Enduring Dilemmas in U.S. Technology Policy

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During the 1992 Presidential election campaign, candidates Bill Clinton and Albert Gore emphasized their commitment to a new U.S. technology policy. According to President Clinton and Vice President Gore, their "new direction" departed from traditional U.S. technology policy, which "has been limited to support of basic science and mission-oriented research in the Defense Department, NASA [the National Aeronautics and Space Administration], and other agencies. This strategy was appropriate for a previous generation but not for today's profound challenges. We cannot rely on the serendipitous application of defense technology to the private sector. We must aim directly at these new challenges and focus our efforts on the new opportunities before us, recognizing that government can play a key role helping private firms develop and profit from innovation."[1]

The statement committed the Clinton Administration to a technology policy that would encourage the development of civilian technologies and other advances with dual uses in defense and civilian applications. No longer would U.S. technology policy rely on military-civilian technology "spillovers."

Its emphasis on support for technology adoption, its increased requests for spending in civilian technology programs, its expansion of "dual-use" technology development programs, and its rhetorical commitment to a new approach

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all distinguish Clinton Administration technology policy from those of its predecessors of the 1980s. Nevertheless, the Clinton Administration in fact carried forward many of the policies that emerged under the Reagan and Bush administrations. These pre-Clinton initiatives, most of which received bipartisan support within the Congress, have been undertaken since 1980 in response to changes in the international economic and technological environment that have reduced U.S. technological dominance and have deepened the technological and economic interdependence of the U.S. and foreign economies. These new realities not only sparked a reorientation of technology policy in the United States, but also have created persistent dilemmas for the design and implementation of technology policies.

One enduring dilemma is the tension between technology and trade policies. The economic and political changes of the past 50 years have increased the financial, trade-based, and technological links between the U.S. and foreign economies. Liberalization of the global trading system has broadened the agenda of trade policy to include many items of technology policy (e.g., domestic R&D subsidies, intellectual property protection, and even domestic competition policy). Meanwhile, the growing interest of national governments, including that of the United States, in using these instruments of technology policy for national economic goals has heightened the trade-policy implications of national technology-policy decisions since the late 1970s. Yet throughout the Reagan, Bush, and Clinton Administrations, technology and trade policies have been coordinated fitfully if at all, and frequently have been contradictory.

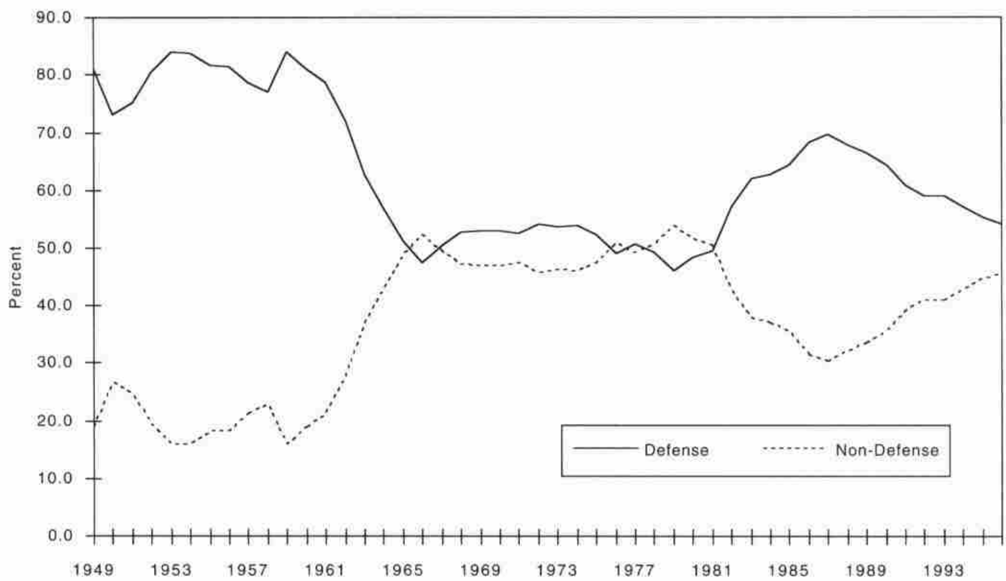
A second dilemma concerns the relationship between defense-related R&D programs and civilian technology development. This dilemma has acquired a new currency since the political upheaval of November 8, 1994, which cast a pall of uncertainty over the future survival of many of the Clinton Administration's technology policies. Although the Clinton Administration has committed itself to redirecting federal R&D spending toward non-defense activities, defense-related R&D may increase or at least maintain its present share of total federal R&D spending, regardless of how severely spending on "defense conversion" is cut. Rather than "demilitarizing" U.S. technology policy, a "remilitarization" of policy may occur, with greater emphasis on dual-use technologies in such areas as electronics and flat-panel displays. Such a development would complicate still further the relationship between the trade and technology policies of this and future Administrations.

Background: Change in the Economic and Political Environment

The Cold War Underpinnings of U.S. Technology Policy

Historically, U.S. technology "policy" has been the outcome of loosely coordinated and often inconsistent decisions made in diverse policy areas

FIGURE 1. The Conduct of Federal R&D: Defense and Non-Defense Shares (Fiscal Years 1949-1996)



Source: U.S. Office of Management and Budget (1995). Note: Outlays for FY 1995 are estimates. Outlays for FY 1996 are proposed.

designed to further the missions of individual federal agencies. These policies were motivated more by national security concerns than by any comprehensive economic strategy. During the late 1950s (see Figure 1), defense-related spending accounted for as much as 80% of federal R&D outlays. Along with defense-related procurement, this spending assisted the development of such U.S. high-technology industries as semiconductors, computers, and commercial aircraft, and it supported the enormous growth of university-based research in such areas as computer science. By the early 1980s, however, military-funded R&D and procurement contributed less and less to civilian applications, and many technological developments flowed from civilian to military applications. Because of this change in the direction of technological spillovers and the declining share of total demand accounted for by the U.S. military, the economic viability of many U.S. defense suppliers of high-technology components and systems now depends more heavily on their competitive strengths in civilian markets. The economic consequences of these developments have been heightened still further by the end of the Cold War. Combined with intensified pressure for sustained levels of domestic spending without tax increases, total defense spending during the next decade will fall below its levels of the mid-1980s.[2]

The New International Economic and Technological Environment

U.S. firms historically benefited from the postwar federal R&D budget, which amounted to nearly $73 billion in fiscal 1993 (the last pre-Clinton budget), through the spillovers from defense programs, through the relatively slow diffusion of research results across international boundaries and through the inability of many foreign firms to quickly apply these results in commercial markets. None of these conditions now applies—defense technology spillovers are less significant, scientific and technological knowledge move more quickly within the international economy, and foreign firms have dramatically improved their ability to apply the results of publicly financed R&D. During the past three decades, foreign trade and investment flows have grown in importance within the domestic U.S. economy,[3] and foreign technological capabilities have strengthened relative to those of the United States.[4] In many industries, U.S. firms now are first among equals in technological capabilities (and in others, well behind the state of the art), rather than dominant, and the economic returns from federal R&D investments are available to U.S. and foreign firms alike.

For many U.S. firms, access to foreign science and technology is increasingly important to their competitive future. This factor, the need for more rapid access to foreign markets and capital, and the obstacles to market access or investment in many industries have led U.S., Western European, and Japanese firms to broaden the international reach of their R&D operations. One response by U.S. firms has been the formation of "strategic alliances" with foreign firms to pursue joint development, manufacture, and marketing of high-technology products. During the 1980-89 period, nearly 600 "strategic technology alliances" were formed between U.S. and Japanese firms, and more than 900 between U.S. and European firms.[5] These alliances now link U.S. and foreign firms in such high-technology sectors as semiconductors (most of the members of the U.S. semiconductor consortium SEMATECH participate in alliances with European and Japanese semiconductor firms) and commercial aircraft, as well as automobiles and steel.[6] These alliances have accelerated the pace of international technology transfer and the internationalization of components sourcing, further increasing the economic and technological interdependence of U.S. and foreign firms.

Technology Policy Initiatives Prior to Clinton

Despite their rhetorical rejection of intervention in the market, significant technology policy initiatives were undertaken during the Reagan and Bush Administrations. Faced with more intense foreign competition from firms that had improved their abilities to exploit scientific advances made in U.S. and other foreign laboratories, federal policymakers began to experiment with programs that sought to strengthen civilian technological capabilities by subsidizing and promoting joint research, encouraging collaboration between U.S. universities and industry in technology development, and supporting collaboration between U.S. industry and the federal laboratories.

Programs such as the National Center for Manufacturing Sciences (NCMS), the semiconductor research consortium SEMATECH, the Defense Department's Technology Reinvestment Project (TRP), the Advanced Technology Program (ATP) of the Department of Commerce, and even the National Science Foundation's Engineering Research Centers all represented significant departures from the postwar structure of federal science and technology policy. The NCMS, SEMATECH, and TRP programs relied on expanded funding by the Defense Department for civilian technology development in dual-use technologies.

Other U.S. initiatives in technology policy during the Reagan and Bush Administrations reduced antitrust restrictions on collaboration in research and improved enforcement of intellectual property protection. In antitrust policy, these Administrations adopted a substantially more lenient enforcement posture than their predecessors, arguing that international competition had reduced the ability of U.S. firms to increase their market power through domestic mergers and acquisitions. Justice Department guidelines and review procedures for mergers were relaxed somewhat, and major federal antitrust suits against high-technology firms were dropped or settled in the early 1980s. The Reagan Administration also supported the 1984 National Cooperative Research Act, which reduced the antitrust penalties for collaboration among firms in pre-commercial research. The NCRA has been credited with facilitating the early growth and operation of the Microelectronics and Computer Technology Corporation, a research consortium involving U.S. computer and electronics firms. Nearly 400 R&D consortia have been registered during 1985-93 under the terms of the NCRA.[7] In 1993, the NCRA was extended to cover joint production ventures.

Shifts in U.S. policy toward intellectual property rights began with the 1982 legislation that established the Court of Appeals for the Federal Circuit, which strengthened the protection granted to patentholders.[8] The U.S. government also pursued stronger international protection for intellectual property rights in the Uruguay Round trade negotiations and in other bilateral venues. The faith in intellectual property rights as a critical policy tool in improving U.S. competitiveness was exemplified in two other statutes of the 1980s that sought to transform the large system of federal laboratories into sources of innovations for U.S. firms. First, the Bayh-Dole Patent and Trademark Amendments Act of 1980 (sponsored by a leading Democratic senator and Republican senator) permitted federal agencies to grant licenses to small businesses and nonprofit institutions, including universities, for patents based on research funded by federal agencies at federal and contractor-operated laboratories. Second, the Federal Technology Transfer Act of 1986 and amendments passed in 1989 authorized federal laboratories to conduct cooperative research and development agreements (CRADAs)[9] with private firms.

These pre-Clinton initiatives expanded the federal role in supporting civilian technology development, especially in specific high-technology sectors that were believed to be important to both civilian economic competitiveness and national security. A small but growing share of the defense R&D budget began to flow to dual-use technology development projects, under the approving oversight of Congress. As Figure 1 shows, the sharp increase in the ratio of defense to non-defense outlays in the federal R&D budget from approximately 50% to nearly 70% that occurred during fiscal 1979-87 was reversed before the end of the Reagan Administration, and declined further under Bush, to approximately 58%. Both of these developments prefigured trends that would continue under President Clinton.

Change in Federal Technology Policy under Clinton

Although the Clinton Administration has not dramatically shifted the direction of post-1980 U.S. technology policy, several notable changes have occurred. The Clinton Administration has endorsed and supported policies for the support of civilian technology adoption and has launched several new initiatives in support of dual-use technology development.

Commercial Technology Development and Adoption

The most dramatic shift in federal R&D spending under the Clinton Administration has occurred *within* civilian R&D spending.[10] In contrast to its role in previous Administrations, the Commerce Department became a key agency in the management of jointly funded technology development and adoption programs with firms, and its R&D budget more than doubled since fiscal 1993.[11] Much of this increase was linked to the Advanced Technologies Program (ATP), which provided matching funds for firms and consortia for the development of "pre-commercial" technologies. ATP's budget grew from $47 million in fiscal 1992 to a requested spending level of $431 million in fiscal 1995.[12]

Another area in which the Clinton Administration shifted the rhetorical posture of U.S. technology policy was in its strong backing for federal programs supporting the adoption of advanced technologies, most of which began (at the behest of Congress) under the Bush Administration.[13] The Commerce Department also received increases in budgets for industrial technology adoption, such as regional manufacturing extension programs that provide technological and management assistance to firms. For example, funding for the Manufacturing Extension Partnership program, which is administered by the National Institute for Standards and Technology (NIST) of the Commerce Department, has increased markedly under the Clinton Administration.[14]

Dual-Use Technology Development

The Clinton Administration launched several initiatives in the dual-use technology area that expanded efforts predating its accession to power. The first sought to reform defense procurement policies to encourage greater use of commercially available components, by reducing the use of "military specification" requirements for such components and revising these specifications to better accommodate commercial components. The second initiative sought to increase R&D and technology development in dual-use technologies through programs such as the TRP and others, many of which are managed by the Pentagon's Advanced Research Projects Agency. The Pentagon estimated in February 1995 that total Defense Department investment in such R&D for fiscal 1995 was slightly more than $2 billion, 25% of the Pentagon's total fiscal 1995 budget of $8.4 billion devoted to science and technology.[15]

The Department of Energy (DoE) played a prominent role in the dual-use R&D initiative. In order to sustain the weapons R&D capabilities of its huge defense-related laboratories (Los Alamos, Lawrence Livermore, and Sandia National Laboratories), DoE has expanded support for cooperative R&D agreements (CRADAs) in dual-use technologies. Energy Secretary O'Leary assigned a high priority to improving the laboratories' role in "industrial competitiveness and job creation" and argued that "the department can and should help bring taxpayer-financed research into the marketplace."[16] The number of CRADAs between DoE weapons laboratories and private firms that are supported by the Energy Department's nuclear weapons R&D budget increased from 122 in January 1993 to 326 in July 1994.

Among the most widely noted dual-use initiatives is a program to support (with over $580 million over the next 5 years) the development and production of flat-screen displays in the United States.[17] The flat-panel display initiative may be the first of several technology development programs in this area that seek to support the development of U.S. technological and manufacturing capabilities for products embodying these technologies for civilian and military markets.

Enduring Dilemmas

However consistent many of the Clinton Administration's technology policy initiatives were with the precedents established by the Reagan and Bush Administrations, the elections of November 1994 transformed the domestic political environment within which these policies are developed and implemented. The shift to Republican control of both Houses of Congress alone might not have affected the survival of many of the domestic technology programs that were initiated before Clinton's inauguration in the 1980s and early 1990s, since these enjoyed substantial bipartisan support. But the Republican membership of each House also has changed (more than 50% of the Republican Members of the House of Representatives have been elected since 1990), and has become far more conservative. The future survival of ATP and other civilian technology programs is uncertain, and the severe budget pressures that will typify the next two years will almost certainly force sizable spending reductions in these and other programs.

The new political environment likewise may frustrate the efforts of this Administration to reduce the role of defense-related R&D funding in U.S. technology policy. As the flat-panel display initiative indicates, the Pentagon budget is likely to remain important for the support of dual-use technology programs, many of which are directly relevant to the high-technology sector of this economy.[18] Given the hostility of many members of the current Congress toward civilian technology programs, technology initiatives may once again seek political shelter under a national security rationale. Rather than reorienting federal R&D toward greater support for technologies with purely civilian applications, the Clinton Administration now faces strong incentives to use defense R&D programs to support its goals in civilian technology development, in effect "remilitarizing" U.S. technology policy, and expanding the defense share of the federal R&D budget.

This new environment will intensify two dilemmas in U.S. technology policy that have been prominent since the early 1980s:

- the search for policies that support civilian technology goals through greater use of defense-related R&D spending; and
- the tension between international economic and technological interdependence and domestic technology policies that seek national economic advantage.

The Search for Dual-Use Technologies in Defense R&D

We noted earlier that the Administration's dual-use technology initiatives have focused on two key areas: procurement reform and selected technology development programs. Reform in the defense procurement process is long overdue, as are reductions in the complexity and inflexibility of the military specifications imposed on many items purchased for military uses. The second initiative, including the flat-panel displays program, is far more costly and uncertain. Indeed, Western European nations' experiences in using defense procurement to support "national champions" in high-technology industries are not encouraging—these programs frequently have resulted in weapons systems that do not meet mission requirements, manufactured by firms that are not competitive in civilian markets.[19]

Previous U.S. efforts in this area also present a mixed picture. The efforts of the past decade to expand Defense Department use of commercially available, packaged software for computer applications have been unsuccessful, while the Defense Department's "standard" software language, Ada, has languished for lack of commercial interest in developing applications.[20] The effectiveness of the Department of Energy's recent efforts to use CRADAs with U.S. firms in dual-use technologies has been impaired by administrative oversight requirements that seek to ensure that these projects benefit both industry and the laboratories' defense mission.[21]

▪ *A Test Case: The Flat-Panel Display Initiative*

The flat-panel display (FPD) initiative provides a dramatic test of the "spin-on" hypothesis. Although the program may prove to be successful, surprisingly little evidence supports the Defense Department's argument that flat-panel displays manufactured for the cost-competitive commercial market can be adapted easily to military applications. Nor do Defense Department data support its argument that existing sources of domestic supply of military-specification displays (a domestically owned, U.S. manufacturing facility) are insufficient to meet its projected requirements for these components. Some industry experts, for example, argue that military demand for displays in the year 2000 will not exceed 6-8,000 units, roughly half the Pentagon estimates of future demand. Moreover, the existing U.S. production facility is scheduled to expand its annual production capacity to at least the 15,000 units that the Pentagon's own analysis suggests will be needed by the year 2000 for military applications.[22]

Although the Pentagon argues that foreign suppliers have refused to provide the needed components to U.S. weapons systems producers, the specific instance cited in such accounts refers to a single Japanese supplier. As the Defense Department's report on flat-panel displays points out, there are a number of other Japanese suppliers of flat-panel displays.[23] Defense Department accounts of the inability of the U.S. military services to obtain the desired displays from Japanese suppliers also do not mention any efforts by U.S. agencies to invoke the obligations of the Japanese government under its 1983 Memorandum of Understanding with the U.S. government to supply militarily relevant technologies on request to U.S. defense contractors. In other words, there is little evidence that the political pressure employed on this issue was commensurate with its stated importance for U.S. national security.[24]

A number of other accounts have noted that South Korean firms are preparing to enter the production of flat-panel displays,[25] which presumably will further limit the alleged ability of Japanese firms to deny supplies to U.S. military purchasers. Indeed, the probability of entry into this industry by well-financed South Korean firms suggests that the "strategic technology" of flat-panel displays may come to resemble that of DRAMs, the semiconductor memory chips whose dominance by Japanese firms in the 1980s was supposed to result in the technological decline of the U.S. semiconductor industry. Japanese strength in DRAMs during the 1980s led to serious consideration by the Defense Department of a public-private consortium, U.S. Memories, for the production of this "strategic" commodity, in order to reduce dependence on foreign firms. In the event, U.S. Memories foundered on the unwillingness of U.S. firms to invest hundreds of millions of dollars in a risky venture. In retrospect, as the entry of South Korean firms into the production of memory chips has increased supply and depressed price and profitability, the failure of the U.S. Memories proposal seems providential.

The structure of the flat-panel display initiative also does not support the arguments of its proponents that it avoids "picking winners" among firms or technologies. This program is a multi-stage one, in which the winners of one round of competition (e.g., pre-commercial prototypes) are candidates for financial support in the next round.[26] But choices among competitors and their technological solutions at one stage will constrain and channel choices at subsequent stages. As a consequence, faced with a dynamic technology that can follow any one of a diverse array of paths of evolution, Defense Department planners will be forced to commit to specific technological alternatives under conditions of high uncertainty if the program's goal of 4 "testbed" production lines is to be realized. Moreover, Pentagon planners will have to incorporate commercial, as well as military mission, requirements into their decision making. One cannot be optimistic about the probable outcomes of such an exercise.

If the affirmative case for the flat-panel display initiative is weak, the case against it is relatively strong. First, the initiative's proponents note that it does not run afoul of prohibitions on subsidies for the production of commercial products, because of the national security rationale for the program. However faithful to the letter of these undertakings, this argument nevertheless could vitiate the hard-won Uruguay Round agreement on subsidies for high-technology industries that was among the highest priorities of U.S. trade negotiators.

Second, rather than substituting for restrictive trade policies, technology development programs like the FPD initiative may increase the incentives for firms and policymakers to pursue protection against imports. If this program results in 3-4 production plants that serve both commercial and military markets, U.S. plants could be saddled with an inefficient "dual production line" structure,[27] they will produce in smaller volumes, and will begin production at a higher (i.e., a higher-cost) point on their learning curves. As a result, the operating costs of these plants may exceed those of foreign producers. Faced with lower-cost foreign competition, the temptation to resort to protection of these plants will be strong. "Dumping" by foreign producers of lower-cost displays could be the subject of countervailing duties, leaving the United States with high-cost, technically backward displays that are of little interest to U.S. producers of civilian products.

If the flat-panel display initiative creates a noncompetitive U.S. source of supply of these components, many of the civilian economic benefits associated with the application of these components in a wide variety of consumer and industrial products could be lost or sharply reduced. Proponents of the flat-panel display initiative argue that a domestic source of supply is essential for this goal, since it prevents the interruption of supplies from foreign sources, and since close interactions between would-be users and manufacturers are necessary for successful adoption and application of the technology. Nevertheless, if it fails to produce low-cost, high-quality products, this initiative may retard, rather than promote, the adoption by U.S. firms of flat-panel displays.

National Technology Policy in a Global Economy

As we noted above, the political and economic environment of U.S. technology policy has changed greatly during the postwar period. International flows of goods, technology, and capital now play a much more prominent role in the domestic U.S. economy, the ability of U.S. firms to reap the preponderance of economic benefits from U.S. programs in science and technology has declined, and the central issues in trade negotiations now are more tightly interconnected with domestic policies in the environmental, consumer protection, and technology areas. These changes have created at least two broad challenges to U.S. technology policy that are apparent in any review of developments since 1980. The first is the need to reconcile domestic technology policies with the increasingly complex and "domestic" menu of issues on the trade policy agenda. The second challenge is the design of policies that are compatible with the current realities of international economic and technological interdependence.

Since the early 1980s, both Congressional and Executive branch policymakers seeking to redefine U.S. technology policy have found it difficult to maintain consistency between trade and technology policy initiatives. The efforts of the Clinton Administration are no exception. Indeed, the position of the U.S. government on subsidies in the concluding stages of the Uruguay Round of GATT-sponsored multilateral trade negotiations went through several tortuous changes. Although the U.S. government was primarily responsible for the original, restrictive language of the agreement, federal agencies subsequently fought to relax restrictive provisions on subsidies that confined "allowable" subsidies to activities far removed from commercialization.[28]

Following the precedents established by the Reagan and Bush Administrations (e.g., SEMATECH), a number of Clinton Administration technology programs extend R&D subsidies to U.S. firms in technology development activities that are close to commercial application, and therefore resemble practices in other industrial economies that have been severely criticized by U.S. trade policymakers. For example, U.S. trade officials have devoted great effort during the past 15 years to combating the development and production subsidies provided by Western European governments to the Airbus consortium. Western European governments have justified their support for Airbus in part on the basis of the dangers of monopolization by foreign producers of commercial aircraft, and in part on the basis of the national security value for these nations of preserving a "strategic" industry like commercial aircraft. U.S. justifications for the flat-panel display initiative echo many of these arguments, and can hardly strengthen the effectiveness of U.S. opposition to these and other high-technology subsidies from foreign governments.

The second policy challenge in this area reflects the incipient conflict between national technology policies and international technological and economic interdependence. The ability of U.S. firms to reap the economic benefits from federal R&D programs has arguably declined during the past 30 years, while the domestic political demands for programs designed to ensure that domestic firms capture the majority of their benefits have grown. This political reality exacerbates tensions between U.S. trade and technology policies, and ill-conceived responses to it paradoxically may reduce the economic returns to U.S. firms and taxpayers from these technology policies.

Reconciling the political requirements for such a distribution of benefits with the economic and technological realities of the late 20th century has proven difficult. Rather than acknowledging interdependence, many of the technology policies of the Reagan, Bush, and Clinton Administrations have attempted to restrict foreign firms' access to domestic programs or have attempted to limit the international diffusion of the results of such programs. The White House restricted foreign access to public discussions of research in high-temperature superconductivity in 1987,[29] and foreign firms' access to the results of federally funded research in the national laboratories has been restricted in several cases.

A similar logic has led SEMATECH, NCMS, and USCAR (the U.S. Consortium for Automotive Research, which was announced by the Clinton Administration in 1993) to exclude foreign firms from formal membership. Foreign participation in the Commerce Department's ATP is subject to various restrictions, which include determinations by U.S. policymakers that the home-country governments of these firms provide nondiscriminatory access to similar technology development programs, that they provide significant protection for intellectual property, and other conditions that have little bearing on the benefits to the U.S. economy of foreign participation (these conditions have resulted in the denial of funding thus far for only one ATP project, which included a Japanese firm among its participants).[30] Transfer of NCMS-developed technologies by member firms to their foreign subsidiaries is selectively restricted. Finally, cooperative research and development agreements between federal agencies (including the National Institutes of Health or the Department of Energy laboratories) must include provisions to ensure "substantial domestic manufacture" of the resulting technologies or products.

Many of these U.S. government restrictions on foreign access to U.S. technology programs are a response to similar restrictions on U.S. firms' access to the "strategic technology" programs of other industrial economies. Japan's cooperative R&D programs have long excluded foreign firms, although these restrictions have been relaxed somewhat in recent years. In addition, many of the programs of the European Union and its member states have restricted participation by non-European firms, although partial exceptions have been made in the case of such firms as IBM.

Regardless of the importance of formal and informal obstacles to their access to foreign R&D systems, most of the U.S. restrictions on foreign participation or international dissemination of results will have little effect on the distribution of the economic returns to these programs. For example, the automobile firms participating in USCAR maintain extensive manufacturing and product development links with foreign firms, as do the U.S. semiconductor firms participating in SEMATECH. These and other restrictions also create some risk that restrictions on U.S. firms' participation in foreign nations' technology programs will grow.

- ***Projection X-Ray Lithography: The Dilemmas of Technology Policy in Global Industries***

  A vivid illustration of the dilemmas created by policy-based attempts to capture the bulk of the benefits associated with public R&D programs is the case of projection x-ray photolithography technology for the production of advanced integrated circuits. Important advances in this technology have been made at DoE's nuclear weapons laboratories, especially Lawrence Livermore and Sandia National Laboratories. Projection x-ray technology (also known as "soft x-ray" photolithography, SXPL) has the potential to revolutionize the manufacture of integrated circuits with far smaller feature sizes than current techniques. But it is far from certain that U.S. semiconductor equipment producers will be able to commercialize this technology for the exclusive benefit of U.S. semiconductor manufacturers.

  The U.S. semiconductor lithographic equipment industry consists of two relatively small firms, Ultratech and SVGL, with limited financial and technical resources. Acting on their own, these firms will find it difficult to commercialize this costly and complex technology successfully, especially when U.S. semiconductor producers in the past have been unwilling to purchase advanced equipment from small U.S. firms with poor histories of product quality and product support. U.S. semiconductor manufacturers may prefer to purchase equipment embodying this technology from established Japanese producers of lithographic equipment, such as Canon or Nikon, which historically have provided high levels of product quality and support.

  This dilemma becomes even sharper when one confronts the realities of the market for such advanced semiconductor process equipment. Even if one of the current U.S. producers of such equipment can commercialize this technology, the market for this advanced technology will be a global one in which U.S. firms will account for no more than a plurality of total demand. For example, in the 1993 world market for "advanced wafer processing equipment," which is dominated by the photolithography

TABLE 1. Global Demand for "Advanced Wafer Process Equipment" (Regional Shares, 1991-1993, percentage)

	1991	1992	1993
North America	32	36	36
Japan	44	36	29
Europe	12	15	16

Source: Semiconductor Materials and Equipment Institute, 1993

equipment that SXPL would replace, U.S. demand accounts for less than 40% of total sales (see Table 1). Although U.S. demand may well account for a higher share of the sales of more advanced equipment, the U.S. market still is unlikely to exceed 50% of this smaller market. Faced with the need to penetrate the Japanese, South Korean, and Western European markets, and compelled to recover its development costs as quickly as possible, any U.S. firm bringing this advanced lithography technology to market will almost certainly have to team with a foreign partner in these markets. Some technology "leakage" is inevitable through such an alliance. Moreover, the commercial necessity to sell early models of this equipment to foreign semiconductor producers means that the benefits of its commercialization for U.S. semiconductor producers will be diminished.

Conclusion

The Clinton Administration defined a new vision of the federal government's role in technology development and adoption. This vision drew heavily on the change in thinking within the policy-making community that occurred during the 1980s, initially in response to the changed economic circumstances of U.S. citizens and firms, and subsequently in response to the transformation of the international geopolitical environment. Although its policies are not entirely novel, the Clinton Administration endorsed this new approach to technology policy more strongly than its predecessors. The political upheaval of the 1994 elections has not eliminated the need to redefine U.S. technology policy, and considerable bipartisan support remains for many of the elements (if not their budgets) of Clinton Administration technology policy. Nevertheless, military programs retain a very important role in both the R&D budget and the technology programs of this Administration, and defense-related dual-use programs may expand their importance. Illustrating this trend is the Clinton Administration's shift away from its previous support for "industrial competitiveness" as a central goal of DoE weapons laboratory R&D. The Task Force on Alternative Futures for the Department of Energy Laboratories stated in its February 1995 report that these facilities were not well-suited to an "industrial competitiveness" mission, and argued that the weapons laboratories should pursue civilian technology co-development activities with U.S. firms only in areas that are closely related to their traditional missions.[31]

The use by the Clinton Administration of dual-use technology development programs to simultaneously achieve economic and national security policy goals must be viewed with some skepticism, especially when (as in the flat-panel display program) these efforts extend to the subsidized manufacture of complex devices whose commercial prospects cannot be predicted with confidence. The high risks and costs of this component of a national dual-use technology strategy mean that proponents of the flat-panel display and other initiatives should be held to a high standard of proof and evidence in addressing these and many other questions. The overall costs and feasibility of the federal program to create the high-volume production "testbeds," for example, should be compared directly with the costs of continued support for the military production plants currently in operation. More generally, dual-use technology policy initiatives should avoid commitments to the manufacture of specific product designs, and their incipient conflicts with long-standing U.S. trade policy positions demand a tougher review. The FPD initiative could open a Pandora's Box of subsidy wars and create an industry of protected, noncompetitive U.S. suppliers of important high-technology components.

The Clinton Administration's expanded support for "adoption-oriented" programs represents an intriguing new element of federal technology policy, but other elements of Clinton Administration technology policy are not entirely consistent with this orientation. Domestic policies that seek to promote the adoption and application of flat-panel displays and other high-technology components may be less trade-distorting and could reduce the potential conflict between technology and trade policies. Some forms of assistance for technology adoption (e.g., industrial extension, equipment leasing, cooperative research, and small-scale demonstration projects)[32] are likely to prove less disruptive to the multilateral trading system than targeted subsidies or government procurement policies that exclude foreign firms. Other instruments of technology policy that may be less trade-distorting include tax expenditures and other support for on-the-job training of production and professional employees. In addition to their potentially smaller trade-distorting effects, adoption-oriented policies also support the element of the overall innovation process—technology adoption—that accounts for much of the economic benefits associated with innovation.

Reconciling the demands of technology and trade policies remains a difficult task for the Clinton Administration, no less than its predecessors, and the change in political control of the Congress will not reduce the political demands that U.S. technology development programs benefit U.S. firms and citizens. This tension is not unique to this Administration, but its severity has scarcely decreased. Its persistence underlines the need for U.S. technology policy to respond to the realities of international economic and technological interdependence. The establishment by the Clinton Administration of high-level economic policy coordinating bodies such as the National Economic Council, as well as the more recent creation of the National Science and Technology Council, has done little to address the fundamental tension between trade and technology policies' development and implementation. U.S. trade policy has developed a government-wide system of coordination that is imperfect, but reasonably effective. The same cannot yet be said, however, of U.S. technology policy. Without a more coherent process or structure for the development of federal technology policy and its coordination with other policy areas, the dilemmas facing U.S. technology policy will remain and could well intensify.

References

1. W.J. Clinton and A. Gore, Jr., *Technology for America's Economic Growth, A New Direction to Build Economic Strength* (Washington, D.C.: U.S. Government Printing Office, 1993), p. 1.
2. During 1960-1986, real defense spending on R&D and procurement increased 2-4% on an annual basis. According to the *Economist* ["Downdraft: A Survey of Military Aerospace," September 3, 1994], this trend will likely be replaced by 4% annual reductions in these expenditures through the end of this century. Defense Department spending on research, development, and procurement has already fallen by nearly 50% in real terms since 1986.
3. U.S. trade with other nations (imports plus exports) has grown from 9% of GDP in 1960 to nearly 23% in 1994. President's Council of Economic Advisers, *Economic Report of the President, 1995* (Washington, D.C.: U.S. Government Printing Office, 1994).
4. Much of this foreign challenge to U.S. economic and technological hegemony reflects a remarkable policy success, the reconstruction of foreign economies that was a central goal of postwar U.S. foreign policy.
5. National Science Board, *Science and Engineering Indicators, 1993* (Washington, D.C.: U.S. Government Printing Office, 1993).
6. D.C. Mowery, ed., *International Collaborative Ventures in U.S. Manufacturing* (Cambridge, MA: Ballinger Publishers, 1988); D.C. Mowery, "Collaborative Ventures Between U.S. and Foreign Manufacturing Firms," *Research Policy*, 18 (1989): 19-32.
7. National Science Board, op. cit.
8. According to Katz and Ordover, at least 14 Congressional bills passed during the 1980s focused on strengthening domestic and international protection for intellectual property rights, and the Court of Appeals for the Federal Circuit created in 1982 has upheld patent rights in roughly 80% of the cases argued before it, a considerable increase from the pre-1982 rate of 30% for the Federal bench. M.L. Katz and J.A. Ordover, "R&D Competition and Cooperation," *Brookings Papers on Economic Activity: Microeconomics 1990*, pp. 137-192.
9. Under the terms of a CRADA, federal laboratories may assign private firms the rights to any intellectual property resulting from the joint work (the federal government retains a nonexclusive license to the intellectual property). The Acts further stipulate that federal agencies can allocate funds for collaborative projects only to the federal entities engaged in the project; transfers of funds to private firms are not allowed.
10. Despite its high profile within Clinton Administration goals, support for the National Information Infrastructure thus far has had little visible impact on reallocations of agency R&D budgets. The $1.3 billion requested for this program in fiscal 1995 is spread among a large number of programs within NIST, NSF, and the National Telecommunications and Information Administration (also a part of the Commerce Department), and represents less than 0.5% of the total federal R&D

budget of $73 billion. American Association for the Advancement of Science, Intersociety Working Group, *AAAS Report XIX: Research and Development, FY 1995* (Washington, D.C.: American Association for the Advancement of Science, 1994).

11. Growth in the Commerce Department's R&D budget occurred largely at the expense of the Department of Energy, which lost considerable funding with the termination of the superconducting supercollider.
12. U.S. Office of Management and Budget, Executive Office of the President, *The Budget of the United States Government for Fiscal 1995* (Washington, D.C.: U.S. Government Printing Office, 1994); U.S. Office of Management and Budget, Executive Office of the President, *The Budget of the United States Government for Fiscal 1996* (Washington, D.C.: U.S. Government Printing Office, 1995).
13. Federal and state governments traditionally have invested little in programs designed to assist firms in adopting technology, which may have contributed to the relatively slow adoption by U.S. manufacturing firms of advanced manufacturing technologies. D.C. Mowery and N. Rosenberg, *Technology and the Pursuit of Economic Growth* (New York, NY: Cambridge University Press, 1989); C. Edquist and S. Jacobsson, *Flexible Automation* (Oxford: Blackwell, 1988). U.S. agriculture, of course, is a prominent exception to this characterization, with its elaborate network of federal and state-funded extension agents. R.E. Evenson, "Agriculture," in R.R. Nelson, ed., *Government and Technical Progress: A Cross-Industry Analysis* (New York, NY: Pergamon, 1982).
14. The fiscal 1995 Presidential budget requested $61 million, more than twice the Congressional fiscal 1994 appropriation for this program. Congress further increased the fiscal 1995 appropriation to $91 million. For fiscal 1996, the Clinton Administration requested $147 million for this program, an increase of more than 60%.
15. Illustrating the elastic character of current definitions of "dual-use" R&D spending, the February 1995 estimate omitted "dual-use S&T investments" in the Defense Nuclear Agency, the Ballistic Missile Defense Organization, and the three uniformed services that had been included in earlier tabulations, presumably by redefining them as "military-only" R&D programs. U.S. Department of Defense, *Dual Use Technology: A Defense Strategy for Affordable, Leading-Edge Technology* (Washington, D.C.: Defense Department, 1995), p. 10.
16. *New York Times*, November 14, 1994, p. F13.
17. B. Davis and G.P. Zachary, "Electronics Firms Get Push from Clinton to Join Industrial Policy Initiative in Flat-Panel Displays," *Wall Street Journal*, April 28, 1994, p. A16.
18. Indeed, on March 8, 1995, the Senate adopted a "sense of the Senate" resolution as an amendment to the Defense Department supplemental appropriations bill "affirming the importance of, and the need for, cost-shared partnerships between the Department of Defense and the private sector to develop dual-use technologies,' and arguing that "...such partnerships, including SEMATECH and the Technology Reinvestment Project, need to become the norm for conducting such applied research by the Department of Defense." U.S. Congress, *Congressional Record*, March 9, 1995 (Washington, D.C.: U.S. Government Printing Office, 1995), p. S3584.
19. R.R. Nelson, *High-Technology Policies: A Five-Nation Comparison* (Washington, D.C.: American Enterprise Institute, 1984).
20. R. Langlois and D.C. Mowery, "The Federal Role in the Development of the American Computer Software Industry: An Assessment," forthcoming in D.C. Mowery, ed., *The International Computer Software Industry* (New York, NY: Oxford University Press, 1995); Institute for Defense Analyses, *DARPA Technical*

Accomplishments, vol. II, *An Historical Review of Selected DARPA Projects* (Alexandria, VA: Institute for Defense Analyses, 1991).

21. U.S. General Accounting Office, *Technology Transfer: Implementation of CRADAs at NIST, Army, and DOE* (Washington, D.C.: U.S. Government Printing Office, 1993).
22. According to the Defense Department report on its flat-panel display initiative, this domestic production facility is scheduled to "expand its capabilities to manufacture advanced AMLCDs [Active Matrix Liquid Crystal Displays], with the plant sized to start 36,000 substrate pairs per year." U.S. Department of Defense, Flat Panel Display Task Force, *Building U.S. Capabilities in Flat Panel Displays* (Washington, D.C.: U.S. Department of Defense, 1994), p. iv-6. At a yield of 50%, which is relatively low for a mature production process, this level of "wafer starts" would produce 18,000 units annually.
23. Ibid., p. vi-17.
24. For comments from former Deputy U.S. Trade Representative Michael B. Smith on this point, see C. Barfield, "Flat Panel Displays: A Second Look," *Issues in Science and Technology* (Winter 1994-95), pp. 21-25.
25. See P. Singer, "Flat Panel Displays: An Interesting Test Case for the U.S.," *Semiconductor International* (July 1994), pp. 78-88.
26. The structure of the process is similar to that of a defense procurement competition, in which winners of a development competition compete for production contracts
27. Kelley and Watkins note that a large number of U.S. firms in the "machining-intensive durable goods" sector currently produce military and civilian products in such "dual-use" production facilities. M.R. Kelley and T.A. Watkins, "In from the Cold: Prospects for Conversion of the Defense Industrial Base," *Science*, 268, April 28, 1995, pp. 525-532. Their analysis does not reveal the share of defense contractors' manufacturing capacity devoted to such joint production, however, since they report only the proportion of establishments that sell to both defense and civilian markets. The authors also report nothing about the competitive performance of these firms, located in a sector that has includes many industries that have lost market share to import competition. For both of these reasons, their conclusions must be treated with care. More specifically, these findings do not provide a sufficient basis for insisting that such dual production be pursued in a very different industry. Policies that discourage cost-effective dual production clearly should be discarded; but assuming that such dual production can be undertaken from the outset in a very complex and novel manufacturing process seems risky.
28. Describing the shift in the U.S. position in the subsidy negotiations in the final stages of the Uruguay Round trade negotiation, Lepkowski noted that "The entire episode essentially exposed one of the weaker aspects of the Clinton Administration—too little coordination between technology policy and international economic policy." W. Lepkowski, "Last Minute Maneuvering Rescues U.S. Technology Policy," *Chemical and Engineering News*, January 3, 1994, p. 13. These problems of coordination and consistency appear to have been just as severe in the Bush and Reagan Administrations.
29. The "U.S. discovery" of high-temperature superconductivity that led to the White House symposium was in fact accomplished by two German scientists working in a Swiss industrial R&D laboratory owned by a large U.S. multinational firm, IBM. Establishing the "national ownership" of this scientific accomplishment is as futile as it is counterproductive.
30. Many of the current restrictions on foreign participation, which differ among U.S. technology programs, determine foreign firms' eligibility for these programs based on assessments of home-country government policies, on the assumption that

denial of access to foreign firms will increase pressure for change in the policies of their governments. The basis for such assessments of home-government policies are relatively subjective, and are surprisingly "non-transparent" (i.e., they are not based on any single or comprehensive published assessment, and there is no well-developed process for review of these determinations). These statutory requirements for the fulfillment of a lengthy, inconsistent, and complex set of conditions across programs also mean that foreign-firm participation that is deemed by policymakers to be economically beneficial for U.S. firms and taxpayers may be prohibited for one or another reason that has little to do with the specific merits of an individual proposal. U.S. Office of Technology Assessment, U.S. Congress, *Multinationals and the U.S. Technology Base* (Washington, D.C.: U.S. Government Printing Office, 1994).

31. "The government-funded technology transfer/industrial competitiveness activities of the national laboratories should be focused on industries and areas of technology that contribute directly to the DoE's primary missions in national security, energy, and environment." U.S. Department of Energy, Task Force on Alternative Futures for the Department of Energy National Laboratories, *Alternative Futures for the Department of Energy National Laboratories* (Washington, D.C.: U.S. Department of Energy, 1995), p. 80.
32. Indeed, an important component of "adoption-oriented" U.S. technology policy has been the industrial extension and modernization programs of the Defense Department, the annual budgets of which during the 1980s exceeded spending by all state-level programs on technical assistance programs. Kelley and Watkins, op. cit.