafted by Duncan M. Brown, and the manuscript was edited by Jeannette L. Aspden.

The report is endorsed by the task force and was approved by the Commission at its June 1992 meeting.

SUMMARY AND RECOMMENDATIONS: MEETING THE CHALLENGES OF AMERICA'S THIRD CENTURY

Since the Second World War, the federal government has taken the dominant role in applying science and technology to national needs. Over this period, the Cold War made national security the prime consideration, and it is the responsibility of the federal government to protect the nation against military threat. More recently, three broad trends have combined to offer new national challenges and to demand new ways of organizing the responses. These trends are the growing national importance of science and technology; the increasing strength of the states in managing these assets; and the end of the Cold War, with the consequent release of resources, especially human resources, once devoted to defense. The opportunity is to devise fresh new responses to many national challenges, among them the reform of education, the preservation of the environment, the promotion of economic competitiveness, and the provision of health care.

These issues are largely domestic, and major aspects of all of them traditionally fall within the purview of the states. In addition, the past 20 years have seen increasing devolution of many of these responsibilities from the federal to the state level.

Effective responses to these challenges will place a premium on flexibility, efficient distribution of resources, and organizational entrepreneurship in place of the centralized, coordinated response that was appropriate to the challenges of the Cold War. New partnerships of federal and state government, academic research, and private industry will be needed, and building these partnerships will require changes in our systems and institutions of government at both levels. Many of these changes are well under way. Some have yet to begin.

Many states, in their industrial technology programs, have demonstrated the ability to achieve the necessary flexibility and responsiveness, working closely with industry and academic institutions. While these efforts are still relatively small on a national scale, their structures provide models of government–industry partnership that can be extended to the federal government, and that can help shape responses to other great national challenges.

The central issue is how to determine the most effective roles of federal and state government. Their roles should be developed not on the basis of which level raises (and spends) revenues, but according to their relative effectiveness in a given situation, including their effectiveness in catalyzing private-sector action. Determining the appropriate balance in a particular case will require an unprecedented degree of communication and cooperation, with consultation about needs and priorities and timely sharing of information about programs of potential joint interest.

Ensuring effective communication and cooperation will require new advisory and policy development mechanisms. Whether they are helping shape national science and technology priorities or addressing closer-to-home problems of the environment, health care, education, energy, and economic development, states must have ways of gathering knowledge, of learning from one another, and of putting their ideas and priorities forward in national science and technology forums. New scientific and technological advisory organizations will be needed at three levels:

- Within states, today's formal and informal advisory bodies will become more significant, and their charters will have to be reshaped to include the development of broad policy positions, integrating knowledge from many fields and from all available sources, including especially the private sector. States will need well-defined mechanisms for mobilizing science and technology expertise to meet strategic goals.
- Interstate organizations will be needed to support information exchange, interstate cooperation, regional collaboration, and the develop-

ment of opportunities for cooperation with the federal government and with industry.

■ States will need to become more heavily involved in federal policy deliberations, both for setting broad priorities and for designing programs that share state and federal resources. This should include representation on federal advisory committees at all levels, from the highest national policy-making councils to the individual laboratory. States and the federal government will need to work toward a partnership that reflects their potential contributions and needs.

In creating this new partnership, the nation will draw on the vision of great predecessors: the Founders, who defined the initial balance of state and federal powers; the authors of the Morrill Act of 1862, who melded scientific and technological innovation with education in the state Land Grant institutions; and Vannevar Bush, whose seminal report forged a strong and durable link between government and science after the Second World War. Another opportunity for a new relationship between government and science and technology is at hand: the Cold War is ending; old assumptions about the world are being put aside, and new truths are emerging. In a changed and changing world, science and technology are increasingly central to effective democracy and economic prosperity. By grasping this opportunity for renewal, the nation can increase its industrial competitiveness and meet the challenges of education, health care, environmental protection, and other vital domestic concerns.

FINDINGS AND RECOMMENDATIONS

Shaping Policy within States

■ **Each governor should have a designated science and technology advisor** (see pages 24–27). *Governors are increasingly called upon to make decisions that have scientific and technological dimensions. However, they generally lack staff sources of science and technology advice and assessment.*

Each governor's science and technology advisor should act as a focal point for advice on the full range of scientific and technological issues that a governor faces, including health care, environmental quality, telecommunications, and science and technology for economic development. The science and technology advisor should serve on the governor's executive advisory team, as a trusted source of objective advice, integrating the views and knowledge of experts in academic institutions, industry, and elsewhere throughout the state and the nation. This official would have several important functions:

■ Bringing knowledge of science and technology to bear at the highest level of decision making in the state

■ Helping the governor respond quickly to emergencies by assembling the appropriate experts

■ Serving as liaison with the science and technology community in industry, federal agencies, and universities

■ **Each state should have an independent science and technology advisory body** (see pages 26–27). *No state has the benefit of a sufficiently well-organized process for developing broad, comprehensive positions on issues that involve science and technology, such as economic development, health, and environmental protection. Sound decision making about major public issues requires such a process.*

Such a group, with members representing all elements of the science and technology community in the state, should be charged with providing broad views on key policy challenges. With its help, the governor, legislature, and the public would be able to engage science and technology leaders from throughout the state in their efforts to respond to technological change and promote technological competence. The body would also provide continuity and institutional memory, bridging political cycles.

The group should be independent and representative and should have access to the science and technology community. In some states, an existing organization, such as a state academy of science, might serve this advisory function.

■ **The proposed state advisory body should develop and periodically update a vision of science and technology's role in meeting the state's strategic goals** (see pages 26–27). *Partnership between government, industry and academia requires consensus about broad issues. Few states have a formal process for developing such views.*

A critical responsibility of the advisory group is to provide the framework within which the major components of the state S&T community can convene, discuss, and forge consensus. This consensus then forms the basis of direct and compelling communication to the executive and legislative branches of state government. The consensus supports S&T-related policy and programs and enhances the state's ability to work in partnership with industry, federal agencies, universities, and other states. The advisory body would also provide the forum for consideration of the very complicated issues of state S&T policy: performance evaluation, distribution of resources, and practical goals.

■ **Each state legislature should have access to a standing source of objective analysis of science and technology issues** (see page 27). *Legislators have even less access to sound science advice than governors.*

The legislative advisory body might be legislative staff or a standing panel in a university, a state academy of science, or another institution with broad scientific and technological capability. It should maintain links to national science and technology resources, such as the U.S. Congress's Office of Technology Assessment and the National Academy of Sciences. In some states, size or resource limitations might mean that the same advisory body could serve both executive and legislative branches; in other states, separate bodies may be practicable or desirable.

Shaping National Policy

■ **The states should form a new organization to coordinate their science and technology activities and to speak for the states in national science and technology councils** (see pages 27–28). *When necessary, states must be able to speak with a single voice to shape national policy. The current interstate organizations for developing science and technology positions are inadequate to the task of developing, analyzing, and expressing unified policy positions.*

The proposed group must have the standing and the analytical capacity to develop credible broad priorities and recommendations for the states as a body, and to be heeded by federal agencies. A formal interstate compact, underpinned by state and federal enabling legislation, would have these characteristics. The Education Commission of the States may be a suitable model.

The group would have several main functions. First, it would serve as the focus for continuing exchanges of views with senior federal decision makers in both the legislative and executive branches. In the current administration, for example, it would make regular contributions to the priority-setting proceedings of the White House's Federal Coordinating Council for Science, Engineering, and Technology (FCCSET).

Second, it would develop reliable sources of information to support policy development. Reliable statistics on state science and technology investments and their outcomes would help both in the setting of broad national or regional priorities and in the management of individual state programs. It should also have the ability to analyze state and federal policy options. Finally, the organization should serve as a point of access and information for federal officials, Congress, the news media, and the public.

■ **States should become partners in defining the new missions and operations of federal science and technology institutions** (see pages 47–50). *Many federal technology programs are undergoing radical change, as the nation adjusts to the reduced threat to its security. Some of these programs and institutions offer resources that could be applied to other important national needs. States can help give direction to the search for a new mission, through the networks of industry and universities that most have established in their technology programs.*

In seeking new industrial missions for federal programs in technology development and diffusion, care should be taken that these successor activities serve the economic interests of state and federal government as well as industry. The new interstate compact recommended earlier should be involved in these deliberations. In addition, steps should be taken to increase state representation on the advisory committees of the federal executive and legislative branches.

■ **Any national strategy for diffusing federal technology to the private sector should build on the foundations that states have already laid** (see pages 38–46). *States, using their knowledge of local conditions, have developed channels for diffusing technology to companies, especially the small and medium-sized ones that are most difficult to reach.*

Policymakers at all levels should recognize the value of states as natural interfaces between government and industry, and should take advantage of state programs of technology transfer and diffusion. A national partnership, encompassing industry and all levels of government, should be cultivated.

■ **Through the recommended new coordinating and policy development organization (the interstate compact), states should work with federal agencies to plan and hold a national summit on science and technology goals of common concern** (see page 46). *To make the most of defense conversion and other emerging opportunities, a new federal–state partnership to apply science and technology to national goals is urgently needed. A broadly chartered gathering of all key leaders would promote wide discussion and action on these issues.*

The summit meeting, to be attended by the President, cabinet officials, governors, and members of Congress, would identify common interests and concerns of state and federal governments, industry, and universities and develop a joint agenda. Prominent among these interests would be the sharing of access to science and technology resources, such as federal laboratories.

I
HISTORIC DECISIONS

History occasionally offers this nation an opportunity to renew its institutions. In the past, there have been two such turning points in the relationship of government with science and technology. The first, the enactment of the Morrill Act of 1862, created the land grant colleges, whose "leading object" was to teach subjects related to agriculture and "the mechanic arts," or technology. The second watershed was Vannevar Bush's historic 1945 report, *Science—The Endless Frontier*, which held that "Science is a proper concern of government."[1] That report opened a chapter in the federal government's relations with science that will never be closed. The National Institutes of Health, the Office of Naval Research, and the National Science Foundation were founded as a result of the proposals made in that report. Thanks to the undoubted success of those agencies, and others that followed, many Americans—and probably most scientists—today view the funding of basic research as a natural role of government, nearly as fundamental as any of the functions enumerated in the Constitution.

In 1945, however, such a role was revolutionary. Bush's position was opposed by many experts, and his proposals were debated heatedly by Congress for years. The proposals matched the revolutionary times: one war, in which applied science had played an heroic role, had ended. Hopes were high that science could be equally heroic in peacetime, revealing the workings of the universe, conquering disease, reducing poverty, and solving a wide array of social problems. A darker side of that revolutionary period was the world's gradual descent into what became known as the Cold War; here the hope was that science and its applications would hold world war at bay. In both cases, those hopes have been rewarded.

THE FEDERAL-STATE BALANCE, PAST AND FUTURE

The historic balance of federal and state government, devised by those who founded the Republic, will respond to these revolutionary changes. For two generations the balance in the realm of science and technology has been heavily weighted toward the federal government. This balance was appropriate to the task that dominated the national agenda, namely responding to the challenges of the Cold War. However, with the end of the Cold War, the demands of national security have lost their primacy. Today's challenges—better schools, more efficient and accessible health care, refurbished public infrastructure, a cleaner environment, and firms that are more competitive in world markets—require the striking of a new balance. All demand national responses, but these responses cannot be the nearly exclusive province of one level of government, or, indeed, of the public sector. They require partnerships between the public and private sectors and between federal and state governments. While the balance will vary depending on the issue at hand, it will generally involve the states more deeply and intensely than at any point in the past half century. These adjustments will require changes in our systems and institutions of government, both federal and state. Many of these changes are well under way. Some have yet to begin.

The balance of federal and state roles is a great issue. But the founders of our nation devised this balance with sufficient flexibility to offer scope for self-renewal. Working together, we can evolve a vision of the future to match our opportunities.

NEW ROLES FOR THE STATES

In the late 1940s, the debate revolved around the appropriateness of a new federal role in research. This time it involves new roles for the states, too, in maintaining the national capability in science and technology and in pursuing industrial excellence, environmental quality, health care, education reform, and other domestic goals. The states are growing strong and sophisticated enough, many believe, to take a greater, more independent role in pursuing these peaceful but still fundamental national goals.

The states have developed these strengths through decades of confronting issues with science and technology implications. The Morrill Land Grant Act of 1862 produced a strong federal–state partnership that built great universities, universities that became a vital source of technology. In particular, the agricultural extension system carried the benefits of research to the end of every farm road in the nation. Over the years, problems of agriculture, resource management, and transportation, as well as higher education and graduate research, gave the states further experience in managing and exploiting science and technology.

Higher education has been a major channel for states' contributions to the nation's science and technology needs, through education, research, and public service. It continues to offer important opportunities for investment and for cooperation with the federal government. However, the task force saw a comprehensive review of this subject as beyond its scope.

The past two decades have added challenging issues of environmental planning, health care, energy, and a new model of technology-based economic development based on cooperation between industry and government. As a result of this experience, the states are well prepared today to take a more active role in meeting the nation's domestic needs. Their traditional domestic concerns have become the national concerns of the 1990s.

As a model for developing responses to these national concerns, the task force focused on one of them: the application of science and technology to economic competitiveness. Meeting this challenge will require a balanced national response with significant roles for the states and the federal government, as well as the private sector. The nation cannot rely on the heavily centralized structure used during the Cold War. That challenge, which demanded a single tightly coordinated response, was greatly different from today's.

States, in their industrial technology programs (see Chapter 2), have demonstrated decentralized structural approaches that can ensure the rapid responses, efficient distribution of resources, and organizational entrepreneurship that today's national challenges and those of the future will demand. While these programs are still small on a national scale, their decentralized structures and their close cooperation between government and industry give them a natural role in any national effort to improve industrial competitiveness. Experience gained by states in promoting their own industrial competitiveness can be extended to enhancing the nation's industrial competitiveness in a changing world.

States compete with one another for some kinds of resources (notably the siting of large employers). They are learning to cooperate as well in developing the economic and educational infrastructure through which regional and national growth can take place. While healthy competition will continue, in itself it cannot guarantee future economic success.

Industrial competitiveness is only one of the great challenges facing the nation. On such issues as transportation and health, several states have undertaken bold initiatives—for example, fundamental changes in access to health care and new mass transit programs designed to yield economic and environmental benefits. A balanced federal–state response to the challenge of industrial competitiveness will set an example that will help shape responses to other national challenges. The central issue is how to determine the optimal roles of federal and state government. These new roles should be based not on which level raises (and spends) revenues, but on which level is most effective at specific tasks, including catalyzing private sector action.

States and the Private Sector

The private sector has a significant stake in the resolution of many of the issues targeted by the federal–state partnership. This means that the private sector will be involved in the partnership in a new way. The key understanding on which the state programs have been built is that it is in the private sector that the program outcomes accrue—it is here that new jobs and new wealth will be created.

Access to industry is the state technology programs' greatest strength. These programs are joint activities of government, industry, and academia to promote technology development and technology transfer and to share experience of markets and economic conditions. Through these activities they provide channels to the market for the products of academic and public sector research programs.

For these reasons, the federal–state technology partnerships will involve the private sector in nearly every program decision, from the technology emphases of joint research centers to the nature of training and education programs.

Science and Technology Advice for the States

The states have recognized a growing need for scientific and technical advice as they are increasingly forced to address issues that would, a few years ago, have presented almost unimaginable technological complexity. In addition to the problems of industrial competitiveness, these issues include environmental protection and health care, which have been shifted by federal action to the states. Many complex policy problems lie at the intersections of these issue areas.

Some states have arranged for high-quality advice, but often only as an afterthought or in response to emergencies. In other states, decision makers have no single reliable source of such information and must depend on informal sources. Good sources of advice enable decision makers to interpret scientific and technical information from agencies and advocacy groups, to balance conflicting claims, and to weigh alternatives objectively. Without such advice, governors and legislators must interpret scientific and technical information using criteria such as familiarity or trust in the agency or group advocating the position, the packaging of the information, or its perceived relationship to other technical issues. It is critical that states develop their own systems, especially at the gubernatorial and legislative levels, to ensure the flow of advice from the broad science and technology community into the state government at its highest decision-making levels.

A NEW FEDERAL ROLE

The framers of the Constitution of the United States defined the new nation in the balance between the 13 states and the new federal republic. During the Cold War, that balance was heavily weighted toward the federal government. Recent developments on both the international and domestic scenes, however, require a balance closer to the original. That balance will no doubt shift again as states and the federal government join in various ways to respond to the challenges of the 1990s and the next century.

A new federal–state partnership will require the federal government to play a new role, very different from the one it has been forced to play for the past 50 years. In the case of economic competitiveness, new federal leadership roles have begun to take shape. The White House's Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) has suggested a policy of federal funding for applied research in areas such as high-performance computing, biotechnology, and advanced materials and processing.[2] The National Science Foundation (NSF) and the U.S. Department of Commerce have established programs of research in "precompetitive" or "generic" technologies.[3]

These initiatives may be viewed as the first expressions of a new direction for federal policy, which could serve as the basis for the transformation of the federal–state partnership. The nation must go much further if it is to achieve its domestic goals, from reinvigorating the economy to improving access to health care. A firm partnership must be based on shared interests, shared information, and clearer ideas of the respective roles of state and federal government.

Federal research and development programs command resources of technology, personnel, and facilities that should be valuable assets for the nation. Indeed, for many years federal agencies have sponsored an extraordinarily large proportion of the nation's research and development, including industrial R&D, but success in bringing the results of government-sponsored R&D to the marketplace has been spotty. States can help increase the return on this huge investment, especially through their partnership programs with the private sector.

The defense conversion process now beginning represents a fundamental transition for the United States, industrially, technologically, and culturally. While federal and state governments must join with industry to effect this transition, the federal government will clearly be the leading government partner, because it established and funded the multitrillion-dollar defense effort. But to conduct defense conversion as an exclusively federal program, to treat it like national defense programs themselves, would be a fundamental error. Converting the defense base into a civilian industrial tool requires engaging industry in new and innovative ways throughout the United States. The private sector cannot be effectively galvanized from a single point in Washington, DC. Its involvement must reflect the diversity of the U.S. industrial base and the rapid change it is now experiencing. States bring indispensable assets to the partnership, in the form of industrial contacts and local knowledge.

S&T AND THE STATES: GROWING CAPABILITIES, GROWING NEEDS

The evolving federal–state partnership must have the flexibility and responsiveness to recognize and pursue new opportunities. Both parties must commit themselves to sharing in the benefits of the partnership's initiatives. States have already created varied programs to further this role. Many, for example, have well-established programs in precisely the technology-related areas only now being identified as national priorities, such as biotechnology, advanced materials, computers, and communications. This capability complements the technological competence that states have been forced to develop as they assume program responsibilities from the federal government in areas such as the environment, energy, and health care.[4] Many of these new state responsibilities have strong science and technology implications.

States have been building the capacity for this partnership for many years, beginning nearly a century before Vannevar Bush's 1945 call to national renewal through science, with the 1862 Morrill Act. That act created a historic federal–state partnership that helped states establish their Land Grant institutions and defined their vital interests in research and technology. Since then, states have built, staffed, and equipped universities. They have funded research in agriculture, resource conservation, education, transportation, and other areas of state responsibility (some states have even funded basic research). They have supported higher education in the sciences and engineering, to improve their business environments and research capabilities. Since the 1970s, they have assumed new obligations for science- and technology-intensive missions such as environmental enforcement, health care financing, and education reform—often as a consequence of new federal requirements.

In the early 1980s, several industrial states, suffering a deep and intractable manufacturing recession, formed new partnerships with industry and academic researchers, aimed at building economic strength through the development and deployment of technology. These grassroots programs were so successful that they have been widely replicated throughout the nation. States share research costs with industry, award grants to technology-oriented firms, and offer technical advice and business services to industry. States rely on industry to make technological investment decisions. Most of the programs are funded under economic development programs, but some, such as Texas's $30-million-a-year Applied Technology and Research Fund, are supported through higher education systems.[5] They depend heavily on universities for research, and this dependence has led to the strengthening of academic research in fields relevant to industry. The great public universities—legacies of the Morrill Act—have been a mainstay of these programs.

As a rule, the programs give industry the deciding vote in investments: initiatives are supported only if industry signals its commitment by providing significant cost-sharing. In this way, states avoid putting themselves in the position of trying to "pick winners." Success depends on maintaining close ties with industry, to help reveal both broad economic opportunities and specific company needs. With their new technology programs, National Academy of Sciences president Frank Press has said, the states "recognized the missing link that weakens our innovative strength," displaying "a greater awareness of the way the world is going than you find in many places in Washington."[6,7] In the aggregate, writes another observer, the state programs are "probably as close to an industrial policy as we will see in the U.S."[8]

Science and technology in state government goes far beyond industrial competitiveness. It is a nearly pervasive element in the daily decisions of state policymakers and program managers. In many policy areas, such as radioactive waste management, utility regulation, and health care strategies, the scientific and technical aspects are recognized in decision making. In other fields, such as the empirical analysis and behavioral research underpinning social policy, they are not so clearly recognized. Only a few states have set out deliberately to create systems of technical and scientific advice to support decision making. Even in those states, the advisory systems are specialized, generally with a focus on industrial technology activities, with little scope to integrate and interpret information across wider ranges of issues. Arrangements for advice should become more formal and better integrated, as the advantages of technology advisory bodies are more widely recognized. (See Chapter 2 for a detailed discussion of this central issue.)

REDEFINING AMERICAN FEDERALISM

From this process of renewal and redefinition will emerge a new partnership between the federal government and the states. States will play increasingly important roles in the national science and technology system. As they interact more and more with that national system, they will need to work both individually and collectively to develop and influence national policy. The states themselves, with their industrial and academic partners, must take the initiative in this effort to redefine American federalism, for only through a true partnership of federal and state governments, with the full involvement and support of the private sector, will this effort succeed.[9]

2

STRENGTHENING THE STATES' CAPACITY TO USE SCIENCE AND TECHNOLOGY

To be effective in their new partnership roles, states will need new advisory and policy development mechanisms. Whether they are helping to shape the national debate or addressing closer-to-home problems of the environment, health care, education, energy, and economic development, states must have ways of gathering knowledge, of learning from one another, and of putting their ideas and priorities forward in federal science and technology deliberations. New scientific and technological advisory organizations will be needed at three levels:

- Within states, today's formal and informal advisory bodies will become more important, and their charters will be reshaped to give states well-defined mechanisms for mobilizing science and technology expertise from government, industry, and academic institutions to meet strategic goals.
- Interstate organizations will be needed to support information exchange, interstate cooperation, regional collaboration, and the development of opportunities for federal–state cooperation.

■ States will become more heavily involved in federal policy deliberations, both in setting broad priorities and in designing programs that share state and federal resources. The states will need to be represented on federal advisory committees at all levels, from the highest national policy-making councils to the individual laboratory. They will need to work toward a balance of influence that reflects their potential contributions.

One challenge of the emerging partnership will be for state programs to retain their valued flexibility and creativity—and their ties to industry—while at the same time maintaining stable relations with other agencies at both federal and state levels. To achieve this balance, states will need leadership and vision. The states' federal partners will need to make due allowance for states' diversity and innovativeness, seeking joint objectives rather than imposing rigid requirements. On the most fundamental issues of federal-state relations in science and technology, states need to work toward consensus, even while fostering diverse points of view in many areas of policy. In this way, states can bring their full political strength to national policy deliberations.

SCIENCE AND TECHNOLOGY ADVICE FOR GOVERNORS AND LEGISLATURES

In the past decade, governors have increasingly required reliable science and technology advice, on topics ranging from solid waste disposal to materials science and manufacturing. Science and technology are now part of everyday decision making in each state. The 1980s saw a shift to the states of responsibilities previously considered federal, including many aspects of environmental management and health care. These reallocations of responsibilities coincided with the increasing complexity of traditional state issues and the burgeoning movement to promote technology-based economic development. As these responsibilities have mounted, the old informal state-level channels of communication with the science and technology community (university and business leaders, cabinet officers, and so on) have become more organized and, in many states, have focused on strategic questions, and new sources of advice are being developed.

Advice for Governors

Governors, in particular, often face competing claims, whose resolution requires science and technology advice that is reasonably independent of the narrow interests of a given industry or of a set of state and federal agencies. Every governor needs a trusted advisor in his or her inner political circle who can help synthesize the scientific and technical aspects of policy issues into concrete options. Several kinds of conflict that may involve science and technology issues arise in every governor's work:

- Conflicts between agencies. The state department of transportation, planning a highway, assures the governor that wetland protection measures are adequate. The natural resources department disagrees. Both cite scientific and technical analysis in support of their positions. What is the best decision?
- Citizens' safety and health concerns. A citizens' group petitions the governor on the safety of a nuclear reactor. The owner claims adherence to federal standards to show that the reactor is safe. Are federal standards actually being met? If federal standards are being met, are they adequate?
- Conflicts with other states. One member of a regional low-level radioactive waste compact agrees to provide the region's waste site. The site, near the border of another member state, raises citizen concerns in that second state. The first state argues that geological and other analysis was sufficient. The second state's governor must decide how valid the safety concerns are and what options are available under prevailing environmental standards and existing contracts.
- Conflicts with federal agencies. State investigators find violations of environmental law at a federal research or defense production facility. What are the risks associated with those violations? What legal options are available?

In most states, the first formal state advisory bodies were established in the 1960s, with funds from the U.S. Department of Commerce's State Technical Services (STS) program. (New York formed its own advisory unit in 1963.[10]) Many states used STS funds to create science and technology commissions and advisory offices, to help policymakers address issues such as pollution, solid waste disposal, and energy. The program was canceled in 1969.[11]

In another initiative to help states address the growing number of problems that involved science and technology, Congress in 1977 authorized the National Science Foundation to establish the State Science, Engineering and Technology (SSET) program. SSET was intended to support state legislatures and governors in their efforts to develop and implement S&T plans. In all, 49 governors and 42 legislatures applied for and received SSET planning grants. The planning stage ended in 1979, but federal funds for implementation grants never materialized. Of the state organizations charged with overseeing the planning, only two, the New York State Science and

Technology Foundation and the North Carolina Board of Science and Technology, still exist today.

The new wave of advisory organizations now being established, however, is not the result of federal perceptions of state needs; rather, the states themselves have taken the lead. Each state has arranged for science and technology advice in its own way. In the areas of health and the environment, governors generally rely on directors of the responsible departments for advice. Sources of advice on technology for economic development are far more varied; a recent National Governors' Association (NGA) study places them in four categories[12]:

- Science advisor. A few states have formally designated science advisors, who generally report directly to the governor and are expected to mediate between the governor, the legislature, the science and technology community, and often the public and news media. State science advisors often serve also as directors of technology development agencies.
- Program director. Many states have housed their technology programs in economic development or commerce departments. In that case, the governor usually relies on the cabinet official responsible for that organization for science and technology advice.
- Independent organization. Many states have created independent organizations to plan and carry out their technology strategies. These bodies have boards made up of senior representatives from industry, academic institutions, and government, and are largely state-funded. The states maintain a degree of control, usually by appointing specified members to the boards.
- Informal network. Almost all governors rely on networks of varied contacts throughout their states for advice, whether or not they have a formal advisory apparatus. In a few states such informal channels are the sole source of advice, sometimes supplemented by special committees established to consider specific issues.

The precise form of the advisory organization aside, few governors have a single source of advice that can interpret and focus information from across the range of relevant scientific and technical fields. This lack of a single point of contact with the science and technology community raises concerns about the management of individual programs and about the cooperation among different state programs. For example, few governors are equipped to consider health care reforms in light of their impact on state economic development strategies. Rarely do environmental and health policy leaders work together to address problems of joint concern.

To the extent that a state intends to formulate long-term policy, to work with other states, or to interact with federal agencies, it will need increasingly formal and comprehensive advisory resources. Each governor should be able to call on a single reliable and well-defined mechanism that can transmit the knowledge and views of the broad science and technology community, in academic institutions, industry, and government.

Advice for Legislatures

Legislatures need advice, too. At the federal level, Congress established the Office of Technology Assessment in 1972 as a source of technical advice independent of the Executive Branch. State legislators have small staffs and generally serve part-time. As states assume a greater role in national science and technology policy deliberations, legislatures will increasingly be called upon to make important decisions in this realm, and they are likely to need legislative science advice offices. Several of the larger states have already established such organizations. The not-insubstantial costs of setting up and maintaining an office or an advisory body might be borne better by sharing these services with other states, either regionally or through a national network.

The very nature of legislative bodies imposes different requirements on the provision of scientific advice. In the executive branch, there is ultimately a single decision maker, but in legislatures there are many, and they are divided by party affiliation, regional interests, committee assignment, and personal idiosyncrasy. Given these factors, and others, ensuring that state legislators have access to adequate scientific and technical information and advice is a complex and challenging task. Some states may find a joint executive–legislative advisory mechanism practical; in others, the two functions can be separate.

INTERSTATE CHANNELS OF COMMUNICATION

States began to establish interstate channels of communication on technology matters in the early 1980s, as the success of North Carolina's pioneering program became obvious. They have maintained and strengthened these channels since, generally using the National Governors' Association as the forum for discussions.

In 1981, the NGA Task Force on Innovation was established under the leadership of Edmund G. (Jerry) Brown of California and William Milliken of Michigan. The first attempt at a network of governors' offices, it produced a seminal report that reviewed state activities aimed at encouraging technological innovation.[13] The task force was later chaired by Governors James Hunt of North Carolina and Richard Thornburgh of Pennsylvania. In 1985, it was succeeded by the NGA Working Group on State Initiatives in Applied Research, initiated and chaired through 1990 by Governor Richard Celeste of Ohio. This group continues in operation as the Science and Technology Council of the States, chaired by Governor Mario Cuomo of New York. As of 1992, every state is represented on the Council.[14,15]

The NGA remains vital for exchanges of information and development of alternatives in the area of science and technology. Through the Science and Technology Council of the States, governors have helped each other refine their approaches to technology-based development and have begun to make their voices heard nationally on these issues.

Yet the national effectiveness of this organization is limited by its reliance on consensus and its part-time nature. A dedicated institution that can set priorities and follow them through over a period of years is needed; such an institution would also provide analytical support to state decision makers. The goal is to create a national science and technology focal point for states as they confront new challenges. Only in this way will states be able to act as true partners in promoting national economic competitiveness. That goal argues for an effective and professional independent organization that can serve as a locus for discussions, collect and disseminate information, provide interpretation and analysis, and maintain a strong corporate memory. Such an organization should bring together all the important parties to state programs, including representatives of industry, legislatures, universities, and nonprofit research organizations. An interstate compact, with a statutory basis in both state and federal law, may offer the appropriate combination of persistence, independence, and inclusiveness. Such an organization should also lend itself to interacting with federal agencies, programs, and policymakers, by providing a single source of information and access to state technology leaders.

HARMONIZING FEDERAL AND STATE ACTIVITIES

Federal–state cooperation requires the two levels of government to share information about goals, while leaving room for states' diversity and innovation. It will require a growing volume of two-way communication. States will have to communicate their needs and priorities directly to federal agencies in many fields of science and technology, with regard to many different federal and state programs. Federal programs will need to consult states about programs of potential joint interest. For this process to be successful, states

Box 1. Early Attempts at Cooperation

Before the 1980s, moves to harmonize federal and state science and technology activities were few and ineffective. Federal programs were expanding, as federal agencies assumed wider roles in the economy. States had little to tell federal agencies, and the agencies had little incentive to listen.

The short-lived Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP), established by federal law in 1976, was charged with identifying technical problems important to states and localities, and directing federal aid to their solution. Frank Press, President Carter's Science and Technology Advisor, commented in 1977:

> If science and technology are to benefit our people more effectively, a better R&D partnership must be established between the Federal Government and the States, counties, and cities. Properly designed and directed toward State and local needs, federally supported R&D could help to protect regional and local environments, reduce demands on energy and various natural resources, and improve delivery of State and local services. . . .
>
> Governors, mayors, state legislators, and country and local officials have far better ideas of the problems and the needs of their communities than do Washington officials. They should have more of an input into the decision making that results in Federal R&D budgets in the civilian sector.

The panel, with an impressive roster of federal, state, and local officials, was co-chaired by the President's Science Advisor and a governor. It was abolished in 1981, with the change in administration, before it could become a force for cooperation.

will require an organization that can promote at the federal level the priorities and policies developed by the states in their interstate science and technology deliberations.

In an attempt to meet this need, the Intergovernmental Science, Engineering, and Technology Advisory Panel (ISETAP) was established in 1976 (see Box 1). ISETAP was intended to involve state and local governments more deeply in federal science and technology strategies and programs. It reported to the White House and was co-chaired by the President's Science Advisor. The organization devoted its first few years to workshops and other activities aimed at identifying high-priority problems. It was abolished in early 1981, before it could embark on the next stage: addressing those problems.[16]

Several general criteria should be considered in creating the new national partnership and establishing state–federal program cooperation:

- The program's position on the research and development spectrum. Research near the "basic" end of the spectrum is likely to be the responsibility of the federal government, and work at the more "applied" end, that of the states and industry. There is considerable overlap, however.

- The program's national or local scope. Benefits of national scope may deserve federal support. More localized benefits are likely to be of interest to states.
- The potential benefits of the program to the state and federal partners. Once a decision has been made to cooperate, the extent of involvement in a program should reflect the benefits that each partner expects to realize from it.[17]

For these criteria to be met in practice, states and federal agencies will need to discuss their relations frankly and freely. The appropriate forum for these discussions remains to be created. The National Governors' Association—through the Science and Technology Council of the States—is today the most prominent forum for governors wishing to affect national science and technology policy. While vitally important, the group is effectively a committee, and its organization is too informal to allow it to exert consistent influence on policy.

Another valuable but limited channel of communication is the National Research Council's Government–University–Industry Research Roundtable (GUIRR), composed of senior federal research officials and representatives of industry and universities. In 1988 GUIRR established a subcommittee on federal–state dialogue, which has tried to promote increased federal–state understanding in science and technology initiatives.[18] The group, however, is barred by its charter from actively advising government.

Shared Goals, Shared Investments: Federal–State Cooperation in Education

One promising example of state–federal cooperation in pursuit of comprehensive change in a field with science and technology implications is the National Science Foundation's Statewide Systemic Initiative (SSI) program of education grants (see Box 2). SSI awards federal funds to states over periods of several years, in return for the states' agreement to pursue education goals that they set themselves (so long as the goals meet certain minimum standards). SSI is significant for three reasons: it recognizes the diversity of the states, it entails a long-term joint commitment of federal and state agencies in pursuit of shared goals, and it allows substantial flexibility in the design of each specific state–federal relationship. These features suggest the hallmarks of successful federal–state relationships in other areas involving science and technology.

Box 2. NSF's Statewide Systemic Initiative: Honoring the Diversity of the States

The National Science Foundation's Statewide Systemic Initiative (SSI) is a program of competitive grants to states, intended to give all students a better chance to acquire the skills and mental habits of mathematics and science. Described by NSF as an experiment in intergovernmental cooperation, SSI brings federal and state government together in pursuit of joint goals. It capitalizes on states' diversity by building on existing state programs and meeting state-defined needs.

Each participating state develops its own "coordinated action plan" for improving elementary and secondary math and science education. Before NSF will review the plan, it must be endorsed by the governor as well as the chief state school officer and the commissioner for higher education.

NSF offers states great latitude in selecting their own approaches. A state may designate a university, a private organization, or a state agency to apply on its behalf. The action plans are tailored to the specific resources and needs of the states.

NSF grants (of up to $2 million a year) are awarded for periods of five years. The first year's awards, in 1991, were made to 10 states (Connecticut, Delaware, Florida, Louisiana, Montana, Nebraska, North Carolina, Ohio, Rhode Island, and South Dakota). A second round of grants was announced in the spring of 1992.

NSF hopes that these relatively small grants will encourage the participating states to focus more clearly on math and science education and make fundamental improvements in teaching.

In addition to the five-year grants, the SSI program will offer technical assistance to all states interested in improving their science and mathematics education.

Nevertheless, SSI is at its core a federal program. States are free to compete for grants or not, but the program's educational standards are imposed by NSF, and states had no influence on the fundamental program design. It should be considered, not as a model for future cooperative activity, but as a step in the right direction.

Need for Information

A productive partnership will depend on a full understanding by each party of the other's activities. Federal agencies have sometimes failed to consult states about projected activities, as noted earlier. The lack of information on state science and technology initiatives is also an obstacle to harmonizing state and federal policies. Federal and state policymakers and program managers, for example, do not have accurate, current data on the goals or outcomes of the state industrial technology programs (these programs are discussed in Chapter 3). They may find it hard to identify whom to contact, or even where to obtain basic information. Under these conditions, cooperation is obviously difficult.

Good information is scarce largely because the state programs are so diverse and adaptable. The programs pride themselves, after all, on their flexibility and entrepreneurial nimbleness. They were founded, and are supported, with varied goals, and their design varies accordingly. The powers and degrees of centralization of the agencies that operate the programs also vary. While flexibility and variety are generally considered signs of vitality, they can also be barriers to mutual understanding. An illustration of this effect is the fact that neither states nor analysts of the programs have arrived at consistent definitions of such basic terms as "research," "technology transfer," and "seed capital," which are often used to designate state programs intended to improve industrial technology.[19,20] (This problem of taxonomy is also seen in federal technology programs, where it raises similar problems in program evaluation.)

Some observers believe that most of the available studies of state programs overemphasize aggregate state-level data. These studies attempt to total the sums states spend on various categories of activities, such as research centers or technical extension services, without investigating the different activities associated with such spending. For true cooperation, state and federal policymakers need much more precise information on the activities and outcomes of state programs. NSF researcher Lawrence Burton has called for detailed, state-by-state data on "technology resources and relationships," rather than simple spending totals.[21] To mount the kind of comprehensive study that would produce such data, however, would require leadership, and sufficient funds.

Staying Power

Each participant needs to assess the other's capability to maintain a long-term commitment. For instance, many federal programs have been characterized by short-term considerations; more recently, however, emphasis has been placed on longer-term commitment. Federal policymakers also must make judgments about the state programs' political stability (and thus their reliability as partners). Among the difficult questions that need answering is whether political support in a given state is solid enough to warrant long-term commitments by the federal government or private industry. State officials, it should be emphasized, need similar assurances from the federal side. In both cases, these commitments are subject to political cycles.

The stability that a strong state commitment can bring to a federal program is illustrated by the experience of the NSF Science and Technology Center in Advanced Liquid Crystalline Optical Materials (ALCOM), established at Kent State University in Ohio in 1990 under an agreement calling for cost-sharing by the state. Adjustments in the NSF budget reduced the federal share for the first year and the shortfall called into question the center's viability. The state of Ohio, however, came forward with its full share, so that the ALCOM center could begin operating immediately at nearly full capacity.[22]

Similarly, a steady federal commitment can stabilize state programs. The Statewide Systemic Initiative education reform program of NSF, with its five-year funding cycle, is a promising attempt at promoting sustained state efforts in the field of education.[23]

NEW FUNDING ARRANGEMENTS

Better federal–state cooperation in health, environment, economic competitiveness, education, and other science- and technology-intensive areas demands better-organized funding. The expected reordering of priorities and reallocation of responsibilities will probably not require additional appropriations; rather, efficient reallocation of current resources and optimal distribution of roles are called for. In order to achieve this level of efficiency, state and federal governments must plan and budget for national needs together, seeking opportunities for joint investments.

The most pressing need, perhaps, is for secure streams of revenue to fund state–federal partnerships. Some programs to convert federal defense-oriented laboratories to civilian purposes could be largely self-funding. For example, state centers or extension programs might assume the technology transfer functions now performed by federal laboratory personnel, so that no net increase in federal spending would be required.

In other cases, where additional funds are needed, it may be desirable to engage the public directly in providing long-term support for some state science and technology programs, for instance through bond referendums. State governments often use such mechanisms to finance capital expenditures. Some states, such as New Jersey, have gone further, with special bond issues dedicated to science and technology investments. The advantage to the state, in addition to stable long-term funding, is a clear signal of taxpayer support.

New principles are also needed to govern federal–state cost-sharing in joint projects. Cost-sharing requirements at present are unilaterally determined by federal program directors, to meet short-term program budgeting needs. This practice can be wasteful, and it does not promote real cooperation. A cost-sharing system that deploys resources optimally and divides tasks according to established federal and state roles would be better than one that auctions off federal programs to the highest-bidding states. The current system's short-term advantages to federal agencies are so great, however, that change will not come without a high-level policy decision, perhaps arrived through a formal state–federal agreement, or perhaps in Congress.

GROWING NEED FOR PROGRAM EVALUATION

The development of new forms of partnership, new institutions, and new funding sources requires new accountability. This need will grow as investments increase and as costs are more frequently shared with other levels of government and with industry. States and federal agencies will need better management information about the goals and progress of their programs, both individually and in the aggregate. Industrial and academic participants will also require information.

To satisfy these demands, the art of program evaluation must improve and evaluation will need to be carried out more widely and more consistently (see Box 3). All parties will need to collect more precise data on their investments and the outcomes of those investments. To ensure that such data are meaningful, a more accurate and consistent classification of activities will be needed.

Meeting these requirements will be challenging, and sophisticated and expensive research programs will be called for. Even if such research is successfully completed, program participants have little or no incentive to perform the necessary data gathering, which they may see as a time-consuming and expensive distraction with little impact on operations, unless evaluation methods so improve that they have perceptible benefits to individual organizations.

Until then, less sophisticated measures can be useful. Most of the state programs have made progress in their evaluation methods. In the 1980s, for example, legislators often demanded that the new state industrial technology programs demonstrate quantitative "results," sometimes in the form of estimates of numbers of new jobs or companies created, in the relatively short term. Such criteria have long been applied to traditional economic development programs. Technology-based economic development, however, cannot be measured in such terms in the short run. It is a process that may

Box 3. The Art of Program Evaluation

Program evaluation has been a challenge for state technology initiatives and the many new similar federal initiatives. Some early programs tried to justify themselves by claims of jobs or businesses created. It soon became apparent, however, that, as in any research program, benefits are difficult to measure, especially in the short term. The full cycle of innovation takes place over periods of years or decades.

Accordingly, more informative evaluation measures have been developed. Evaluations have used such measures as "leverage" of industry and federal dollars and enhanced high-tech industrial development, as well as "process" measures such as numbers of firms involved or numbers of grants made. States have used diverse means of program evaluation, ranging from straightforward self-evaluation to sophisticated reviews by outside experts.

According to David Mowery of the University of California, program evaluation has several general limitations. First, it is virtually impossible to measure a program's impacts on economic development, because many other factors (such as macroeconomic changes, tax policies, and investments in education) are also at work during the program's course. Second, one cannot construct a "counterfactual case," to test what would have happened without the program. Finally, some states place too much weight on the attraction of high-technology facilities as measures of success, when these facilities may or may not be contributing to state economic development.

Evaluations are growing more sophisticated. Today, they are likely to be carried out on a regular cycle, to include measurements of progress in terms of explicit goals, and in general to use longitudinal data. Outside experts are more frequently called on, to avoid conflicts of interest and ensure meaningful results.

One of the most ambitious evaluations has been that of Ohio's Thomas Edison Program, which arranged for a review of its technology centers by a committee of the National Research Council. The review committee pointed out that the program's diversity makes it impossible to use a uniform set of evaluation procedures even within the state. Additional difficulties include the long time horizons of the state investments and the impossibility of controlled experiments to test contrary cases. "The only realistic evaluations are qualitative," the NRC said in its report, and the Edison centers must be judged by "evidence of networking, a broad base of industrial and academic support, the willingness of larger companies to invest money and of smaller companies to invest time, and clearly defined missions and programs aimed at regional economic development."

show lasting results only over periods of a decade or more, and whose progress must be measured by more subtle and sophisticated means.[24,25]

Evaluation requires measures based on both near-term and ultimate goals. A few initial payoffs from state research and development investments may appear in the first 5 years, but only after 5 to 10 years can the first meaningful returns from those investments be discerned, and then only in the case of the most successful investments. After 10 to 15 years, sponsors can expect to have measurable results in the form of clear economic impacts. In programs emphasizing immediate diffusion of technology, such as industrial extension programs, results may be observable much more quickly.

To date, most state technology programs and similar federal initiatives have been assessed according to measures of "process variables," such as rates of participation by industry. Industry's willingness to continue paying membership fees in state-sponsored technology programs may be a better market test of effectiveness than any artificially constructed assessment measure.

One academic observer, Irwin Feller of Pennsylvania State University, writes that the state programs "would appear to offer a 'natural' testbed for comparative analysis, for they offer a distinctive array of the organizational forms, mechanisms of support, technologies, and industrial sectors needed to transform emerging theoretical perspectives into effective and efficient operational programs." [26] From the standpoint of technology policy, he adds, the programs should be seen as "a set of working hypotheses," whose outcomes should be carefully evaluated. Feller argues elsewhere that, "although state advanced technology programs . . . are cast as 'experiments,' most current or prospective evaluation activities lack even a modicum of experimental design."[27] Most federal technology programs share the same defect, he adds. The remedy is to include evaluation in the program design, so that performance data will be adequately collected and analyzed.

AMERICA'S THIRD CENTURY: PARTNERSHIP AND RENEWAL

The genius of the American federal system, displayed again and again in its first two centuries, is a capacity for self-renewal. The institutions of our government have survived war, panic, and depression. They have been elastic enough to encompass the enormous territories added as the frontier pushed West. They have welcomed wave after wave of immigrants, and offered all of them access to power. Today is no different. The system is responding to the revolutionary times not by retrenching, but by offers of partnership to meet human needs.

The federal–state technology partnership is not new. It dates at least from the Lincoln administration, when the Morrill Act granted federally held resources to the states on a grand scale, for each to deploy in its own way to achieve agricultural abundance and the general advance of technology. The Land Grant institutions that resulted were major sources of new technology for much of America for many decades. The federal assumption of responsibility for basic and defense research after the Second World War was another fruitful phase of that partnership, which helped carry society forward.

Today we are offered the opportunity to renew the partnership, entering into a new compact that will lead to a more dynamic economy and better lives for the nation's citizens. The states have shown the way, by forming their own partnerships, engaging citizens and companies and academics in support of technology development and diffusion. With their growing technical skills and their creativity, the states are testing diverse responses to the nation's domestic challenges. They have strong and direct incentives to find effective, low-cost solutions to an array of human needs: health care, education, environment, energy, and economic competitiveness.

To achieve these goals, the nation will need better ways to manage science and technology at all levels. It will be necessary for state leaders to keep developing their methods for assessing technology-dependent issues and their institutions for coordinating and evaluating programs. The states will also need new means of working with other states, regionally and nationally. Federal and state governments must form cooperative relationships with each other and with industry, bringing to bear the complementary strengths of each party.

The 1990s can mark the opening of a new chapter of renewal in the history of America. States can devise new mechanisms for taking advantage of technological change and for collaborating with other states. They can also create and nurture a new partnership with the federal government that will guarantee to all Americans the benefits of science and technology.

3
A NEW MODEL: STATE INDUSTRIAL TECHNOLOGY PROGRAMS

The best-developed examples of public–private partnership in the nation are the varied state programs that have been established to promote the development and application of industrial technology. These programs involve the states with industry and academic researchers in long-term programs with shared goals and shared decision making. Such cooperation will provide an important model for structuring national responses in other science- and technology-intensive areas, such as health care, environmental protection, and education. In these areas, and others, the complementary strengths of the two levels of government, joined in productive partnership, will enable the nation to address the pressing issues that confront it now and in the future.

ROOTS OF THE STATE TECHNOLOGY PROGRAMS

The state technology programs have their roots in a desire to reproduce the concentration of high-technology development in Silicon Valley and Boston's

Route 128 (though in neither case was this development the result of conscious government policy). Led by its innovative governor, Luther Hodges, North Carolina pioneered the state role in technology-based economic development, beginning in the 1960s; Governors Terry Sanford and James Hunt continued this emphasis through the 1970s. Their investments in education and in the Research Triangle Park complex, encompassing the state's major universities, were aimed at raising living standards in what was then one of the poorest states in the Union. The initiatives were striking successes. By 1985 North Carolina had attracted billions of dollars in new investment, created hundreds of thousands of new jobs, and brought its unemployment rate to two percentage points below the national average.[28]

Meanwhile, other states had followed North Carolina's lead, driven by the widespread industrial recession of the early 1980s and a continuing withdrawal of the federal government from the civilian economy. Pennsylvania Governor Richard Thornburgh founded the Ben Franklin Partnership. Ohio Governor Richard Celeste proposed a public–private system of R&D grants and research centers, later christened Ohio's Thomas Edison Program. Other economically depressed states followed suit, with their own industrial R&D and technology diffusion programs. By 1988, 45 states reported more than 250 technology-based development initiatives, with annual expenditures of $550 million.[29]

Private–public partnerships are pervasive in state government. The state technology programs in particular are distinctive for their partnerships of industry and academic research. These programs tend to give industry a prominent role in decision making, through industry advisory boards, cost-sharing, and other devices, so that programs live or die with industrial participation.

HELPFUL FEDERAL INITIATIVES

The federal executive branch opposed direct federal aid to industrial R&D in the 1980s. Nevertheless, when the new state technology programs were taking shape and providing hundreds of millions of dollars of aid to support industrial R&D, several federal initiatives were helpful. Among the more important are the following:

- The University and Small Business Patent Procedure Act of 1980 (PL 96-517) granted universities greater control over licensing of patents resulting from federally funded research on their campuses.

- The Stevenson-Wydler Technology Innovation Act (PL 96-480), enacted in 1980, required all federal laboratories to mount industry-oriented technology transfer activities, and established a central source of information on federal laboratories' technology.[30]
- The Small Business Innovation Development Act of 1982 (PL 97-219) established the Small Business Innovation Research (SBIR) program, which sets aside a small proportion of federal research funds for small business.[31]
- The Federal Technology Transfer Act of 1986 (PL 99-502) authorized cooperative R&D agreements between federal laboratories and other entities, including state agencies.
- Presidential Executive Order 12591, signed April 10, 1987, directed agency heads to help transfer technology to the marketplace, and granted title to innovations growing out of federally funded research to the institutions that performed the research.[32]
- Clarification by the Federal Trade Commission of certain antitrust provisions, beginning in the early 1980s, made industrial research consortia (including state-sponsored ones) feasible. The National Cooperative Research Act of 1984 (PL 98-462) confirmed the antitrust protection.

These measures gave states access to new resources, including federal research funds, R&D results, and expanded intellectual property rights.[33] Many states have used these resources as incentives to encourage industry to participate in state-sponsored academic research centers and other technology initiatives.

CHANGING THE LANDSCAPE OF DECISION MAKING

While not accounting for a very large share of total U.S. research investment in dollars, state technology programs are in many ways the thin edge of a large wedge. States, with their industrial and academic partners, have a flexibility, diversity, and knowledge of local and regional conditions that federal agencies cannot match. Their small investments can therefore be focused accurately to promote technological advances that yield important returns in industrial strength. Successful state programs bring about structural change in the relations between government and industry, between industry and universities, and even between state and federal agencies. In this way, they make possible new research and development alliances and broader research opportunities.

Over the past four years, state spending on applied science and technology programs appears to have been on the order of $1.2 billion (see Appendix A). This figure is restricted to state funds and does not include the matching funds that are typically required. With matching funds considered, total spending has probably exceeded $2 billion. Eleven states have spent more than $50 million each on the programs from FY90 to FY93.

Additional science and technology spending by states, on colleges and universities, on basic research, and on science and technology for regulatory and mission agencies may total in the hundreds of millions, but it is difficult to determine an exact figure.

These sums may not seem significant in the context of a national research and development enterprise, public and private, that spends more than $150 billion per year. State science and technology investments, however, have several features that amplify their effectiveness:

- The state programs are tightly focused on the specific goal of technology-based economic development.[34]
- The investments are highly "leveraged." That is, states use them as incentives to enlist industry and universities in the programs, which are supported by significant industry cost-sharing in both cash and kind.[35]
- State programs often build on research that has received substantial federal funding.
- The state programs have a flexibility that would be difficult, if not impossible, to obtain in a federal program. They can shift their objectives swiftly and smoothly to meet changing conditions. For example, many seem to have met recessionary pressures on their budgets by shifting toward nearer term goals more certain of economic payoff, such as industrial extension services, and away from longer term research programs (see Appendix A). The director of New York's technology program, which is oriented strongly to long-term research, said in early 1991 that, while not abandoning longer term work, "like a Wall Street fund manager, we will move our investments away from risk toward more likely payoffs."[36]

The state programs have reshaped competitions for national facilities, such as Sematech and the Superconducting Super Collider. They have made it easier for states to make strong, timely proposals by giving them the capacity to manage science and technology programs, as well as enabling them to form supportive constituent groups. (By the same token, state programs can be vulnerable to bidding wars in federal competitions, when awards hinge excessively on bidders' cost-sharing offers, rather than on strategies, policies, priorities, or substantive capabilities.)

The states are significant, then, not because they have assumed responsibility for an appreciable fraction of the nation's R&D. Their claim to national significance is instead that they are changing the landscape of decision making for science and technology initiative, and reshaping federal–state relationships. Not the least of their significance is the potential they hold as partners for the federal government.

There is a remarkable solidarity of interest among the academic, corporate, and government institutions that participate in the state programs. Universities have revised their patent policies, and in some cases their mission statements, to emphasize economic development goals.[37] (As mentioned above, patent reforms have given universities substantially more control over licensing and other forms of commercialization of federally funded research on their campuses.) University faculty are becoming accustomed to moving easily between "theoretical" and "applied" issues, and industry leaders are acquiring a greater appreciation of the value of long-range research.[38] Industrial research is increasingly a matter of long- and short-term projects, carried out through strategic partnerships with academic research. Governors and legislators have discovered that the alliances made in the technology programs have political advantages in other areas, such as education reform.[39]

One student of the state technology programs writes, "if state advanced technology programs are successful in fostering new alliances, they can have important impacts beyond those associated with the specific projects supported by state dollars or job-creation outcomes."[40] By lowering "the future cost of collaborative relationships," he says, the programs may promote "increased rates of technological innovation and human-resource capital formation that do foster increased rates of state economic growth." In doing so, he adds, they may improve the competitiveness of U.S. business in the fields of technology selected for emphasis.

To ensure that the nation reaps the benefits of these programs, federal and state agencies will find it necessary to work together to plan and implement technology investments. To do so, they will need better information about each other's activities, and better means of cooperation.

Recent Federal Cooperative Technology Programs

In the past there have been some attempts at promoting federal–state cooperation, but their success has been limited, at best. Today, truly cooperative technology investment programs are extremely rare. The only federal science and technology program designed with cooperation in mind is the National Science Foundation's new State/Industry–University Cooperative Research Centers program, a small experiment with joint decision making in research funding. States are responsible for initial selection of proposals, and the National Science Foundation makes the final awards, through a standard review process. Costs are shared equally by NSF, state, and industry. In 1991, the first year of the program, six centers were funded, with four-year NSF grants of between $100,000 and $300,000 per year; several more grants are expected in 1992.[41]

The Commerce Department's Clearinghouse for State and Local Initiatives, established under the Omnibus Trade and Competitiveness Act of 1988, is intended to be a force for coordination, but has not pursued that goal vigorously. The act gives the clearinghouse broad responsibilities for gathering and disseminating information about state initiatives, establishing liaison relationships, and finding and recommending ways for federal agencies to support state initiatives. However, according to its former director, the clearinghouse, in the Department's Technology Administration, has accomplished little of its mandate beyond developing and operating a computer database of state and local programs.[42]

The new partnership needs to draw on the lessons of the past. One such lesson may be learned by recalling the first round of awards in the NSF's Engineering Research Center (ERC) program, which is an illustration of the federal failure to discuss its plans with the states. The program, which involves industry and universities in joint research, was one of the federal government's main economic competitiveness initiatives in the 1980s. Although valuable as a means of promoting development and diffusion of technology, it was formulated almost entirely in the White House Science Council during the early years of the Reagan administration, with little or no advice from the states.[43]

The lack of consultation resulted in some apparent duplication of effort. For example, in the mid-1980s, without even notifying the state of New York, much less consulting with it, NSF sited an Engineering Research Center in telecommunications in New York City, where the state had already established a center with substantially the same mission.[44]

Some have argued, in support of NSF procedures, that federal and state roles must be distinct, and that too close a coordination of programs can harm both. The federal ERCs were awarded in an open competition without geographic or institutional limitations, they say, while state centers are often sited with such considerations strongly in mind, to help a particular region's industry or improve the geographic balance of science and technology resources. In the case of the duplicate telecommunications centers, they add, New York City, as the nation's telecommunications hub, has the necessary infrastructure to accommodate this kind of activity, so there is no undue redundancy. Nonetheless, better means of sharing information would have helped the state make the most of its investment, and would probably have helped the NSF, too. (The NSF has since significantly modified its approach and is a leader among federal agencies in emphasizing cooperation with the states.)

Informal Cooperation

Some informal cooperation does take place. The Manufacturing Technology Centers of the National Institute of Standards and Technology (NIST), for example, although they are awarded in open competitions, tend to be sited near existing technology centers. (This practice makes good sense, because the NIST centers have grown out of the technical extension programs pioneered by states, and because the states provide significant matching funds for these centers.) It should be noted, however, that the rules of these competitions are rigidly dictated by NIST and are not the result of consultation between NIST and the states.

Informal cooperation is also beginning to occur at the higher levels of policymaking. The National Science Foundation, for example, has established a state liaison position in the NSF Office of Legislative and Public Affairs and has publicly encouraged efforts by states to cooperate with federal science and technology programs. NSF recognized the state efforts as a new element in the national science policy establishment through the public statements of senior agency staff and through technical advice on such issues as peer review and technology center criteria. It also commissioned a recent major study of the states' R&D investments (see Appendix A).

MECHANISMS OF COOPERATION

A new partnership to spur U.S. economic competitiveness and to improve the health and welfare of citizens and their communities is emerging. At its roots is the concept of cooperation between the federal and state governments, with the involvement of the private sector. In the short term, a combination of need and opportunity motivates action. The most obvious short-term benefit is efficiency, through better sharing of resources. Less obvious, but arguably as real, are the benefits of synergy: innovation can be enhanced by the effort to find common purpose with another party (see Box 4).

Successful cooperation stems from clear understanding by each participant of the others' capabilities and of the roles that each can best play. In support of industrial technology, for example, the federal role is to provide the nation's research base in the sciences and generic technologies and to invest in national infrastructure such as research institutions, equipment, and instrumentation. States are responsible for building university research facilities, equipping them, and maintaining the necessary faculty, as well as for regulating and funding precollege education and vocational training; an important emerging state function is supporting technology activities that are close to the product development phase. Industry is responsible

Box 4. State–Federal–Industry Synergy: A Case Study

State and federal research programs can combine with industrial resources to produce a healthy synergy. In the Edison Polymer Innovation Corporation (EPIC), Ohio joined with industry to make its wealth of academic polymer research more easily accessible to industry.

EPIC is one of Ohio's largest state technology centers. Established in 1984, it takes advantage of the internationally known polymer research programs at Case Western Reserve and the University of Akron, and of the Cleveland–Akron corridor's industrial strength in polymer technology. With a pool of researchers numbering more than 400, EPIC represents one of North America's greatest concentrations of scientific and technical capability in polymers.

Later, the two universities joined with Kent State University (with its fine liquid crystal chemistry program) to seek an NSF Science and Technology Center. EPIC provided seed money for the proposal. Its industrial associates participated in the NSF site visit, to show the strength of its industrial ties. Thanks to this joint effort, the Center for Advanced Liquid Crystalline Optical Materials was established in 1990, with initial federal funding of $1 million per year. Industry, state, and federal funds will total $18 million over 5 years.

Industry and state and federal agencies have continued building on these gains. In 1991 Case and Akron proposed a polymer composite center to the NSF State–Industry–University Cooperative Research program. The state endorsed the proposal, committing itself and, through EPIC, its industry each to match the NSF funds, dollar for dollar. The Center for Molecular and Microstructure of Composites began operation in 1991. Over the first 4 years, funding from federal, state, and industry sources will total $5 million.

for designing, manufacturing, and marketing products, conducting sector- or company-specific research in the sciences and technologies, and keeping its work force well trained.

A partnership to spur U.S. economic competitiveness might thus be based on a division of roles in which the federal government supported research near the basic end of the spectrum, while the states and industry supported applied research and development of more direct interest to industry. It should be recognized, though, that the research and development process does not conform to such neat distinctions. In some cases, such as defense and biomedicine, the federal government has traditionally supported R&D along most or all of the continuum from basic research to applications, because it was the customer for the ultimate product, or because it viewed that product as of special national importance. (It is worth noting that commercial applications of the resulting technologies — aircraft, computers, and drugs — are among the most competitive of U.S. industries in world markets.)

State technology programs, too, blur traditional distinctions between

R&D stages. Through them, according to a leading practitioner, university faculty are becoming accustomed to moving easily between "theoretical" and "applied" issues, and industrial research is seen increasingly as a "portfolio" of long- and short-term projects conducted in both university and industry labs.[45]

At a minimum, true cooperation in such an environment requires state and federal officials to be well enough informed about each others' activities and goals to share resources, such as laboratory facilities. An effective partnership will depend on the involvement of all partners at the earliest project definition stage, and not after plans are completed. Partnership does not mean one partner presenting a final plan, or even a project that has already begun, to the others, leaving them with only two options: acquiescence or nonparticipation. States should be involved in defining individual projects that are expected to have industrial impact at some stage, as well as in designing new programs to create centers intended to aid industry.

Closer, more comprehensive cooperation is possible. States and federal agencies, for example, might engage in continuing consultations on their plans, with shared strategic goals.[46] For such consultations, states would need a seat at the federal table around which these priorities are set and broad funding decisions made. In the current administration, priorities in a number of important areas of research are set by the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET), a White House advisory committee.

More generally, federal executive and legislative agencies could make greater efforts to appoint members from the states to their science and technology advisory committees. There are hundreds of these bodies, and many are highly influential. States are poorly represented on them, even in areas—such as industrial technology—where the state perspective is vital.

The institutions to foster federal–state exchanges and to create the desired partnership in policy development do not exist today. Among the steps that might be taken to foster such cooperation are to create a system of joint advisory and consultative bodies and gather accurate data to help determine how state, federal, and industry investments can be matched most effectively. Building on these shared institutions, states should sponsor a national summit meeting on science and technology, at which governors would join the President, members of Congress, business, academic, and labor leaders, and others to discuss common problems and begin developing a state–federal–industry science and technology agenda. States must also build mechanisms to communicate among themselves and with the federal government. Without such efforts, federal and state agencies will continue to operate independently, with little cooperation, and sometimes at cross-purposes.

4
TOWARD A FULL PARTNERSHIP

A NEW BALANCE OF COOPERATION

Carrying out the nation's post–Cold War agenda will require a new balance of cooperation between federal and state governments. Both parties will need to make efforts to share resources and decision-making authority. The ultimate prize is nothing less than a renewal of our republican institutions, with new national goals and a new balance of federal and state roles.

Tightly coordinated joint planning is not advisable. Rather, a cooperative effort to exploit the two parties' complementary strengths will be needed, bolstered by a variety of new institutions to make consultation easier and more productive. These new institutions might include new sources of science advice for governors and legislators, joint policy development channels for the states, and federal–state forums for discussing priorities.

The appropriate division of roles in science and technology between federal and state governments is a vital issue that demands attention at every level. A broad new division of roles may be evolving, as states assume important responsibilities in areas that have heretofore been considered federal responsibilities.[47] The only certainty is that federal–state partnerships will continue to increase both in number and in significance.

The states have taken important first steps, steps that exemplify in many ways the kinds of partnerships that will be necessary. They have developed their own entrepreneurial industrial technology initiatives with industry and universities; these initiatives in the aggregate are a strong force for national economic competitiveness. To widen the circle of renewal, these partnerships must be extended to the federal government, and to other fields of endeavor, beyond industry.

Federal and state governments must assume their fundamental new roles deliberately. A good example of the forces demanding a bigger state role in decision making can be found in the question of the future of the federal defense laboratories. Managers and policymakers envision civilian missions for these institutions, often in commercial research and development. These billion-dollar federal labs will not easily adapt to the pursuit of fast-moving commercial technologies, because playing such a role successfully requires detailed appreciation of industrial activities and needs; this must be reflected throughout the laboratories' operations. States, with their networks of industrial contacts and established programs of technology diffusion, can help the laboratories and businesses communicate about their mutual needs and resources. The state of New Mexico, in a move in this direction, has entered into a three-year agreement with the Air Force Space Systems Command's Phillips Laboratory, in which state personnel will manage the lab's technology transfer activities. New Mexico's industries will gain improved access to aerospace, laser, propulsion, and other technologies.[48] Such initiatives are likely to be increasingly common in the future.

In such state–federal cooperative ventures, state agencies should be involved early in the planning process, while new mission statements are being developed for the labs, and not as an afterthought. Otherwise, their contributions may be limited to supplying incremental funds (for example, through federal cost-sharing program requirements), and both the states and the nation will be poorer. Opportunities for synergy of the kind described in Chapter 3 will be lost. States, as a matter of self-protection, must—and will—insist on participating in the setting of the federal R&D agenda, as it moves away from its strong emphasis on defense.

More generally, if the nation is to turn federal technology resources to civilian purposes, states should participate in setting goals and investment strategies (see Box 5). The states have a long tradition of local market and business development, as well as long experience of engaging multi-

Box 5. Cooperation in National Competitions

Many recent federal competitions have required that part of the costs be borne by the recipient institutions. In principle, cost-sharing is a healthy and necessary expression of commitment and cooperation. But states sometimes find themselves bidding against one another until only one is left with the costly prize. The desire for cooperation with the federal government thus leads to competition between states. Overemphasis on cost-sharing has short-term gains for federal agencies but often decreases actual opportunities for cooperation.

The Superconducting Super Collider and the National Magnet Laboratory are well-known federal competitions that hinged on cost-sharing. The practice has become increasingly pervasive, with similar requirements imposed in many smaller programs. New York's success in winning the competition for a National Earthquake Engineering Research Center was interpreted as a consequence of the state's agility in quickly committing $5 million in annual matching funds. Federal agencies have even demanded state cost-sharing in individual research proposals.

Joint planning and shared participation in projects of common interest make for more solid support and a more profitable partnership. For example, the Manufacturing Technology Centers of the National Institute of Standards and Technology have been sited to take advantage of existing state technology centers. NSF's experimental State–Industry–University Cooperative Research (SIUCR) centers are sited according to joint decisions with states. But such cooperation is the exception, rather than the rule.

sectoral support for S&T programs in industry, agriculture, health and welfare, environmental protection, and other areas that are coming to dominate the national agenda. Their growing technical sophistication and their unique relationships with industry and universities suit them for full partnership.

A GREAT AND HISTORIC OPPORTUNITY

The nation has a great and historic opportunity to mount fresh new responses to many national challenges, while renewing and reinvigorating its republican institutions. But taking advantage of this opportunity will require hard work and planning, shaped by a broad vision of the future. Science and technology have become central concerns in the federal–state relationship. The two parties have much to discuss, as they reorder their roles to face the nation's domestic challenges. These discussions must be based on good information and expert analysis, and both sides must prepare their positions well. Channels of communication must be improved within states and among states, between states and the federal government, and between both levels of government and industry. This new partnership based on national needs is well worth seeking. The recommendations offered in this report outline a path toward that partnership.

Such an opportunity for national renewal is rare. If we fail to grasp it now, it will not come again.

APPENDIX A
HOW MUCH DO STATES SPEND ON SCIENCE AND TECHNOLOGY?

The most comprehensive study thus far of state science and technology spending was carried out for the National Science Foundation and published in 1990.[49] The study surveyed state agencies' spending for research and development and R&D plant, and found expenditures of $1.2 billion in fiscal year 1988.[50] This sum represented an increase of 62 percent, in real terms, over the 1977 total. Although the available data are not exact, it is reasonable to assume that industrial cost-sharing for the programs and additional state science and technology funding would bring the total to about $2 billion.

CHANGING CHARACTER OF STATE FUNDING

Between 1977 and 1988, the character of state-funded work changed substantially, reflecting the industrial emphasis of the new state programs. Basic

Table A-1. Surveys of State S&T-Related Expenditures

Unit of Analysis	Estimates of State Expenditures ($1,000)	Fiscal Year	Survey
State expenditures for R&D	764,677	1988	Lambright *et al.*, 1989; National Science Foundation, 1990
Academic R&D funded by state and local governments	1,003,000	1987	Lambright *et al.*, 1989; National Science Foundation, 1990
State S&T initiatives; "total state technology budget"	550,000	1988	Minnesota Office of Science and Technology, 1989
State technology development programs; "annual state government expenditures"	400,000	1987	Atkinson, 1988
State S&T agency program expenditures	203,000	1987	National Governors' Association, 1988
State research grant and contract programs	143,000	1988	Forrer, 1989

Source: Adapted from Lawrence Burton.[20]

research, 23 percent of the total in 1977, shrank to 9 percent by 1988, and applied research and development together grew from 77 to 91 percent.

These figures tell far less than the full story, however:

- They exclude expenditures that did not come directly through the state agencies' budgets, such as industry matching funds (a substantial part of many state programs).
- They exclude state support of higher education. Higher education, of course, is the foundation of the research base for the United States. More to the point, some states (such as California) use their universities as their major research arms, and most use higher education funds as matching funds in federal competitions for research centers and the like.
- States submitted data only on their main science and technology agencies, and the study thus ignored some R&D spending in health, the environment, and other important areas.
- The study treats only research and development *per se.* Most of the state technology programs are intended to operate as integrated pack-

Table A-2. Budget Trends of State Technology Programs: Appropriations for Fiscal Years 1990–1993[a]

State	FY90	FY91	FY92	FY93	Total
Alabama	$ 2,245,200	$ 3,721,257	$ 3,418,472	$ 1,619,552	$ 11,004,481
Alaska	3,500,000	3,500,000	3,500,000	1,000,000	11,500,000
California[b]	6,600,000	3,000,000	3,000,000	–	12,600,000
Colorado	2,515,772	2,828,606	2,366,756	3,116,089	10,827,223
Connecticut	10,100,000	10,300,000	19,200,000	19,900,000	59,500,000
Georgia	10,896,000	10,949,000	9,053,000	22,768,000	53,666,000
Illinois	24,231,000	18,625,000	8,202,000	2,100,000	53,158,000
Indiana	7,500,000	7,500,000	5,900,000	5,900,000	26,800,000
Iowa	10,000,000	4,600,000	3,965,000	7,400,000	25,965,000
Kansas	5,570,486	8,084,976	7,829,896	8,449,079	29,934,437
Louisiana	1,213,870	1,403,089	843,834	1,221,646	4,682,439
Maine	629,000	1,029,680	737,000	636,000	3,031,680
Maryland	1,700,000	1,900,000	2,300,000	2,500,000	8,400,000
Massachusetts	9,195,029	6,222,484	13,828,879	16,954,205	46,200,597
Michigan	20,000,000	20,000,000	20,000,000	20,000,000	80,000,000
Minnesota	23,106,350	25,592,350	23,343,000	23,334,640	95,376,340
Missouri	3,150,000	3,087,500	2,308,000	2,337,000	10,882,500
Montana[c]	7,950,000	450,000	5,550,000	450,000	14,400,000
New Jersey	21,212,000	17,216,000	16,804,000	15,528,000	70,760,000
New York	21,451,300	21,850,195	18,845,300	18,733,500	80,880,295
North Carolina[b]	25,000,000	25,000,000	25,000,000	–	75,000,000
North Dakota[d]	0	1,500,000	1,500,000	0	3,000,000
Ohio	18,159,967	18,727,917	21,289,718	12,890,745	71,068,347
Oklahoma	3,100,000	3,100,000	3,100,000	3,100,000	12,400,000
Pennsylvania	31,777,948	32,100,000	27,800,000	28,562,000	120,239,948
Rhode Island[e]	0	0	0	0	0
Tennessee	200,000	180,000	180,000	134,000	694,000
Texas	30,063,000	30,239,000	30,657,000	30,192,000	121,151,000
Vermont	100,000	200,000	348,115	25,000	673,115
Virginia	13,013,910	10,998,113	9,979,031	8,666,936	42,657,990
Washington[f]	5,750,000	5,750,000	4,500,000	4,500,000	20,500,000
Wyoming	500,000	2,450,000	500,000	500,000	3,950,000
TOTAL	$320,430,832	$302,105,167	$295,849,001	$262,518,392	$1,180,903,392

[a] States unable to report a specific amount spent on applied science and technology programs: Hawaii, Idaho, Nebraska, Nevada, South Dakota, and West Virginia. States that failed to respond to the survey: Arizona, Arkansas, Delaware, Florida, Kentucky, Mississippi, New Hampshire, New Mexico, Oregon, South Carolina, Utah, and Wisconsin.
[b] FY93 appropriation had not been made at time of survey.
[c] FY90 and FY92 appropriations reflect the year in which authority to use funds from the Coal Trust Fund was given.
[d] $3M was appropriated for the FY91–92 biennium.
[e] A one-time $3.4M grant to the Rhode Island Partnership for Science and Technology was made in 1988.
[f] Figures reflect biennial appropriations divided in half.
Source: Survey conducted for the Task Force on Science and Technology and the States, Carnegie Commission on Science, Technology, and Government, August 1992.

ages, which may include — in addition to R&D — seed or venture capital funds, technical assistance programs, and other assistance.

On the other hand, the NSF data include much spending outside the technology development agencies themselves. Those agencies were reported by a Minnesota state study to have spent $550 million in fiscal 1988.[51]

QUANTIFYING STATE PROGRAMS

Although they have attracted much attention among students of science and technology policy in the past decade, the state programs remain poorly quantified. The fundamental reasons for this lack of precise data are the relative newness of the state programs and their emphasis on flexibility and responsiveness to local needs. They have grown up quickly, and the language of policy analysis has yet to classify their spending in useful program categories. In addition, there is little agreement on basic terminology; terms such as "technology transfer," "manufacturing extension," or "seed capital" may be used rather freely, leading to some confusion.[52]

Table A-1, with estimates of state S&T expenditure from a variety of recent studies, shows how conclusions about total spending can vary. The variety of approaches used, and consequently of spending estimates, is kaleidoscopic. Simple funding data will never capture the significance of these programs; what is needed is social science studies that outline the relationships of participants and the flows of resources, including funds, among those participants.

RECENT TRENDS

State science and technology programs seem generally to have weathered the recession-driven budget cuts rather well. A survey conducted for this report (see Table A-2) indicates that state programs have experienced funding reductions, hardly surprising given the fiscal difficulties that states have experienced in recent years. Illinois has suffered the most significant reductions. Virginia and New Jersey have seen a steady reduction in spending, and Ohio has recently undergone severe cuts. Pennsylvania and New York programs have been trimmed, while Texas, Michigan, and Minnesota have remained relatively stable. On the other hand, Connecticut and Georgia have experienced significant growth.

APPENDIX B
TASK FORCE MEMBERS AND PARTICIPANTS IN TASK FORCE MEETINGS

TASK FORCE MEMBERS

William O. Baker retired in 1980 as Chairman of AT&T Bell Laboratories, Inc. He joined Bell Labs in 1939, becoming Head of Polymer Research and Development in 1948, and from 1951 to 1954 he was Assistant Director of Chemical and Metallurgical Research. After a year as Director of Physical Sciences Research, he became Vice President of Research in 1955; for the next twenty-five years, he had overall responsibility for Bell Laboratories research programs, and in 1973 he became president. Dr. Baker received a PhD from Princeton University, where he held Harvard and Proctor Fellowships, following a BS in physical chemistry from Washington College. He has served on the President's Science Advisory Committee, the National Science Board, the Regents of the National Library of Medicine, the National Cancer Advisory Board, the President's Foreign Intelligence Advisory Board, the National Commission on Libraries and Information Science, and the President's Intelligence Advisory Board.

Arden L. Bement, Jr., is the Vice President for Science & Technology at TRW, Inc. He joined TRW in 1980 as vice president, technical resources. Dr. Bement began his professional career in 1954 as a research metallurgist and reactor project engineer with the General Electric Company. In 1965 he joined Battelle Memorial Institute as manager of the metallurgy research department; three years later, he became manager of the fuels and materials department. In 1970, Dr. Bement joined the faculty of the Massachusetts Institute of Technology as Professor of Nuclear Materials, and in 1976 he became Director of the Materials Science Office of the Defense Advanced Research Projects Agency. In 1979, he was appointed Deputy Under Secretary of Defense for Research and Engineering. In 1990 the U.S. Senate confirmed Dr. Bement's appointment to the National Science Board for a term expiring in 1994.

Erich Bloch is the Distinguished Fellow at the Council on Competitiveness. An electrical engineer, Mr. Bloch joined IBM in 1952; he served in a variety of capacities, including vice president of the company's Data Systems Division and general manager of the East Fishkill facility. He became IBM Vice President in 1981. From 1981 to 1984, Mr. Bloch served as chairman of the Semiconductor Research Cooperative and was the IBM representative on the board of the Semiconductor Industry Association. In 1984, Mr. Bloch was confirmed by the Senate as Director of the National Science Foundation. Mr. Bloch was the recipient of the 1985 National Medal of Technology for his part in pioneering developments related to the IBM/360 computer that revolutionized the computer industry.

Richard F. Celeste was a two-term Governor of Ohio, from 1983 to 1991. During his tenure he led an aggressive program to promote international trade and investment with trade offices worldwide. At present, Celeste operates Celeste & Sabety Ltd., a company that specializes in providing linkages to world markets. Celeste attended Yale University, graduating *magna cum laude* in 1959, and taught at Yale for one year as a Carnegie Teaching Fellow. Selected as a Rhodes Scholar, he also studied at Oxford University. Celeste has been actively involved in the fields of international technology and the role of government in science, research, and development. As Governor, he chaired the National Governors' Association Committee on Science and Technology. He is a member of the Advisory Board at Oak Ridge National Laboratories. From 1979 to 1981, Celeste directed the U.S. Peace Corps, which had programs in 53 countries. He served in the Foreign Service under Ambassador Chester Bowles in India from 1963 to 1967.

Lawton Chiles was elected Governor of Florida in his fourth successful statewide political race in November 1990. Chiles began his professional career practicing law in Lakeland from 1955 to 1971 and served as an instructor at Florida Southern College from 1955 to 1958. He was elected to the Florida House of Representatives in 1959. He served his Lakeland district in that capacity until his 1967 election to the Florida Senate, where he served three years until his election to the U.S. Senate. Chiles became the first U.S. Senator from Florida ever to chair a major committee, the Senate Budget Committee, and he helped to found the National Commission to Prevent Infant Mortality, which he still chairs today.

Daniel J. Evans has been Chairman of Daniel J. Evans Associates since 1989. Trained in civil engineering at the University of Washington, Evans practiced structural engineering from 1949 to 1965. In 1956 he was elected to the Washington State House of Representatives, where he was Republican Floor Leader from 1961 to 1965. Evans was elected Governor of Washington in 1965; a University of Michigan study later named him "One of Ten Outstanding Governors in the 20th Century." After retiring as Governor in 1977, Evans became the President of Evergreen State College, a position he held until 1983, when he became a one-term United States Senator for the State of Washington. Currently, Evans is Chairman of the National Academy of Sciences Commission on Policy Options for Global Warming; he is also a political commentator for a Seattle television station.

Admiral Bobby R. Inman, USN (Retired), entered the Naval Reserve in 1951 and was commissioned as an ensign in March 1952. Over the next nineteen years he served on an aircraft carrier, two cruisers, and a destroyer as well as in numerous assignments ashore in Naval Intelligence. He graduated from the National War College in 1972 and was selected for promotion to Vice Admiral in July 1976. In February 1981, he was promoted to the rank of Admiral, the first Naval Intelligence Specialist to attain four-star rank. He retired with the permanent rank of Admiral in 1982. Between 1974 and 1982 Admiral Inman served as Director of Naval Intelligence, Vice Director of the Defense Intelligence Agency, Director of the National Security Agency, and Deputy Director of the Central Intelligence Agency. From 1983 to 1986 he was Chairman and Chief Executive Officer of the Microelectronics and Computer Technology Corporation (MCC). Following this, he was Chairman, President, and Chief Executive Officer of Westmark Systems, Inc., a privately owned electronics industry holding company. Admiral Inman served as Chairman of the Federal Reserve Bank of Dallas from 1987 to 1990.

H. Graham Jones is Executive Director of the New York State Science and Technology Foundation, a government agency that sponsors the development and application of new technology and encourages entrepreneurship in New York State. Mr. Jones earned his bachelor's and master's degrees in the natural sciences from Cambridge University and pursued further graduate work in physics at Cornell. Coming to government from a career of over thirty years in the computer industry, Mr. Jones played a lead role in the development and marketing of IBM's early scientific computers, the System/360, and special-purpose computers for military and space applications. In his present position, he administers programs that sponsor research and development in government and industry and that provide financing and consultation to small technology-based companies in New York.

Frank E. Mosier is vice chairman of BP America's advisory board. He was formerly president of the Standard Oil Company, which he joined as an engineer in the refining department in 1953. In July 1987, after the merger between Standard Oil and the British Petroleum Company, he became president of BP America. He relinquished that position upon being appointed vice chairman of the advisory board in April 1988. Frank Mosier is a graduate of the University of Pittsburgh with a degree in chemical engineering. In 1987 he received the honorary degree of Doctor of Science from Marietta College. The University of Pittsburgh Engineering Alumni Association honored him with the Distinguished Alumnus Award in March 1988.

Walter H. Plosila is President of the Montgomery County (Maryland) High Technology Council, Inc., and the Suburban Maryland Technology Council, both educational nonprofit membership organizations of high tech firms, support industry, federal laboratories, and higher education institutions. Dr. Plosila has a PhD from the University of Pittsburgh and an MA from Pennsylvania State University. Before holding his current position, Dr. Plosila was Deputy Secretary for Technology and Policy Development of the Pennsylvania Department of Commerce, where he was responsible for formulating overall economic development strategies and policies, and developing and implementing such technology programs as the Ben Franklin Partnership Programs. Dr. Plosila has served as President of the National Council on State Planning Agencies and was the Director of the Pennsylvania Governor's Office of Policy and Planning.

Donna E. Shalala is professor of Political Science and Chancellor of the University of Wisconsin–Madison. Dr. Shalala was recently named one of the top five managers in higher education by *Business Week* magazine. Dr. Shalala spent her academic career on the faculty of Columbia University. During the Carter Administration she served as Assistant Secretary for Policy Development and Research at the U.S. Department of Housing and Urban Development. Before coming to the University of Wisconsin–Madison, Dr. Shalala was President of Hunter College of the City University of New York for seven years. Dr. Shalala has been the recipient of a Guggenheim Fellowship and a Japan Society Leadership Fellowship. She has published extensively in the areas of politics and finance.

Luther S. Williams was appointed Assistant Director of Education and Human Resources for the National Science Foundation on June 1, 1990. Dr. Williams earned a BA degree in biology with distinction from Miles College, an MS from Atlanta University, and a PhD in microbial physiology from Purdue University. Dr. Williams's academic career in biology included appointments at Purdue University, the Massachusetts Institute of Technology, and Washington University. Williams joined the National Institutes of Health in 1987 as Special Assistant to the Director, National Institute of General Medical Sciences. He chaired the White House Biotechnology Science Coordinating Committee and is Vice Chair of the Committee on Education and Human Resources of the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET). Before his appointment as Assistant Director at the NSF, Dr. Williams served as Senior Science Advisor to the Director of the Foundation.

Linda S. Wilson became the seventh president of Radcliffe College on July 1, 1989. A graduate of Sophie Newcomb College, Tulane University, Dr. Wilson earned a PhD in inorganic chemistry at the University of Wisconsin. She went on to teach and conduct research, and then pursued a second career devoted to the fostering and oversight of research. Dr. Wilson served on the National Commission on Research and was chair of its subcommittee on accountability. She was a member of the Director's Advisory Council of the National Science Foundation for nine years. Dr. Wilson currently serves as chair of the National Research Council's Office of Science and Engineering Personnel and is a member of the National Science Foundation's Advisory Committee of the Directorate for Education and Human Resources. She is also a member of the National Research Council's Coordinating Council for Education.

Charles E. Young is Chancellor of the University of California, Los Angeles. Chancellor Young received a BA with honors in political science from the University of California, Riverside, and an MA and a PhD in political science from UCLA. He serves as a member of the Administrative Board of the International Association of Universities, is Chairman of the Foundation for the International Exchange of Scientific and Cultural Information by Telecommunications, is a former Chairman of the Association of American Universities, and was a member of the Los Angeles Olympic Organizing Committee. He also is a member of the Government–University–Industry Research Roundtable of the National Academy of Sciences and the Business-Higher Education Forum. Chancellor Young serves as a trustee of the UCLA Foundation. He is Chairman of the Theater Group, Inc., and a director of Intel Corporation.

STAFF AND MEETING PARTICIPANTS

Duncan M. Brown is a McLean, Virginia, science writer and editor who specializes in science and technology policy, energy technology, and the environment. Since 1983, he has been president of Duncan Brown Associates, an editorial services firm whose clients include national and international research organizations. Mr. Brown holds a BA degree in philosophy and mathematics from St. Johns College in Annapolis. Mr. Brown spent six years, beginning in 1977, at the National Research Council. While there, he served as Senior Editor and principal staff writer for the Committee on Nuclear and Alternative Energy Systems, which carried out a major study of the nation's long-term energy options, published in 1980. Following completion of that study, he worked as a staff officer of the Council's Energy Engineering Board. Before joining the National Research Council, Mr. Brown was a freelance writer. From 1972 to 1975 he supervised a team of editors at Macmillan Educational Corporation in Washington, DC.

Christopher M. Coburn is Director of Public Technology Programs at Battelle Memorial Institute. At Battelle he directs a unit working with federal, state, university, and private sector organizations in cooperative technology development, commercialization, and transfer initiatives. Mr. Coburn received his Master's degree in Public Administration from George Washington University, with a concentration in science policy. He holds a BA from John Carroll University in Cleveland, Ohio. Before joining Battelle, Mr. Coburn served as Executive Director of Ohio's Thomas Edison Program and was Science and Technology Advisor to former Ohio Governor Richard F. Celeste from 1984 through 1990. He also served as Assistant Director of the Ohio Department of Development.

Marvin E. Ebel is the Acting Director, Office of Research Services at the University of Wisconsin–Madison. He earned his PhD in physics from Iowa State College and continued his academic career at Yale University and later at the University of Wisconsin. Before assuming his current responsibilities at the University of Wisconsin–Madison, Dr. Ebel was Chairman of the Physics Department, Associate Dean of the Graduate School, and Acting Director of the Office of Research Services. Dr. Ebel is a member of Phi Kappa Phi, Sigma Xi, the American Physical Society, and the American Association of University Professors.

Richard Florida is Associate Professor of Management and Public Policy in the School of Urban and Public Affairs and the Department of Engineering and Public Policy at Carnegie Mellon University. Professor Florida received his BA in political science from Rutgers College in 1979, studied political science and urban planning at the Massachusetts Institute of Technology during the early 1980s, and received his PhD in urban planning from Columbia University in 1986. Before coming to Carnegie Mellon University, he was on the faculty of Ohio State University. Professor Florida has served as principal investigator on grants from the National Science Foundation, Ford Foundation, Joyce Foundation, U.S. Economic Development Administration, and U.S. Department of Agriculture. He has been a consultant to state economic development and technology agencies, and is currently North American editor of the journal, *Regional Studies*, published by Cambridge University Press.

Stephen J. Gage has been president of the Cleveland Advanced Manufacturing Program (CAMP) since November 1990. Trained as a mechanical and nuclear engineer, Gage began his professional career in teaching and research with the University of Texas at Austin in the mid-1960s. During the 1970s, Dr. Gage was with several federal agencies in Washington, DC, including serving as EPA's Assistant Administrator for Research & Development under President Carter. He was also a White House Fellow in the President's Office of Science and Technology in 1971–1972 and spent the next two years with the President's Council on Environmental Quality. During the late 1980s, Dr. Gage headed Indiana's Corporation for Science and Technology and the Midwest Technology Development Institute. Dr. Gage is currently Vice President of Operations of the Technology Transfer Society; he has served on the Society's Board of Directors since 1987. Dr. Gage also serves on committees of the Government–University–Industry Research Roundtable.

Thomas H. Moss is Dean of Graduate Studies and Research at Case Western Reserve University, a position he has held since 1984. Dr. Moss obtained his BA from Harvard College and his PhD in physics from Cornell University. From 1968 to 1976 he was a Research Staff Member at IBM Research and adjunct assistant professor of Physics at Columbia University. In 1976 he became Staff Director and Science Advisor to Congressman George E. Brown, Jr. He became Staff Director of the Subcommittee on Science, Research, and Technology, House Committee on Science and Technology, in 1979. In 1982 Dr. Moss left Congress to join Case Western University. Dr. Moss serves as Chair of the Regents Advisory Council on Graduate Studies and is Chairman of the AAAS Committee on Science, Engineering, and Public Policy.

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3. Generic technologies provide a base of knowledge that serves many industrial sectors and many companies. They tend to be precompetitive, in the sense that the knowledge they create is far removed from marketable products. Most federal R&D programs are in this category, except for those that the federal government funds because it is the ultimate consumer. The states, being closer to the marketplace and to the companies within their boundaries, are likely to fund technology closer to the product design and production end of the technology spectrum, and more in line with the near-term needs of local industry. In addition, states are better qualified to engage in technology transfer, because they are often closer to the points of action, such as employees, plants, and public infrastructure.

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