TECHNOLOGY AND ECONOMIC PERFORMANCE

ORGANIZING THE EXECUTIVE BRANCH FOR A STRONGER NATIONAL TECHNOLOGY BASE

SEPTEMBER 1991
Reprinted MAY 1993

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.

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EXECUTIVE SUMMARY

Improved national economic performance requires sustained growth in productivity. The development and diffusion of new technology and its underlying science have been a major source of such growth.

Historically, the federal government has contributed to technological growth in many ways, indirectly through economic policies, and directly as part of traditional governmental interests in defense, space, health, science, and agriculture. Military research and development in particular created a defense industry technology base which in certain fields both led and assisted commercial technology development. In the two decades that immediately followed World War II, American commercial technology was the strongest in the world.

Three major changes have occurred in recent years. First, American commercial manufacturing leadership has eroded in many sectors—particularly the automotive, electronic, and semiconductor industries—at the same time that growth in the world technology base and the globalization of industrial activities have increased international economic interdependence. Second, in fast-moving dual-use fields (those with both commercial and defense applications), the Department of Defense has gone from being a technological leader to a follower, as commercial demands for increasingly complex components determine research and development priorities. Third, the commercial technology base has become more and more inaccessible to the military technology base in part because of complex military accounting and procurement policies and in part because commercial research and development have grown much more rapidly.

Primary responsibility for the advance and use of commercial technology rests with private industry. There is, however, an important federal role in supporting "generic" technology, i.e., technology that can contribute to a broad spectrum of uses. The Department of Defense and other federal agencies should have programs that enable their technology developments to serve commercial industry as well. In particular, the Department of Defense should replace military with dual military-industrial standards which will be guided primarily by industrial needs wherever commercial applications dominate the market.

Although in the long term there might be major organizational changes required to support generic technology, the Task Force believes that any approach that does emerge will be evolutionary and require careful evaluation and monitoring. The Task Force recommends, as a start:

- *that the National Institute of Standards and Technology (NIST) in the Department of Commerce have a central responsibility for supporting generic and pre-competitive research and development (R&D) not within the missions or R&D programs of other departments and agencies.* The recently started Advanced Technology Program could, in time, become an important vehicle for such support, although it is now funded at a very low level ($35 million). NIST should also have a key role in promoting diffusion of technology to the commercial sector.

- *that the Defense Advanced Research Projects Agency (DARPA) be transformed into a National Advanced Research Projects Agency (NARPA), to provide stronger linkages between modern military needs and high-technology commercial industry.* NARPA must retain its responsibility to the military services while helping to create a national, rather than solely a defense, technology base. In addition to its role in support of military technologies that affect more than one service, it should support (a) dual-use technologies, (b) long-range, high-risk, and generic technologies with potentially high payoff, and (c) advanced technologies leading to products designed to meet the mission objectives of non-defense government agencies when requested and supported by those agencies.

- *that other departments and agencies that support technology, such as the National Aeronautics and Space Administration (NASA), the Department of Energy, the National Science Foundation, and the National Institutes of Health, develop mechanisms for funding and diffusing pre-competitive, generic technologies that fall under their purview.*

There is need for a structure in the White House and Executive Office of the President that can develop and review federal programs and initiatives for advancing and diffusing technology, and can assure consistent and timely policy and program decisions. Many agencies and policy councils are now involved in these decisions. The Task Force recommends:

- *that the Office of Science and Technology Policy (OSTP) exercise lead responsibility in the Executive Office of the President for identifying, formulating and evaluating policy issues related to the national technology base for consideration by other appropriate Executive Office councils and offices.* OSTP should strengthen its internal analytical capabilities, and fully use the legislative

authority granted to the recently mandated Critical Technologies Institute to enable it to perform technology policy research and analysis. In analyzing and formulating technology policy issues bearing on economic performance, OSTP should work jointly with the Council of Economic Advisers.

- *that the National Security Council include in its purview broad issues of science and technology policy related to strengthening the national technology base, reflecting the substantial overlap between military and commercial technology and the rising interdependence of economic strength and national security.*

The Task Force makes additional recommendations to OSTP, to the Department of Defense, the Department of Commerce, and the other departments and agencies aimed at strengthening and broadening their interactions with the private sector, and suggests that a Presidential directive be issued to implement the recommendations.

INTRODUCTION

The assumptions upon which our economic decisions have been made in the past are changing.

The only permanent source of improved economic performance is the sustained growth of productivity, and advances in the development and use of technology and its underlying science have been a major source of such growth.[1] That is the fundamental connection between science, technology, and economic performance.[2]

The new economic context has been discussed in a variety of reports analyzing U.S. competitiveness—a world economy transformed by developments in science and technology, the rapid rise in technology-based productivity of U.S. trading partners, globalization of high-tech industry, and a relative decline in the performance of American companies.[3] Most of these trends have been evident since the early 1960s, when the U.S. share of world exports began its decline.

If the care and feeding of this vital connection could be consigned safely to normal commercial processes, our task would be easy. But both theory and experience tell us that the private sector is likely to underinvest in science and technology from the standpoint of returns to society.

The changing defense context is more recent and more radical. The relaxation of East-West tensions and the corresponding long-term reduction in defense expenditures (with its impact on the defense technology base) are forcing a restructuring of our military establishment.[4] The U.S.

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1. See, for example, *The Economic Report of the President, 1990*, or Dale W. Jorgenson et al., *Productivity and Economic Growth* (Cambridge: Harvard University Press, 1987).

2. Technology will be even more important in the future as competition for natural resources increases, and environmental protection and sustainable development become a higher priority.

3. See, for example, the reports of the Council on Competitiveness, e.g., *Picking Up the Pace: The Commercial Challenge to American Innovation* and *Gaining New Ground: Technology Priorities for America's Future* (Washington, D.C.: The Council on Competitiveness, 1988 and 1991). Another report is MIT Commission on Industrial Productivity, *Made in America: Regaining the Productive Edge* (Cambridge: MIT Press, 1989). Several related reports have discussed the defense technology base and the defense industrial base, including *Deterrence in Decay* (Washington, D.C.: Center for Strategic and International Studies, May 1989); *Holding the Edge* (Washington, D.C.: Congress of the United States, Office of Technology Assessment, OTA-ISC-420, April 1989); and National Academy of Engineering, *Technical Dimensions of International Competitiveness* (Washington, D.C.: National Academy Press, 1988).

4. *New Thinking and American Defense Technology* (New York: Carnegie Commission on Science, Technology, and Government, August 1990), pp. 11-12.

is shifting from a bipolar strategy to a new approach based on the need to respond to regional conflicts. These changes are long-term in nature, and their implications for government policies and decision-making structures are profound. This is particularly true as government and the private sector grapple with the challenges confronting our nation's continued economic pre-eminence.

In the past, U.S. defense research expenditures were large scale and defense technology was more advanced than most commercial technology. Government investments in the defense technology base helped build the commercial technology base almost inadvertently. But U.S. defense technology expenditures are now a much smaller fraction of total global expenditures, and defense-supported technology lags rather than leads the marketplace in many areas.

In the future, both economic and military security will depend on commercially-driven technology,[5] and the government must work deliberately to advance civilian as well as military capacity in order to create a true national technology base. Separate enclaves serve neither the commercial economy nor national security.

Technology innovation, development, commercialization, and distribution are fundamental to our economic performance, and industry has the primary responsibility for their effective management. Government policies and programs, however, play a crucial role in promoting that process and require a coherent decision-making structure at the highest levels of government. The organization of the Executive Branch to invent, propose, and carry out sound federal technology policy is the major focus of the Task Force and this report.

What we propose is not an industrial policy. Our proposals are designed to favor a vital national *capability*—the creation and application of new technology. The whole technical complex is involved in this process, including basic research, technology development, and the embodiment of technology in the design and production of commercially usable products.[6]

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5. The critical technology lists in appendix A substantially overlap. They are from (a) *Emerging Technologies: A Survey of Technical and Economic Opportunities* (Washington, D.C.: U.S. Department of Commerce, Technology Administration, Spring 1990), and (b) *The Department of Defense Critical Technologies Plan* (Washington, D.C.: Department of Defense, May 1989).

6. Incipient technologies, such as nuclear energy and space communication, could never have gotten started at all in a purely private market unless they had been helped to reach a certain scale or get a certain distance down the "learning curve" before they could hope to compare with existing technologies.

Successful technology policies by themselves will not ensure economic success. Many variables, including trade policies, cost of capital, investment in production capabilities, industrial structure and management, education and work-force skills will continue to affect economic performance. But the government should have the organizational capability to create and maintain a climate conducive to investment and risk-taking. The President's official statement on U.S. Technology Policy makes that point:[7]

> . . .A nation's technology policy is based on the broad principles that govern the allocation of its technological resources. Competitive market forces determine, for the most part, an optimal allocation of U.S. technological resources. Government can nonetheless play an important role by supplementing and complementing those forces. . . .The principal role of the Federal Government will be to provide an environment conducive to long-term economic vitality, and not to allow special interests to divert attention or resources from this goal.

7. Executive Office of the President, *U.S. Technology Policy* (Washington, D.C.: Office of Science and Technology Policy, September 26, 1990). See appendix B.

PART I
TECHNOLOGY POLICY AND THE CHANGING PARADIGMS

The government's ability to formulate and execute effective policies which support the development of the national technology base will be of central importance in dealing with the challenges ahead. Distinctions between the defense technology base and the civilian technology base have blurred, and their effective integration will provide an additional source of technological strength for government and industry.[8]

ECONOMIC/TECHNOLOGICAL PERFORMANCE

The erosion of U.S. technological dominance has received widespread attention. A recent report by the Department of Commerce, for example, states that the U.S. is losing ground to Japan in all but two of twelve key technologies.[9] The Computer Systems Policy Project, sponsored by the nation's largest computer manufacturers, has concluded that, if current trends continue, we will face serious problems in sixteen critical information processing technologies.[10]

Other indicators of lagging performance in leading technologies relative to those of other nations have been widely reported—for example, a decreasing percentage of U.S. patents issued to U.S. citizens, declining market shares and trade balances, and less frequent citations of U.S. research in professional literature.[11] The U.S. also faces particular problems in process technology and its application—the technology of manufactur-

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8. By technology base, we refer to both "public" technological knowledge capable of being shared and used by a large technical community and proprietary technological knowledge embedded in specific organizations.

9. *Emerging Technologies, A Survey of Technical and Economic Opportunities* (Washington, D.C.: U.S. Department of Commerce, Technology Administration, Spring 1990).

10. *Perspectives: Success Factors in Critical Technologies* (Computer Systems Policy Project, 1735 New York Avenue, NW, Suite 500, Washington, D.C. 20006; July 1990).

11. Detailed statistics are available from several sources and, for the purposes of brevity, are not repeated in this report. See, for example, the publications of the Council on Competitiveness, particularly *Gaining New Ground*, March 1991. The *Science and Engineering Indicators* reports of the National Science Board also provide great detail in these areas.

ing and production. U.S. firms have been notably slow in adapting production lines to new technologies, and where they have adapted they have done so conservatively.

The ultimate result of this erosion can be seen in the poor competitive position of particular U.S. industries dependent on those key technologies in which the decline has been most significant and of longest duration. Consider two examples: Fifteen years ago U.S. companies made 95 percent of the telephones and 80 percent of the television sets for U.S. homes. Today, U.S. companies make 25 percent of the telephones and 10 percent of the television sets sold here.[12] The Department of Commerce recently documented the shift in the U.S. telecommunications industry from a $1.1 billion trade surplus in 1978 to a $2.6 billion deficit in 1988, and concluded that the U.S. has lost the low end of the global telecommunications market.[13]

Perhaps the most widely cited example of U.S. technological erosion is the U.S. semiconductor industry. Semiconductors are vitally important since they represent the basic technology for most modern electronic processes and products. In 1970, the Japanese had none of the world market share in dynamic random access memories (D-RAMs), a particular type of semiconductor device; by 1988, the Japanese share of the vendor marketplace had reached 80 percent.[14] The 1989 report of the National Advisory Committee on Semiconductors extensively documents this and other disturbing trends in U.S. technological capability in semiconductor-related areas.

In addition to consumer electronics and computer memory chips, Japanese firms have made great inroads in autos and machine tools. German firms have built market share in many lines of industrial machinery. The loss of U.S. industrial leadership is not, however, uniform across all industries. In some important sectors such as chemicals, pharmaceuticals, aircraft and aircraft engines, U.S. firms continue to compete very effectively,[15] although even here U.S. market share is eroding.

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12. Abelson, Philip H., "Federal Policies in Transition," *Science*, 242:4886 (December 13, 1988), p.1621. The Task Force concern is not primarily about ownership of specific corporations, but rather how much of the value added is produced in the United States. Many American firms have overseas plants, and many foreign firms have American plants.

13. *U.S. Telecommunications in a Global Market* (Washington, D.C.: U.S. Department of Commerce, Technology Administration, August 1990).

14. *A Strategic Industry at Risk* (The National Advisory Committee on Semiconductors, 1555 Wilson Blvd., Suite 500, Arlington, VA 22209; November 1989), p.9.

15. The recent Council on Competitiveness report, *Gaining New Ground: Technology Priorities for America's Future* (footnote 2) describes in depth the situation in various industries.

Dominating the low end of the market provides Japanese firms with the high cash flow necessary to enable them to attack the high end successfully, and this is the "trickle-up" strategy they have followed in automobiles, machine tools, consumer electronics, personal computers, microwave ovens, and countless other areas. They have also used their mass production markets to build up a demand-driven world market share in manufacturing capital goods. Much of this involves ingenious design, but not much in the way of radical technological innovation.

Military/Strategic Posture

Scientists and engineers were mobilized in World War II, and the United States emerged from that war as the dominant international power—politically, economically, and technically. The Department of Defense strongly supported the advance of military technology after the war, and some of that technology spun off into the civilian economy. The size and scope of defense technology investments still have a powerful impact on commercial technology, but the defense technology base is increasingly dependent on developments in the commercial sector.

The importance of economic considerations in national security policy is reflected in the 1990 White House statement on "National Security Strategy of the United States":[16]

> America's national power continues to rest on the strength and resilience of our economy. To retain a position of international leadership, we need not only skilled diplomacy and strong military forces, but also a dynamic economic base with competitive agricultural and manufacturing sectors, an innovative research establishment, solid infrastructure, secure supplies of energy, and vibrant financial and service industries.

Traditionally, the national security of the United States has been viewed in terms of its military capability. Since the end of World War II, the United States has maintained an effective deterrent to war, focused primarily on the threat from the Soviet Union and the possibility of confrontation in Europe.

With the advent of profound changes in the Soviet Union, the U.S. military is undergoing a comprehensive reassessment of its strategy. In the face of Congressional criticism that the U.S. defense establishment lacks a

16. *National Security Strategy of the United States* (The White House, March 1990), p.21.

long-range strategic vision, the Pentagon is engaged in a major effort to define an effective strategy for a dramatically changing world. Despite the rather substantial scale of the Gulf war, all indicators are that the future will require a substantial reduction and re-deployment of forces, increased reliance on rapid reaction forces, and increased emphasis on reserves for support functions.

The Carnegie Commission report, *New Thinking and American Defense Technology*, emphasizes the importance of technology to this emerging defense strategy:[17]

> . . .Technology is an important insurance policy against an uncertain strategic future. It will help to preserve future options to meet a possible renewal of the Warsaw Pact threat, as well as the varied and changing but pressing demands of regional conflicts, proliferation of military technology to unstable nations, terrorism, and drugs. Preserving, and indeed broadening, the defense technology base in the face of a reduction in overall defense spending is thus an example of the "new thinking" required by the dramatic turn in world events.

Throughout the 1950s and 1960s, a major source of U.S. technological advance was the support of research and development by the Department of Defense (DoD). In 1960, DoD funded half of all U.S. R&D, and the U.S. accounted for two-thirds of all the R&D in North America and Western Europe combined.[18] Thirty years later, DoD supports just one-third of U.S. R&D, and the U.S. share of the total has dropped off to one-half. In fast-moving dual-use fields (those with both commercial and defense applications) like microelectronics, DoD has gone from being a technological leader to a follower, as commercial demands for increasingly complex components determine research and development priorities.[19]

At present, military technology, even in firms that do substantial commercial business, is essentially segregated from commercial technology. In effect the United States has two technology bases, a defense technology base and a commercial technology base. This separation could be afforded when the United States led the world in both commercial and military

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17. *New Thinking and American Defense Technology*, pp. 10-11.

18. John Alic, Lewis M. Branscomb, Harvey Brooks, Ashton B. Carter and Gerald Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World*, to be published by the Harvard Business School Press, Winter 1991-92. The title is provisional.

19. See *New Thinking and American Defense Technology*, particularly pp. 11-13.

technology. However, overall defense budgets will decline in the future, and the defense technology base will have to draw more easily from the commercial sector for national security needs. This will require the nation in the long run to have a single technology base that will serve both military and commercial needs—a *national technology base.*[20]

Moving toward a national technology base will be necessary as well for advancing the technological component of economic performance. Defense support of technology will continue to be very substantial, and—particularly in so-called "dual-use" fields—can contribute substantially to the growth of the economy.

Thus, two challenges face our national technology policy: to ensure a sufficient level and quality of effort in technology generation, and to apply technology more effectively in support of our national security and economic health.

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20. Ibid., pp. 24-27.

PART II
THE ROLE OF GOVERNMENT IN TECHNOLOGY POLICY AND PROGRAMS

Government can do many things to create and maintain an environment within which industry based in the United States can achieve success in the marketplace for goods and services. For example, it can:

- promote fiscal and monetary policies that encourage innovation and make capital readily available for technological development and its embodiment in productivity improvement.

- maintain a legal system that protects intellectual property and adapts to changes in the nature of intellectual assets, with an equitable allocation of rights as an incentive for meaningful investment.

- support a trade policy that ensures an open multilateral trading system.

- maintain a regulatory climate that stimulates innovation while promoting common benefits such as a clean environment, a stable financial system, and sound business practices.

Working with state and local governments, the federal government can help to insure:

- that the current and future work force attain a level of skill and motivation equal to or better than that of any other nation.

- that the country has in place a physical and technological infrastructure—roads, communications (including new technologies such as fiber optics), available energy and water, a capacity for investment, police and fire protection—that preserves its status as a cost-effective, efficient, and secure place to do business.

A History of Government-Industry Teamwork

In addition to these actions, of course, the federal government has had a historic role in supporting research and technological development underpinning economic performance. For example, over the last century, the government has invested in research and development in many areas that advance government missions in cooperation with the private sector:

- Agriculture — where the investment in agricultural research and extension work has multiplied crop yields and productivity.
- Health — where the National Institutes of Health and other federal agencies have greatly increased our understanding and capacity for control of disease.
- Space — where our concern over Sputnik made possible a revolution in communications and opened up new vistas for deeper understanding of the planetary environment and the universe.
- Defense — where government and industry teamwork has established U.S. international leadership, particularly in aircraft and computing.
- Energy — where research on peaceful use of nuclear energy led to the development of civilian reactors.
- Basic science — where it is generally agreed the U.S. still leads the world, albeit with a declining margin.
- Graduate training — where government support has helped most of today's scientists and engineers to obtain doctoral degrees.

While this record is remarkable, it would be serendipitous if the aggregate of individual agency missions covered the full range of base technologies required for a modern competitive industrial society. Indeed, this is not the case. Some policy broader than simply the support of federal missions must drive our national technology investments. Furthermore, with the singular exception of agriculture, government is paying inadequate attention to the diffusion of government-generated technology to the people and firms that can make best use of it in the economy.

Organizing for a Strong National Technology Base

The country is strongly committed to economic advance through a market economy, one that is not directed top-down from government but rather relies on decentralized initiatives and competition within the private sector. However, there is much to be done by both the government and private industry, separately and in cooperation, to build and draw on the national technology base.[21]

The government needs an effective mechanism or process by which it can decide when it is appropriate to support or aid technological development and when that support should come exclusively from the private sector. For example, the Bush Administration believes that it is appropriate for the federal government to support "pre-competitive, generic technology."[22] What does this statement mean in operational terms? What are the criteria for deciding which technologies to emphasize? Which departments and agencies should undertake technology support? Where is the proper boundary line between government action and private initiative? Should government support be contingent upon the rapid dissemination of results to accelerate adoption? If so, how can incentives for private development investments be maintained? There must be a government decision-making structure to address these questions and then to get beyond rhetoric to build effective programs. The government must also have an assessment and evaluation capability regarding the national technology base and the ability of firms to contribute to and draw on that base.

This report centers on government's role in ensuring a strong national technology base—specifically on changes in government organization and decision making that are needed to improve its contributions to economic performance. These changes should take place within an overall strategy that takes full account of the global nature of modern industrial

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21. See *New Thinking and American Defense Technology* and appendix B.

22. The Federal Register suggests the following definitions for these terms: *Generic Technology*—A concept, component, or process, or the further investigation of scientific phenomena, that has the potential to be applied to a broad range of products or processes across many industries; *Pre-competitive Technology*—Research and development activities up to the stage where technical uncertainties are sufficiently identified to permit assessment of commercial potential and prior to development of application-specific commercial prototypes (Federal Register, Vol. 55 No. 65, April 4, 1990), p. 12505.

technology.[23] The following mechanisms are needed in the Executive Branch to develop and implement effective government technology policies:

- a structure for formulating, developing, reviewing, and evaluating federal programs and initiatives for technology, and for oversight and review of key programs.

- analytical support for that structure that is competent in both economics and technology and can assess likely long-term developments as well as respond to issues of the moment.

- a top-level decision-making process that will use the analyses effectively in reaching sound and timely policy and program decisions.

- mechanisms for assuring funding allocations to implement key science and technology programs approved by the Congress.

- effective execution, management and coordination of key programs by the appropriate departments or agencies.

23. Another task force of the Commission is dealing with improving science education, which many members believe is one of the most critical problems affecting economic performance. For this reason, this report does not deal with that issue.

PART III
FEDERAL EXECUTIVE ORGANIZATION FOR TECHNOLOGY

Decisions about federal policies involving technology and the economy are currently made in various offices and policy councils within the Executive Office of the President, depending on the issue. This division of responsibility may be appropriate for dealing with many specific questions related to technology or economic performance, but an improved mechanism for consistent policy formulation, implementation, review, and oversight is essential. There is need for a place in the Executive Office that has a comprehensive understanding of what is happening in the economy, especially in relation to technology development and diffusion, and some means to insure that policy initiatives and instruments of implementation do not act in conflict with each other.

OSTP AND THE SCIENCE ADVISER

The key official of the Executive Branch with regard to overall technology policy is the Assistant to the President for Science and Technology (the President's Science Adviser). The Science Adviser also serves as the director of the Office of Science and Technology Policy (OSTP), which was established within the Executive Office of the President by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to:

- advise the President of scientific and technological considerations involved in areas of national concern;
- evaluate the scale, quality, and effectiveness of the federal science and technology effort;
- advise the President on technological aspects of federal budgets and assist the Office of Management and Budget (OMB) with an annual review and analysis of proposed funding for research and development (R&D); and
- assist in providing leadership and coordination of federal R&D programs.

OSTP staff work with the director to discharge these responsibilities. They review agency programs, attend budget review sessions at OMB, and help the director on issues on which he advises the President. The Associate Director for Industrial Technology takes primary responsibility within the office for issues dealing with technology policy, represents OSTP on the Committee on Industry and Technology of the Federal Coordinating Council for Science, Engineering and Technology (FCCSET), and oversees the preparation of the critical technologies report mandated by Congress. He also oversaw preparation of the report, *U.S. Technology Policy*.[24]

Other Executive Office Organizations

Several offices and policy councils in the Executive Office of the President, in addition to OSTP, address issues related to technology policy.

The **Council of Economic Advisors** (CEA) advises the President on all matters of economic policy. The importance of technology and the government's role has been discussed in its annual reports. The chairman of CEA is a member of the Economic Policy Council, the Council on Competitiveness, and the Council on Foreign Investment in the United States.

The **Office of Management and Budget** has the primary budget decision-making role where agency programs are concerned or where organizational changes or legislation are called for. Its director is a member of the Economic and Domestic Policy Councils. OMB is also responsible for promoting interagency operational coordination as well as overall government procurement policy.

The **U.S. Trade Representative** is a central figure in the decision-making process on international trade matters.

The **White House Office**, and particularly the Chief of Staff, plays a key role in technology policy when Presidential decisions are called for. The Chief of Staff and the Assistant to the President for Economic and Domestic Policy are also involved on many issues before they reach the President.

The principal mechanism for analyzing policy issues for Presidential decisions that involve multiple agencies is the Cabinet-level council in the Executive Office. Five councils now deal with issues involving technology and economic performance:

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24. Executive Office of the President, *U. S. Technology Policy* (Washington, D.C.: Office of Science and Technology Policy, September 26, 1990). See appendix B.

National Security Council (NSC): The NSC staff is directed by the Assistant to the President for National Security Affairs, and its meetings are chaired by the President. The Vice President and Secretaries of State and Defense are among its members. The Chairman of the Joint Chiefs of Staff and the Director of Central Intelligence are statutory advisers. Within the policy council structure, NSC is the first among equals. The Assistant briefs the President daily. Its staff of about 100 brings together materials and policy positions from the key departments and agencies involved, and it has a formal process for implementing its decisions through the same agencies. NSC has been involved in issues involving technology required to meet national security needs and international technology transfer. It has tended to operate at the policy rather than the program level.

Economic Policy Council (EPC) and **Domestic Policy Council** (DPC): These interagency councils are chaired by the President but have chairmen *pro tem*, the Secretary of the Treasury in the case of EPC,[25] and the Attorney General for DPC.[26] EPC is the primary focus for economic policy and trade issues. It has been the major council dealing with interagency issues involving technology and the economy. DPC is concerned with interagency questions in which economic and international concerns are not considered primary. These councils have very small staffs, and their work is accomplished by using interagency working groups to develop options for review by council members. A joint EPC/DPC interagency group on science and technology has been established under the Science Adviser, but it has not been active so far.

Council on Competitiveness: The President's Council on Competitiveness is chaired by the Vice President.[27] It establishes interagency working groups, and its reports are presented to the President. The Council has focused on five issues: biotechnology, protection of property rights, product liability, regulatory relief, and the federal drug approval process.

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25. The members of EPC are: President (Chair); Secretary of the Treasury (Chair, *pro tem*); Vice President; Secretary of State; Secretary of Agriculture; Secretary of Commerce; Secretary of Labor; Secretary of Transportation; Director, Office of Management and Budget; U.S. Trade Representative; Chairman, Council of Economic Advisers; Chief of Staff to the President; Director, Office of Science and Technology Policy.

26. The members of DPC are: President (Chair); Attorney General (Chair, *pro tem*); Vice President; Secretary of Education; Secretary of Interior; Secretary of Health and Human Services; Director, Office of Management and Budget; Chief of Staff to the President; Director of the Office of Science and Technology Policy; Secretary of Housing and Urban Development; Secretary of Energy; Administrator, Environmental Protection Agency.

27. The members of the Council on Competitiveness are: Vice President (Chair); Attorney General; Secretary of the Treasury, Secretary of Commerce; Director, Office of Management and Budget; Chairman, Council of Economic Advisers; Chief of Staff to the President.

Federal Coordinating Council for Science, Engineering and Technology (FCCSET): Chaired by the director of OSTP, FCCSET membership includes department and agency heads or chief technical officials from departments and agencies involved with technical issues.[28] FCCSET's primary function is to recommend policies to promote more effective planning and administration of federal scientific, engineering, and technological programs affecting more than one federal agency. FCCSET, which often meets at Cabinet level, works through interagency working groups, often with the participation of a representative from OMB. Its reports are dealt with through the normal budget process, although OMB gives special consideration to interagency programs developed through FCCSET. It has established a Committee on Industry and Technology chaired by an Undersecretary of Commerce.

Other Executive Office councils consider special aspects of technology policy, such as the National Space Council and the Council on Environmental Quality. The President's Council of Advisers on Science and Technology (PCAST) provides an important means by which the President can obtain advice on science and technology (S&T) issues from sources outside of government.

The large number of organizations involved in the Executive Office make it difficult to have consistent mechanisms for identifying, formulating and reviewing technology policies and programs. If, in the future, the nation is to have a single national technology base, such mechanisms need to be developed.

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28. The members of FCCSET are: Assistant to the President for Science and Technology and Director, Office of Science and Technology Policy (Chair); Secretary of the Interior; Secretary of Agriculture; Secretary of Health and Human Services; Secretary of Energy; Secretary of Education; Administrator,Environmental Protection Agency; Administrator, National Aeronautics and Space Administration; Assistant to the President for National Security Affairs; Director, National Science Foundation; Under Secretary for Economic Affairs, Department of State; Deputy Secretary of Defense; Secretary, Department of Commerce; Under Secretary, Department of Housing and Urban Development; Deputy Secretary, Department of Transportation; Deputy Secretary, Department of Veterans Affairs; Director, Office of Management and Budget.

PART IV
DEVELOPING AND IMPLEMENTING TECHNOLOGY POLICY

The focus of this report is the organization of the Executive Branch to address technology policy. The report addresses several key questions:

- How should policy issues be identified and formulated?
- Where should analytical support for policy options and responses reside?
- How well does the decision-making process deal with these issues and options?
- How are decisions executed and funded?
- How is the implementation of policies monitored and evaluated?

IDENTIFYING, FORMULATING, AND EVALUATING POLICY ISSUES

Some office within the Executive Office of the President should have responsibility for dealing with the technological dimension of economic performance: developing and responding to new ideas; interacting with the nongovernmental community; and making sound and cost-effective technological judgments. The office should formulate as well as collate ideas and facilitate their consideration. Most importantly, it should be a central focal point for identifying policy issues involving more than one department or agency for consideration by the appropriate body in the Executive Office.

THE TASK FORCE RECOMMENDS that the Office of Science and Technology Policy retain and exercise lead responsibility within the Executive Office for identifying, formulating, and evaluating policy issues related to the technological aspects of economic performance.

THE TASK FORCE RECOMMENDS FURTHER that the two organizations chaired by the Science Adviser continue to play central roles in technology policy and program oversight and evaluation:

- the Federal Coordinating Council for Science, Engineering and Technology, by reviewing new program proposals and monitoring interagency policies and programs.

- the President's Council of Advisers on Science and Technology, by tapping the ideas, experience and independent views of an outstanding group of scientists, engineers, social scientists, and technologists drawn from universities and the private sector.

FCCSET and PCAST provide a broad view of pressing science and technology issues and a means to develop and monitor government-wide approaches to technology policy. PCAST, whose membership should continue to include social as well as natural scientists, has met on a number of occasions with the President and senior White House staff. Senior policy makers are increasingly active in the meetings of FCCSET. Its committees now include staff from the Office of Management and Budget (OMB), and its reports are accepted broadly within and outside the government.

The Task Force believes that OSTP and FCCSET must play central roles within the government in technology policy and program oversight and evaluation. While operational oversight should be the responsibility of each specific mission agency, policy oversight should be the responsibility of OSTP and FCCSET. Special emphasis should be given to agency activities and national technical capabilities that contribute to economic performance, including technology transfer and diffusion to and within the commercial sector. Information gained in the oversight process should feed into the policy research and analysis mechanisms proposed below, with OSTP and FCCSET playing the central role. OSTP also has an important role in monitoring agency performance. As new programs are developed, their evaluation will be a critical responsibility.

The Task Force is convinced of the vital importance of establishing productive relationships with the widest possible range of industrial and scientific/engineering organizations. The National Academies complex and particularly the recently established Manufacturing Forum can provide a

rich sounding board. Scientific, trade, and professional associations are useful resources in particular areas. OSTP is a critical link, and should be clearly charged to work with PCAST in initiating and coordinating a broad-based outreach program aimed at creating a wide network of resources.

Analytical Support for Technology Policy Development

The Task Force concludes that existing analytical support for technology decision making is inadequate. Decision making embracing economic, trade, regulatory, and technology policies would benefit from enhanced analytic capabilities. Some of the analytical work should be long-term.

The following questions illustrate the kinds of issues requiring analysis by OSTP or other Executive Office agencies:

- How do particular economic, fiscal and regulatory policies influence technological innovation and related investment and risk taking?

- What criteria should guide federal investment in pre-competitive, generic technologies and federal involvement in promoting cooperation with and among private organizations?

- How well do the various methods of coupling government-sponsored R&D with potential commercial technology work? Where are the shortcomings and successes (e.g., technology transfer from national laboratories, the Defense Advanced Research Projects Agency's technology insertion program, SEMATECH)? What are successful models of technology transfer and diffusion?

- How effective are the many state initiatives in technological development for economic growth, and what mechanisms should be used to promote their interaction with the federal government?

- What do the European and Japanese technology support programs actually involve, and in what ways are they successful or unsuccessful? Would corresponding approaches fit in our different cultural context?

THE TASK FORCE RECOMMENDS that OSTP increase its capability for technology policy analysis through a dedicated in-house analytical staff backed by adequate resources. Impartial evaluation of new and proposed government programs will be a major part of the analysis.

The National Science and Technology Policy, Organization, and Priorities Act of 1976 calls on OSTP to "initiate studies and analyses, including systems analyses and technology assessments, of alternatives available for the resolution of critical and emerging national and international problems, and insofar as possible, determine and compare probable costs, benefits, and impacts of such alternatives."

The difficulties encountered by OSTP in the past in executing its congressional mandate were documented in a 1989 report of the House Committee on Science, Space, and Technology:[29]

> The view that OSTP has been unable to execute the broad S&T policy and coordination responsibilities outlined in Public Law 94-282 has been more prevalent in recent years. In particular, the perception exists that OSTP has failed to provide the needed long-range planning required to develop a coherent national R&D effort and that coordination between federal agencies, in most cases, is suboptimal. . . . These deficiencies may be attributed to the decrease in permanent staff that has occurred in OSTP in recent years.

Since that comment was written, the OSTP budget was increased from $1.6 million in FY 1989 to $2.8 million in FY 1990 and $3.6 million for FY 1991. The FY 1989 staffing level of twelve was increased to an authorized level of thirty-nine in FY 1990 and to forty-three in FY 1991, about half of whom are professionals. Given the broad range of analyses needed, the staff will probably have to increase further, and given the recent large increase in federal pay scales, the budget will probably have to increase as well.

Outside dedicated analytical institutions such as the Rand Corporation, the Institute for Defense Analyses, and the Urban Institute have been used successfully in other areas of government, particularly defense and

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29. *Setting Priorities in Science and Technology,* Report of the Committee on Science, Space, and Technology of the U.S. House of Representatives, 101st Congress, 1st Session, HR 101-310 (Washington, D.C.: U.S. Government Printing Office, 1989), p. 9.

intelligence, where deep technical knowledge and independent technical judgment are required. If proper relationships are established, such an organization can also assure continuity and institutional memory through changing political administrations.

A possible step in this direction was taken in 1990 with the creation of the Critical Technologies Institute (CTI). CTI was created in the Defense authorization bill as a Federally Funded Research and Development Center (FFRDC) to provide research and analytic support to OSTP. Oversight is provided by a twenty-one-member board of trustees, chaired by the director of OSTP and including the Secretaries of Defense, Energy, Health and Human Services, and Commerce, the administrator of NASA, and the director of the National Science Foundation (or their designees). The board also includes four other members of FCCSET and ten members from industry and universities.

CTI's first year's budget of $5 million (which can be spent over two years) is to be used for an assessment of critical technologies and related national objectives. If this latter part of its mandate is broadly defined, the institute's reports could be very valuable not only to OSTP, but to the Executive Office as a whole. However, its initial funds come from the Department of Defense and there is no assurance that funds will be appropriated in future years. After this initial period, the bulk of the funding should come from the OSTP budget.

The Administration requested recision of the appropriation for CTI on July 23, 1991, and has opposed additional funding in the OSTP budget, on the grounds that such an office was unnecessary. The Task Force believes that the broader part of the CTI mandate concerning assessment of "related national objectives" can be an important task consistent with Administration goals.

While this potential new resource for OSTP and the Executive Office could greatly increase the government's analytic capability, contracted-for analytic capability is by its nature coupled less closely to the other parts of the Executive Office of the President than in-house capability. Both are needed.

THE TASK FORCE RECOMMENDS that OSTP establish the recently mandated Critical Technologies Institute so that it can perform technology policy research and analysis responsive to Executive Office requirements. This external capability must complement and not supplant enhanced in-house resources for OSTP.

Executive Decision Making for Technology Policy

There is a pressing need to increase the level of Presidential attention to science and technology issues bearing on economic performance. The Executive Office of the President is the locus for top-level policy decisions involving technology and the economy. Decisions about these policies are made in a large number of individual White House and Executive Office agencies and policy councils (See Part III, above). An effective mechanism is needed for assuring consistent policy oversight and decision making. An area of particular importance is the need for integration of the defense and commercial technology bases.

There is no organizational mechanism at the Presidential level currently addressing the critical policy linkage between the defense technology base and the commercial technology base. The National Security Council (NSC) is the only council with a sufficiently high stature and a sufficiently broad mandate to bridge the other councils and to consider issues of technology and economic performance within a common framework for Presidential decision making. Specifically:

- NSC has the broadest scope and capabilities of any policy council and is regularly chaired by the President;
- the Assistant to the President for National Security Affairs has daily access to the President; and
- NSC has the most highly developed staff and decision-making process among the White House councils.

THE TASK FORCE RECOMMENDS that the role of the National Security Council include concern with broad issues of science and technology policy related to the strengthening of the national technology base. This approach is based on the view that economic performance is critically important to national security and that technological vitality is of central importance to the economy.

This recommended expansion of the role of NSC is consistent with the original charter included in the National Security Act of 1947, which stated that the National Security Council should:

> . . .advise the President with respect to the integration of domestic, foreign, and military policies relating to the national security so as to enable the military services and the other departments and agencies of the government to cooperate more effectively in matters involving the national security, and
>
> . . .consider policies on matters of common interest to the departments and agencies of government concerned with the national security, and. . .make recommendations to the President in connection therewith.

In offering this approach, the Task Force recognizes that NSC has not traditionally concerned itself with economic or technology policy issues, and that certain economic and policy issues fall within the purview of other policy councils. Furthermore, the march of events around the world inevitably results in NSC giving priority attention to relatively short-term questions.

Several members of the Task Force also question whether NSC has the staff capability and outlook to permit this kind of reconceptualization of its mission. Clearly, the current structure of NSC would need to be revised, and financial and staff allocations would be required to strengthen substantially the council's economic and technological orientation and capability. NSC membership would have to continue to be augmented on occasion by the Secretary of Commerce, the Secretary of the Treasury, the United States Trade Representative, the chairman of the Council of Economic Advisers (CEA), or/and the Science Adviser.

The mechanisms already developed by the National Security Council and its staff, including ways to get decisions made and to follow up on them, lead to a consistency in approach and implementation in national security matters that is needed in the area of national economic performance. While there may be other mechanisms for the Executive Office to develop this consistency, the broadening of NSC seems the most straightforward.

Even without a reconceptualization, or as a step in that direction, NSC's mandate should be understood to include technology policy issues of immediate national security relevance. These issues include:

- maintaining an adequate technology base for military needs in the face of major defense budget cutbacks;

- controlling the international export of vital technology, while forging productive research partnerships with other governments and empowering U.S. firms to compete effectively in world markets;

- establishing national security requirements for the domestic technology base; and

- encouraging the integration of the defense technology base and the civilian technology base.

In suggesting a broader role for NSC, the Task Force stresses that it is not intended to displace related functions of the other Executive Office policy councils, such as the Economic Policy Council, the Domestic Policy Council, and the Council of Economic Advisers.

When NSC deals with issues of technology and the economy, the director of OSTP and the chairman of CEA should be involved as a matter of course. To the extent that the implemented recommendations of this report are successful, a number of the day-to-day activities of NSC will be focused on the use of science and technology to enhance economic performance and military strength.[30]

Since the role of CEA is to be the President's economic analysis staff, it cannot stand apart from the work of NSC. However, the purview of CEA goes well beyond that task. It covers advising the President on matters of fiscal and monetary policy, exchange rates, and regulation, among many others.

The staff of CEA should be available along with OSTP to provide backup for NSC, even if that means some enlargement of CEA. (It should be kept in mind, however, that the relatively small size of CEA may be an important element in its ability to maintain high intellectual standards.)

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30. The increasingly intimate interrelationship between the economic and social performance of American society and its national security and global influence is the subject of a recent article by Robert Hormats in *Foreign Affairs*. Dr. Hormats writes, "To succeed the United States will require not only vision but also more investment, more savings, more emphasis on education and more ambitious goals for research, development, and health care. It will require stronger, more purposeful economic leadership at all levels." See Robert D. Hormats, "The Roots of American Power," *Foreign Affairs* 70, no. 3 (Summer 1991), pp. 132-149.

THE TASK FORCE RECOMMENDS:

- that the National Security Council serve as a mechanism for coordinating and integrating the various policy perspectives of councils and offices in the Executive Office of the President on those matters that link national security, economic performance, and technological strength; and

- that OSTP be given responsibility for analyzing and formulating technology policy issues jointly with the Council of Economic Advisers for consideration by other appropriate Executive Office councils and offices.

Funding Technology Investment Decisions

Decisions regarding the use of technology to improve national economic performance take a variety of forms. While decisions regarding regulatory, trade, and tax policy might not require specific appropriations, decisions involving government support of technological advances or infrastructure do require funding. Timely and adequate funding is critical. The Task Force concurs with the procedure proposed in the "Federal Science and Technology Budget Priorities":[31]

> We believe that the President's Science and Technology Adviser, working closely with the director and professional staff of OMB, is best suited to coordinate both phases of the proposed S&T budget priority process. . . .
>
> Early in the budget cycle, the President should provide the agencies and departments with specific guidance on his S&T priorities in cross-cutting areas and on major S&T initiatives.
>
> Agency budget submissions should be developed, analyzed, and adjusted in terms of this initial guidance and the questions posed in the preceding discussion of the framework.

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31. National Academy of Sciences, National Academy of Engineering, Institute of Medicine, *Federal Science and Technology Budget Priorities: New Perspectives and Procedures* (Washington, D.C.: National Academy Press, 1988), p.12.

Within this framework, the Science Adviser and OMB act in a capacity of "certifying" that budget submissions reflect the Administration's technology priorities.

THE TASK FORCE RECOMMENDS:

- that OMB and OSTP interact closely throughout the fiscal year to ensure that department programs are technically strong and meet the criteria for support set by the President. The FCCSET mechanism should review for gaps or overlaps in support.

- that departments and agencies with technical missions (such as NASA, the Department of Energy, and the National Institutes of Health) develop mechanisms for funding generic and pre-competitive commercial technology under their purview. They should also act as catalysts to convene industry groups and to supply seed money for ad hoc initiatives.

- that the Department of Defense (DoD), especially through the Defense Advanced Research Projects Agency (DARPA), continue to support critical defense technologies. However, because of the importance of the commercial sector to DoD, this support should include specific mechanisms for incorporating commercial technology in military systems and shared development of dual-use technologies for use in both commercial and military markets.

- that the Department of Commerce, through the National Institute of Standards and Technology (NIST), be funded to support generic technologies that apply to a number of industries and firms through the Advanced Technology Program.[32]

- that funding for the National Science Foundation programs of research and education in both science and engineering be considered a vital part of the overall federal program to assure a strong national engineering base.

32. See pp. 36-41 for a discussion of the role and charter of DARPA and NIST.

Implementing Technology Policies

Sound technology policy decisions, based upon thoughtful and careful analytic input, are only a first step. The responsibility for implementation must rest in the Executive departments and agencies.

Particular departments and agencies (for example, NASA, National Institutes of Health (NIH), and the Departments of Defense, Commerce, Agriculture, and Transportation) have responsibilities for supporting research and development within assigned mission areas.[33] Within DoD, the Defense Advanced Research Projects Agency (DARPA) supports high-risk military technology complementary to or beyond the individual service missions. The Department of Commerce, through the Advanced Technology Program (ATP), supports pre-competitive technology that will enter the industrial base. The National Science Foundation has principal responsibility for research in the basic sciences and engineering, primarily in universities. In each case, the existing organizations contribute to the national technology base, but their missions need to be augmented or clarified to make a more effective contribution.

THE TASK FORCE RECOMMENDS:

- that the role of departments and agencies with R&D missions (DoD, USDA, DoE, NIH, NSF, NASA, etc.) be clarified with regard to the generation and diffusion of commercially relevant technologies.

- that a Presidential directive be issued defining the responsibilities of the federal government and the roles of Executive agencies for developing generic and pre-competitive R&D benefiting U.S. economic performance. The directive should be based on Presidential statements on technology policy and the 1990 annual report of the Council of Economic Advisers which endorse federal support of pre-competitive, generic technology.

33. The Steelman Report of 1947 led to the policy that agencies should support basic research that was relevant to their missions. It did not recommend that the agencies should support relevant technology development. See John R. Steelman, *Science and Public Policy: A Report to the President* (Washington, D.C.: The President's Scientific Research Board, 1947). President Eisenhower issued an executive order establishing the principle that every agency making substantial use of S&T resources should proportionally reinvest in the source of that knowledge—basic science.

No national consensus has yet emerged on whether there should be a central agency with the mission of supporting technology advancement benefiting economic performance, much less how such an agency might be organized. Some have proposed a major organizational change such as restructuring the Department of Commerce into a Department of International Trade and Industry, or creating a new R&D agency with a commercial focus—a "Civilian Advanced Research Projects Agency."

The Task Force believes that any approach which does emerge is likely to be evolutionary, which will require careful evaluation and monitoring. As a start, the Task Force has focused on (a) reinforcing a key role for the National Institute of Standards and Technology (NIST) in the Department of Commerce, and (b) enlarging the role of the Defense Advanced Research Projects Agency.

The Department of Commerce and NIST

The Technology Administration in the Department of Commerce coordinates the department's technology activities with the goal of enhancing U.S. competitiveness. It is headed by the Undersecretary for Technology. Its Office of Technology Policy has responsibility for developing policy initiatives on particular domestic and international issues, such as Japan/U.S. cooperation on intelligent manufacturing systems, identifying means of eliminating barriers to technology commercialization, and promoting technology transfer. The administration also supervises the National Technical Information Service, and NIST. Major responsibilities in the area of technology support were given to the department in the Trade Act of 1988. Among them were the Advanced Technology Program (ATP), the Manufacturing Technology Centers, and industrial extension activities. These programs are managed by NIST.

ATP enables NIST to begin to play a strong role in the development of generic technologies with commercial promise—filling in the technology gaps in agency missions and executing special commercial technology projects. It can also perform a key role in helping to catalyze scientific and technological cooperation among companies.

As envisioned by the Task Force, ATP would emphasize precompetitive, generic commercial technologies applicable over a range of industries. NIST would be expected to maintain a close relationship to commercial industry and to understand the commercialization process. It would seek to catalyze and stimulate R&D cooperation and joint ventures between and among firms. NIST's predecessor, the National Bureau of Standards, already had close connections with some industries through industrial experts serving on advisory panels as well as collaborative projects and "guest workers" from corporate laboratories.

NIST's in-house program includes materials characterization, test method development, the invention of new tools and scientific instruments, and a broad range of scientific and technical information services of industrial importance. The ATP program offers an opportunity to expand the scale of this work, and to develop mechanisms for coupling to user interests.

Manufacturing technology deserves special emphasis. Commercial industry's primary competitive problems include the cost and quality of its product and the speed with which a firm can react to market information. This is a task of incremental advance, centered on the production process. Building on the broad range of NIST experience, ATP should invest in research that supports process characterization and realization, and in the automation required to reduce cost and increase quality. The development of tools, techniques, and generic design information has been a characteristic of successful federal programs in aviation (through NASA and its predecessor, the National Advisory Committee on Aeronautics). This is also the focus of SEMATECH, the joint industry-government program to develop the semiconductor industry, and the same route taken by the Ministry of International Trade and Industry (MITI) in Japan.

An important feature of the NIST program will be to maximize the diffusion of the benefits to end users, especially those small- to mid-size firms that often are unable to perform up to the existing state of the art.[34] It would not be inappropriate for NIST to spend as much as half its development funds to insure the successful diffusion of results from the other half.

Unlike DARPA, NIST has not had much experience in contracting for external R&D projects. It will have to develop criteria for the choice of programs and direction, and these will change over time. Furthermore, mechanisms will have to be developed for coordination of the ATP program with programs in the other agencies. The FCCSET Committee on Technology and Industry could be an important forum for such exchange of information and advice.

The biennial list of critical technologies, prepared for the President by a panel of individuals from government and industry selected by OSTP, could be a useful guide to the program as it develops its priorities and criteria for choice.

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34. Erosion of the technology base may be even worse in small and intermediate supplier firms that provide components and subsystems to the large manufacturers, and their position relative to their foreign counterparts may be much weaker than that of the large multinational firms that receive the most policy attention both on the commercial and military sides. These firms, often defined by their technical specializations, are the least well connected to the U.S. science and technology system, with the exception of a few regional high-tech clusters mainly in biotechnology and microelectronics.

Over the longer term, if ATP and other external programs grow, the Technology Administration will have to develop mechanisms to enable NIST to both manage important technology programs and continue to be a major national laboratory serving the nation's industries. This may have to include new organizational arrangements within DoC.

NIST should also play an important role in increasing the ability of DoD to use commercial technology. One of the major barriers to such use stems from a rigid insistence on military specifications ("milspecs"). In some semiconductor purchases, for example, because of the need for suppliers to meet milspecs, defense buyers pay up to ten times as much as commercial buyers for equivalent parts. As quality continues to improve in U.S. manufacturing, the need for military specifications designed to insure reliability should decline. NIST should take the lead in cooperating with DoD in establishing standards that would be functionally applicable both to industrial and defense applications.[35]

THE TASK FORCE RECOMMENDS:

- that NIST have a key role in government policies for promoting technology diffusion to the commercial sector.
- that NIST be recognized as having a central responsibility for supporting generic and pre-competitive R&D that has potential commercial application over a range of industries and does not fall within the missions or R&D programs of other departments and agencies (including the proposed National Advanced Research Projects Agency). The Advanced Technology Program, although very small at present, has the potential to grow into this role.
- that NIST and DoD jointly develop standards that are functionally applicable both to defense and commercial industry.

35. See *New Thinking and American Defense Technology*, pp. 26-27.

A National Advanced Research Projects Agency

The mission of DoD's Defense Advanced Research Projects Agency is to "develop revolutionary technologies that can make a significant impact on the future of the United States defense posture, and ensure that those technologies effectively enter the appropriate forces and supporting industrial base."[36] DARPA operates with a budget of approximately $1.46 billion and approximately 160 full-time staff.

THE TASK FORCE RECOMMENDS:

- that DARPA be transformed into the National Advanced Research Projects Agency (NARPA). The precise form and timing of subsequent changes within NARPA should reflect experience with the new organizational arrangement and the need to maintain the momentum of its R&D program and close ties with the military services.

- that the charter of NARPA, building on present DARPA responsibilities, should include direct support of:

  - dual-use technologies;

  - long-range, high-risk, and generic technologies with potentially high payoff; and

  - advanced technology leading to products that would be used to meet the mission objectives of non-defense agencies, when requested by them.

The proposed restructuring of DARPA to provide stronger linkage to the technology developed by high-tech commercial industry is not intended to dilute the historic scope of DARPA and its predecessor the Advanced Research Projects Agency. The renamed agency, NARPA, would continue to be in the Department of Defense, and would continue to invest in technologies of great potential military importance viewed from a longer-term perspective than the services will or should take. Many of

36. Testimony of DARPA director Craig I. Fields before the Committee on Science, Space, and Technology of the U.S. House of Representatives, March 1, 1990.

NARPA's projects will doubtless continue to draw on firms specializing in defense work. Some, like the Stealth fighter developments in the 1980s, may be highly classified or even "black" programs. No relationship with the commercial sector can be expected with these latter programs.

An increasing fraction of the work supported by NARPA, but not all, will be dual-use technology, that is, those technologies that are useful in both the defense and commercial markets. The number of technologies vital to defense that are also the focus of heavy private investment will grow. For example, command, control, communications, and intelligence activities will be of increasing importance; these are areas in which the private sector often leads defense firms in the technical sophistication of products in the field. NARPA should help move the nation toward the creation of a national technology base. As we approach this goal, defense will benefit by getting timely and low-cost access to commercial technology, and commercial companies will benefit by the increase in research and development funds available to them for defense purposes.

Collaboration with commercial firms will change how NARPA works. With the likely contraction of defense R&D budgets, along with a substantially smaller defense establishment, NARPA will find it necessary to seek collaboration with commercial industry. This implies changes in NARPA's mode of operation and its criteria for project selection: In order to attract the collaboration of industry, there will have to be some give-and-take. NARPA will not be able to control all decisions about management or about technical goals. The cooperative agreement may prove a more appropriate tool than the contract for much of this work.

NARPA will continue to invest in qualitatively new capabilities. However, the type of work funded will probably not change that much from what DARPA is currently funding. Most DARPA technologies are aimed at exploring the feasibility of new concepts that bring qualitatively new function to defense capability. Thus, the projects often involve relatively new science and are addressed at the level of prototypes to test technical feasibility. Relatively few DARPA projects are concerned with incremental improvements for existing weapons systems—to make them cheaper, extend their accuracy, or to provide interfaces to other subsystems. This is the role for the service design and acquisition organizations.

NARPA's charter must include an emphasis on both product and process technologies.[37] Furthermore, a deep knowledge of, and close work

37. The Task Force had extensive discussions on the definitions of process technology. Though no final definition was reached, process technology, as used here, is intended to mean to improve productivity, efficiency or output, increase yield, and/or lower cost. Process technology might include such areas as manufacturing, engineering design, software design, and office productivity. There is a close relationship between product and process technology, and the Task Force does not believe the distinction is clear enough to serve as a means of defining a research mission.

ing relationship with, industry will be vital to NARPA's success. NARPA should stimulate cooperative ventures with, and within, industry, and develop techniques for the commercial diffusion of the technologies it generates. However, NARPA should not have a role in developing products for the commercial marketplace and should develop criteria for closing off funding when the technology is ready and able to be commercialized.

NARPA should approach advanced technology projects that may be requested by non-defense agencies just as DARPA currently approaches projects for the military services. The new mechanism by which OSTP develops a list of critical technologies (using input from DoD and DoC) could be a useful way to establish priorities. The Task Force recommends that the President's Science Adviser review dual-use and non-military projects of NARPA. This is in line with the recommendation contained in the Carnegie Commission's *New Thinking* report that the Assistant to the President for S&T "review and recommend new modalities for the transfer of defense technology to commercial applications and for the timely use of commercially developed technology in defense systems."[38]

The Task Force further believes that the funding for NARPA projects of interest to non-defense departments and agencies should come from those departments. Clearly, DoD would retain the major stake in NARPA and be the major source of funds. However, where non-military departments and agencies have technology needs which they believe DARPA could address effectively, they should assist it by defraying the cost of research.

The Task Force emphasizes that the proposed NARPA would not supplant the R&D activities of defense or non-defense departments and agencies. Just as the individual services currently maintain their own R&D efforts, often working in cooperation with DARPA, the non-defense agencies would continue to maintain R&D programs required to perform their missions. If NARPA shows that it can manage technology programs efficiently, these agencies can choose to fund certain NARPA projects as part of their program.

The Department of Defense

The Task Force has two additional recommendations affecting DoD, in addition to the recommendations regarding the further development of DARPA's role. First, the Department of Defense is still a major consumer of science and technology, funding more than one-seventh of the R&D performed in the industrialized world. One-third of all American scientists

38. *New Thinking and American Defense Technology*, p.25.

and engineers outside of biomedical fields work on defense projects. DoD "withdraws" from the high technology pool, and will continue to withdraw substantially in the future. It should therefore continue to make "deposits" into that pool through support of basic and applied research. It will be necessary to increase the percentage of the research, development, test and evaluation (RDT&E) budget allocated to basic and applied research if deposits are to be brought closer into balance with withdrawals.

Second, the Department of Defense reimburses contractors' overhead expenses for independent research and development (IR&D). The IR&D program should be used to encourage companies to align their defense and commercial technology efforts to the mutual benefit of both. Present DoD regulations and practices for cost recovery tend to discourage diffusion of dual-use technologies into commercial industry.

In these recommendations, the Task Force reflects its endorsement of proposals contained in the Carnegie Commission's *New Thinking* report.[39]

THE TASK FORCE RECOMMENDS:

- that, in view of the substantially increased reliance by DoD on the commercial sector for procurement of R&D-intensive products and as a major consumer of science and technology, DoD resupply the national technology base from which it draws, by increasing the proportion of the RDT&E budget that goes to basic and applied research.

- that DoD reimbursement policies for independent research and development should be interpreted to cover commercial as well as defense research expenditures, particularly where dual-use technologies or technologies identified in a national critical technology plan are involved.

Foreign Technology Assessment

Increased awareness of the contribution of R&D and technological innovation to economic growth has led U.S. trading partners to devise

39. See *New Thinking and American Defense Technology*, pp. 19 and 25.

policies and programs aimed at the support of domestic technology-intensive companies and industries. Direct government intervention in Japan and in European countries has led to pressures for similar support policies and practices in the U.S.—both individually and through the European Community.

It is difficult to gauge the effectiveness of such programs, and they may not work in the American culture. To the extent government interventions are effective, we can gain from that experience. To the extent the interventions are trade distorting, we need to resist them bilaterally and in intergovernmental forums.

THE TASK FORCE RECOMMENDS that the Department of Commerce monitor and assess the policies and practices of foreign countries and the European Community in promoting R&D and technological innovation for commercial purposes, and provide those assessments to OSTP and FCCSET for subsequent referral to a White House/Executive Office policy council, where policy response is indicated.

Other Issues

There are several other issues that the Task Force considered in its discussions. While these issues are beyond the scope of the report, they deserve mention and more detailed consideration in related or subsequent studies by the Carnegie Commission.

The Role of Congress

It is impossible to discuss the organization and decision-making aspects of national technology strategies without addressing the role of Congress. For example, Congress has taken the lead in establishing the ATP program in the Department of Commerce, in requiring OSTP to establish a list of critical technologies, and in establishing the Critical Technologies Institute. Congress's Office of Technology Assessment has written useful analyses of technological issues. Although the Task Force discussed aspects of congressional organization, it defers to the Commission's Committee on Science, Technology, and Congress to assess the mechanisms by which Congress decides on technology policies and programs.

The National Laboratories

The Task Force discussed the role of the national laboratories in the Departments of Defense and Energy in technology transfer and diffusion. The challenges and impediments in this area have been the subject of many reports, and the Task Force believes that brief mention in this document cannot do the subject justice. The Task Force does note, however, that the national laboratories, including contractor-operated laboratories, should be utilized more systematically as a source of R&D and S&T personnel for the benefit of the commercial sector. Industry personnel need to be involved early enough in the development process to influence the evolution of the technology and acquire a sense of "ownership." There may also be areas of pre-competitive, generic technology, such as improving manufacturing productivity or reliability, where the laboratories could contribute. This would be consistent with recent congressional actions amending the Stevenson-Wydler Act to emphasize the importance of technology transfer to industry.

State and Local Initiatives

State and local governments have made large investments in support of industrial development, primarily in R&D-intensive companies. Their programs and support mechanisms offer a test bed for the development of federal programs and policies promoting civilian technologies. In its discussions, the Task Force noted its concern about the adequacy of efforts by the Department of Commerce to fulfill its congressionally mandated responsibility to collect and assess information on state and local initiatives in the promotion of productivity, technology, and innovation. These assessments are important to OSTP and the FCCSET Committee on Technology and Industry as they consider the design and support of federal civilian technology programs.[40]

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40. The Commission has established a Task Force on Science, Technology and the States to review these issues in depth.

CONCLUSION

The effectiveness with which the nation as a whole acts in developing and promoting technology-based economic growth is an important factor in the future well-being of the country. As the lead actor in the national interest, the federal government has an inescapable role to play.

In the 1989 edition of its annual assessment of Soviet military power (the first in the wake of changing East-West relations), the Department of Defense states:[41]

> If the United States proves unable to compete effectively in areas of advanced technologies, it would incur the most severe economic and security consequences: markets would be lost, the U.S. industrial base would erode, and the United States would become increasingly dependent upon offshore technologies for its defense at the same time as its economic health weakens.

Of course, even high market share in areas of the most advanced technology with limited markets may not be enough. During the 1960s and most of the 1970s the U.S. comforted itself with the belief that while it was losing market share and trade balance in low-tech goods, its position at the highest-tech end of the spectrum remained secure. It failed to recognize that continuing technological change was important to the low-tech sector of commodity-like manufactured products, and that revenues from the "high end" of the technological spectrum might not be sufficient to support the rate of innovation necessary to stay ahead. The much greater mobility of technical know-how and capital that exists today leaves a much narrower window for recovery of innovation costs before a new product is superseded in the world market. Unless the U.S. can continue to enjoy the revenue for the larger low-tech end of the market it may lack the resources to sustain the required pace of innovation at the high-tech end.

Ultimately, the willingness of the Administration to move from the organizational status quo in the area of technology policy depends upon (a) its assessment of the seriousness of the domestic situation and the international threat, and (b) its view of the extent to which government technology policies will really make a difference in U.S. economic performance.

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41. United States Department of Defense, *Soviet Military Power* (Washington, D.C.: Department of Defense, 1981), p.139.

At present, there is no high-level mechanism for assessing the nature and seriousness of the problems and developing policy options to address them in cooperation with the private sector. The federal government must recognize that an international competition for technological-industrial leadership is now under way, and effective technological transfusions take a very long time.

APPENDIX A
Comparison Between Military and Civilian Critical Technologies Lists

Department of Defense Critical Technologies Report[42]	Department of Commerce Emerging Technologies[43]
composite materials	advanced materials
machine intelligence and robotics	artificial intelligence
software productivity	high-performance computing
data fusion	digital imaging technology
simulation and modeling	—
computational fluid dynamics	—
parallel computer architecture	—
signal processing	—
photonics	optoelectronics
semiconductor materials and microelectronic circuits	advanced semiconductor devices
biotechnology materials and processes	biotechnology
—	medical devices and diagnostics
—	flexible computer-integrated manufacturing
superconductivity	superconductors
passive sensors	sensor technology
sensitive radars	—
signature control	—
air-breathing propulsion	—
pulsed power	—
weapon system environment	—
hypervelocity projectiles	—
high energy density materials	—

42. *Department of Defense Critical Technologies Plan* (Washington, D.C.: Department of Defense, May 1989).

43. *Emerging Technologies: A Survey of Technical and Economic Opportunities* (Washington, D.C.: U.S. Dept. of Commerce, Spring 1990).

APPENDIX B
EXCERPT FROM *U.S. TECHNOLOGY POLICY*[44]

A nation's technology policy is based on the broad principles that govern the allocation of its technological resources. Competitive market forces determine, for the most part, an optimal allocation of U.S. technological resources. Government can nonetheless play an important role by supplementing and complementing those forces. Technology policy is not something that, once set in place, remains immutable. Broad principles exist, but effective technology policy requires sufficient flexibility to permit response to changing national and international situations. We are in an era marked by increased international economic interdependency and increasingly stronger technological capabilities in other industrial nations. These factors pose competitive challenges for U.S. firms as well as opportunities. In formulating a national technology policy, consideration must be given to a nation's traditions, its strengths and weaknesses, and the international environment in which it exists.

In almost all respects, the U.S. science and technology base remains the world's strongest. The Nation's research universities and the ability of its people to innovate remain the envy of the world. Nonetheless, industrial competitiveness depends on many factors besides technology. Our strengths in technology and innovation have not prevented an erosion in market shares of U.S. companies in many industries. As new products mature, the advantage quickly shifts from the innovator to the efficient producer. We have also seen the importance of high rates of capital investment for the industrial competitiveness of Japan, Europe, and the Pacific Rim countries.

The competitive challenges American firms face are multifaceted and complex. There will be no facile, short-term solutions. We, in this Administration, believe it is essential that we recognize and use the strengths of our economic system more effectively to help U.S. firms remain competitive. In order to do so, all elements of our society must recognize that while we possess many strengths and assets, problems do exist, and that we can mobilize our resources and solve them. At the same time, we need to refrain from actions that might distort our basic system of free enterprise — the Nation's ultimate strength.

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44. Executive Office of the President, *U.S. Technology Policy* (Washington, D.C.: Office of Science and Technology Policy, September 26, 1990), pp. 1-6 (out of 13 pages).

In order to build on its strengths, U.S. society needs to focus on ensuring:

- a quality workforce that is educated, trained, and flexible in adapting to technological and competitive change;
- a financial environment that is conducive to longer-term investment in technology;
- the translation of technology into timely, cost competitive, high quality manufactured products;
- an efficient technological infrastructure, especially in the transfer of information; and
- a legal and regulatory environment that provides stability for innovation and does not contain unnecessary barriers to private investments in R&D and domestic production.

In addition, the Federal Government, industry, and academia need to take advantage of opportunities for:

- technology transfer and research cooperation, particularly involving small and mid-sized companies;
- building upon state and regional technology initiatives; and
- mutually beneficial international cooperation in science and technology.

With its proven human resources and successful tradition of manufacturing, U.S. industry can assert the leadership required to meet the competitive challenges and to capitalize on its opportunities. The principal role of the Federal Government will be to provide an environment conducive to long-term economic vitality, and not allow special interests to divert attention or resources from this goal.

The following sections provide more detail on the Administration's goals and strategy to implement its technology policy, and then highlight some of the steps that it has already taken to improve the economic and technological competitiveness of U.S. industry.

Goal of Technology Policy

The goal of U.S. technology policy is to make the best use of technology in achieving the national goals of improved quality of life for all Americans, continued economic growth, and national security.

Strategy to Implement U.S. Technology Policy

The goal of U.S. technology policy is to be achieved by maintaining a strong science and technology base, a healthy economic environment conducive to innovation and diffusion of new technologies, and by developing mutually beneficial international science and technology relationships. Implementation of the policy must recognize that all parts of the economy — the Federal Government, state and local governments, industry, and academia — have roles to play. The education system provides the essential flow of well-trained, innovative manpower. Researchers in academia, the Federal laboratories, and industry all contribute to the science and technology base. Industry makes the investments necessary to turn this knowledge base into commercial products and processes. Federal, state, and local governments support research both directly when they fund specific R&D projects, and indirectly through tax and other incentives for private sector R&D investment. The Federal Government also sets the overall macroeconomic and legal environment in which industry's decisions about product and process development and commercialization take place.

In that context, the Administration's strategy to implement U.S. technology policy includes the following major elements:

Role of the Private Sector

While the government plays a critical role in establishing an economic environment to encourage innovation, the private sector has the principal role in identifying and utilizing technologies for commercial products and processes. In particular, the private sector has the responsibility to:

- conduct research and development to advance industry-related knowledge and technology;
- identify and aggressively pursue potential commercial applications for technologies developed by its own laboratories as well as by universities, Federal laboratories, and foreign sources;

- increase quality, output, and productivity by undertaking necessary investments in physical capital;

- improve the skills and abilities of its workforce to meet its specific needs; and

- participate cooperatively in improving the quality of U.S. education.

Government policies can help establish a favorable environment for private industry to conduct these activities, but cannot substitute for aggressive private sector action.

Government Incentives for the Private Sector

- Create an environment conducive to technological competitiveness by ensuring that technology policy concerns are factored into the formulation of related policies (e.g. fiscal, monetary, trade, environmental, etc.) with the overall objective of enhancing U.S. economic growth.

- Encourage private technology-related investment through Federal monetary and fiscal policies. For example, reducing the capital gains tax differential and making permanent as well as enhancing the tax credit for research and experimentation will provide incentives for added investment. Incentives can also be provided through appropriate tax policies.

- Provide an appropriate legal environment at the Federal level that removes unnecessary obstacles to innovation. Reducing the uncertainties about antitrust enforcement related to interfirm cooperation in research and technology development encourages the pooling of limited resources and a rapid diffusion of results while still protecting against anticompetitive practices. Reducing the antitrust uncertainties about joint production ventures will also enable firms to cooperate in the development and introduction of new products.

- Revise Federal procurement regulations and practices to permit greater integration of government and commercial production at the factory level, as well as encourage greater innovation and efficiency in development and production. Also encourage the

use of commercial products, to the extent feasible, for defense, space, and other government applications.

- Improve opportunities for companies to commercialize technologies and computer software developed during the performance of government contracts by allowing the contractors to
- retain rights in technical data and by protecting their trade secrets.

- Provide a stable regulatory environment in order to decrease risk for private investment.

- Seek greater harmonization of regulations and standards for products and processes with our major trading partners.

- Encourage increased U.S. participation in multi-lateral international standardization efforts through the standards activities of the National Institute of Standards and Technology.

- Seek better international protection of intellectual property to allow more benefits to be recovered from R&D investments.

Education and Training

- Revitalize education at all levels including not only the training of scientists, engineers, and the technical workforce, but also educating our population to be sufficiently literate in science and technology to deal with the social issues arising from rapid scientific and technical change. Achieving such a goal will require a broad-based approach involving business, academia, and educational organizations, as well as Federal, state, and local governments.

- Develop a framework for Federal interagency coordination and collaboration in mathematics, science, engineering, and technology education. The goal is to define an effective and appropriate role for the Federal government in support of the states, localities, and universities as they improve science and technology education to build human capital in the U.S.

- Encourage continuing education and training, recognizing that, particularly in scientific and technological fields, education must be a lifelong activity.

Federal R&D Responsibilities

- Increase Federal investment in support of basic research. Private industry does not invest heavily in basic research because the payoffs are so unpredictable and diffuse that individual firms cannot be confident of fully recovering their investments. However, the long-term potential benefits of this research are so large that society cannot afford not to make the investment, especially in university research, which, in addition to new knowledge, also produces trained scientists and engineers of the future.

- Participate with the private sector in pre-competitive research on generic, enabling technologies that have the potential to contribute to a broad range of government and commercial applications. In many cases these technologies have evolved from government-funded basic research, but technical uncertainties are not sufficiently reduced to permit assessment of full commercial potential. In pre-competitive research, which occurs prior to the development of application-specific commercial prototypes, research results can be shared among potential competitors without reducing the financial incentives for individual firms to develop and market commercial products and processes based upon the results.

- Continue the Federal Government's development of products and processes for which it is the sole or major consumer, such as national defense, provided that no commercially available products can be substituted. The government, in such cases, must rely principally on the private sector to undertake the development process. Revise current Federal procurement regulations to strengthen the abilities of companies involved in developing and demonstrating these products to use the same research results and technologies for commercial purposes.

- Maintain a strong Defense technology base to provide options for future weapons systems development and to help avoid technological surprises by potential adversaries. Special emphasis needs to be placed on shortening the time required for transferring R&D results to production and on using commercial products.

- Streamline Federal decision-making structures and mechanisms to eliminate unnecessary and cumbersome regulations and practices that inhibit industrial competitiveness.

- Encourage international cooperation in science and technology, where mutually beneficial, and inform U.S. researchers of opportunities to participate in R&D initiatives outside the U.S.

Transfer of Federally Funded Technology

- Improve the transfer of Federal laboratories' R&D results to the private sector. Where appropriate, these laboratories should give greater consideration to potential commercial applications in the planning and conduct of R&D, and these efforts should be guided by input from potential users. To achieve this goal, there must be a closer working relationship among these laboratories, industry, and universities. Defense-related laboratories can make major contributions while still providing adequate safeguards for classified information.

- Promote increased industry-Federal laboratory-university collaboration, including personnel exchanges, to help convert Federally-supported R&D into new technologies that the private sector can then turn into commercial products and processes.

- Promote and encourage access by U.S. industry to Federal laboratories within the guidelines established by the Federal Technology Transfer Act of 1986 (P.L. 99-502), other existing legislation, and Executive Order 12591.

- Expedite the diffusion of the results of Federally-conducted R&D to industry, including licensing of inventions and removal of barriers to commercialization of Federally developed computer software.

- Encourage direct laboratory-industry interaction within broad, flexible Federal guidelines, since effective technology transfer occurs at the operational level.

Federal-State Activities

Recognize the importance of decentralization, and encourage states to develop programs that take into account the individual characteristics of each state. Federal programs in such areas as education, training, the national infrastructure, and regional generic technology centers, should build upon state initiatives.

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