INVESTING IN INNOVATION:

A Project Assessing Federal Technology Policies and Programs

PROMOTE PRIVATE INNOVATION

SUPPORT BASIC TECHNOLOGY RESEARCH

EMPHASIZE TECHNOLOGY DIFFUSION

USE ALL POLICY TOOLS

ADVANCE GLOBAL INNOVATION

IMPROVE GOVERNMENT EFFECTIVENESS

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The Competitiveness Policy Council
Steering Committee
Lewis Branscomb
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Investing in Innovation

Toward A Consensus Strategy for Federal Technology Policy

The Steering Committee of the Project on Technology Policy Assessment

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PREFACE

This report provides a set of six principles to guide policy for promoting innovation in support of the national policy objectives of economic growth and improved living standards. These principles are in evidence in past policies but, until now, have not been clearly articulated. It then gives specific program recommendations drawing on these principles.

The paper is a result of a project undertaken by the Science, Technology and Public Policy Program at Harvard University and sponsored by the Competitiveness Policy Council, a bipartisan federal advisory commission. The Council brings together representatives from business, labor, government, and the public to develop policy recommendations aimed at improving productivity and raising U.S. living standards. This interim report is intended to stimulate discussion and represents solely the opinions of the Steering Committee members who constitute its authors.

We have drawn heavily on the ideas and counsel of a diverse set of experts who participated in a policy conference held jointly by Harvard and the Competitiveness Policy Council in Washington, DC, on November 18–19, 1996. The conference brought together senior federal technology officials, scholars, and other stakeholders to discuss and critique the structure, goals, and performance of current technology initiatives and institutions.

The authors do not assert that these views are in every case the best course of action for the nation; the diversity of views on this point is a reflection of the decentralized nature of technology policy in America, which we strongly support. But we do hope that these principles, and the program suggestions we make to illustrate the principles, will help bring the country together in an enduring agreement for bipartisan investment that will prepare the nation for the opportunities of the next century. A comprehensive, book length discussion of these topics will be published by the MIT Press in the Spring of 1997.

We are most grateful to the Competitiveness Policy Council and its executive director Howard Rosen for their support of this project. The Sloan Foundation generously provided additional support. We would also like to express our gratitude to all of our friends and colleagues whose knowledge and insight we have relied on, and hope that this report can help to establish a stable foundation for ongoing investment in innovation as a critical national resource.

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Why Technology Policy Matters

There are few capabilities as important to our national life as those which allow us to generate, diffuse, and employ new technologies. Our standard of living is directly linked to productivity growth driven by technological innovation; both profits and higher wages depend on this growth. The nation's defense, the health of its children, the quality of its environment—all of these public goods and many others can be provided more effectively and at lower cost if the United States continues to stand at the forefront of technological achievement.

Innovation does not arise spontaneously. It is the product of private entrepreneurship, intellectual creativity, and collective effort. Patterns of innovation are growing more complex every day as countries around the world join in a global effort to create and exploit new possibilities. It is our conviction that the U.S. requires a carefully crafted, broadly supported approach to the global challenge. In short, the nation needs a sophisticated technology policy, based on a widely shared consensus.

> *The capacity of the United States both to develop new technology and to use it as a source of productivity improvement, economic growth, and rising living standards in the face of rising technical competence and competition around the world, will in large measure determine our ability to succeed and to prosper into the next century. Our nation must invest in this capacity now to secure the future.*

The 1990s: A Decade of Transformation

Although the federal government has long played an active role in developing and diffusing new technologies, and the 1972 Technology Policy Act lays down the legislative framework, it was only in 1990 that the Bush Administration published an official technology policy. Bill Clinton proposed to build aggressively on this foundation during his campaign for the Presidency, and his Administration initiated an array of programs in its first two years. The Republican victory in the Congressional elections of 1994 precipitated a backlash against these efforts and a bitter struggle ensued in which the rapid growth of federal technology programs was curtailed and in some cases reversed.

Meanwhile, American firms continued their dramatic recovery in industries that had come under extreme pressure in the 1980s. In microelectronics, computers, and automobiles, to name but a few key sectors, U.S. firms have been gaining market share. Japan and Germany, our most impressive competitors in high-tech industry, have been experiencing economic difficulties while the U.S. has enjoyed period of steady growth with low inflation. This growth has also reached the service sector, where the U.S. economy is rapidly spreading its wings. Services are now the largest contributor to our balance of trade and the source of new, higher paying jobs. Technology-based innovation in service delivery is bringing high rates of productivity growth to this sector.

A Time for Consolidation, Not Complacency

In our view, the partisan conflicts and ideological rifts of the past few years, while helping to clarify the terms of the debate over public investments in research, have made it difficult to develop a much needed consensus on the nature and scope of government investment in and promotion of innovation. This report outlines a set of principles that we believe can bring about that consensus. Continuing the current policy impasse will not only deny Americans the full fruits of its creative talents, but will also handicap the nation as it competes throughout the world.

The principles for government technology policy take into account new realities. It recognizes that the Cold War is over and that direct federal spending on R&D and procurement to meet well-defined public missions is no longer the default mode for technology policy. The public sector must engage with private institutions to deliver economic benefits and to satisfy health, energy, environmental, and many other needs. It recognizes that the structure of industry and the strategies for industrial innovation have profoundly changed.[1] There are new critical sectors and new ways of doing business in established industries. And it recognizes that money is tight. Every dollar is carefully scrutinized before it is invested, and the returns must be accounted for afterwards.

The Opportunity

This new model for technology policy is based on encouraging and leveraging private investment in the development and effective use of technology, for realizing both public and private goals. If increased reliance is to be placed on private institutions for solving public as well as private problems, government must invest in the knowledge base and the training of creative people. While human resource development is not the focus of this paper, it is an essential element of the nation's capacity for innovation.

The model encourages initiative in problem-solving at the state and local government level as well as in the private sector. The states, for example, have demonstrated that innovation-based economic development strategies, if properly managed, can succeed without attracting criticisms

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[1] See Appendix A for a more detailed discussion of this topic.

about improper government interference with the market or concerns about inappropriate uses of public funds. The federal government must be a partner in problem-solving, guiding and collaborating, rather than dictating solutions. Public-private partnerships have encouraged technology transfer from government funded institutions to private industry and have provided market-based incentives to strengthen private investment.

Today, the President and the Congress have an opportunity to leave an important and enduring mark on the nation by coming to a common understanding about appropriate policies for stimulating innovation and investing in research. We believe that a technology policy based on strong principles can address the concerns of the skeptics and alleviate the fears of those who cling to the old model. To overcome the current stalemate and to help engage in a constructive dialogue over the future of federal technology policy, this report outlines six key principles which can help to revise America's technology strategy during the next four years and into the twenty-first century. We suggest, through a series of inset boxes, how these principles might be applied to specific government programs.

Six Principles

These principles reflect the view that the most appropriate and effective role for the federal government is to ensure that organizations and individuals have the knowledge, skills, and incentives to stimulate private investment in innovation. These principles are, therefore, entirely consistent with the government's central economic strategy: to encourage savings and investment rather than driving consumption. These principles can guide both a reexamination and restructuring of existing technology policies and programs and the design and development of any new technology initiatives.

1. **ENCOURAGE PRIVATE INNOVATION** *Leverage private investment in innovation to spur economic growth, improve living standards, and accomplish important government missions by creating incentives for and reducing barriers to technology development and research-based innovation.*

2. **EMPHASIZE BASIC TECHNOLOGY RESEARCH** *Focus government direct investment in science and technology for economic purposes on long-range, broadly useful research in basic technology as well as basic science—both of which produce benefits far in excess of what the private sector can capture for itself.*

3. **MAKE BETTER USE OF AVAILABLE TECHNOLOGY** *Promote effective use and absorption of technology across the economic spectrum, with special attention to the role of higher education and the states in technology diffusion.*

4. **USE ALL POLICY TOOLS, NOT JUST R&D SUPPORT** *Utilize the full range of relevant policy tools (e. g. tax incentives, regulatory reform, standards, and intellectual property rights), recognizing that different industries, technologies, and regions may call for different mixes of these policy tools.*

5. **LEVERAGE GLOBALIZATION OF INNOVATION** *Encourage U.S.-led innovation abroad as well as at home, and enable U.S. firms to get maximum benefit from world-wide sources of technical knowledge.*

6. **IMPROVE GOVERNMENT EFFECTIVENESS** *Make government a stable and reliable partner in a long-range national research effort through more effective institutions for policy development, strong and stable bipartisan support, and stronger participation by the states in policy formulation and execution.*

Investing in Innovation

PRINCIPLE 1. ENCOURAGE PRIVATE INNOVATION *Leverage private investment in innovation to spur economic growth, improve living standards, and accomplish important government missions by creating incentives for and reducing barriers to technology development and research-based innovation.*

The engine of American innovation and productivity growth is the private sector. The fuel is private investment. The combination of public and private research enables economic progress and informs decisions about the most fruitful avenues for technical advance. Private firms perform three quarters of all the R&D in America. They carry out the transformation of new science and engineering ideas into products and services from which wealth is created. Private firms are also prime sources of innovation when the government is the primary consumer of the innovation. One important federal role should be to foster an economic climate which favors private investment in R&D, and the effective and innovative use and absorption of technology by firms and organizations. Wherever possible, pursuit of technology policy should favor the use of market mechanisms, such as tax incentives and creating markets for non-market entities, such as the tradable permits for sulfur emissions, over direct government funding of R&D. But policy makers must recognize that private firms underinvest in longer range research and in research to meet public purposes. Federal interventions must encourage private investment in technology development, rather than substitute for it.

Many of the policies for encouraging private innovation are indirect and involve a wide variety of policy tools in addition to those that involve funding of technical activities. These policy tools are discussed briefly under our fourth principle, below. But there is an important middle ground in policy, especially when the government has a job to do that calls for innovative solutions. Rather than government funding the total cost of captive industries, as it has done in the past in defense, policy makers have been looking for ways to leverage private investment to get the public's needs fulfilled, while providing incentives for increased private investment that serves broad economic objectives as well as specific government requirements. The use of public-private partnerships has begun to fill that middle ground.

The Technology Reinvestment Program (TRP), now renamed the Dual Use Applications Program (DUAP), and the Defense Advanced Research Projects Agency (DARPA), both at the Department of Defense (DoD), pioneered a partnership policy by focusing on dual-use technology. The DoD moved to dual-use acquisition because it found that a captive defense industry cost too much, responded too slowly, and frequently failed to push technology as fast as market-driven firms. Rather than developing much of the Defense Department's technology through contracts with defense-specialized firms, the Dual Use Applications Program (DUAP) reaches out to commercial firms whose technology moves faster, costs less and responds more quickly to market needs. Through public-private partnerships, DoD can push the rate of advance of commercial technology and gain effective access to it for future defense needs. This is an excellent example of how strong market forces can be leveraged by prudent government cost-shared investment.

The DoD strategy can be widely applied to other agency technology missions as well. Instead of government paying 100 percent of the cost of technologies it may need to fulfill its own operational needs, government should leverage private investment in industry sectors that most nearly satisfies those needs. This can be done through cost-shared investment in technology in anticipation of both public and private use. This strategy may raise difficult problems of accounting for the distribution of public and private costs and benefits, requiring careful management of cost-sharing policy, but if America is to continue to embrace smaller, more agile government and is to rely more on private innovation for addressing public issues, it will have to balance public costs and benefits with private interest and investments.

POLLUTION REDUCTION: INCENTIVES FOR PROCESS INNOVATION COUPLED WITH REGULATORY COMPLIANCE

Environmental protection is an area where targeted incentives can advance agency missions, while promoting industrial innovation and competitiveness. Regulatory incentives alone can either discourage or motivate process innovations. This is also a ripe area for R&D partnership. Such a partnership has been conceived in the form of the Environmental Technology Initiative (ETI) in the EPA. This program is intended to balance the EPA's regulatory role with partnership with industry to encourage process technology innovations. This strategy is based on evidence that it may be possible, in many firms, to decrease polluting outputs while increasing overall process efficiency and lowering costs. Such a two-handed strategy is sound and if properly structured could accelerate environmental compliance without the economic burden that is generally assumed to be the price of a cleaner environment. Both the Japanese and German governments are providing incentives for such environmental process innovations in the conviction that the industries that move first with the best pollution reducing processes will have an advantage in world competition. To date, ETI has found little success—reflecting, perhaps, EPA's lack of experience with technology program management. For this strategy to be successful, industry must commit to an investment program which couples government research incentives with more tolerant enforcement of end-of-pipe regulations during the period when the innovations are being sought.

Appropriate cost-sharing arrangements should be a basic precept of federal technology initiatives where both public and private value is produced. The division of investment between public and private sources should reflect the relative public and private interests in the work. Basic science and technology research should be fully funded by government in most cases. Public-private partnerships, especially those from which the private partner expects to derive a near term commercial benefit, should require investment by both parties. Cost-sharing requirements from industry might be reduced in those cases where firms allow or even encourage the technology to be widely shared, for example, through a consortium of participating institutions or by holding the work non-proprietary. Cost-sharing requirements will be greater when the investment area is closer to the market.

Federal technology programs, such as the Defense Department's Dual Use Applications Program (DUAP), the Commerce Department's Advanced Technology Program (ATP), the Partnership for a New Generation of Vehicles (PNGV), and EPA's Environmental Technology Initiative (ETI), should adjust their funding ratios to reflect the minimum public investment needed to entice their participants to develop the technology. The optimum ratio will shift from project to project and in some cases during the life cycle of a project. If, as we recommend in the next section, government shifts the emphasis of these programs to more basic technology, firms may be more willing to share the results and the funding ratio may reflect the increasing public stake in the outcome.

PRINCIPLE 2: EMPHASIZE BASIC TECHNOLOGY RESEARCH *Focus government direct investment in science and technology for economic purposes on long-range, broadly useful research in basic technology as well as basic science—both of which produce benefits far in excess of what the private sector can capture for itself.*

The support of "basic research" has long enjoyed broad support as an important and appropriate role for government—and for good reason. Investments in basic scientific research since the 1940s have made the U.S. the preeminent scientific power in the world. The power of science to create opportunities for new industries has overshadowed the importance of research in "basic technologies"—the tools, materials, processes and systems thinking that, like basic science, are essential to all technical progress. It may be the discovery of a new material, the understanding of a new process, or the creation of an idea leading to a new kind of instrument. Basic technology includes activities such as the research behind the blue laser, the exploration of biosensors, and the process of polymer cross-linkage. It defines an area for federal investment that starts early in the innovation process and leads to knowledge that is often non-proprietary and widely diffusable though clearly on course for—but not yet including—industrial applications. Basic science and basic technology are inextricably linked and dependent upon one another.

When the political debate divides the world of "R&D" into basic scientific research on the one side and lumps everything else—basic technology research, applied research and development—together on the other side, a huge and vitally important area is omitted. This is the world of need-driven, creative research on new kinds of materials, new processes or ways of exploring and measuring, and new ways of doing and making things. The consequence of leaving out this "gray area" between science and commercial development is the facile assumption that if the work is not basic science it must be commercial development and therefore government has no business investing in it. Yet this represents a critical area which may otherwise be unaddressed. Product development cycles have been dramatically compressed in many industries, and competitive pressures have increased from sources both domestic and international. As a result, companies have become more and more reluctant to put resources into basic technological research that is long term, high-risk, or both, even though this research could eventually pay handsome returns to society as a whole. Increasingly, companies look outside for the innovations that basic research makes possible. As they "outsource" innovations from their supply chains (see Appendix A) and downsize their corporate research laboratories the work shifts to nearer horizons, increasing short term profits perhaps, but at the expense of intellectual assets for future growth. If the U.S. is not the most fertile seed bed for this innovation, companies will—and do—look overseas.

When the primary goal of technology investment is the stimulation of private sector innovation, government should concentrate most of its investment at the end of the innovation chain which offers the most diffuse benefits. The appropriate mix of federal investment in basic science and technology research enables new technologies and informs choices among technical strategies. When developing products for its own use, as in the military and space programs, it is appropriate for government to fund not only research but development as well. Product development is not an appropriate area for government funding when the goal is general economic development. Thus, while there are many areas of government activity where funding of basic science and technology research may be appropriate, how far government goes beyond this toward commercialization should depend on the extent to which there is a public stake in the production of the end products.

R&D agencies should receive strong support for their investments in basic technology research as well as in basic science. They should select the institutions most competent to perform the work at a high level of excellence and most able to diffuse the new knowledge to those who can best use it. A mix of institutional performers may be best, since industry, universities, and national laboratories each have their unique ways of ensuring that new work reaches the users. Firms engaged in federally funded research only need to move the ideas from laboratories to business units to see them put in practice. Students trained in universities take the new knowledge with them to their jobs. Government funded national laboratories may be particularly capable of interdisciplinary work, exchanging ideas across disciplinary boundaries. All government investment in basic technology can and should meet the same test as government investment in basic science: Is it an effective, high quality contribution to the nation's knowledge and innovation infrastructure?

This view of a balanced portfolio of publicly funded basic research—research leading to new science and new technology—is the right approach to federal research funding, not only for the National Science Foundation (NSF) and the National Institutes of Health (NIH), but also for the long term investments supporting the missions of agencies such as the Department of Commerce (DoC), the Department of Energy (DoE), the Department of Defense (DoD), and NASA. It should also be a focus of much of the government's funding for research in public-private partnerships such as ATP, PNGV, ETI, recognizing that industrial partners will also be investing in applied research and development. When government funds research in industry, government may take a share of the technical risks when returns to the public may be attractive, but firms should take most of the market risk. If this is the division of risk, much of the concern about government R&D programs distorting markets, substituting for private investment, or causing anti-competitive impacts on individual firms should be allayed. In addition, basic technology research, while longer range in nature, will generally be less expensive than development, allowing some shift in resources from development to research in public-private partnerships.

FOCUSING ON BASIC TECHNOLOGY IN PUBLIC-PRIVATE PARTNERSHIPS

When federal agencies collaborate with consortia or individual firms it is appropriate for the government to focus its investment on that part of the program which has a potentially high payoff to society, based on an attractive, if risky, technical opportunity. This has been the primary emphasis in NIST's ATP program. Keeping the technical goals ambitious and attractive means focusing on technologies that are not likely to be quickly commercialized. If a larger fraction of the work is not proprietary the rate of diffusion of benefits would increase, and concerns about anti-competitive effects (which may arise regardless of the rigor of the competitive selection process) might be reduced.

The Congress must be patient in judging the economic outcomes from these programs. The time required to realize economic benefits from industrial partnerships is longest for the most appropriate federal role—investing in basic technology research. It is quickest for the least desirable investments, such as federal subsidies to product development. This is one of the unavoidable dilemmas of technology policy.

The federal government should pursue a science and technology funding strategy of making many small bets and move away from funding large-scale megaprojects aimed at technology and market demonstrations. In the past, technology policy often centered upon taking a few large risks, pouring large sums of money into government selected technologies in the hope that such a concentrated investment would ensure success. These projects were often politically attractive but rarely achieved their goals. A better strategy is to make numerous, smaller technology investments, and to do so with a project selection mechanism that is market-based, wherever possible. Simply stated,

- Follow the NSF/NIH model of relying primarily on relatively small awards spread out among many performers, awarded competitively but funded over multiple years.

- Fund a variety of technology areas chosen with input from the technical experts from the private sector as well as from research institutions, as is done in ATP.

Of course, there are specialized research facilities that are highly capital intensive—telescopes, oceanographic ships, accelerators and the like—which, by their nature, require large capital investments. Many of these projects will, in the future, have to be planned and executed as international collaborations. Such large scale international collaborations can prove effective if grounded in sound scientific and economic—rather than political—justification, and resilient and institutionalized funding mechanisms—conceptually the same type of criteria we would advance for funding of national-level, industry consortia. However, to address the issue of commitment and accountability there must be an international institutional context to build a sense of ownership and confidence in these projects within the U.S. Congress and Administration . A multi-year appropriation of funding, subject to performance review against agreed milestones, could create such "ownership."

PRINCIPLE 3: MAKE BETTER USE OF AVAILABLE TECHNOLOGY *Promote effective use and absorption of technology across the economic spectrum, with special attention to the role of higher education and the states in technology diffusion.*

Firms need access to all available technology, not just the most recently created knowledge. Many small firms have a limited ability to choose among technologies and to make effective use of them. Public investments in technology utilization, usually made at the state and local level, have proved to have high economic leverage. The 1988 Omnibus Trade and Competitiveness Act established the Manufacturing Extension Partnership as a federal-state collaboration, and it has enjoyed an unusual degree of bipartisan support.

Technology can only be effective when people can use it. The development of a capable and competitive workforce is a key factor in this nation's business climate and is a vital area of public concern. The federal government, working closely with states and regions, should develop closer links between technology policy and work-force training and development. This will help spur the diffusion and use of technology and create strong links between technology and the creation of high-wage, high-skill jobs. America's industrial work-force varies widely in skill and education level. Some firms have adopted industrial processes normally used in low-wage developing countries to accommodate poor worker skill levels. Other firms are rapidly restructuring their manufacturing process and facilities so as to demand only a limited amount of expensive, highly skilled labor. Congress has created many publicly funded and operated training programs, but inadequate attention has been paid to creating incentives for firms to do this training as part of their overall recruiting and employment strategy.

MAINTAIN THE MANUFACTURING EXTENSION PARTNERSHIP (MEP) AND BUILD ON ITS STRENGTHS

The MEP is an effective example of federal-state partnership in technology diffusion and regional economic development. Development of the MEP Program should continue. Federal policy makers can learn from the success of this model in the development or redesign of other federal technology efforts, particularly those conducted in collaboration with the states. The existing MEP system should be linked through national networks for work-force training and development. Alliances among states have proved advantageous and should be encouraged. The sunset provisions in the 1988 Act establishing manufacturing technology centers should be modified after careful evaluation of the appropriate levels of sustaining income by each center to ensure that they do not jeopardize the continued services of the most successful centers. This evaluation should be conducted to establish whether there is a residual federal role which should be maintained to ensure the continued functioning of those high value activities which may not be fully self-sustaining. Driving MEP Centers wholly towards self-sufficiency could be counter to keeping the Centers focused on the markets they were intended to serve, and towards large firms with deeper pockets.

A historic strength of U.S. science and technology policy has been the decentralization of initiative both among and within federal agencies, and—more importantly—to universities, laboratories and industry. Today state governments are better prepared than in the past to play a growing role in this decentralization of initiative and of program management. Even as we call for more careful choices guided by national goals, we urge more attention to input from the performers and beneficiaries of federal policy. Firms in specific industry sectors tend to cluster regionally, generating an opportunity for an alliance between state governments and industry consortia for collaboration with federal agencies in technology-based development activities.

Consortia can be used to share costs and to stimulate the absorption and use of science and technology. Congress encouraged the formation of R&D consortia through the Cooperative Research Act of 1984. Consortia stimulate the diffusion of technology through the movement of people between firms and the sharing of information among participating firms. They may also generate competitive pressures which tend to keep research less proprietary and more long range in nature. Consortia will be more likely to diffuse research results rapidly and will generate less concern that federal R&D expenditures might disrupt markets or respond to political pressures. Government participation in such consortia also reduces the danger of anti-competitive behavior within the consortium.

States vary at least as much as industries in their approaches to technology-based development. Federal collaborations with states must have enough flexibility to respond to these local and regional differences. As noted above, many states have over a decade of experience at operating innovation-based economic development strategies. Increasing recognition of the significance of regional economic specialization makes the idea of geographically defined programs of development rational for economic as well as political reasons.

MAXIMIZING ATP ECONOMIC EFFECTIVENESS THROUGH REGIONALLY BASED CONSORTIA

The NIST Advanced Technology Program (ATP) may be viewed two ways: (a) as a cost-shared R&D program in which the government takes no active interest in commercialization beyond selecting one or more firms as the primary performing party; or (b) a program to use cost-shared support of advanced research as a stimulus to industrial innovation with beneficial consequences to the economy. In the first case, the technical quality of the work is the primary measure of success; commercialization and diffusion are left to activities in which the government does not participate.

In the second case government expects to see measurable economic outcomes but must avoid interfering with competitive markets. Commercialization of the research it supports is not the government's responsibility, but should be undertaken by firms organized into consortia. By this means the private sector can accelerate the diffusion of the innovations and assure the breadth of industry interest in the work, while NIST focuses its investment on opening up new technical possibilities. There are situations in which such consortia can best be realized by relying on state authorities to assemble all of the relevant institutional commitments to maximize the likelihood of economic benefits if, indeed, the objective of the program is economic development.

Applying the approach used by the NSF in its State Systemic Initiatives Program to ATP, states—or regional groups of states—would be invited to compete for selection by NIST as a regional technology-based *economic development program. Such a region-based approach should not* exclude firms located in other parts of the country from participating To qualify for selection, the state(s) would identify an industry sector—perhaps including the main elements of the supply chain as well—and create a non-profit consortium of institutions representing state agencies, the selected industries, labor, finance, education, and research. State funded technology and economic development programs might participate and cost share. The plan would delineate not only the case that the chosen sector is ripe for dramatic technical progress, but would also outline the consortium's commitments to investment, exports, worker training, and other activities that would maximize the economic leverage to be gained from ATP research support. This type of cooperative activity would be expected to go beyond the promotion of technological development, to advance industry development through development of new types of economic networks. The consortium might take responsibility for choosing specific firms for participation, subject to evaluation by NIST of technical merit. The consortium would also agree to make post-project evaluations for NIST of the economic outcomes of the total program. This proposal gets more economic leverage for NIST dollars, preserves the national standard for technical excellence, devolves to the states the task of selecting among individual firms, and creates a broadly based constituency for the program. Since ATP already invests most of its funds through "focus" areas—specific industry sectors with a compelling case for technology support—this would simply extend the principle by sharing responsibility with the private sector and the states.

PRINCIPLE 4: USE ALL POLICY TOOLS, NOT JUST R&D SUPPORT *Utilize the full range of relevant policy tools (e. g. tax incentives, regulatory reform, standards, and intellectual property rights), recognizing that different industries, technologies and regions may call for different mixes of these policy tools.*

A "one size fits all" technology policy is almost certain to be unsuccessful. Every industry is different and government agencies musts be sensitive to these differences, which may call for use of different policy tools and different mixes of science, technology, and systems research. For example, strong patent protection is essential to business success in pharmaceuticals, but less so in the computer industry, where most large firms are cross-licensed internationally. Biotechnology firms draw directly on forefront basic science, while chemical and materials firms are more dependent on advanced process technology. Furthermore, industry structures are very different. In some (chemicals, energy, communications) scale economies are vital. In others (software, materials, instruments) small and new firms are an essential source of vitality. These realities demand that government acquire much more effective means of informing itself about the conditions, needs, and opportunities of many sectors of service and manufacturing industry.

There are two broad types of policy tools: those involving the direct provision of federal funds for R&D and those which seek to further the goals of technology policy through indirect means, such as tax incentives, regulations, standards, and the like. These indirect tools may be used to provide incentives for private sector investment in research and development or may aim at enhancing the accessibility and utility of research results, both new and old. The effective use of the full range of science and technology policy tools can stimulate and encourage private investment and make those investments more effective. A variety of policy instruments can also help ensure that technology strategies meet the often quite distinct needs of different industries, regions and missions.

These indirect tools include:

Tax incentives	Broadly deployed, tax incentives can be a blunt instrument. R&D tax incentives should be targeted towards narrow policy objectives, such as encouraging diffusion, training, university-industry collaboration, or specific stages of firm development.
Trade policy	Both controls on and incentives for exports and direct foreign investment contribute to or retard U.S. firms' access to foreign technology and R&D investment.
Regulatory reform	Regulatory reform is a promising alternative to spur private investment in innovation, replacing the current framework of command-and-control regulations with a more flexible, outcome-based approach. Such efforts should not forsake high environmental standards.
Facilitation of standards development	Encouragement of commercial performance-based standards (rather than prescriptive design standards) can advance innovation and facilitate market growth.
Intellectual property law	Patent and copyright policy should be viewed as an integral part of technology policy. As such, the Patent and Trademark Office, together with the Copyright Office in the Library of Congress should be more closely linked to (and perhaps located in) the DoC Technology Administration.
Federal procurement	The large purchasing power of the federal government is a potentially powerful lever for advancing new markets.
Antitrust law and competition policy	Globalization and other factors have changed the nature of competition such that policy makers must recognize that firms compete internationally and in dimensions beyond price. Policy makers should more clearly recognize the place for technology partnerships.
Consensus building & policy analysis	The government's ability to convene stakeholders to share views and search for consensus can be very helpful, particularly if supported by policy analysis and research, like that performed by the defunct Office of Technology Assessment.

The administration has demonstrated the coordinated use of many of these tools in its management of the National Information Infrastructure (NII). The origins of the Internet were in the government funded R&D activities of universities. As computer networking matured and other telecommunications services proliferated and converted to digital technology, private investment grew and the government relied increasingly on deregulation and other indirect policy tools for the further development of the NII.

THE NATIONAL INFORMATION INFRASTRUCTURE (NII) AS A MODEL

The NII is an important, if not entirely successful, departure from prior forms of infrastructure development which were typically government-defined, government-led, and to a significant degree, government-financed. In the NII the government's role is cautiously defined but it is broad in scope. Almost every organ of government is in a position to contribute—or to impede—the development of the NII in the public interest. While the experiment is far from over, and the complex interplay of issues and pace of the market made this a difficult area in which to charter efforts at large-scale policy coordination, there is no doubt that the Internet has done a tremendous amount to advance research, education, and commerce. Serious attention must be given to the manner in which the NII can be used most effectively to advance the goals of technology policy.

Continued commitment to infrastructure development is required through the Next Generation Internet initiative and depends upon U.S. leadership in the development of a Global Information Infrastructure (GII). The development of information and communications technologies and commerce is centered in the U.S., which is uniquely positions America to play a leadership role in the development of the GII. As with the NII this will require the application of a coordinated array of policy tools. The U.S. government should encourage the development of private sector-driven organizations and standards for Internet commerce in preference to top-down regulation. It should ensure that poorly designed and implemented tax regimes do not inhibit national and global commerce, that barriers to participation and commerce remain low, and that intellectual property is appropriately protected. To succeed over the long run, this leadership effort must be principled and transparent without lapsing conspicuously into strategies to advance particular domestic interests.

PRINCIPLE 5: LEVERAGE GLOBALIZATION OF INNOVATION *Encourage U.S.-led innovation abroad as well as at home, and enable U.S. firms to get maximum benefit from world-wide sources of technical knowledge.*

U.S. technology policy must encourage and facilitate globalization and transnational collaboration, not impede it. The U.S. must learn to cooperate as well as compete, given the rapidly growing technical assets in other countries, assets which are in many cases the product of public investment. The criterion for participation should remain the U.S. self-interest, but not defined in zero sum fashion. In most cases the U.S. will prefer to leave such collaborations to firms, universities and technical associations without government involvement. But the U.S. government should consult with U.S. firms and take an active role in defining the forms of transnational technological cooperation that will be most useful to both their business interests and the larger public interest here at home.

NATIONAL TREATMENT OF FOREIGN DIRECT INVESTMENT (FDI) IN R&D ACTIVITIES

The U.S. should aim for an international investment code of policy, such as that being developed by the OECD, that allows the U.S. to permit foreign-owned R&D establishments in the U.S. to participate in domestic technology programs, such as public-private partnerships, by ensuring that foreign subsidiaries of U.S. firms enjoy equivalent access. The USTR should take increasing responsibility to press for the multilateral elimination of FDI constraints under the World Trade Organization and in efforts to establish a Multilateral Agreement on Investment (MAI).

While resolving trade conflicts tends to capture more public attention, investment in transnational collaboration and cooperation in the development of new science and technology can bring even bigger benefits. Innovation opportunities in the U.S. increasingly require access to foreign resources and markets and compatibility with the policies of other countries. The GII, where U.S. firms and institutions enjoy a commanding lead today, is an excellent example of the need for U.S. leadership in developing a harmonious international environment.

PRINCIPLE 6: IMPROVE GOVERNMENT EFFECTIVENESS *Make government a stable and reliable partner in a long-range national research effort through more effective institutions for policy development, strong and stable bipartisan support, and stronger participation by the states in policy formulation and execution.*

Strong and stable bipartisan support for technology policy is of critical importance, since technology is increasingly crucial to the health and welfare of all Americans as well as to economic growth, job generation, and rising living standards. A second requirement for bipartisanship arises from the long term nature of most government investments in research, especially under the policies we are recommending, which move back from public funding of proprietary commercial technology except when the government expects to be the purchaser of the resulting products (as in defense procurement). Just as bipartisan support for science is essential to give scientists time to complete their explorations, so too basic technology research needs continuity of support to maximize public returns. A key requirement is multi-year appropriations for research investments.

American science and technology thrives because it is supported by a pluralistic system. There are many sources of support, many types of performers and a maze of linkages amongst funders, performers, and users of science and technology. This pluralism was intended by the nation's founders, who included a patent clause in the Constitution in rejection of monopolies protected by the Crown. Pluralism has grown with the nation, through the Morrill Act establishing the land grant colleges in 1862, the development of corporate R&D laboratories in the early decades of this century, and the defense, energy, space, and medical research complexes of the past fifty years. Pluralism works because the outcomes of technological innovation cannot be predicted; they can only be discovered through real-world trials of competing ideas.

The ideas that innovators try out are organizational as well as technical. Firms may bring competing products to market but they may also develop these products in different ways. One firm might rely more heavily on external sources of technology, such as universities and government laboratories, while the other stresses in-house R&D. The final competition in the market adjudicates not only among the products, but among the competing modes of product development as well. Because of our pluralistic tradition, the U.S. has had a rich menu of technical and organizational possibilities to select from, both in the market and in pursuit of government missions, and hence a stronger probability of generating a successful option. The results are evident.

MANAGING NATIONAL LABORATORIES

One of the most successful institutional innovations of World War II and the early Cold War period was the development of a network of national laboratories based in or operating on behalf of the federal agencies. Most of them have highly qualified staffs; many of them serve pressing agency missions. But though they dominate the R&D funding portfolio of the federal government they have had considerable difficulty in adjusting to the changing needs of the nation. This is not a function of the labs so much as the rigidity of agency authorities and Congressional committee charters. The Clinton Administration attempted with little success to come to grips with the re-missioning and possible down sizing of these laboratories during its first term in office. This remains a problem of managing priorities, and requires collaboration with both Congress and the states if it is to be satisfactorily addressed.

Cooperative research and development agreements (CRADAs) solve some of the problems faced by national labs. These agreements and related mechanisms were initiated in the 1980's and, though viewed favorably by most observers, they can be made more effective. One way is to require the sharing of personnel so that the deep cultural canyons that often separate technology producers and users, and federal researchers from industrial researchers, can be crossed.

There is not and should not be a centralized technology policy process that undermines the value of pluralism. The mix of technology policy tools must be adapted across regions and industries in accordance with particular needs and established patterns. Attempting to specify the exact mix from the center would be both foolhardy and counterproductive.

Technology policy should be explicitly experimental, continually adjusted, and informed by access to expert advice and analysis

Although the market provides a relatively demanding environment for selecting the most promising private sector organizational and technological innovations, the policy process in the public sector has generally not led to equally sharp selection mechanisms. In part this is because of the difficulty of finding sufficiently measurable and objective measures of success for public policy goals in the way that corporate profitability is for corporate goals. The greater difficulty in measuring the ends of policy compared to corporate profitability contributes to this problem. Nonetheless, it is essential that policy-makers attempt to define their goals, to measure the effectiveness of technology policy in reaching them, and to use these measures as feedback for improvement. Efforts at comparison, with other nations, across missions and regions, and with private sector innovation processes, are essential. Intentional experiments, in which different arrays of tools are voluntarily employed by different agencies and their state, non-governmental, and private partners, should be encouraged. Every program should have an explicit element for evaluation and learning.

Stakeholders must be involved in technology policy development and delivery

Involving the stakeholders, such as scientists and technologists, state and local governments, industry, labor, professional associations, and public interest groups, will bring new perspectives to the development of technology policy options and rigor to testing them. The federal government has no monopoly on good ideas. It often lacks information about practices and relationships on the ground as well as about scientific and technological opportunities. With the U.S. Congress Office of Technology Assessment (OTA) *no longer available as a source of analysis, a gap remains in the* area of informed policy assessment. Federal policy-makers should systematically seek out technology policy ideas. Technology roadmaps offer a potential venue for coordination and information sharing. So do the mission-oriented forums suggested by the Carnegie Commission on Science, Technology and Government.

MAKING INFORMED TECHNOLOGY POLICY DECISIONS

In an atmosphere of decentralized decision-making, the federal government must have access to advice, data and analysis that will enable technology policy to be tailored to fit particular industries and regions. One important requirement is that the President have direct access to experienced technical professionals and innovators from the private sector. The White House Office of Science and Technology Policy (OSTP) should serve as the nerve center for this advisory process in support of the President and the NEC. The President's Council of Advisors on Science and Technology (PCAST), if better financially supported, and a restructured Critical Technologies Institute (CTI), a Federally Funded Research and Development Center dedicated to the support of the Executive Office of the President and other federal agencies, should be viewed as valuable resources for OSTP in this regard. Since PCAST also advises the President on science policy, it may be useful to link technology policy making to the National Science Board's (NSB) responsibility for both science and technology basic research by appointing the Chair of the NSB to PCAST.

The DoC Technology Administration also needs direct channels of communication with private sector technology decision-makers on issues related to innovation and commercialization of R&D. An Innovation and Technology Advisory Board could serve this purpose well, as indeed the Commerce Technology Advisory Board did in the 1960s and 70s.

State-Federal Relationships

State governments are increasingly responsible for the delivery of technology and training services and, more generally, for technology diffusion and utilization. Furthermore, innovation-based development strategies, especially those that are regional in nature, call for integration of innovation programs with training and education, as well as with other areas of policy for which the states are better equipped than are federal agencies. If state-federal collaboration is optimally to combine the best capabilities of both, the states need earlier and more influential access to federal technology policy making processes while adjustments are still possible.

U.S. INNOVATION PARTNERSHIP

The Executive Office of the President, together with the National Governors Association, is working to implement the recommendation of the State-Federal Technology Partnership Task Force, and establish the U.S. Innovation Partnership. This effort should be encouraged and supported as a mechanism for policy coordination in areas such as state-federal investment in technology-based economic development, identification of state and federal roles in the Intelligent Transportation Systems program, and strategies for environmental containment, monitoring, and remediation.

Technological innovation needs an advocate in the White House and an explicit link to economic policy

Although we oppose centralization of technology policy-making, the President and the White House staff must serve as advocates for technological innovation and coordinate the array of federal S&T activities. The Executive Office of the President must also provide the locus for linking broad national policy objectives, such as economic and security policy, with the technology agenda. The President has the long time horizon and national purview that justifies an intense interest in innovation towards advancing the quality of life in the United States. The President has the authority to promote change in the face of vested interests bent on preserving the status quo. But this does not mean that the White House should advocate every R&D program. It means that the White House should be the constituency for policy options that encourage technological innovation in the pursuit of agency missions (including non-R&D options), particularly in times of tight budgets when investments in the future are likely to be squeezed out. The Executive Office of the President must have structures that link broad national policy objectives, such as economic growth and military security, with the technology agenda. Such structures will allow S&T policies to be compared against other alternatives in the pursuit of the same mission.

INTEGRATING TECHNOLOGY POLICY WITH ECONOMIC POLICY AND OTHER NATIONAL INTERESTS

The EOP must have structures that link broad national policy objectives, such as economic growth and military security, with the technological agenda. The structures will allow S&T policies to be compared with other alternatives in pursuit of the same broad objective. The National Economic Council is the appropriate forum for weighing technology policy options as they relate to the economy. OSTP and the NSTC committees should strengthen their connections to the NEC, developing policy options for NEC consideration as well as coordinating agency activities that implement the President's decisions.

Congress must be an active, but patient and sophisticated, participant.

Members of Congress have narrower constituencies and, as a group, face the electorate more regularly than the President. It is understandable that they will be eager for immediate results. We hope that Members will recognize more fully both the importance and unpredictability of technological innovation and the necessity for the federal government to play a facilitating role in it. Congress has valuable knowledge to add to the technology policy process. Members can identify key stakeholders and ensure that their voices are heard. The Congressional support agencies perform needed program evaluations. Congress also has a central decision-making role, adjudicating among technology policy experiments. Policies that have failed must be terminated; policies that succeed must be maintained or expanded. But most importantly, policy experiments have to be tried for a sufficiently long time and under sufficiently reasonable conditions in order to be judged. The Administration's technology policy program in the first term perhaps moved to expand the experiments too quickly; Congress perhaps moved too far to hamstring or deauthorize these experiments. We hope for more patience on all sides during the next four years.

APPENDIX A: THE NEW REALTIES

Why are new technology policies needed when the old policies have brought the U.S. to a preeminent position of scientific excellence among the nations? Three changes in the world environment have made the old technology policies less effective and which necessitate the shift to a new perspective on the government's role in technology development: Changing corporate structures and relationships, globalization, and the tight fiscal constraints at the federal government level. By updating its technology policy to take into account these new realities, the United States will build for itself a better technology policy and a better future.

Changing Corporate Structures and Relationships

Mounting domestic and global competition have drastically altered the internal structure of corporations. The old mass production model of industrial organization was based upon highly centralized decision-making, an extreme functional specialization of tasks, and the separation of R&D, manufacturing, and other corporate activities. This model has given way to strategies and structures referred to variously as "lean production," the "knowledge-based firm," or the "high-performance organization." This transformation has altered the internal structure of the firm, with new emphasis on the use of teams, a high degree of task integration, decentralized decision-making, continuous innovation, organizational learning, and a blurring of the sites of innovation and production.

Firms have also changed the way they relate to other organizations—suppliers, end-users, and customers. Large multinational firms are moving away from steep vertical integration. They are focusing their activities on core functions and services and are depending upon suppliers for a much larger range of inputs. This in turn has lead to the downsizing of large corporate R&D organizations, while increasing the focus on systems integration, distribution, and full service delivery. Even as the largest service firms and manufacturers seek economies of both scale and scope through alliances, mergers and acquisitions, they seek to increase their productivity and accelerate product cycles by looking outside the firm to technologically specialized, first-tier suppliers. An important consequence of this is that an important source of technological innovation has shifted across the industrial chain to these first-tier suppliers, which are typically middle-sized or small firms without the formal R&D structures found in the larger firms.

This shift in corporate structures and relationships poses important challenges for technology policy. American technology policy has long stressed new firm creation from federally supported universities and national laboratories and emphasized federal reliance on the research talents in the largest firms, such as IBM, AT&T, and Dupont, which easily collaborate with those universities and national laboratories. In doing so, technology policy neglects several dimensions of the new corporate reality. First, it fails to take into account the organizational dimension of technological innovation—the fact that innovation requires organizational change as well as advances in technology. Second, current technology policy focuses almost exclusively on the development of new technology as opposed to bolstering the capacity of firms and organizations to more effectively absorb and utilize that technology. Technology policy has long failed to give highly innovative small and medium-sized firms the central role that they deserve. Part of the reason for this reluctance was the fact that, by necessity, small and medium sized firms had a short term perspective on research. But, as the center of industrial research shifts to these firms and away from fundamental, long-term, high-risk research, technology policy must find a way to compensate for this short term perspective.

The Global Shift

Globalization of markets, production, and technology is a defining feature of the new economy. Goods are increasingly produced where they are sold. This is reflected in the simple fact that the sales of goods produced in the global factories of multinational enterprises now totals some $6 trillion, an amount which far exceeds the $3.5 to $4 trillion generated by international trade, according to the most recent statistics compiled by the United Nations' Division on Transnational Corporations and Investment.

The past decade has seen the sweeping globalization of R&D, as corporate innovation systems have become international in scope. Today, American multinational enterprises invest nearly $15 billion per year, roughly 10 percent of their total R&D spending , in R&D laboratories located in foreign nations. Foreign companies account for more than 15 percent of all R&D conducted in the United States, and constitute large and significant shares of the American technology base in fields like chemicals and pharmaceuticals. In fact, foreign direct investment in R&D by foreign enterprises comprises the most rapidly growing segment of U.S. R&D.

Globalization challenges some of most fundamental assumptions of U.S. technology policy. Foremost among these is the notion that technology policy can somehow act upon self-contained "national systems of innovation." To the extent which all highly industrialized economies are tightly linked through the flow of technology, components, and services, U.S. technology policy must take into account the systematic, priority investments of other governments in the technological health of their private sector firms. The policy must shift to systematic concern for the quality of the U.S. work-force, the depth and breadth of new technical knowledge, the American spirit of entrepreneurship—in short the infrastructure for innovation and productivity that will make America the most attractive place for innovation.

The New Fiscal Realities

The federal budget deficit has risen in prominence and has now become the litmus test of the wisdom and efficiency of all federal programs. The deficit that was created from spending in all parts of the federal budget must now be balanced by the one seventh of the budget that makes up its discretionary spending. This is a painful process, especially for federal R&D efforts, which make up about 15% of the discretionary portion, but the commitment of both political parties to a balanced federal budget requires that government extract the maximum value from every dollar invested in the research and development of technology. This clearly places increased pressure on those very public investments which stand at the heart of U.S. technical excellence.

The new fiscal realties are also shaping a rethinking of how government can most effectively support innovation, both in the private sector and in its own operations. Such a rethinking creates the opportunity to develop new models and strategies for technology policy which can overcome existing ideological and partisan differences. A bipartisan strategy is essential to the long term stability needed to foster technology and the economic benefits that flow from technological leadership.

APPENDIX B: PROGRAM RECOMMENDATIONS

The following are intended to provide practical, programmatic recommendations, based on the principles established in this paper. This list is not intended to be exhaustive, it is merely intended to be instructive in exemplifying the type of policy action inferred by our position. And, as we explain, adhering to these principles means that specific technology initiatives will and should be stimulated by broader policy goals and missions. These recommendations are not intended as criticism, but rather as steps to fine tune and more precisely target what we see as a right-minded set of initiatives.

NSF: Support for basic technology support

The NSF budget for support of research leading to new and promising technological knowledge and capabilities should be substantially expanded, not at the expense of basic science support but as a complement to it. Indeed, the distinction between research in science and research leading to new technology is often artificial. The important distinction to be made is between research that creates new possibilities, both technical and scientific, and industrial problem solving and development, which NSF need not support directly. Industry collaboration in NSF's research work would be welcome where investigators desire, but should not be required.

NII: Coordinating a multi-policy strategy

The NII model, characterized by a decentralized authority and participation by a variety of governmental and non-governmental actors, appears to have been largely successful in guiding the development of the U.S. information infrastructure. Policy makers should consider the NII as a model for federal activity in technology development, particularly in areas in which the federal role is indirect. This is in line with Principle 4, which encourages the full utilization of all available policy tools.

For the NII itself, the NII Task Force should be replaced by an Information Technology Policy Council under the aegis of the NSTC but with close ties to the NEC. This Council should continue the decentralized, enabling strategy of the past, but should ensure that the government is well informed about the pace of change in the NII and GII, assure the funding and completion of Internet II, promote the effective use of IT to improve government efficiency and service, and coordinate the use of indirect policy tools to address issues such as universal access, privacy, security, authentication, intellectual property protection, and electronic payments.

IRS: the R&D tax credit

While the tax credit has many supporters, it has failed to gain a permanent authorization and thus does not have the influence on strategic private investments it was designed to have. In addition, it is an expensive and blunt policy tool. It is clear that a targeted R&D tax credit would be more effective than the inclusive one we now have. A study should be made to determine the most efficient incentive levels, on an industry by industry basis. Those industries which increase their R&D spending more strongly for every dollar of lost tax revenue should be favored over those industries which respond weakly to the tax credit incentive. In no case should an industry receive a tax credit where increased R&D spending is less than the loss in tax revenue. Alternative tools should also be considered, such as adjustment of depreciation rates to reflect their true rates of technical obsolescence.

EPA and DoE: ETI—Promoting industrial process change to reduce pollution at minimum cost

The EPA's Environmental Technology Initiative was an attempt to add positive incentives for process change through R&D partnerships, to the negative incentives of regulatory compliance, but it has not been successful. There are, however, many industries in which technological innovations might be discovered that would reduce effluents while actually increasing the productivity of commercial industrial processes. The government could bring to such an endeavor an imaginative and flexible approach to end-of-pipe regulation in those industry sectors where firms commit to a partnership program to explore science-based process innovations with environmental promise. The Department of Energy, with much greater experience in S&T project management and a large R&D budget, should jointly manage with EPA in a program to replace ETI with the right mixture of carrots and sticks to induce private investment and commitment to effluent minimization through process change.

Executive Office of the President: Linking technology policy to economic goals

The new U.S. Innovation Partnership brings state governments into the federal technology policy process. It can help ensure that federal agencies take full advantage of the experience and the investments of state governments in research-based economic development activities. This new institutional mechanism must be linked to agency policy making and implementation plans.

The President should ensure that the NEC incorporates the role of technology and innovation policy in its economic strategy and looks to the NSTC, the USTR and the OSTP to develop the supporting technology policies, based on ideas from the agencies and the private sector.

Technology Administration: Department of Commerce

The Technology Administration (TA) should be the primary (but not sole) focus in the executive branch for understanding the views of industry and compiling the information about U.S. industry performance and needs, on which sound technology policy must rest. To assist the TA in understanding what policy choices are available to government in its support of commercial innovation and productivity, the TA should appoint an Innovation and Technology Advisory Board, comprised primarily of entrepreneurs, innovators, and experts on innovation incentives, disincentives, and processes. Just as the Commerce Technology Advisory Board was useful in the 1960s and 1970s, the ITAB could help build the appropriate relationships between private innovators and federal policy.

ATP-NIST

ATP should stress basic technology in its award choices, especially when awards are made to single firms The ATP program has encouraged participation by firms organized into consortia, and by this means has accelerated the diffusion of the innovations and assured the breadth of industry interest in the work. There are situations in which such consortia can best be realized by relying on state authorities to assemble all of the relevant institutional commitments to maximize the likelihood of economic benefits, if, indeed, the objective of the program is economic development.

Applying the approach used by the NSF in its State Systemic Initiatives Program to ATP, states—or regional groups of states—would be invited to compete for selection by NIST as a regional technology-based economic development program. To qualify for selection, the state(s) would identify an industry sector—perhaps including the main elements of the supply chain as well—and create a non-profit consortium of institutions representing state agencies, the selected industries, labor, finance, education, and research. State funded technology and economic development programs might participate and cost share. The plan would delineate not only the case that the chosen sector is ripe for dramatic technical progress, but would also outline the consortium's commitments to investment, exports, worker training, and other activities that would maximize the economic leverage to be gained from ATP research support. The consortium might take responsibility for choosing specific firms for participation, subject to evaluation by NIST of technical merit. The consortium would also agree to make post-project evaluations for NIST of the economic outcomes of the total program. This proposal gets more economic leverage for NIST dollars, preserves the national standard for technical excellence, devolves to the states the task of selecting among individual firms, and creates a broadly based constituency for the program. Since ATP already invests most of its funds through "focus" areas—specific industry sectors with a compelling case for technology support—this would simply extend the principle by sharing responsibility with the private sector and the states.

MEP–NIST

The Manufacturing Extension Partnership (MEP) is a successful experiment in diffusing technology in collaboration with the states and should funded to allow it to continue in its development. Now that the existing MEP system has achieved national coverage with 70 centers, it should be leveraged by being linked through national networks for work-force training and development. Its mission in the diffusion of technology should broaden to include the diffusion of technical knowledge, including the tacit knowledge diffused through the work-force.

The sunset provisions in the 1988 Act establishing manufacturing technology centers should be modified after careful evaluation of the appropriate levels of sustaining income by each center to ensure that they do not jeopardize the continued services of the most successful centers. This evaluation should be conducted to establish whether there is a residual federal role which must be maintained to ensure the continued functioning of those high value activities which may not be fully self-sustaining.

PNGV and other mission-oriented partnerships

Program design and funding decisions should recognize that the technologically specialized and innovative first-tier suppliers are becoming a nexus of industrial innovation. These first-tier suppliers should be included in PNGV more directly in order to quickly facilitate the development of a new generation of vehicles and the array of complementary assets needed to successful make the transition to the new technology. With a focus on basic technology, PNGV should look to the most qualified institutions—firms, universities, or government-funded labs—to do the work, using partnerships and consortia to encourage diffusion of the benefits.

SBIR: Serving Agency Missions

All agencies are required to reserve a percentage of all R&D purchases for small business. This politically popular program has the advantage that it is unique in being dedicated to small firms, and it welcomes unsolicited proposals. With recent legislative enhancements it now represents over $1 billion in federal R&D money, which must be taken from other agency R&D activities. If the agencies are to fund not only research, but (in phase II grants) commercialization, it should be in pursuit of a "dual use" strategy, with the technical goal demonstrably related to the agency's principle—that the government should not fund commercial product development unless the resulting product contributes significantly to the government mission. NSF in particular should focus its SBIR program on technology to support the advance of the nation's S&T research capacity: instruments, new materials, sensors, platforms and systems for data acquisition, information technology, and the like.