Summary and Findings 1

OVERVIEW

The end of the Cold War frees the Nation to turn more of its energies into building a stronger civilian economy. There are hardships in adjusting to a peacetime footing that demand national attention, but there are opportunities to grasp as well.[1] This report concentrates on new opportunities to advance civilian technologies and improve industrial competitiveness. Part One asks how government R&D may be put on a new course, shifting from the military goals that dominated Federal technology efforts for half a century to a greater emphasis on civilian purposes. Part Two considers some options for new national initiatives that meet public needs while fostering the growth of knowledge-intensive, wealth-creating industries.

A key issue in Part One is whether the Nation can put to good use on the civilian side research talents and institutions that were formerly devoted to defense. Many diverse R&D institutions—in government, universities, and private defense companies—were part of the defense effort, but this report concentrates on three of the Nation's largest R&D institutions, the U.S. Department of Energy's (DOE) multiprogram nuclear weapons laboratories, Lawrence Livermore, Los Alamos, and Sandia. Public concern is fixed on these labs because they are big, they

[1] This is the second of two reports by the Office of Technology Assessment on the implications for the civilian economy of the end of the Cold War. The first was *After the Cold War: Living With Lower Defense Spending, OTA-ITE-524* (Washington, DC: U.S. Government Printing Office, February 1992). It considered effects of deep, sustained cutbacks in defense spending on defense workers, defense-dependent communities, and defense companies.

are publicly funded, and they face a clear need for change. They still have important nuclear weapons responsibilities, including decommissioning, non-proliferation, and environmental cleanup, as well as modernizing existing weapons; they do nondefense energy work as well. But their central task, the design of the Nation's arsenal of nuclear weapons, is much diminished.

A widely asked question is whether the labs should take up other tasks in place of weapons development. Proposals range from radical downsizing of the labs, with possible closure of at least one, to using their resources for new national initiatives devoted to peacetime goals. Whatever their longer term future--whether they shrink, take on new missions, or do some of both-a more immediate question is whether the labs can work effectively with industry. This involves two further questions: Do the labs possess technology and abilities that could be of substantial value to industry? And if so, can these be made available without too much trouble or delay?

Recent evidence strongly indicates that the labs' technology, and their ability to develop new technologies, are indeed valuable to industry. Despite earlier disappointments in technology transfer, industry interest in cooperative cost-shared R&D projects is now at an all-time high, and is matched by interest on the labs' side. Far more proposals for cooperative R&D are being made than can be funded. The answer to the second question is less certain. In early 1993, there were still delays and difficulties in signing agreements, partly because of red tape, but also partly because DOE, the labs, and their industrial partners were blazing new trails in government/industry cooperation. It is not yet clear whether the way can be smoothed enough to make the process work swiftly and easily, or that it can be done before the new enthusiasm cools. For the near term, the issue is whether lab/industry partnerships can yield concrete benefits for industry. A few years' experience should be enough to tell whether good results are coming out of the many projects begun in 1992-93, and whether industry interest in signing new agreements is holding up.

For the longer term future, R&D partnerships with industry, *per se*, are not likely to prove a satisfactory central mission for the weapons labs. As public institutions, the labs' existence is best justified if they serve missions that are primarily public in nature. The lab technologies that are currently exciting high interest from industry are drawn from the well of public missions of the past half century, especially nuclear defense. As the defense task fades, other public missions could replenish the well. The labs' traditional missions are quite broad, encompassing not only military and nonmilitary uses of nuclear energy, but also basic high energy physics research and applied research into various forms of energy supply and use, including their environmental implications. There is also a growing interest in expansion of the labs' public missions into newly defined areas, based on expertise they have developed in such fields as high performance computing, new materials, and advanced manufacturing technologies.

Broad expansion of the labs' missions, by itself, is often interpreted as an effort to ''save the labs. Another approach would be for the Federal Government to set R&D priorities for selected national initiatives, and then to allocate funding to whatever performers, public and private, can make the best contributions. There are few such coordinated Federal R&D initiatives; the best example is the High Performance Computing and Communications Program, which is aimed at well-defined dual-use goals and involves eight government agencies, including DOE and its labs. Up to now, no Federal agency has had both the responsibility and the authority to coordinate technology development efforts in selected areas of national importance.

Selecting areas of national importance that call for a substantial infusion of public funds for R&D involves political choices at the highest levels of government. There is no lack of candidates for new programs. Some of the most attractive are in the area of sustainable economic growth, the development of knowledge- and technology-intensive industries that do not burden the environment. Energy efficiency is almost always a critical element in environmentally benign industrial growth.

Part Two of this report opens a discussion of broad new initiatives the Nation might adopt to serve peacetime goals. The illustrative case chosen for analysis is that of transportation systems that offer greater energy efficiency, reduced pollution, and lesser dependence on foreign oil-all public benefits that could justify public investment. The systems include cleaner cars, powered by electric batteries or a combination of fuel cells and batteries; intelligent vehicle and highway systems; and high-speed mass ground transportation systems, including steel-wheel train cars on rails, such as France's TGV (Train a Grande Vitesse), and magnetically levitated vehicles on guideways.

Without attempting to analyze all the transportation policy issues involved, the discussion here looks at the systems from a defense conversion perspective. It concentrates on the benefits these environmentally attractive systems might offer in the way of advancing critical technologies, promoting world-class industries, and creating good jobs—benefits that defense spending often provided in the past—plus their potential for using human talents and institutions formerly devoted to defense. The analysis suggests that nonpolluting cars, though farther from technological success than high-speed ground transportation systems, hold greater promise for pushing technological frontiers and could, if they succeed, create larger numbers of well-paid productive jobs in America. There may be other good reasons, however, for government support of the high-speed ground systems.

However desirable they may be, it is not likely that any of these systems would create nearly enough jobs at the right time and in the right places to compensate for the hundreds of thousands of defense jobs being lost as the Nation adjusts to post-Cold War military budgets. Some of the initiatives could use the talents of people now working in the defense sector-especially research scientists and engineers-but the match would not be perfect.

This is the second of two Office of Technology Assessment (OTA) reports on the implications for the U.S. civilian economy of the end of the Cold War. The greatest effects, of course, are relief from the threat of global nuclear war and the freedom to pursue national goals other than military security. Nevertheless, adjustment to deep sustained cuts in defense spending is not simple or painless. The first report of this assessment, *After the Cold War: Living With Lower Defense Spending*, considered effects of the cutbacks on defense workers, men and women in the armed services, defense-dependent communities, and defense companies. It concluded that there would be hardships-greater perhaps than the relative size of the cutback suggests, because our economy is burdened with more debt and higher unemployment than in times past, and is under much greater challenge from foreign competitors. First aid to affected workers and communities, in the form of reemployment, retraining, and redevelopment assistance, can help them through the transition. But the best conversion strategy is a broad one: investment in programs that train workers well, help businesses perform better, promote technology advance, and invigorate local and national economic growth.

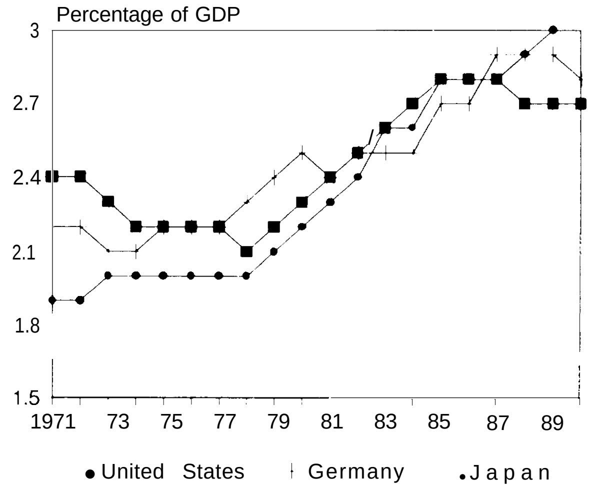
BACKGROUND

The 1990s are uncharted territory. For the first time in half a century, the United States faces no massive military threat from a superpower foe. Instead, the major challenge is to keep up with the economic competition from friendly countries. Some are doing better than we are in industries that disproportionately advance knowledge, generate new technologies of wide application, and support rising living standards.

This Nation's success in reaching a peaceful conclusion to 40 years of Cold War will bring sustained cuts in defense spending; that, ironically, threatens to handicap us in rising to new challenges in the economic realm. Military spending should and will continue to decline. Yet military spending and the military-industrial complex are concentrated strongly in things that increase our potential for growth-research and development, technology and knowledge intensity. In fact, military spending has sometimes been described as America's *de facto* technology and industry policy. If so, it is a blunt instrument of policy; it is an unfocused and expensive way of advancing important commercial technologies. Nevertheless, there is enough commonality in military and commercial applications of some critical core technologies that defense spending over the years has strongly supported both. It has produced semiconductor chips of various kinds that find uses in autos and engineering work stations as well as guided missiles; programmable machine tools that can make parts for fighter aircraft or lawn mowers, tractors, and commercial airliners; computational techniques that model nuclear explosions or analyze what happens to cars in crashes.

This report focuses on one element of military spending that has greatly benefited the U.S. civilian economy—sustained, generous funding for research and development. Of course, R&D is not the only benefit defense spending has bestowed. Having the Department of Defense (DoD) as a large, reliable first customer for groundbreaking new technologies was at least as important; it was the combination of defense R&D and defense purchases that launched the semiconductor and computer industries. Moreover, R&D is far from the whole story in industrial competitiveness.

Figure 1-1—R&D Spending as a Percentage of GDP: United States, Germany, and Japan, 1971-90



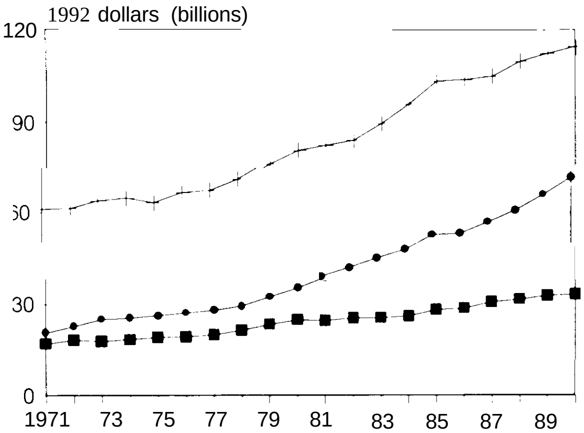
SOURCE: **National Science Board, *The Competitive Strength of U.S. Industrial Science and* *Technology: Strategic Issues* (Washington, DC: 1992), table A-9.**

Many other factors are at least as important. Among them are a Nation's financial environment, whether hospitable or not to long-term private investments in technology and production equipment; training and education of managers, engineers, and shop floor workers; and management of people, equipment. and the organization of work to produce well-designed, reliable goods at reasonable prices.[2] Neglect of R&D was not the main reason for one U.S. industry after another to fall behind our best competitors in the 1970s and 1980s. Much more important were inattention to the tasks of improving quality and efficiency, linking design and production, and getting new products to market quickly.

Nevertheless, R&D is an essential element in the mix, and it has been a traditional source of strength for the U.S. economy. Today, American preeminence in R&D is fading. By the late 1980s,

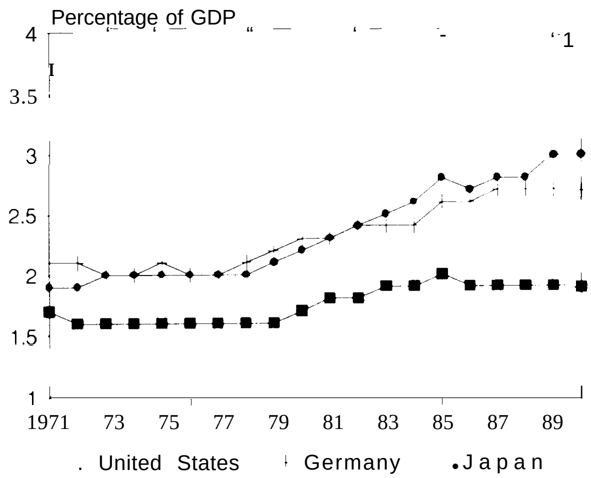
[2] OTA reports over the past dozen years have analyzed the international competitiveness of U.S. industries, pointed to problems, and suggested policy options for improving the Nation's performance. Recent studies include *U.S.-Mexico Trade: Pulling Together or Pulling Apart* (October 1992); *Competing Economies: America, Europe, and the Pacific Rim* (October 1991); *Worker Training: Competing in the New International Economy* (September 1990); *Making Things Better: Competing in Manufacturing* (February 1990); *Paying the Bill: Manufacturing and America's Trade Deficit* (June 1988); *Commercializing High-Temperature Superconductivity* (June 1988); and *International Competition in Services: Banking, Building, Software, Know-How* (July 1987).

Figure 1-2—Nondefense R&D Expenditures: United States, Germany, and Japan, 1971-90



SOURCE: National Science Board, The *Competitive Strength of U.S. Industrial Science and Technology: Strategic Issues* (Washington, DC: 1992), table A-10.

Figure 1-3—Nondefense R&D as a Percentage of GDP: United States, Germany, and Japan, 1971-90



SOURCE: National Science Board, The Competitive *Strength of U.S. Industrial Science and Technology: Strategic Issues* (Washington, DC: 1992), table A-10.

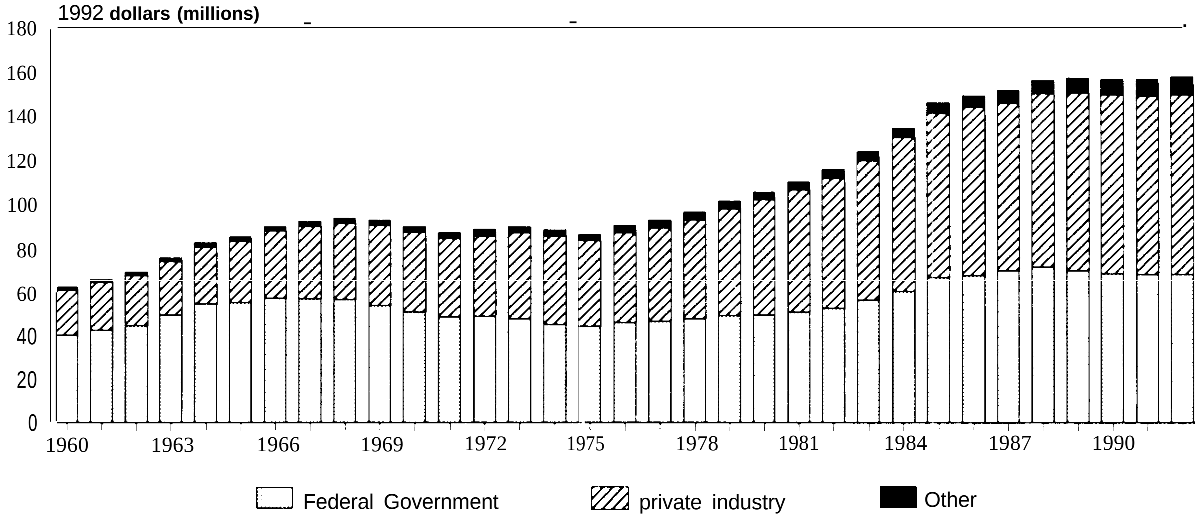
Japan, West Germany, and Sweden all spent a higher proportion of gross domestic product on total R&D than the United States. As for nondefense R&D, those nations devoted 2.6 to 3.1 percent of Gross Domestic Product (GDP) to the purpose in 1990, compared with 1.9 percent in the United States (figures 1-1 and 1-2). Moreover, the U.S. position is deteriorating. While foreign countries have stepped up the pace of their R&D spending in recent years, this Nation's has stagnated. In the United States, total and industry-funded R&D hit high points in 1989, have remained essentially flat in constant dollars since, and have dropped as a percentage of GDP. Government R&D has declined in constant dollars, mostly due to defense cutbacks (figures 1-3 and 1-4).

The reasons for the current lackluster R&D record in the United States reflect several factors. Declines in military R&D have certainly affected the government's R&D spending and probably industry's as well (figure 1-5). The recession and sluggish recovery of the early 1990s may have dampened industry's R&D spending; this happened in the recessions of the 1970s, although not in the turndown of 1981 -82.[3] Corporations are burdened with more debt today than in earlier times when industry's R&D spending was rising steadily. Some American companies that were traditionally the flagship R&D performers of private industry have recently suffered stunning, unprecedented losses. Even innovative companies are now more ready than heretofore to abandon R&D in areas where they see foreign competitors ahead of them. Leading corporate labs that formerly undertook large-scale, long-term R&D projects and produced such innovations as the transistor, have been scaled back, broken up, or sold.

Government policy has a variety of options for directly encouraging more R&D by private industry, but there is also a good case for government sharing with industry some of the large risks and

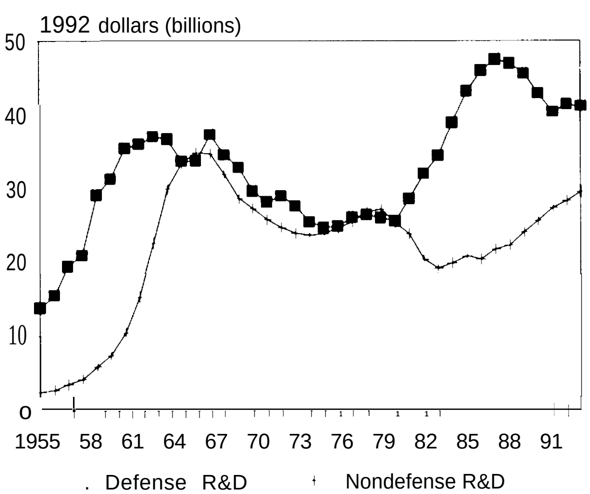
[3] Possibly, this was because defense spending was rising so fast during this period that defense companies were confident R&D investments would pay off later in large military procurements.

Figure 1-4-U.S. R&D Spending by Source of Funding, 1960-92



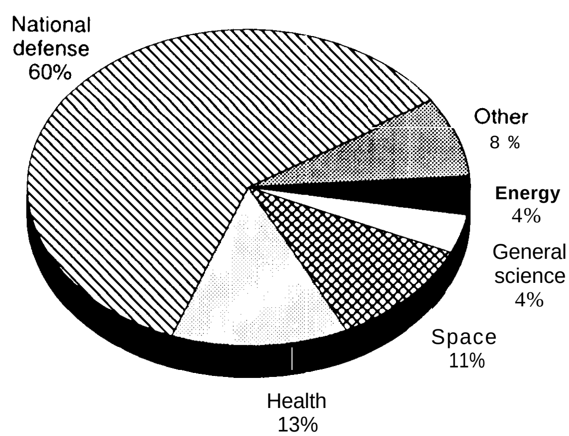
SOURCE: National Science Foundation, ***National Patterns of R&D Resources: 1992*** **(Washington, DC: 1992), table B-3.**

Figure 1-5—Federal Budget for Defense and Nondefense R&D, 1955-93



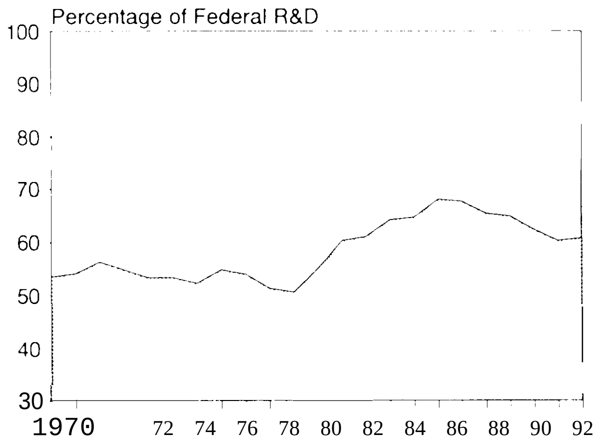
SOURCE: National Science Foundation, National *Patterns* ***of R&D Resources: 7992*** **(Washington, DC: 1992), table B-21; National Science Foundation, unpublished data.**

Figure 1-6-Federal R&D Funds by Budget Function, 1992



SOURCE: National Science Board, *Science and Engineering Indicators—1991* (Washington, DC: U.S. Government Printing Office, 1991), table 4-17.

Figure 1-7—R&D for National Defense as a Percentage of Total Federal R&D, 1970-92



SOURCE: National Science Foundation, *National Patterns of R&D: 1992* (Washington, DC: 1992).

high costs involved in today's leading edge R&D. Most other advanced Nations do this as a matter of course. There is increasing evidence to show that, in competition with foreign firms whose governments share the costs of developing technologies, American firms are handicapped. And the financial environment in the United States has for a long time been less friendly than that of our best competitors-especially Japan—for long-term private investments in technology development and equipment.[4]

The Nation does not inevitably have to lose the benefits of government supported R&D as defense spending declines. The Federal Government pays for 43 percent of the Nation's R&D spending, most of it for defense purposes; some could be redirected from military to economic goals. Opportunities to do that are present in DOE's nuclear weapons laboratories but they are certainly not the only candidates. Assuming that some former defense R&D spending is rechanneled to civilian-oriented R&D (instead of being applied to many other worthy purposes, from Federal debt reduction to improved health care), other claimants for public R&D funds include universities, private research laboratories, and civilian government R&D institutions. The DOE weapons labs have human and physical resources that they are eager to redeploy into dual-use or civilian efforts, but conversion of defense resources is only one consideration in deciding how best to put public funds into R&D partnerships with industry.

THE STRUCTURE OF FEDERAL R&D

The U.S. Government is a major force in the Nation's research and development, and defense dominates the government's share. In 1992, the Federal Government spent $68.2 billion overall for R&D out of a national total of $157.4 billion; $41.5 billion of the Federal share was defense-related.[5] Health is a distant second to defense in Federal R&D, followed by civilian space and aeronautics, energy, and scientific research (figure 1-6). At times in the past, defense has been even more dominant, reaching a recent peak of 69 percent of Federal R&D in the mid-1980s (figure 1-7).

The leading performers of federally funded R&D are private companies, which account for 45 percent of the total.[6] Eighty percent of their work is for DoD, and the National Aeronautics and Space Administration (NASA) occupies most of the rest. Universities and colleges, which receive

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[4] For discussion of the reasons and principles for government-industry collaboration in developing technologies with commercial promise, see U.S. Congress, Office of Technology Assessment *Making Things Better*, OTA-ITE-443 (Washington DC: U.S. Government Printing Office, February 1993) ch. 2; and Competing *Economies*, OTE-ITE-498 (Washington, DC: U.S. Government Printing Office, October 1991), ch. 2; also, John Alic, Lewis Branscomb, Harvey Brooks, Ashford Carter, and Gerald Epstein, Beyond *Spinoff: Military and Commercial Technologies in a Changing World* (Boston, MA: Harvard Business School Press, 1992), ch. 12.

[5] National Science Foundation, *National Patterns of R&D Resources:* 1992, by J.E. Jankowski, Jr., NSF 92-330 (Washington DC: 1992), tables B-3 and B-21.

[6] National Science Foundation, *Selected Data on Federal Funds for Research and Development: Fiscal Years 1990,1991, and 1992,* NSF 92-319 (Washington, DC: July 1992), table 9.

Table l-l—R&D by Selected Government Agencies and Laboratories, FY 1992 (millions of dollars)

Department/Agency	Total R&D	Total Lab	Intramural	FFRDCs
Department of Defense	$38,770	$11,596	$9,890	$1,707
Department of Energy	6,499	4,698	449	4,249
National Aeronautics and Space Administration	8,543	3,499	2,613	886
Department of Health and Human Services	9,781	2,039	1,966	74
National Institutes of Health	8,253	1,559	1,486	73
Department of Agriculture	1,256	826	826	•
Department of Commerce	539	431	431	0
National Institute of Standards and Technology	186	144	144	0
National Oceanic and Atmospheric Administration	337	272	272	0
Department of the Interior	562	482	479	3
National Science Foundation	2,102	211	89	123

“Indicates amount less than $50,000.

KEY: Federally Funded Research and Development Centers.

SOURCE: National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1990, 1991, 1992,* Volume XL, NSF92-322 (Washington, DC: 1992), table C-O..

15 percent of the government’s R&D budget, are less defense-dependent. They are the biggest performers in the areas of health and general science, with a substantial presence as well in defense, energy, and agriculture.

Laboratories owned or principally funded by the Federal Government receive 35 percent of Federal R&D funds. Their growth and strength are largely a phenomenon of post-World-War-II years, and their work reflects the Nation’s priorities during that period. About half the $25 billion they received in 1992 went for defense, with aerospace, energy, health, and agriculture sharing much of the rest (table l-l).

In considering how to redirect R&D resources from military purposes to strengthening the civilian economy, this report concentrates on the government’s own research institutions. Although two-thirds of defense R&D dollars are spent in private industry, public policy has a stronger and more direct influence on the conduct of government R&D than on how private firms manage their laboratories and research teams. (Box 1-A briefly describes some public policies related to technology conversion by defense companies). The report therefore focuses on government laboratories that, up to now, have put most of their effort toward military goals.

Federal Laboratories

The often-quoted figure of “more than 700” Federal laboratories summons up a rather misleading picture of a national network of large well-equipped research centers. In fact, the Federal research, development, testing, and evaluation (RDT&E) system includes everything from single offices staffed by a handful of people to sprawling weapons testing centers like the Flight Test Center at Edwards Air Force Base in California, or large campuses with thousands of researchers, such as the National Institutes of Health (NIH) in Bethesda, Maryland. Some Federal labs are owned by the government and managed and staffed by Civil Service employees (government-owned, government-operated, or GOGOs), like the labs of the National Institute of Standards and Technology (NIST) and most DoD labs. Some, including many of the biggest, are government-owned but operated by universities, companies, or non-profit institutions acting as contractors (GOCOs); these include all nine of the DOE multiprogram labs and NASA’s biggest lab, the Jet Propulsion Laboratory. Some are owned by other institutions but do virtually all of their work for the government (Federally Funded Research and Development Centers, or FFRDCs) like the Lincoln Laboratory at the Massachusetts

Box l-A—Conversion of Military Technologies by Defense Companies

Among private defense companies there is no lack of military technologies that might be adapted for use in commercial products. Some major companies, in fact, have taken steps to reorient a portion of their R&D toward civilian applications. For example, Westinghouse Electronics Systems, TRW, Martin Marietta, and Lockheed Electronics are using information, data processing, and remote sensing technologies of military origin for such civilian uses as air and highway traffic control systems, drug interdiction, and office security systems.[1] Although most of the customers so far have been civilian government agencies, and sales are small compared to defense contracts of the recent past, opportunities for converting technologies are certainly there and could be sizable. Nevertheless, there are serious barriers to technology conversion by private firms. The barriers are not so much at the technical or engineering level, but rather at the broader level of how the company operates.

Many studies and reports have called attention to the gulf in company culture and management practice between defense and commercial firms.[2] During 45 years of Cold War, most large defense companies and defense divisions of diversified corporations withdrew from commercial markets into what has been termed the "defense ghetto." The reasons are several. Defense contractors that make complex weapons systems or major subsystems are geared to producing at low volume while meeting very exacting demands for technical performance. By contrast, the emphasis in the commercial world is on high-volume production that combines product reliability with affordable cost. And while some U.S. commercial industries have fallen behind their best foreign competitors in getting new generations of products to market quickly, they are years ahead of defense industries. The time from design to production for military systems is often 15 to 20 years, compared to 3 to 5 years for many commercial items. Furthermore, major defense companies **typically have little acquaintance with commercial marketing and distribution.** DoD prime contractors have very few buyers to deal with and no need for a distribution network.

Department of Defense (DoD) requirements are another major source of division between commercial and defense companies. DoD often imposes rigid, detailed specifications and standards, not only for the product itself but also for the process of manufacture. These "roil specs" and "roil standards" have blocked technological progress for defense applications in fast-moving fields such as electronics, and have locked into defense contracts technologies that commercial companies no longer produce. Even more important are the government's special auditing, review, and reporting requirements for defense contractors, which are intended to guard against waste and fraud but which also impose heavy extra costs. A leading reason why many companies keep defense and commercial work separate is to avoid burdening the commercial business with overhead from the defense side.

It is therefore hard for defense contractors to combine their defense business with commercial production, or to change from one to the other. Technology conversion, *per se,* might not be such a formidable challenge. But if defense companies are to adapt their military-generated technologies to civilian use, they must make themselves into civilian, or at least dual-use, companies. This is no small task.

Despite the difficulties, some defense companies are making the attempt. Besides the major defense contractors who are dipping a toe into t he water of commercial markets, there are many smaller companies who

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1 For further discussion of the outlook for and experience of conversion by defense companies, see U.S. Congress, Office of Technology Assessment, *After the Cold War: Living With Lower Defense Spending,* OTA4TE-524 (Washington, DC: US. Government Printing Office, February 1992), ch. 7.

2 See, for example, U.S. Congress, Office of Technology Assessment, *Holding the Edge: Maintaining the Defense Technology Base,* OTA-ISC-420 (Washington, DC: US. Government Printing Office, April 1989); *Integrating Commercial and Military Technologies for National Strength: An Agenda for Change,* report of the CSIS Steering Committee on Security and Technology (Washington, DC: The Center for Strategic & International Studies, 1991); John A. Alic, et al., *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press, 1992).

Box 1-A--Continued

see their only salvation in the civilian economy. Some are getting help from State programs. For **example, Connecticut the State that tops the list in economic dependence on** the private defense industry, provides converting firms with various forms of financial aid, including both conventional low-interest loans and success-dependent investments in new product development, to be repaid in royalties. Even wit h help, these firms face years of effort and uncertain prospects.[3]

The Federal Government has very broad interests, both military **and** civilian, in encouraging defense firms to convert to more civilian production and to integrate the military and civilian sides of their business. Most of the Federal programs are framed to promote the development of dual-use technologies and integrated companies. Efforts to raise the share of DoD purchases off the shelf from commercial vendors are at least 20 years old,[4] but the incentive to do so today is far stronger today as defense budgets tighten. The same motive is pushing Federal policymakers toward removing some of the burdens of military accounting requirements? Moreover, new laws and policies already allow defense companies to recover more of their own R&D expenses--for dual-use as well as strictly military technologies-as allowable overhead on government contracts.[6]

These changes should help to breach the walls of the defense ghetto and support a more effective, efficient defense industrial base. However, defense contractors still face the need to find more commercial business or else shrink, or possibly perish. At least one Federal program is explicitly directed at helping defense-dependent companies enter the commercial marketplace with dual-use products. The $1.7 billion defense conversion package that Congress passed in 1992 includes a $97 million Defense Dual-Use Assistance Extension Program. It provides cost-shared grants to centers sponsored by Federal, State, or local governments that offer defense firms technical assistance in developing, producing, and marketing dual use products; it also provides for government-guaranteed loans to small defense businesses. For the most part, however, Congress took a broader view of defense conversion and threw open to all firms-whether or not they are defense-dependent--new or enlarged technology development and diffusion programs. Two of the new programs, each funded at $97 million for fiscal year 1993, are a manufacturing extension program supporting State and local agencies that help small firms adopt best practice technologies, and a regional technology alliance program, which concentrates on applications-oriented R&D for locally clustered industries. In addition, several hundred millions of dollars were provided for government-industry R&D partnerships to develop critical dual use technologies

In sum, the issue of technology conversion by defense companies quickly turns into broader policy areas. From the standpoint of military interests and requirements, civil-military integration is highly desirable; but it is not clear whether that can be achieved better by trying to turn defense firms into dual-use companies, or by forming R&D partnerships with commercial companies for defense needs (as **ARPA does, see ch. 5 of the full report) and by changing DoD's acquisition** policies to allow more purchases from companies whose essential nature is commercial. From the standpoint of the nation's economic performance, a very broad definition of conversion seems most desirable. This implies a policy approach that offers transition assistance to defense companies struggling to survive in the commercial world while opening technology diffusion and development opportunities to all companies equally.

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3 **Steven Prokesch, "Companies Struggle** to Adjust As U.S. Cuts Military Budget," ***The New York Times,* Feb. 10,** 1993.

4 **U.S. Congress, Office** of Technology Assessment, ***Building Future Security: Strategies for Restructuring the*** Defense ***Technology and Industrial*** *Base,* **OTA-ISC-530** (Washington, DC: U.S. Government **Printing** Office, June 1992), **pp.** 99-103.

5 **In January 1993** the Advisory Panel on Streamlining and Codifying Acquisition **Laws submitted** to DoD **its report** on reforming the body of **acquisition** law; at **this writing the Department had not yet responded.**

6'rhig **is independent** research and development, or **IR&D,** an important source of funding for defense **companies'** development of **technologies** with no **specific** weapons application. **IR&D is** destined to **become** less important as procurement **declines,** since it **is recovered** from government **contracts.**

Institute of Technology, sponsored by the Air Force.

It is also sometimes mistakenly assumed that all the Federal labs have an untapped potential for contributing to the Nation's economic performance, but that is an exaggeration. Some already have longstanding close relations with industry. Examples are NIST's labs, which have a central mission of serving industry's needs; the NASA aeronautics labs, with their history and explicit mission of R&D support for the aircraft industry, civil as well as military; and the NIH labs, with substantial research that is of immediate interest to the pharmaceutical, medical devices, and biotechnology industries. No doubt some of these laboratories could improve their links with industry, but they are not starting from zero.

DoD has the biggest budget of any Federal agency for its laboratories--$11.6 billion in 1992; this includes not only R&D laboratories per se but also testing and evaluation (T&E) centers, such as the Air Force's Arnold Engineering Center in Tennessee and the Navy's Weapons Center at China Lake, California. Less than half of DoD's total budget for the labs is spent in-house; the rest is passed through to outside performers, mostly defense contractors.[7] With few exceptions (e.g., the science-oriented multiprogram Naval Research Laboratory), the Defense Department's R&D labs pass through well over half of their budgets while the T&E centers spend more than half in-house.[8] overall, more than *$5* billion was available for in-house RDT&E in DoD facilities in 1992.

The next biggest spender was DOE, with $4.7 billion.[9] In contrast with the DoD labs, most of the funding DOE provides its labs is spent in-house, and in fact is supplemented by about $1 billion from other Federal agencies, mostly DoD. DOE labs also differ from most DoD labs (and most other Federal labs as well) in that most are GOCOs.

For this report, with its focus on redirecting government R&D resources from military to commercial or dual-use applications, DOE nuclear weapons labs and DoD labs are most relevant. The former are of prime interest, for several reasons. The term ''weapons labs" usually refers to Los Alamos and Lawrence Livermore, which design nuclear warheads, and Sandia, which develops field-ready weapons using the warheads. These labs are in a class by themselves. Their collective budgets were over $3.4 billion in 1993, and together they had over 24,000 employees.[10] Nuclear weapons-related activities accounted for 51 to 60 percent of their operating budgets (least for Lawrence Livermore, most for Los Alamos); if the labs' work for the DoD is added in, funding for military-related activities ranged from 67 percent at Lawrence Livermore to 78 percent at Sandia. However, a growing share of activities funded by the nuclear weapons accounts is not, properly speaking, military. Nonetheless, funding for the labs from

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[7] *Department of Defense In-House RDT&E Activities* for Fiscal Year 1990, prepared for the Office of the Secretary of Defense, Office of the Deputy Director of Defense, Research and Engineering/Science and Technology (Washington, DC: The Pentagon, n.d.). This document reports spending for total and in-house RDT&E activities in 91 Army, Navy, and Air Force facilities, employing about 100,000 civilian and military personnel. Spending for the total RDT&E program was $8.4 billion, with $3.9 billion (46 percent) spent in-house in fiscal year 1990. These figures are not exactly comparable with R&D data collected by the National Science Foundation. They are mostly limited to RDT&E activities where funding for in-house RDT&E is at least 25 percent of the in-house portion of the facility's budget; they do not include spending in FFRDCs. See also Michael E. Davey, ''Defense Laboratories: Proposals for Closure and Consolidation,'' Congressional Research Service, The Library of Congress, Jan. 24, 1991, p. CRS-6.

[8] Ibid. In 1990, the R&D labs spent $2.4 billion of their total $5.8 billion RDT&E budget in-house (41 percent); the T&E centers spent $1.6 billion of $2.7 billion (59 percent) in-house.

[9] Note that these figures are only for R&D performed in government-owned, - operated, or -funded labs. DoD's total 1992 budget authority for R&D, excluding expenditures for R&D plant and equipment, was about $38.8 billion. DOE's was $6.5 billion.

[10] This counts only regular employees. On-site contract employees amount to many more. In 1993, Sandia's 8,450 regular employees were supplemented by 2,000 on-site contract employees; Los Alamos, with about 7,600 regular employees, had some 4,000 on-site contractors.

the nuclear weapons accounts rose in FYs 1992 and 1993 (in constant dollars, taking inflation into account), but this growth was largely due to big increases for a massive environmental cleanup job, plus rising amounts for non-proliferation work, decommissioning existing weapons, and safety and security of the remaining nuclear stockpile, all of which are funded by the nuclear weapons accounts.

The fact is that the nuclear weapons labs are looking at a future that is very different from their past. Their mission of nuclear weapons design is fading; in 1993, no new nuclear weapons were being designed. Among Federal R&D institutions, the nuclear weapons labs face the clearest need to change with the end of the Cold War.

The DOE **Laboratory Complex**

DOE's laboratory complex consists of the nine multiprogram laboratories (including the weapon labs) that are usually called the national labs, plus eight single-program energy labs.[11] They are funded by six program areas: Defense Programs and related nuclear weapons offices, which includes work in all aspects of nuclear weapons design, safekeeping, non-proliferation, and environmental restoration of the damage from 50 years of weapons work; Energy Research, which supports fundamental scientific research; the Nuclear Energy, Fossil Energy, and Conservation and Renewable Energy Programs, which concentrate on applied energy R&D; and the Environmental Restoration and Waste Management Program.

In 1992, the weapons labs got over one-half of the funding for all the labs in the DOE complex. The biggest part of their funding comes from DOE's atomic energy defense weapons account (including Defense Programs and related nuclear weapons offices); DoD contributes an additional, though declining, share (figures 1-8, 1-9, and 1-10). These labs have fluctuated in size over the last two decades. In the early 1970s as the Vietnam War wound down, their budgets were cut substantially (in constant dollars). With the new emphasis on energy supply and conservation programs in the Carter years, the weapons labs diversified into more nondefense work; both their energy and defense funding rose. Then in the military buildup of the 1980s, nuclear and nonnuclear defense work grew rapidly,[12] pushing the weapons labs' budgets up 58 percent from 1979 to 1992 (in constant dollars), while the energy labs' funding rose 15 percent (figure 1-11).13 The budgets for the three labs combined continued to climb through 1993, when their funding was almost two and one-half times what it was at the low point in 1974 (figure 1-12). Only Lawrence Livermore took a substantial cut in 1993; funding for Sandia and Los Alamos continued to rise.

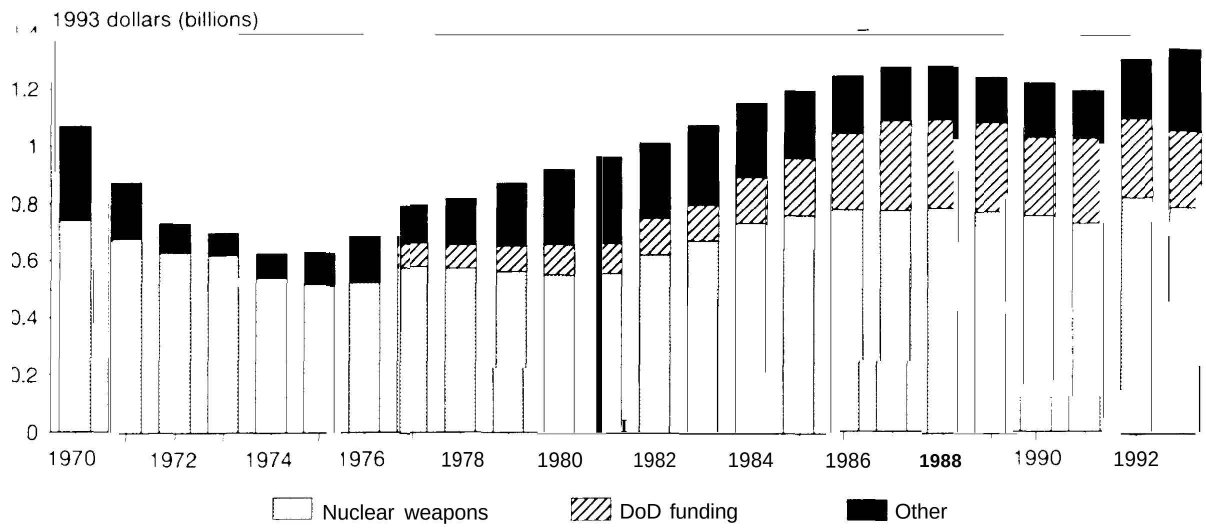
Although details of the FY 1994 budget were not yet available as this report was completed, cutbacks were probably in store for the weapons labs as well as the rest of the defense establish-

11 The number of DOE labs differs as counted by various sources. If small, specialized labs are included, the number can be as @I@ as 29. The figure of 17 comes from Secretary of Energy Advisory Board, *A Report to the Secretary on the Department of Energy National Laboratories* (mimeo), July 1992. The other national labs are the six energy multiprogram laboratories: Argonne National Laboratory, Brookhaven National Laboratory, Idaho National Engineering Laboratory, Lawrence Berkeley Laboratory, Oak Ridge National Laboratory, and the Pacific Northwest Laboratory. DOE's eight single-program laboratories include: Ames Laboratory, Continuous Electron Beam Accelerator Facility, Fermi National Accelerator Laboratory, National Renewable Energy Laboratory (formerly the Solar Energy Research Institute), Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, Stanford Synchrotrons Radiation Laboratory, and the Superconducting Super Collider Laboratory.

12 Much of the non-nuclear defense work was for the Strategic Defense Initiative.

13 U.S. Department of Energy, unpublished data from the Institutional Planning Database, US DOE ST-31 1, These calculations include the Idaho National Engineering Laboratory (INEL) among the energy labs. INEL is sometimes categorized separately as a "nuclear energy" laboratory because its work is concentrated largely in producing nuclear materials (mostly for weapons) and handling nuclear wastes. Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and Pacific Northwest National Laboratories are considered "energy research" laboratories. Excluding INEL, the total funding for the energy research labs rose about 10 percent from 1979 to 1992.

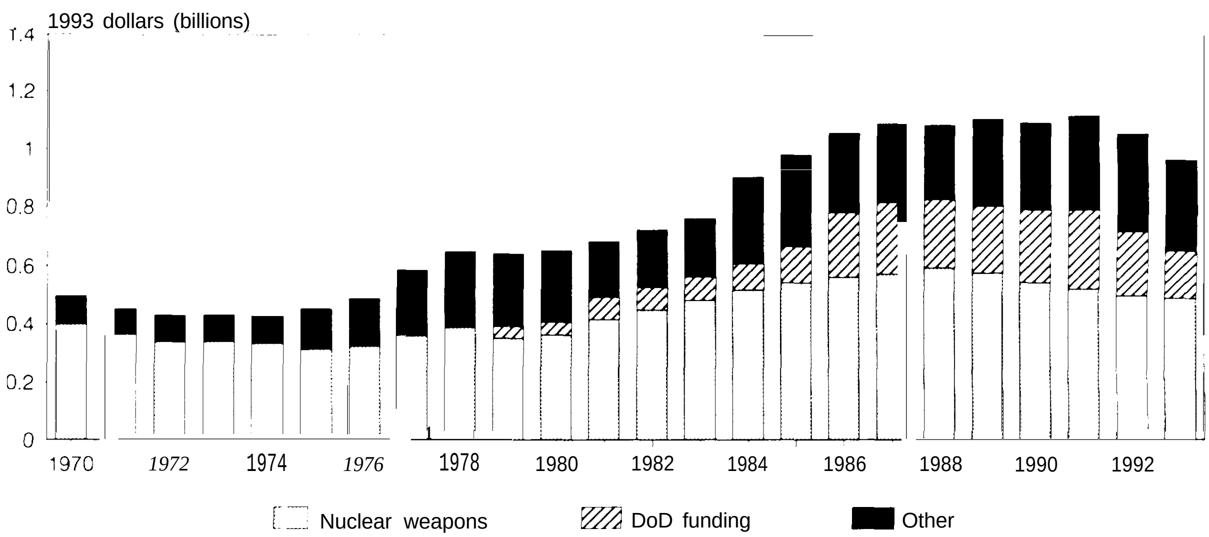
Figure 1-8-Nuclear Weapons and **DoD Funding for Sandia National Laboratories**



NOTES: Operating budget **only. DoD funding data not available prior to 1977.**

SOURCE: Sandia National Laboratories.

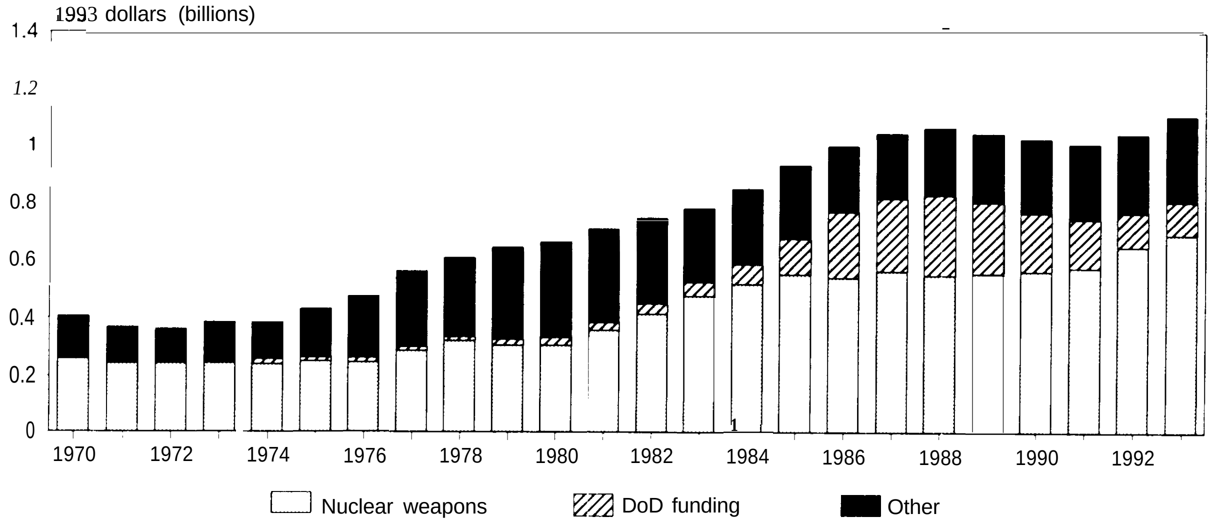
Figure 1-9—Nuclear Weapons and DoD Funding for Lawrence Livermore National Laboratory



NOTES: Operating budget only. DoD funding data not available prior to1979.

SOURCE: **Lawrence Livermore National Laboratory.**

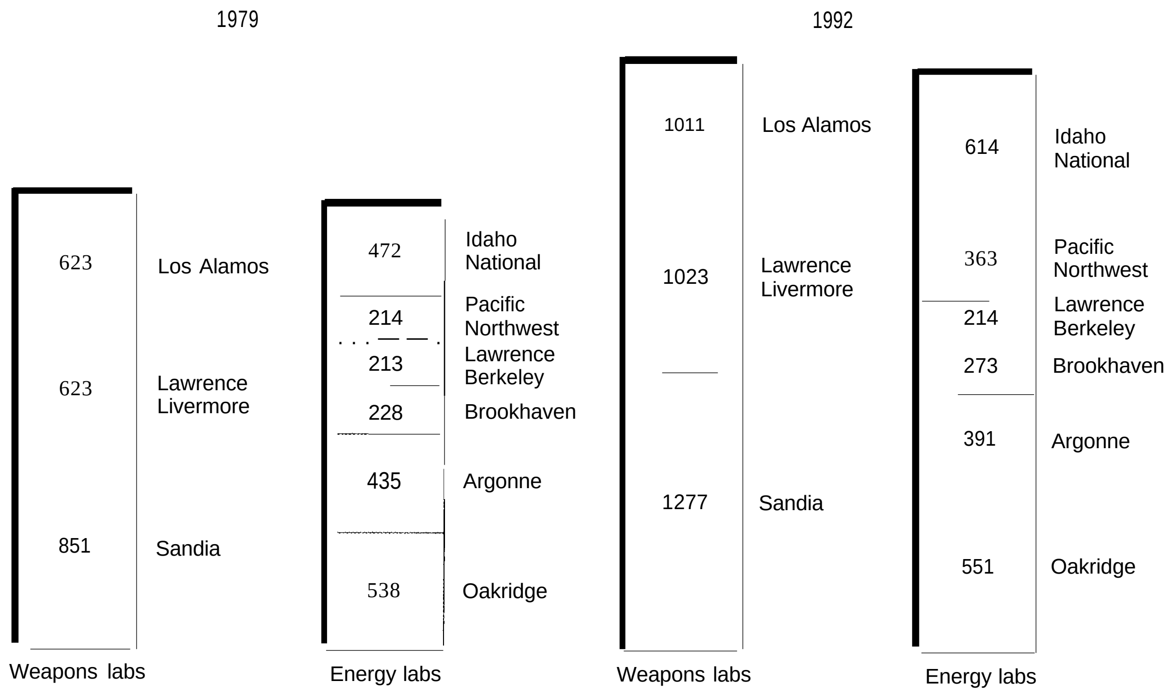
Figure 1-10—Nuclear Weapons and DoD Funding for Los Alamos National Laboratory



NOTES: Operating budget only. DoD funding data not available prior to 1974.

SOURCE: Los Alamos National Laboratory.

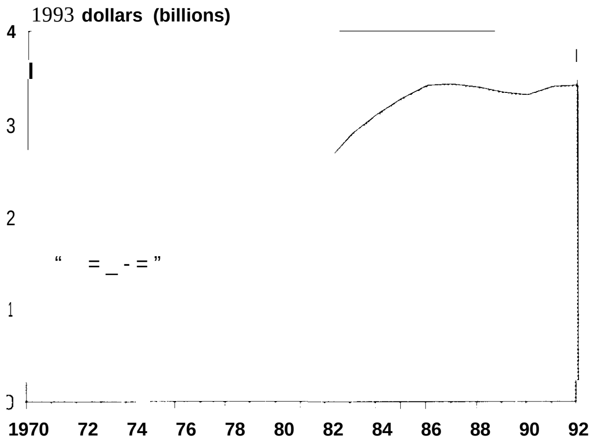
Figure 1-1 l—Funding for DOE Multiprogram Laboratories in 1979 and 1992 (in millions of 1992 dollars)



NOTE: Operating budget only.

SOURCE: U.S. Department of Energy, ***DOE Multiprogram Laboratories: 1979 to 1988 A Decade of*** **Change (Washington, DC: September.1992); U.S. Department of Energy; Los Alamos National Laboratory,** Lawrence Livermore National Laboratory, Sandia National Laboratories. " "

Figure 1-1 2-Combined Funding for Lawrence Livermore, Los Alamos, and Sandia National Laboratories, 1970-93



NOTE: Operating budget only.

SOURCE: Lawrence Livermore National Laboratory, Los Alamos National Laboratory, and Sandia National Laboratories.

ment. In any case, further changes in direction appeared certain. Announcing a new technology initiative in February 1993, President Clinton and Vice-President Gore committed the Administration to altering the mix of government R&D support; the share for civilian technologies would be lifted from 41 percent in 1993 to over 50 percent by 1998, they said.[14] While emphasizing the part to be played by a strengthened Department of Commerce, they also promised a review of all laboratories managed by DOE, NASA, and DoD ''that can make a productive contribution to the civilian economy,' with the aim of devoting at least 10 to 20 percent of their budgets to R&D partnerships with industry.

DISPOSITION OF THE DOE WEAPONS LABORATORIES

The end of the Cold War has raised persistent questions about the future of the weapons laboratories. First, what if anything do the labs have to offer beyond their traditional work in nuclear and nonnuclear defense-in particular, what do they have to offer that is truly valuable to civilian industry and national competitiveness? Second, assuming the labs have outstanding capacities in technologies of importance to industry, how readily available are these capacities? Can the labs work in partnership with private companies without crippling delays or red tape? Finally, assuming private industry can get reasonable access to valuable capacities in the labs, how do these partnerships fit into a national technology strategy? What place does cooperative government/industry R&D in large expensive national laboratories have in a broader scheme for technology development and diffusion that will help U.S. industries keep up with the world's ablest competitors? Answers to these questions are not easy, and some can come only as the fruit of several years' experience.

Opportunities for Technology Transfer

The human talents and physical equipment in the three weapons labs are often described as among the Nation's freest. A central question is whether these resources fit with the needs of industry. Some skeptics have doubted that technologies dedicated to the exotic demands of nuclear warhead and weapon design could be of any use to civilian industry, but this view is too narrow. It is not in the final weapons system itself that synergies with commercial needs are most likely to occur, but rather in core competencies, technologies and production processes. Box 1-B summarizes the core competencies claimed by each of the three weapons labs (see ch. 4 for more detail).

In a report on industry relations with the Federal labs (mainly DOE labs), the private sector Council on Competitiveness concluded that there is clearly "extensive overlap between industry needs and laboratory capabilities. " Citing an informal poll of several of its member companies,

[14] President William J. Clinton and Vice-President Albert Gore, *Jr., Technology for America 's Economic Growth, A New Direction to Build Economic Strength, Feb. 22,* 1993.

Box I-B-Core Competencies of DOE's Nuclear Weapons Labs

Lawrence Livermore National Laboratory
- Measurements and diagnostics
- Computational science and engineering
- Lasers, optics, electro-optics
- Manufacturing engineering
- Electronic systems
- Engineered materials
- Applied physics and chemistry
- Atmospheric and geosciences
- Defense sciences
- Bioscience

Alamos National Laboratory
- Nuclear technologies
- High-performance computing and modeling
- Dynamic experimentation and diagnostics
- Systems engineering and rapid prototyping
- Advanced materials and processing
- Beam technologies
- Theory & complex systems

Sandia National Laboratories
- Engineered materials and processes
- Computational simulations and high-performance computing
- Microelectronics and photonics
- Physical simulation and engineering sciences
- Pulsed power

SOURCE: Lawrence Livermore, Los Alamos, and Sandia National Laboratories, 1993.

the Council said that industry rated several technologies as major technical areas in which they need assistance.[15] The technologies included advanced materials and processing, advanced computing, environmental technologies, and manufacturing processes, testing, and equipment. The labs specified these same areas as ones in which they have unique capabilities that could help industry. Three out of four of these areas have contributed to and been supported by the nuclear weapons program for decades, and the fourth, environmental technologies, is now a prominent part of the program.

Examples of synergies are numerous, especially in computer modeling and simulation. All three weapons labs have demonstrated mastery in high performance computing. They were the first customers of early supercomputers and were close collaborators in developing both hardware and software (the relation between Los Alamos and Cray Research was especially close). They are still leaders today as early purchasers and contributors to the design of massively parallel machines and software. Applications of computing power developed in the labs for weapons purposes have already found many civilian uses and have the potential for many more. For example, computer codes developed to model the effects of nuclear explosions have been adapted to model crash dynamics and are widely used in the auto industry.

In addition, each of the labs has distinctive assets. One of Lawrence Livermore's particular strengths is in laser technology. Sandia, with its experience in engineering weapons that contain nuclear warheads, has special facilities and experience in advanced manufacturing technologies, in particular for semiconductors. Sandia's Combustion Research Facility at Livermore, California, is a magnet for university, industry, and other weapons lab researchers in a variety of fields, including ''lean-burn' combustion of hydrocarbons in auto engines. Los Alamos has traditionally concentrated on basic scientific research; its meson physics laboratory attracts university and other laboratory researchers, and it is a center for the development of complexity theory in mathe-

15 Council on Competitiveness, *Industry as a Customer of the Federal Laboratories* (Washington, DC: Council on Competitiveness\ September 1992), p. 10.

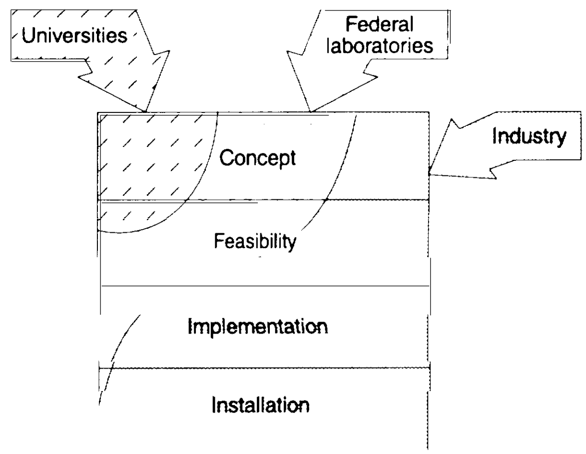
16 DOE's energy research labs also have some distinctive facilities and assets of interest to industry. For example, IBM has used Brookhaven's synchrotrons storage ring as a source of x-rays for advanced lithography technology for semiconductors, and several companies use Oak Ridge's High Temperature Materials Facility for development of advanced ceramics.

matics. All three labs are leaders in developing advanced materials.[16]

Behind the specific technologies in which the laboratories excel are their human resources and their experience with state-of-the-art equipment. Leaders at the labs claim unique capacities to take on large-scale projects where science makes a difference, engineering is also required, and teamwork is essential; the multidisciplinary approach is ingrained in the labs, they say, Recognizing the contribution of universities, especially in scientific research and in training new generations of researchers, they see the labs as having the additional capacity to marshal the people and spend the time required for tackling big, long-term problems. And they believe their ability to concentrate on the long term is a distinctive addition to privately funded industrial R&D, which generally has a shorter term focus—especially since some of the Nation's leading corporate labs have been scaled back or disbanded. The DOE labs' role can be seen as intermediary between the universities, the source of most basic research, and industry, which turns new technologies into commercial products and processes. Their best contribution may be the ability to carry scientific concepts into large-scale demonstration projects. (Figure 1-13 schematically represents the roles of universities, industry, and the DOE labs in various aspects of R& D.)

Assuming that the labs do have technological resources of potential value to industry, there remains the question of whether they can work successfully with industrial partners to transfer technology to the commercial realm. Until the 1990s, most of the evidence suggested that the answer was no. A few Federal agencies and their labs have long worked effectively with the private sector, but most—including DOE--+oncentrated on their public missions and gave relatively little attention to technology transfer. Despite urging

Figure I-13-Capabilities in Semiconductor Technology



SOURCE: Los Alamos National Laboratory.

from various commissions and internal evaluations, despite several laws in the 1980s pushing technology transfer, there was not a great deal to show for it.

Since 1989, the picture has changed, with several significant developments. First, the National Competitiveness Technology Transfer Act (NCTTA) of 1989 allowed the contractor-operated DOE labs, for the first time, to sign cooperative research and development agreements (CRADAs) with industry.[17] Although it was possible for the labs to undertake cooperative projects before, and some had done so, CRADAs have some significant advantages, including clear-cut legislative authority and the ability to protect intellectual property generated in the projects for as long as 5 years. Cooperative projects with the labs often have a good deal more appeal for industry than simply licensing existing technology, because so much of what the labs have to offer needs extensive development before it is useful to commercial firms.

17 GOGO labs had been given the authority to sign CRADAs in 1986, in the Federal Technology Transfer Act of 1986, and Executive Order 12591, issued by President Ronald Reagan in April, directed Federal agencies to delegate to GOGO lab directors authority to negotiate terms of CRADAs.

Second, by 1992, top officials of the Administration as well as Congress were actively pushing technology transfer from Federal R&D programs and labs. DOE claimed technology transfer as a "formal, integrated mission" of all its labs, with the primary goal of 'assisting U.S. based companies in the global race for competitive technologies. '[18] In February 1992, President George Bush launched a National Technology Initiative, with 15 conferences around the country at which 10 Federal agencies[19] invited industry to make commercial use of government-sponsored research.

Interest on the part of industry has been unprecedented—a third major factor. No doubt this was partly because the power and prestige of the President and his cabinet officers were now behind the program. At the same time, many in U.S. industry had come to recognize that they needed the government as a partner in R&D, especially for high-risk, long-term, expensive projects.

Fourth, there is a new pot of money for cooperative R&D projects—at least for the DOE weapons labs and for Defense Programs (DP) in the energy labs. NCTTA and subsequent legislation encouraged the labs to build cooperative projects with industry into their R&D programs to the maximurn extent practicable,[20] and to set a goal of devoting 10 percent of their DP funds to cooperative agreements.[21] But to give the CRADA process a jump-start, Congress also directed that $20 million of Defense Programs' R&D funds in fiscal year 1991 be explicitly set aside for cooperative projects with industry; the sum was raised to $50 million in 1992 and at least $141 million in 1993.[22]

Finally, the labs themselves now have a powerful motive for making technology transfer a central mission. During the 1980s, while Congress was urging this mission on the labs, it was at the same time providing steep rises in funding for both nuclear and nonnuclear defense work. Little wonder that the weapons labs, which saw their nuclear weapons and DoD funding swell by more than half in the 1980s, should redouble their concentration on their historic defense mission and that a new mission of working with industry on commercially promising technologies should be relatively neglected. The end of the Cold War and the dissolution of the Soviet Union has upended these priorities. Although some in the labs still believe they will get the biggest part of a shrinking defense pie, many of the labs' managers and researchers know their defense responsibilities must decline.

This combination of factors means that now, for the first time, there is broad, significant interest in lab/industry partnerships. Evidence can be seen in the fact that in July 1992 there were 1,175 CRADAs joining private companies and Federal laboratories, compared with 33 in 1987. By November 1992, DOE's CRADAs numbered 292.[23] It is noteworthy too that for every CRADA signed with DOE weapons labs there are many more that did not make the cut. The competition for getting CRADAs approved and funded is now keen.

18 U.S. Department of Energy, "The U.S. Department of Energy and Technology Transfer, " mimeo, n.d.

19 Participating agencies included the Departments of Commerce, Energy, Transportation, Defense, Interior, Agriculture, and Health and Human Services as well as NASA, the Environmental protection Agency, and the White House Office of Science and Technology Policy,

20 The Defense Authorization Act for Fiscal Years 1992 and 1993, sec. 3136 (enacted in 1991).

21 U.S. Senate, Committee on Armed Services, *National Defense Authorization Act for F&al Year 1993: Report,* report 102-352, to accompany S. 3114.

22 Ibid. A@ the Clinton Administration proposed in March 1992 to set aside an additional $47 million from DP R&D funds fOr cooperative projects; a set-aside of $47 million from other DOE programs was also proposed.

23 This figure includes all DOE labs, not the weapons labs alone. Data provided to OTA by the U.S. Department of Energy.

Roadblocks to Technology Transfer

Despite the unprecedented interest in cooperative lab/industry projects, the process of getting agreements actually signed got off to a very slow start. In some cases, lags were due to unfamiliarity—on industry's side as well as DOE's—and some was due to bureaucratic foot dragging at DOE headquarters. It took well over a year for DOE to put in place some of the basic procedures for signing CRADAs. From 1989, when DOE's national labs gained authority to sign CRADAs, to early 1991, only 15 CRADAs were signed. Since then the pace has picked up, with close to 300 agreements signed by 1993 and the time for negotiations becoming shorter. Even so, some of the many companies keenly interested in the labs' technological offerings were still expressing impatience with the time and expense involved. Possibly, the windows to cooperative R&D that were opened so recently might close if the difficulties are not soon solved.

REASONS FOR DELAY

In early 1993, it still took 6 to 8 months or more to nail down most individual CRADAs--starting with the submission of a proposal, which itself may have taken many months to develop in talks between lab and industry researchers. Much of the delay is laid at the door of DOE headquarters control, though some also occurs at the labs and at DOE field offices; company legal counsels are also named as sources of delay. The progress of CRADAs at DOE labs is often compared unfavorably (but not altogether fairly) with the process at other Federal labs—in particular NIST labs, whose parent agency, the Department of Commerce, has delegated most of the authority to sign CRADAs to lab directors. NIST agreements are often out the door in a few weeks. Some in the private sector have strongly advocated giving both authority and money for CRADAs to the lab directors, with DOE exercising control through evaluations of the labs' performance and budgets for subsequent years.[24]

This solution is possible and might well speed up the process, but it is not as simple as it may seem. First, the legal authority for CRADAs in GOCO labs (e.g., the DOE labs) is quite different from that in GOGOs (e.g., NIST labs and most DoD and NASA labs[25]). NCTTA requires that the parent agency must *approve every* joint work statement (the first step in preparing a CRADA) from GOCOs as well as the CRADA itself; under the Federal Technology Transfer Act of 1986, GOGO labs may go ahead with a CRADA so long as the parent agency does not *disapprove* within *30* days. This difference in the laws reflects a fairly common attitude in Congress that some GOCO contractors, laboratory directors, and researchers are less reliably committed to public purposes than the government employees who staff GOGOs.[26] Congressional oversight covering details of lab operations is seen as partly responsible for DOE's close management of many of the labs' doings, including CRADAs.

Other factors-probably still more important—are size and visibility. DOE's national labs, especially the weapons labs, are far larger than most other labs in the Federal system, their CRADAs involve much more money, and they get much more scrutiny. DOE feels obliged to be above reproach on issues such as fairness of opportunity for companies wishing to work with labs and requirements that jobs resulting from

24 See, for example, Council on Competitiveness, *Industry as a customer of the Federal Laboratories* (Washington, DC: September 1992).

25 One major NASA lab, the Jet Propulsion Laboratory at the California Institute of Technology, is a GOCO, but in any case NASA labs do not use CRADAs. They have their own legal authority to make cooperative agreements with industry under the 1958 Space Act, and have long done so.

26 Those holding this view do make some distinctions among GOCO contractors and the labs they manage; some are seen as more responsive to public purposes than others. One contractor that has received little criticism is Sandia Corporation, a subsidiary of AT&T, which has managed Sandia National Laboratories for $1 per year since 1949. However, AT&T announced in 1992 that it would not renew the Sandia Corporation contract the following year. AT&T's long stewardship of Sandia comes to an end in September 1993.

lab/industry R&D partnerships stay in the United States.

Finally, some delay is inherent in the system Defense Programs at DOE headquarters has devised to exercise guidance over a cooperative R&D program that has grown to substantial size. By far the largest sum of money available for DOE CRADAs is in Defense Programs, in the set-aside from the atomic weapons RDT&E account for cooperative agreements and technology transfer. The set-aside was $141 million in fiscal year 1993 and was planned to rise to $250 million by 1995. Most of the projects DP funds come from the three weapons labs, since they are the leading performers of atomic weapons R&D, but several of the energy labs also have some DP funding.

DP managers believe that strategic direction is essential in a program of this size, and that it should be a coherent part of multilab initiatives to develop dual-use technologies. As of 1992, DP managers planned to fund initiatives in semiconductor lithography, flat panel displays, a broad array of automotive and transport technologies, and advanced materials and ceramics. Several times a year, DP issues a call for proposals from the labs and potential industry partners for R&D in these areas.[27] Dp then reviews the proposals in two steps (see ch. *4* for details); the purpose of the review process is to minimize unnecessary duplication and encourage complementarily.

All of this precedes the preparation of a joint work statement and CRADA that, by law, DOE must review. The agency has formally delegated to DOE field offices responsibility for these two final reviews, which can take up to 120 days, but in practice has shrunk to less than 90 in most cases.[28] DP aims to keep the time from the formal submission of a lab/industry proposal to approval of the work statement and CRADA to no more than 6 months, and eventually reduce it to 4 months.[29] This goal had not been met by early 1993.

The time for negotiating CRADAs will probably decrease as everyone becomes more familiar with the exercise; it was already somewhat shorter in 1992-93 than a year or two earlier. There were still delays at several points in the system, however; and there is some inherent delay in a system that aims for strategic direction, coherence, and selection on merit among competing proposals.

FUNDING BOTTLENECKS

Up to now, the DP set-aside has been the source of nearly 70 percent of DOE's funds for CRADAs. Another option is to use program funds, rather than tapping into a special set-aside. Indeed Congress has urged DOE to use this route, writing into law that the labs are to use all their weapons R&D funding to the "maximum extent practicable" for cooperative agreements and other forms of technology transfer, and using committee report language to suggest that at least 10 percent be devoted to the purpose.[30] At present, this is hard to do. At the beginning of each budget cycle, DOE and the labs establish how they will spend their program funds and allocate lab budgets to individual projects. Afterwards, it may be difficult for lab project leaders to adjust the focus or scope of project work to accommodate the interests of a potential industrial partner. A project that has been significantly redefined needs

27 There may be only one call for proposals in fiscal year 1993.

28 According to the law, DOE review of the joint work statement must be Completed in 90 days, and review of the CRADA in 30 days. Although the labs have proposed submitting both documents at once, and keeping the time to 90 days, some of the field offices have taken the position that the review periods should be sequential. However, in practice, nearly all the reviews have been completed within the 90 days.

29 As noted, this whole process comes on top of the time that the lab and company researchers take to define the work they want to do together. The same is true of other Federal labs, such as NIST; the CRADA approval process starts after much preliminary work has been done by the researchers involved.

30 Department of Defense Authorization Act for Fiscal Years 1992 and 1993, Public Law 102-190, sec. 3136.

the approval of lab managers and DOE headquarters.

In DOE programs outside DP, funding for CRADAs has been meager. For example, General Motors held a "garage show" at its technical center in Warren, Michigan, in January 1992 to acquaint hundreds of company engineers and scientists with technologies available at DOE labs. The meeting was a success, with enthusiasm on both sides. The upshot was that GM researchers identified over 200 interesting cooperative prospects, afterwards winnowed to 25 formal proposals. About half of these proposed to use DP facilities, and were eligible for funding from the DP set-aside. The other half were submitted to various energy programs; only 2 received funding, compared with 14 submitted to DP. According to GM, this was because money outside DP was lacking.

The DP set-aside is not a bottomless well. In its June 1992 call for proposals, DP received 398 first-round submissions, requesting $170 million in first year funding from DOE; these were later winnowed to 184, requesting $79 million.[31] Eventually, 61 were funded with first-year funding of $40 million (matched by an equal amount from the industry participants). In November 1992, a call for proposals for a still smaller pot of DOE money—about $25 million-drew hundreds of proposals. Even if the DP set-aside were raised to $250 million a year, many proposals would fail to make the cut.

LEGAL BOTTLENECKS

Just as there is a genuine tension between the goal of fast action on CRADAs and that of coherent, strategic direction of cooperative technology development, so there are some real conflicts regarding legal agreements between the labs and industry. One source of disagreement is protection of intellectual property.

The public interest in allowing private companies rights to intellectual property developed in part at taxpayer expense has been recognized in a series of laws, starting with the Stevenson-Wydler Act of 1980. Companies that put their own money into cooperative R&D with government labs are interested in exclusive rights to resulting inventions.[32] If they can't get those rights, at least for some period, they are not likely to find much appeal in the project. On the other hand, government also has an interest in broad diffusion of new technologies, especially those partly funded by public funds.[33]

NCTTA allows the labs to protect intellectual property generated in a CRADA for up to 5 years, and further exempts from the Freedom of Information Act any intellectual property companies bring to the CRADA (thus protecting against discovery by competitors). Although industry welcomed the changes under NCTAA, some potential industry partners still consider the protection of intellectual property insufficient, especially for software. However, some in government foresee trouble down the road if the balance tips too far, and intellectual property developed in part at the expense of the taxpayer is held too tightly by CRADA partners. DOE does

31 Full multiyear funding requested was $778 million for all the CRADA proposals submitted, and $3%? million for the winnowed list. These numbers represent DOE's share, to be matched by industry.

32 Subject, that is, to the government's royalty-free use of the invention for its own purposes.

33 The U.S. patent system, which protects intellectual property and rewards inventors with exclusive rights for a number of years, also has some positive technology diffusion effects in its requirement for disclosure of the technical workings of the patented device or process. Although others cannot freely copy the patented device, they may be able to invent around it, i.e., devise another version with help from the disclosure. NCTTA not only provides patent rights to CRADA partners, but also protection for another form of intellectual property, or proprietary information that is not patented. Data that is generated by industrial partners in CRADAs may be kept free from disclosure under the Freedom of Information Act for up to 5 years. In some industries (e.g., computer software) protection of data is more important than patent rights.

not take a direct hand in negotiations over intellectual property in CRADAs or other cooperative agreements; it assigns the rights from lab activities to the contractors who operate the labs, and the terms are largely up to the labs and their industrial partners, within the general limits set by the law. Nevertheless, DOE can if it wishes exercise some oversight over the labs' handling of intellectual property rights, and the issue remains a live one for public policy.

An attempt to compromise and settle the problem for a whole industry was part of the umbrella CRADA for manufacturing process technologies signed between four DOE labs (the three weapons labs and Oak Ridge) and the National Center for Manufacturing Sciences (NCMS) on behalf of itself and member companies. The CRADA gave NCMS exclusive rights to license commercial applications in fields covered by the project's task statement for 30 months after project completion. The terms are similar to those used by NIH and are somewhat more generous to industry than those of NIST, two agencies generally considered successful in transferring technology from government lab to industry. However, the agreement is coming unraveled. Some NCMS member companies are dissatisfied with the terms; in particular, they want to widen the field of use (breadth of application) to which their intellectual property rights apply. In another industry, computer systems companies are insistent on protecting the source code for software developed in lab partnerships; without this protection, they argue, their investment in the software will gain them nothing.

There is no simple or obvious solution to the problem of balance in disposing of intellectual property rights. It is not just in DOE labs that these rights can become a thorny issue. They are often a sticking point in negotiations with other labs as well, including NASA and NIST. The problems are considerably less when the industrial partners to cooperative agreements are members of consortia, and the technologies being developed are considered generic or precompetitive.

A second field of conflict is the issue of U.S. preference. A central goal of R&D partnerships between government and industry is to improve U.S. competitiveness and thus promote economic growth and rising standards of living. Accordingly, there is a strong public interest in seeing that publicly financed innovations are used in ways that directly benefit the U.S. economy. The Federal Technology Transfer Act of 1986, which authorized GOGO labs to sign CRADAs with industrial partners, directed the labs to ''give preference to business units located in the United States which agree that products embodying inventions made under the [CRADA] will be manufactured substantially in the United States.' '[34] Taking its cue from this law, DOE wrote into its model CRADA a requirement, not just a preference, for U.S. manufacture.

The realities of international ties between businesses have forced departures from this requirement. The first major exception was in the umbrella CRADA with the Computer Systems Policy Project (CSPP), which represents U.S. computer systems manufacturers; in this CRADA the requirement was rewritten to cover R&D only, not manufacture. CSPP insisted that existing networks of manufacturing, R&D, and cross-licensing among computer companies of all nationalities made the requirement for domestic manufacture impossible. Other companies subsequently began to demand the same terms and in February 1993 DOE modified its stance, saying it would consider case-by-case exceptions where substantial U.S. manufacture is shown not to be feasible, and where industrial partners commit themselves under contract to appropriate alternate

34 15 U.S.C. 3710(c)(4)(B).

35 Memorandum from U.S. Department of Energy to Program Secretarial Officers and Field Office Managers, ' 'Restatement of Departmental Technology Transfer Policy on U.S. Competitiveness, " Feb. 10, 1993.

benefits to the U.S. economy.[35] The general rule remains to demand U.S. preference; if industrial partners ask for exceptions they bear the burden of showing in detail why it should not apply.

This probably does not settle the matter. Controversy seems bound to arise when a technology developed under a CRADA yields a successful commercial product that is manufactured abroad, possibly by a foreign company. Whenever foreign companies exploit an American technology in a high-tech field, there are those who regard this as a failure of public policy, and the condemnation is likely to be still stronger if the technology was developed in part with public money. This view, though understandable, is simplistic.

First, it has always been hard to stop the diffusion of technology, even 200 years ago at the dawn of the industrial age. Today, with rapid communication and increasing worldwide trade and investment, the tendency toward technology diffusion is far stronger and to a great extent is beyond the control of governments. Second, and less well-known, is the fact that U.S. fins' ability to use access to technology as a bargaining chip in negotiations with foreign firms and governments can be a powerful advantage. That advantage can, in the end, work to the benefit of the U.S. economy and standard of living. For example, the ability of General Electric's Aircraft Engine division to sell jet engines to European airlines may well hinge on adding some value in Europe, and that in turn may mean licensing some of GE's technology to a European partner. The European company gets some of the manufacturing work and some of the know-how, but the European sales also create good jobs and technology advance in the United States.

The issue of U.S. preference does not simply pose a private interest against a public one, Two conflicting public interests are also involved: the benefits of government/industry R&D partnerships on terms industry finds useful vs. the benefits of keeping manufacturing jobs at home.

One more major difficulty has bedeviled DOE's CRADA negotiations: who is liable in *case* someone sues for injury from a commercial product based on technology developed under the CRADA? DOE'S initial answer, contained in its first model CRADA, was that the industrial partner must reimburse the lab or government for any damages awarded; in other words, the company bears all the liability, no matter who is at fault. So many companies found these terms unacceptable that DOE changed its position, and its policy guidelines now exempt the industrial partner from liability when the damages are due to the negligence of the lab.

The new formula is not entirely satisfactory to industry. In case of a suit, it may be difficult for the partners to sort out responsibility for damages. DOE is considering whether it might be simpler to leave out any reference to liability in CRADAs and let the courts determine who is at fault. This issue is probably best seen as part of the larger product liability problem that plagues some of America's industrial sectors, and is most likely to find satisfactory solution as part of a broader resolution.

The Longer Term Future of the Weapons Laboratories

The discussion so far has assumed that the labs will continue to exist in recognizable form, though they may change in goals, emphasis, or size. However, many people are asking more fundamental questions about the labs. The DOE weapons labs had their origin in the atomic weapons program of World War II, and afterwards expanded their goals, first to peaceful uses of nuclear energy, then to energy supply and use more broadly, including the environmental consequences of both. More than at any time since they were created, insistent questions are arising about what national purposes the labs ought to serve and what size and shape is appropriate to those purposes. Assuming, for the sake Of argument, that the labs have exceptional capacities to work in harness with industry to advance commercially promising technologies, and that they can work out effective ways of doing so, are they also reasonably efficient institutions for the purpose? What part do they have in a coherent U.S. Government technology policy?

Three divergent points of view have begun to emerge. First, drastically shrink and restructure the whole DOE laboratory system, perhaps giving the job to a commission like the military base closing commission. Second, maintain and reinforce the labs' traditional focus on nuclear and energy technologies. Third, give the weapons labs major new civilian missions, including both partnerships with industry and new or enlarged programs directed to public purposes (e.g., environmental protection). Although there are overlaps in these differing positions, they do represent three distinct evaluations of the labs' potential.

SHRINK THE DOE LABORATORY SYSTEM

There is little written or formal expression of this point of view, but some in Congress (especially in committees concerned with government operations) and in the university/industry research community put it forward quite forcefully informally. They are dubious that DOE labs have a useful place in developing commercial or dual-use technologies-or perhaps even in their traditional fields of energy and nuclear power, except for a much circumscribed weapons mission. The criticisms are twofold. First, the weapons labs are too imbued with the culture of national security and a reward system that promotes weapons experts to fit in the civilian world. Second, the labs and the contractors who operate them are not held properly accountable for their use of public funds, and use the money inefficiently.

The first objection might perhaps fade if the weapons labs were to show in a few years' trial that they can in fact work productively with industry. The second is more difficult. Historically, the labs' parent agencies (DOE and its predecessors) have given the contractors and directors of the labs an unusually free hand in management. On the other hand, the labs have been subjected to a good deal of congressional scrutiny on management issues. It is outside the scope of this report to evaluate the prudence or efficiency of the labs' management (or of any one of them; very likely there is a range, with some better managed than others).[36] Nevertheless it is certainly true that for their national defense work the labs have been showered with funds and equipment as few other government institutions have been. This largesse may have contributed to habits of inefficiency. If the weapons lab budgets decline significantly—as they had not yet done as of fiscal year 1993--financial stringency might force greater efficiencies. It is useful to remember, however, that the government's historic generosity and flexibility in funding for the DOE labs have contributed to what is generally thought to be their core strengths: multidisciplinary teams of high professional caliber combined with superb leading edge equipment.

REINFORCE THE LABS' FOCUS ON NUCLEAR AND OTHER ENERGY TECHNOLOGIES

Those who occupy this middle ground regard the DOE national labs as treasures worth preserving, but consider that several of the labs have lost focus and should reconcentrate their efforts in the traditional fields of nuclear power and energy, with their environmental ramifications. These views were stated recently by the Secretary of Energy Advisory Board (SEAB) Task Force, appointed by Secretary of Energy James D. Watkins in November 1990 to advise him on "a

36 This report, responding to the expressed interests of the requesting congressional committees and keeping in mind OTA's technology-oriented mission, concentrates on the potential technological contributions of the DOE weapons labs to the civilian economy. Analysis of complex management and accounting issues related to the labs is outside the scope of OTA'S assessment.

strategic vision for the National Laboratories . . . to guide [them] over the next 20 years. ' '[37]

The future laid out by the Task Force would define these major missions for the DOE labs: energy and energy-related science and technology, nuclear science and technology for defense and civilian purposes, and the fundamental science and technology that underlie these. For the weapons labs, the Task Force recommended a tight focus on nuclear defense (including nonproliferation, verification, and arms control) with whatever reductions and consolidation are necessary in an era of overall reduction of the Nation's defense effort. Major new responsibilities for environmental cleanup and waste management were included, however, for both the weapons and energy labs. Cooperative work with industry won a cautious endorsement. The Task Force suggested that a few flagship labs be designated as centers of excellence for technology partnerships with industry, selecting technologies consistent with their particular missions and devoting as much as 20 percent of their R&D budgets to cost-shared projects.

ASSIGN NEW CIVILIAN MISSIONS TO THE WEAPONS LABS

This approach for more thoroughgoing change has several versions. One suggestion, proposed by Rep. George E. Brown, Jr., Chairman of the House Committee on Science, Space, and Technology, would radically restructure the three big weapons labs. It would consolidate nuclear weapons design and non-proliferation work at Los Alamos; put verification activities at Sandia and continue its responsibilities for engineering the nonnuclear components of nuclear weapons, while also making it a center of excellence for technology transfer; and make Lawrence Livermore a civilian National Critical Technologies Laboratory, building on the lab's strengths in materials science, computational science, fusion, environmental remediation, and biotechnology .[38] Brown also proposed cutting the nuclear weapons RDT&E budget from about $2.7 billion a year to half that level over 4 years, and using all the savings for civilian technology programs in the DOE lab system. Another suggestion, coming from several sources, was to devote from 10 to 20 percent, or more, of the labs' budgets to cooperative projects with industry .[39]

Both these plans would put into the DOE labs an unprecedented amount of money for cost-shared development of dual-use and commercial technologies—possibly $500 million to more than $1 billion a year, depending on the labs' total budgets, with more than half coming from the weapons labs. Compare this with the Advanced Technology Program (ATP), operated by NIST, which has the general mission of supporting commercially promising R&D and awards cost-shared government funding to industry projects, selected on a competitive basis.[40] ATP is the closest thing to a civilian technology agency that

37 Secretary of Energy Advisory Board Task Force, *Final Report*, July 1992, attachment, Memorandum for the Chairman and Executive Director, Secretary of Energy Advisory Board, from the Secretary of Energy, James D. Watkins, Nov. 9, 1990.

38 Letter to the Honorable James D. Watkins, Secretary, U.S. Department of Energy, from George E. Brown, Jr., Chairm an, U.S. House of Representatives, Committee on Science, Space, and Technology, Feb. 8, 1992.

39 See, for example, Council on Competitiveness, *Industry us a Customer of the Federal Laboratories* (Washington, DC: 1992). The Council is sometimes confused with two other groups with similar names: the President's Council on Competitiveness, a government interagency committee made up of Cabinet members and chaired by Vice-President Dan Quayle under the Bush Administration; and the Competitiveness Policy Council, an independent advisory committee created by Congress and composed of Federal and State officials as well as private sector members.

40 Unlike the cooperative activities at DOE and other government labs, the ATP program simply provides cost-shared funding for R&D performed by the industrial partners.

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now exists in the Federal Government.[41] Its initial funding in fiscal year 1990 was $10 million; 4 years later, in 1993, its funding was $68 million.

The possibility of a sudden infusion of a much larger pot of government money for cooperative R&D than ever before raises several important questions. One is whether a lab mission broadly defined as ''economic competitiveness' is workable. Some top officials at the labs fear that such an imprecise definition of their responsibility could lead the labs to scatter their efforts and become nothing but job shops for industry. A particular strength of the billion-dollar weapons labs is their depth and versatility, but even these labs need to focus on technologies that fit their core competencies best.

A different approach would be to assign to the labs responsibilities for new missions that are clearly public in their goals and benefits, but also have the potential to replace defense activities as generators of technology, good jobs, and wealth-creating industries. Although the definition of "public missions'' is not fixed and immutable, there is general agreement on certain areas in which technological progress is important for human welfare, but is not likely to attract adequate private R&D investment because it does not promise individual companies enough profit to compensate for the risks. Some obvious candidates are the large, various, and growing field of environmental cleanup and pollution prevention; a nationwide communications "superhighway;' revitalized education and training that take full, imaginative advantage of computer aids and networks; and energy-efficient transportation systems that offer the public benefits of reduced environmental damage and less dependence on foreign oil (for more discussion, see chs. 7 and 8 and this chapter, below). Public missions could also encompass such things as support of advanced manufacturing technologies-an area of relative neglect for U.S. public and private investment.

It seems unlikely that any one new national mission can attract the generous, sustained level of funding that nuclear defense has received for 50 years, but it is possible that some combination of missions might be sufficient to keep the labs in the frost rank of R&D institutions, able to draw excellent researchers and do outstanding scientific and technical work.

A question that immediately follows is how new national missions might be assigned to the DOE weapons labs. The primary national interest is in the substance of the missions themselves, and there are certainly public and private R&D institutions other than the weapons labs—including industry and universities-that could share some of the tasks. Other agencies and their labs also have abilities that overlap with certain strengths of the weapons labs. Although some overlap in R&D is desirable, money and effort could be wasted if there is no interagency coordination or strategic planning. A coherent, rational R&D plan for a big new national initiative in areas such as environmental cleanup or less polluting transportation systems would set clear, concrete goals, milestones, and measures of performance, and would parcel out work to whichever government agencies are most fit for it, as well as enlisting university and industry collaboration. In fields of most interest to industry, such as advanced manufacturing technologies, industry guidance and cost-sharing would be essential.

Although coherent planning is unusual in government-supported R&D, there is a precedent in the High Performance Computing and Communications Program (HPCCP). The program's goal is "to accelerate significantly the commer-

41 As noted, other agencies have R&D programs that yield results of great benefit to various industries, e.g., NIH, NASA, the Department of Agriculture. But with the exception of NIST's manufacturing engineering and standards and measurements labs, Federal agency R&D is directed toward specific public missions (e.g., health) or to particular industrial sectors identified as important to public purposes (e.g., aircraft, space, agriculture)—not to commercial goals or competitiveness generally.

cial availability and utilization of the next generation of high performance computers and networks' '[42] and allow the private sector to leapfrog over improvements in supercomputers and networks that would otherwise be gradual and incremental. While HPCCP has encountered some criticism, it generally gets high marks both from participating agencies and from industry observers. Some planning for other Federal technology programs (e.g., advanced materials and processing, biotechnology, advanced manufacturing R&D, new energy technologies) is taking place but is in early stages compared with HPCCP, and the planning process is laborious.

Alternative R&D Institutions

Assuming that the DOE weapons labs achieve smooth working relationships with industrial R&D partners, are they too big, too expensive and too encumbered by their nuclear weapons history to serve the purpose efficiently? Some have suggested that a more useful kind of institution might be relatively modest regional centers with an unequivocal mission of doing applications-oriented R&D partially funded by industrial clients. Another model is ARPA. This small, free-wheeling DoD agency has a stellar record of advancing high-risk high-payoff technologies—not only in strictly military systems such as smart weapons and stealth aircraft, but also in dual-use core technologies, including microelectronics and computer hardware, software, and networks. ARPA does virtually no lab work of its own, but uses contracts, grants, and cooperative funding for R&D in private companies and universities.

THE FRAUNHOFER MODEL

Germany's Fraunhofer Society (Fraunhofer Gesellschaft, or FhG) has been proposed as a model for small-scale R&D institutions working in harness with industry. It is the smallest but probably best known and most admired of Germany four major publicly funded research institutions, which are managed and funded by BMFT, the science and technology agency. The FhG consists of 47 regional institutes with combined budgets of about $375 million a year; about 30 percent of their funding comes from contracts with industry, another 30 percent from government contracts, and most of the rest from national and state government grants. The FhG's clear mission is to promote innovation in civilian technologies and rapidly transfer research results to industry. The institutes put their efforts into applications-oriented R&D, often focused on the needs of regionally concentrated industries, and forge links between universities, industry associations, and individual companies.

There is little parallel with the FhG in the United States. Federal support of regional centers working with local industries on application-oriented R&D and technology demonstration has scarcely existed, but a new program called Regional Technology Alliances (RTAs) may develop into that kind of system. Authorized in fiscal year 1992, the RTAs received their first funding in fiscal year 1993, at the very substantial level of $97 million. This new program was part of a $1-billion defense conversion package to encourage technology development and diffusion in both defense and civilian sectors, but the law strongly emphasizes national security goals, and the program is lodged in DoD, managed by ARPA. This might constrain the RTAs from developing the frankly commercial character of FhG.[43] However, in planning the program, ARPA formed close cooperative ties with NIST, DOE's Defense Programs, NASA, and the National

42 Federal Coordinating Council for Science, Engineering and Technology, *Grand Challenges: High Performance Computing and Communications*, a Report by the Committee on Physical, Mathematical, and Engineering Sciences, to Supplement the President's Fiscal Year 1992 Budget (Washington, DC: Office of Science and Technology Policy, n.d.), p. 2.

43 Interestingly, the FhG found its early support from the military, but has long since outgrown that identity. Today, only 7 of the 47 FhG institutes perform primarily military R&D.

Science Foundation, and each was expected to take some of the responsibility for this and other defense conversion programs.

Assuming the RTAs succeed in forming links with commercial companies, they might fill an important niche in U.S. cooperative R&D. They would not be suited, however, to undertaking large-scale, long-term projects with a strong public purpose. Nor does it seem feasible for DOE labs to remake themselves on the FhG model (though that suggestion has been aired). Although some of the labs (Sandia in particular) have already demonstrated some ability to work with small companies in adapting lab technologies to the companies' needs, the labs' main strengths—technical talent in depth, multidisciplinary teams, expensive state-of-the art equipment—seem more suited to big projects.

ARPA

ARPA has attracted even more attention as a model for government-supported R&D. Through its 35 years of existence, ARPA has gained a reputation for rapid, flexible decisionmaking, and for placing its bets intelligently. At times it has been a major player in promoting advanced dual-use technologies and has fostered the development of industries whose main markets were commercial but that also could be an important source of supply for DoD. At other times, political pressures have confined ARPA more narrowly to strictly military objectives (see ch. 5).

The pressures today are running the other way. With defense budgets declining, DoD has more reason than ever before to emerge from the defense procurement ghetto, and buy more from the civilian sector. The advantages are twofold: prices are usually lower on the commercial side, and very often commercial technologies are more advanced--especially in computers and telecommunications. After at least a partial eclipse in the 1980s, ARPA has reemerged as a premier dual-use agency.

Despite the apparent divergence of military and commercial products (no one needs a stealth jet transport), critical technologies embodied in these products—advanced materials, semiconductors, software-are converging. Five of ARPA's 10 offices direct their research toward core technologies in electronics, microelectronics, computing, software, and materials, and they control 80 percent of the agency's budget. Moreover, they are putting more emphasis than ever before on manufacturing process technologies. Many of the agency's projects in this area are cooperative, partly funded by industry. ARPA typically prefers to work on these projects with commercial companies or commercial divisions of companies that also do defense work. The advantage for ARPA is that the company will support continued development of the technologies through its commercial sales, while serving as a source of supply for DoD. The broader economic advantage is wide diffusion of the ARPA-supported technologies and superior commercial performance.

ARPA is so highly regarded as a promoter of advanced technologies that, while the rest of the defense establishment faced shrinking missions and budgets, ARPA received a huge jump in funding in fiscal year 1993, from $1.4 billion to $2.25 billion; this included $257 million for s& defense conversion programs for codeveloping dual-use technologies and supporting manufacturing process technologies and education. In addition, in recent years Congress has mandated ARPA funding for specific dual-use programs, beginning in 1987 with the unprecedented 5-year, $500-million funding for Sematech (the semiconductor manufacturing consortium, cost-shared with industry), and continuing on a smaller scale with programs in high-definition systems, advanced lithography, optoelectronics, and advanced materials.

Besides all this, the defense conversion legislation for 1993 gave ARPA some entirely new responsibilities in areas with which it had no experience. These are the Defense Manufacturing Extension program, which will contribute to the costs of State and regional industrial extension programs for small and medium-size manufacturers; the Defense Dual-Use Extension Assistance program, aimed at helping defense companies develop dual use capabilities; and the RTAs described above. Each of these programs was funded at $97 million; for all of them, including the RTA, ARPA formed a joint Technology Reinvestment Project with four other Federal agencies to plan and oversee the programs.

ARPA is becoming, *de facto,* a dual-use technology agency with a wide range of responsibilities. Congress expressed its intention to formally give the agency a dual-use mission by dropping the word ''Defense" from its title, restoring its original name of Advanced Research Projects Agency; in February 1993, President Clinton directed DoD to make the change. Congress has stopped short of naming ARPA as the Nation's lead agency for technology policy, and there is support in Congress, as well as Administration backing, for much higher funding for the small civilian technology development and diffusion programs lodged in NIST.[44] ARPA, with all its cachet of success in dual-use technologies, is still a defense agency with the primary mission of meeting military needs. Despite the many overlaps in technologies having both defense and commercial applications, the match is by no means complete, nor are priorities necessarily the same.

Coordinating Institutions for New Missions

Whether new missions for the weapons labs are defined as supporting U.S. competitiveness through R&D partnerships with industry, or as taking part in new national initiatives for public purposes, with collateral benefits for competitiveness, the question of strategic planning becomes more insistent the more money is involved. At DOE headquarters, the managers of Defense Programs have felt the need to impose a strategic plan on a cooperative program funded at $141 million. If the amounts available to the DOE labs for industrial partnerships were to rise to $500 million or $1 billion, as is implied by some current proposals for the labs' future, the problems of managing such a big, visible program without order, priorities, and interagency coordination could become still more apparent. Of course, if lab/industry partnerships were managed at the lab level on a first-come-first-served basis, most would likely concentrate on critical technologies, simply because these are of greatest interest to both public and private partners. It is doubtful, however, that uncoordinated, individual projects would advance critical technologies as effectively as a well-planned multiagency strategy, such as the HPCCP.

There is no U.S. Government agency with a clearly defined responsibility for managing technology initiatives that span several agencies. The committees of the Federal Coordinating Council on Science, Engineering, and Technology (FCCSET) in the White House Office of Science and Technology Policy (OSTP) are the nearest approximation, but they have generally operated as consensus groups with no real locus of decisionmaking authority. Other Nations do have institutions that guide technology initiatives, usually in a science and technology agency. Germany has its Federal Ministry of Research and Technology (the Bundesministerium fur Forschung und Technologies, or BMFT) and Japan has its Science and Technology Agency. Also, the Japanese Ministry of International Trade and Industry (MITI) contains another technology agency, the Agency of Industrial Science and Technology.[45] Both have many technology policy responsibilities, including funding and overseeing R&D laboratories that contribute to civilian

44 Bills in the House and Senate in the 103rd Congress (S. 4 and H.R. 820) would greatly increase funding for NIST's manufacturing technology centers and the Advanced Technology Program. President Clinton has proposed similar measures.

45 Japan's Science and Technology Agency had a budget of *522* billion yen ($3.9 billion) in 1991; MITI's Agency of Industrial Science and Technology bad 117 billion yen ($870 million). The German BMFT had a 1992 budget of 9.4 million DM ($4.4 billion).

technology development, often with substantial participation and support from industry.

SUMMARY OF POLICY ISSUES AND OPTIONS

While military needs will continue to consume sizable government resources for R&D, DOE weapons labs may soon face significant reductions in funding. There are plenty of claims for money not spent on development of nuclear weapons. An obvious candidate is deficit reduction. In the long run, a smaller burden of government dissaving could contribute to more private investment, and to the growth prospects of the American economy. Accordingly, deficit reduction will be a policy priority for Congress and the Administration over the next few years.

Deficit reduction is only one of the claims on whatever resources are saved through reduced weapons development. There are plenty of others, from improved education and health care to support for the newly democratic but struggling regime in Russia. There are also persuasive arguments in favor of stronger government backing for American industry competitive performance since R&D-traditionally part of the foundation that supports U.S. competitiveness—shows signs of weakening.

There is substantial support both in Congress and the Clinton Administration for cooperative R&D partnerships between government and industry, including cost-shared agreements between companies or consortia of companies and government laboratories. Those who favor lab/industry collaboration share the conviction that now—at a time when R&D is flat but competitive industries rely more than ever on knowledge intensity-is not the time to cast away technology resources that have taken decades to build up. Rather, every attempt should be made to use them in ways that contribute directly to the civilian economy. This does not preclude cutting the weapons labs to a size appropriate to their new defense missions, which will largely be nonproliferation, safety and security of nuclear stockpiles, and decommissioning of excess weapons, though some nuclear design capability will be maintained. It does require prompt action to solve problems that are hindering cooperative R&D.

This positive point of view is not universal. There is a strongly held opinion that all DOE's national labs—the multiprogram energy labs as well as the weapons labs—have lost their original focus, which was to promote peaceful and military uses of atomic power, and are now an extravagance the Nation can ill afford. They would like to see the lab system given ruthless scrutiny, possibly leading to closure of some labs, downsizing of others, and redirection of government R&D spending.

For the longer term, survival of the DOE lab system may depend on the labs' success in focusing on new missions that provide clear public benefits. The weapons labs built their excellent staffs, equipment, and technologies around their core public mission of national defense (and to a lesser extent, energy technologies and the science underlying them). Peacetime public missions could include a larger and more explicit interest in promoting industrial competitiveness, but the grounds for supporting national labs with the taxpayers' money are more compelling if the labs' missions feature public benefits that the market is not likely to supply.

Options to Shrink the DOE Laboratories

Those who consider the weapons labs too big and their culture too remote from that of private industry to contribute effectively to competitiveness see the present moment as a good one to rationalize, downsize, and consolidate the labs. Many would include all the DOE's multiprogram national labs (and possibly other Federal labs as well) in the scrutiny. But it is the weapons labs, with their lion's share of DOE R&D funding and the obvious change in their mission, that are getting the most attention.

Policy **Option 1: Cut the labs' budgets to fit the scope of scaled-back weapons functions.**

Through their regular budget and appropriations functions, Congress, the Administration, and DOE are already engaged in cutting back nuclear weapons activities at the labs. However, the cuts may be fairly small and gradual as the labs take on expanded nondefense functions, especially in environmental cleanup and energy programs.

Policy Option 2: Create a Laboratory Rationalization Commission.

Should Congress decide to thoroughly restructure and downsize the weapons and other DOE labs, it may wish to create a Laboratory Rationalization Commission composed of experts from DoD, DOE, the private sector, and other appropriate institutions to recommend how to manage the cuts, organize the work remaining to the labs, and make any necessary improvements in lab management. To do this with care and forethought would inevitably take time. It is likely that the commission's recommendations would take at least a year or so to formulate. This argues for postponing any deep cuts or major reorganizations while the commission is at its task, and meanwhile working to improve the technology transfer from the labs, including the CRADA process.

Options to Improve Technology Transfer From the DOE Weapons Laboratories

A second approach is to make the talents and resources of the weapons labs more readily available to private firms. This approach is not incompatible with reduced funding for the labs and might even be combined with a strategy of thoroughgoing restructure and downsizing of the labs, should Congress choose that option.

The months that it usually still takes to conclude a CRADA with the weapons labs is a real threat to the effort's success. There is no simple answer to speeding up and simplifying the process. Some laboratory people and many representatives of companies that have tried to negotiate CRADAs with DOE favor giving more authority to lab directors. They believe, probably correctly, that this would hasten the process, especially if the labs had the power to spend designated funds from their R&D budgets for CRADAs rather than redesigning ongoing projects to include cooperative agreements with industry.

There are several criticisms of this approach that deserve to be taken seriously. A major one is that with the funds for CRADAs in DOE's Defense Programs so large, it makes some sense to take a strategic approach to lab/university/industry partnerships, concentrating resources on critical technologies and minimizing overlaps. Second, there is the question of trust. The view of some at DOE headquarters is that the directors of GOCO labs maybe too willing to compromise the national interest in order to find industry partners, to avoid deep budget cuts in a time of changing missions and uncertain funding. Furthermore, some in Congress have little faith in the dedication of some of the labs' contractors to putting the national interest first. If lab directors are given more authority over CRADAs, fear of congressional investigations might stall the process. Finally, the division of congressional responsibility for DOE authorizations (energy and natural resources committees authorize energy program, and armed services committees authorize defense programs) complicates legislative guidance on funding and managing technology transfer.

In short, there is little consensus among experienced, knowledgeable people on how to streamline the CRADA process while getting the most out of it in technologies that advance the national interest. The lack of a U.S. Government coordinating agency for technology development and diffusion programs makes the uncertainties more acute. Greater coordination might be initiated in the new Administration, which seems committed to a more active government technology policy than the previous administrations but, at this writing, that is unknown.

The specific policy options that follow are mostly confined to short-term issues of making the new process of industry/lab cooperative R&D projects work more smoothly. Broader issues, including the longer term future of the labs, their possible role in R&D support for new national initiatives, and coordination of government-wide technology policy, are discussed in more general terms. Government-supported R&D has entered a genuinely new era, and all the issues involved cannot be solved at once. In the face of the uncertainties, the options proposed here should be regarded as experiments, and results should be monitored. This does not imply that experiments should be tentative, or that monitoring should devolve to micromanagement. Congressional monitors should remember that the labs will need freedom to experiment that positive results take time, and that failures are part of any high-risk undertaking.

Policy Option 3: Shorten the process of initiating CRADAs.

Several actions could be taken under this umbrella (see ch. 2 for details). For example, Congress might wish to shorten the time allowed for DOE field offices to approve CRADA documents; or it might eliminate separate approvals, first for the joint work statement and next for the CRADA itself-a two-step process that can take up to 120 days.

Another option in this connection is to give DOE an exemption from the Freedom of Information Act (FOIA) covering proposals for cooperative R&D. In describing proposed research projects, companies often include information that they wish to keep out of the hands of competitors (including foreign companies). The DOE labs are protected from FOIA requests to see the proposals, but DOE headquarters is not. The labs and their industry partners have on occasion removed or marked proprietor-y information from proposals before sending them to headquarters for review, but this adds delay and aggravation to the process. NIST has, and uses, a FOIA exemption for proposals it receives for R&D projects in its Advanced Technology Program. Congress might wish to give DOE the same authority.

Policy Option 4: Reallocate CRADA authority.

Another option would be to direct that the screening process Defense Programs has established be shortened or dropped. Much of the delay in getting CRADAs out of the weapons labs is due to DP's coordinating process, which involves a call for proposals and then a two-step evaluation of the proposals. All this takes place before the submission of work statements or CRADAs to the field offices. The purpose, as noted, is to minimize overlap, assure complementarily of projects, and determine the fit with the strategic goals of DPs cooperative R&D program. But the effect, inevitably, is delay. DP aims to keep the whole process-its review plus the CRADA negotiation—to no more than 6 months, with the eventual goal of 4. In practice, in the last half of 1992 the DP process by itself was taking 5 or 6 months; with the addition of another 1 to 3 months at the field offices, the total time to initiate CRADAs probably exceeded 6 months for most CRADAs. This counts only the time *after* lab and outside researchers have spent time defining a piece of work together.

Suggestions have come from several quarters for delegating CRADA authority to the lab directors, This could weaken or undermine the system DP has set up to impose a coordination and strategic goals on cooperative agreements. Also, it could mean a change in the law; NCTTA explicitly requires GOCO labs to obtain parent-agency approval of both the joint work statement and the CRADA. Two variants of the option are as follows.

- Option 4a: Give lab directors greater discretion in allocating budgets to technology transfer. This would not necessarily require a change in the law.
- Option 4b: Give GOCO lab directors full legal authority to execute and fund CRADAs. This would require a change in the law.

Some compromise choices, also requiring legislative change, might also be considered.

- Option 4c: Give the lab directors authority to conclude CRADAs of a certain size (up to as much as $1 million, say) without DOE oversight, or on the same terms as the GOGO labs (30 days for parent agency disapproval).
- Option 4d: Put up to one-half the funds available for CRADAs at the disposal of the labs, reserving the other half for a more strategic program managed by DOE headquarters and requiring agency approval; these projects would be national in scope and the labs would submit competitive proposals, as they do in the present DP scheme.[46]

Policy Option 5: Require that DOE allocate a certain percentage of the labs' budgets to technology transfer.

This proposal is gaining currency. In their February 1993 statement of technology policy, President Clinton and Vice-President Gore stated that all DOE, NASA, and DoD labs that can make a productive contribution to the civilian economy will be reviewed, with the aim of devoting 10 to 20 percent of their budgets to cooperative R&D.[47] Congress had previously expressed support for the idea.[48] In 1992, the portion of the weapons labs' budget funded by DOE programs was about $2.7 billion;[49] 10 to 20 percent of that would amount to $270 to $540 million in the weapons labs alone—assuming that their present levels of funding continue.

Although there is some concern that the 10 to 20 percent target is unrealistically high, the concern is probably misplaced. In fiscal year 1993, when DP had $141 million set aside for CRADAs (mostly in the three big weapons labs), there were many more proposals than could be funded; that amount was more than 5 percent of the weapons labs' total DOE funding for 1992 and nearly 9 percent of their DP funding. Another concern is how such a scheme would work its way through Congress. It could prove tricky, since DOE's authorizations are handled by two committees in the Senate and four in the House of Representatives; appropriations are handled by two subcommittees of each chamber's Committee on Appropriations.

Policy Option 6: Establish stronger incentives for technology transfer.

Incentives might compensate for difficulties that now stand in the way of lab researchers spending time on technology transfer projects. In their annual planning process, DOE and the labs decide on the projects the labs will work on in the following year. Once the plans are in place, lab researchers find it hard to devote more than a few days to planning cooperative work with outside partners; they have to account for their time quite strictly. The lab's overhead account is the only place to charge for time spent in planning joint R&D, and there are many claims on that account. When researchers spend time planning cooperative work, it is often their own time, on nights and

46 something like this 50 percent solution was proposed by Albert Narath, President of Sandia National Laboratories, in hearings before the U.S. House of Representatives, Committee on Small Business, Subcommittee on Regulation Business Opportunities, and Energy, "Reducing the Cycle Time in Lab/Industry Relationships,' Dec. 4, 1992. While supporting DOE's role in approving CRADAs, Narath also made a case for greatly streamlining the process.

47 ' 'Technology for America's Economic Growth, " op. cit., footnote 15. A variant is the suggestion from the Secretary of Energy Advisory Board Task Force that certain labs in the DOE system be designated as technology partnership "centers of excellence, ' and devote up to 20 percent of their budgets to the purpose. Somewhat inconsistently with its recommendation that the weapons labs confiie their activities to nuclear defense, the Task Force suggested Sandia as well as Oak Ridge as candidates.

48 In its report on the fiscal year 1993 DoD authorization bill, the Senate Committee on Armed Services directed DOE to set a goal of allocating 10 percent of the Defense Programs R&D budget to technology transfer. U.S. Senate, Committee on Armed Services, *National Defense Authorization Act for Fiscal Year 1993: Report,* report 102-352, to accompany S. 3114.

49 Their total budget was $3.4 billion, but about $700 million was Work for Others (WFO), mostly the Department of Defense. A few CRADAs have been funded by WFO, but most CRADAs currently come from DOE program funds.

weekends. This constraint, combined with lukewarm enthusiasm for technology transfer on the part of some of the labs' middle managers, can slow or abort potential CRADAs.

The law already encourages technology transfer by providing that 15 percent of the royalties of any patent licenses may be awarded to the individual lab researchers who developed the technology. This incentive is chancy and rather remote, however. Top managers at the labs could institute more immediate rewards. These might include giving to project managers active in technology transfer extra staff positions or a coveted piece of lab equipment. The lab managers might make technology transfer a more prominent factor in employees' performance ratings. None of these measures would require congressional action, but might be encouraged in oversight hearings.

Congress might wish to take more direct action, as in the following two suggestions:

- Option 6a: Direct that part of the labs' overhead account be allocated to pre-CRADA development of proposals of joint work.
- Option 6b: Establish a governmentwide set of awards for effective technology transfer from Federal laboratories. Awards of this kind, if sparingly used, can be surprisingly effective.[50]

Policy Option 7: Reassess definitions **of** national interest in the context **of** technology transfer.

Private industry creates most of the Nation's jobs, value added, and technology development. It is clearly in the national interest for American fins, and foreign firms that do business here, to prosper. However, the match between national interest and corporate objectives is not perfect. In the context of cooperative R&D agreements, three issues that have generated conflict, legal wrangling, and delay are U.S. preference for R&D and manufacture, disposition of intellectual property rights, and liability for damages.

A strict requirement for U.S. manufacturing could drive many potential partners away from the labs, possibly leaving only smaller companies with few international ties and limited R&D resources of their own to match lab contributions. Moreover, requiring U.S. preference might even deprive some companies of their best shot at commercializing advanced technologies. A broad portfolio of technologies, including those developed in partnership with the labs, is a distinct advantage to a U.S. company negotiating with a foreign company for access to its technologies. The most reasonable course may be to choose something less than an ideal outcome and accept the discomfort.

- Option 7a: In relevant legislation Congress could either insist on U.S. preference, understanding that many industrial partners will opt out; or permit a form of preference that companies can comfortably handle, as in the umbrella CRADA that DOE signed with computer systems companies, which requires only that companies perform substantial R&D, not substantial manufacturing, in the United States. The latter option would accept the possibility that this Nation may eventually import products based in part on American publicly funded R&D.

Another choice is to establish a general principle of U.S. preference, but to make exceptions case by case. This could be done in one of several ways:

- Option 7b: Congress could direct agencies with cooperative government R&D programs to grant exemptions from U.S. preference only when industrial partners show that substantial manufacturing in this country is

50 An example is the Malcolm Baldridge National Quality Award, created by Congress in 1987 and awarded each year to a few companies or organimations that bave benefited the Nation through improving the quality of their goods and services. Hundreds of companies apply for the award each year, even though bidders must go through a rigorous self-examination merely to apply.

not feasible, and they commit themselves to providing alternative benefits to the U.S. economy. As noted, DOE has adopted a policy along these lines.

- Option 7c: Congress could establish a U.S. Preference Review Board to make case-by-case decisions on exceptions to the U.S. preference rule for any agency with cost-shared R&D projects with industry. Congress might consider empowering OSTP to exercise this function, or creating a small independent agency to consider U.S. preference issues governmentwide. The board would have to pursue the dual aims of acting swiftly but avoiding rubber-stamp approvals.

Both these last options are inclined to cause delay. Having a governmentwide board make these decisions might well be more unwieldy than leaving it to the agencies, though there would probably be more consistency in the decisions. Another disadvantage is that the board's decisions might please no one. It has certainly been difficult for officials in the Commerce, State, and Defense Departments to agree on control over exports of technologies that might, if allowed, threaten U.S. national security but, if forbidden, unnecessarily harm U.S. commercial interests.

The same kind of conflict, and possibly the same kind of resolution, exists for intellectual property rights. This is an unsettled area in DOE CRADAs, and is the subject of much hard bargaining between the labs and their industrial partners and consequent delay. Possibly, settlement of some of these issues may evolve with more experience, but differences among industries, and among companies within industries, are likely to remain. Congress may wish to emphasize one side or another of the intellectual property issue and live with the consequences. If Congress chooses to support the public purpose of wider diffusion, fewer companies may be interested in partnerships; if it chooses to give companies more protection, the public return on taxpayers' investment may be more limited, or at any rate less direct.

DOE turns over to GOCO lab operators most of the authority for settling with industrial partners on the disposition of intellectual property rights, subject to the government's right to use the intellectual property for its own purposes. Congress may wish to provide some guidance that would more clearly define the scope of negotiations over intellectual property.

- Option 7d: Congress might choose, in the form of resolution or law, to provide guidance that discourages the grant of exclusive licenses that have a broad field of use, or that limits the time during which exclusive licenses prevail. Alternatively, Congress might encourage DOE and the labs to accommodate companies' desires for broader intellectual property rights.

One further problem is that some companies have run into frustration and delay in CRADAs involving more than one DOE lab because each negotiates terms separately, and makes differing demands in such areas as intellectual property rights and U.S. preference. DOE's recent guidance to field offices on U.S. preference should make for more uniformity and predictability among the different labs on this issue, but the potential for inconsistency among labs remains in the handling of intellectual property. Though DOE has given GOCO contractors most of the authority over disposition of intellectual property rights in cooperative agreements, it can still exercise oversight and provide guidance.

- Option 7e: DOE might, through technical assistance and policy guidance, encourage the labs to harmonize the terms of their agreements with industrial partners, especially in multilab projects. Through oversight, Congress could encourage such action by DOE, or alternatively require it by law.

Another national interest issue is liability. There may be some practical possibilities of agreement on this issue that would suit both the government and private companies. Both perceive that damage claims are becoming more burdensome, and both would no doubt welcome some general limitation on liability. However, no policy option is proposed here, as OTA has not done extensive analysis of the product liability issue.

Policy Option 8: Measuring the value of cooperative research and development.

Assuming that the CRADA process can be made to work more smoothly, a longer term question will be how to measure the value of the agreements. Success cannot, of course, be measured overnight. Nor is it easy to establish meaningful measures of success for R&D projects, especially from the standpoint of social returns. Economic results such as numbers of jobs created or value added are hard to trace with any precision to R&D; other factors are too important.

A practical measure of success, after 5 years or so of experience, might be the continued or growing interest by industry in submitting proposals for cooperative work. If companies, which have their own internal measures for success of R&D investments, continue to put money and effort into the projects, it is fair to conclude that they consider the ventures worthwhile. In the longer run, cooperative R&D projects may be judged by the general measure of whether they are developing technologies that form the basis for commercial production, keeping in mind that there must be allowance for failures as well as successes in any program of high-risk, potentially high-reward R&D.

Evaluation of the results of public R&D investment may have to be largely judgmental rather than precisely quantitative. That does not argue against making the attempt. If after a fair trial period the labs' cooperative R&D is judged to be seriously disappointing, it would make sense to shift money to other R&D performers. Congress might direct the Secretary of Energy to develop an evaluation procedure for cooperative R&D. Alternatively, OSTP might be directed to develop evaluation procedures for all government/industry cost-shared R&D.

The options laid out above are mostly aimed at streamliningg the CRADA process. In some cases, the streamlining comes at the expense of minimizing strategic guidance at the DOE headquarters level, as Defense Programs is now attempting to provide. Given the large size and scope of DOE's R&D program, a screening process and strategic direction make a good deal of sense—still more so if DOE takes part in governmentwide initiatives to advance certain technologies. The downside is that DP's internal screening prolongs the CRADA process, trading oversight for faster action. A middle course may be possible, giving labs more direct authority over a portion of the funds available for CRADAs, or over CRADAs below a certain size.

In the short run, it might be worth sacrificing some coordination and strategic direction in the interests of getting the program working while industry interest is high. In the longer run, once DOE, its field offices, and its laboratories become more accustomed to cooperative R&D, it may be possible to set priorities for CRADAs and other cooperative work that fit within strategic initiatives without months of delay in selecting proposals.

The Longer Term Future of the DOE Weapons Laboratories

Most of those who see a national role of continuing significance for the labs consider cooperative work with industry an important though not necessarily central part of their future. Thus, the future of the labs will depend in part on their success in making the cooperative process work. In thinking about the long-term future of the labs, however, cooperative R&D and other forms of technology transfer should not be considered in isolation. The option of making at least one of the weapons labs into a center for cooperative development of critical technologies has been floated, but it has some important drawbacks. The weapons labs built their eminence by their work on public missions of national importance, primarily defense. The technologies and talents that private companies are now eagerly pursuing are the legacy of that mission. A national mission of ''economic competitiveness' seems an unlikely replacement, because it is so diffuse.[51] The fear of lab officials that labs with such a mission could become nothing but job shops for industry is probably well-founded.

NEW PUBLIC MISSIONS

There is no lack of candidates for new public missions that might take the place of a much reduced national defense mission and spend at least part of a "peace dividend. ' Not forgetting that deficit reduction will claim a high priority, there are also strong arguments for new public investments to strengthen the foundation of the civilian economy and mitigate the economic and technological losses from defense cuts.

In choosing amongst a number of worthy new national initiatives, one factor to keep in mind is their ability to match the benefits the shrinking defense effort has conferred on the Nation (excepting, of course, the ability to defend the Nation militarily). Foremost is the capacity to meet a clear public need-one that the commercial market cannot fully meet but that is well understood and broadly supported as essential to the Nation's welfare. In meeting such a need, the defense complex also created other public benefits. It supported a disproportionate share of the Nation's R&D, some of which had such important civilian applications that whole industries were founded on them. It provided many well-paid, high-quality jobs. It provided a large market—often the crucial first market-for technologically advanced goods and services. A final factor, though not a determiningg one, in choosing among new national missions is their ability to make good use of valuable human, institutional, and technological resources formerly devoted to defense purposes-such as those in DOE weapons laboratories.

NEW MISSIONS, NEW INSTITUTIONS

If and when the President, his Cabinet, and Congress settle on new national missions, set priorities, and establish finding levels, the next question is who will carry them out. Whatever initiatives are chosen, it seems likely they will involve many agencies, universities and nonprofit institutions, and hundreds, maybe thousands, of private companies. While there are immediate questions of how to deal with the changing size and missions of DOE weapons laboratories and some DoD laboratories and test facilities as well, the answer probably is not to assign any of them, *a priori, the* leading responsibility for a major new public mission. The job calls for management and coordination at a broader level than that of individual R&D institutions.

Lacking a technology agency at Cabinet level, such as many other nations have, the U.S. Government has recently relied on OSTP in the Executive Office of the President for whatever coordination of government R&D programs has taken place. Within OSTP, the job has gone to interagency FCCSET committees. As noted, the committees have had no clear decisionmaking authority. Moreover, at times their influence has gone into complete eclipse, as in the early to mid-1980s when the Reagan Administration saw no need for a government technology policy. As an agency in the Executive Office of the President, OSTP is especially subject to the prevailing outlook in the White House. It also lacks continuity; often it is staffed primarily by detailees from

51 Note, however, that some U.S. Government R&D institutions have successfully directed (heir industries. Examples are the aeronautics R&D program and facilities of NASA ('growing out of the support provided by the National Advisory Committee on Aeronautics, or NACA, from 1915 to 1958) and the cooperative research program of the U.S. Department of Agriculture, States, and land-grant colleges, dating back to the 19th century.

executive branch agencies and l-year fellows from professional scientific organizations. On the other hand, in an Administration interested in technology policy, OSTP could play a particularly influential role, since multiagency policy coordination is usually considered a special responsibility of White House offices.

Other ideas are to transfer some DOE labs, and possibly other Federal laboratories, to a different or new agency with overall responsibility for national technology policies and programs. These might include application-oriented R&D programs, such as Regional Technology Centers, and technology diffusion programs, such as industrial extension services, as well as multidisciplinary, science-based R&D programs. Several bills in past Congresses have proposed to create an agency or Cabinet-level department for the purpose.

Alternatively, an existing agency might be adapted to the purpose. MST, which houses the Advanced Technology Program, a small technology extension program (Manufacturing Technology Centers), and the Baldridge Award, as well as its own laboratories, has been suggested as a possibility. ARPA, with its fine reputation as a funder of long-term, high-risk dual-use technologies, has attracted still more attention. It controls more R&D funds for dual-use technologies than any general purpose civilian agency, and the defense conversion legislation of 1992 gave it new responsibilities in technology diffusion. Still, despite the interest in reaffirming its dual-use character, ARPA is not likely to be given the leading responsibility for overall U.S. Government technology policy, because it is frost of all a defense agency answering to defense needs.[52]

NEW NATIONAL INITIATIVES

Of the possible choices for new national initiatives that meet public needs, some of the most persuasive could not only promote advanced technologies and foster the growth of knowledge-intensive industries, but do so in environmentally benign ways. Environmental protection itself is an obvious candidate; this very broad category includes cleanup of hazardous wastes from past activities, management of wastes currently being generated, end-of-pipe pollution control and, perhaps most promising, clean technologies that prevent pollution. Public support for environmental improvement in this country is strong and growing. Global environmental issues too are rising to the top of the policy agenda, fed by concerns over global warming, the ozone hole over the Antarctic, acid rain from industrialized countries, and deforestation and species loss throughout the world.

Part of the drive for pollution prevention centers on energy. World demand for energy is expected to continue growing well into the next century, especially in the developing world. Technical progress in the last decade raises the possibility that nonpolluting or less-polluting renewable energy sources may be able to meet much of this demand. There are special opportunities to substitute more environmentally benign forms of energy use in the United States, because we are such disproportionately large consumers of energy, especially in auto and air transport.

Energy-efficient transportation is a theme that is often proposed for new national initiatives.[53] New forms of transportation-both advanced rail or guideway systems and cars that use new types of energy—are centers of interest. These systems not only offer the public benefits of reduced

52 The question of where to lodge responsibility for technology policy or for broad initiatives related to U.S. competitiveness is discussed in some detail in U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe, and the Pacific Rim*, OTA-ITE-498 (Washington DC: U.S. Government Printing Office, October 1991), ch. 2. See also John Alic, et al., *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, MA: Harvard Business School Press, 1992), ch. 12.

53 President Clinton and Vice-President Gore included in their program for technology initiatives one to help industry develop nonpolluting cans that run on domestically produced fuels. "Technology for America's Economic Growth," op. cit., footnote 15,

pollution and lesser dependence on foreign oil, but might also provide economic benefits that defense once bestowed on the economy. In addition, some might use technologies and skills formerly devoted to defense purposes. As an example of one such initiative, new transportation systems are considered in this report from the viewpoint of their potential to replace benefits defense formerly provided. This report does not address transportation policy broadly; other OTA studies have analyzed many of the relevant questions, including the degree of greater energy efficiency and reduced dependence on foreign sources of oil that various transportation alternatives might offer, as well as issues such as adequate capacity and convenient connections between highway, air, rail, and water transport.

Less polluting or nonpolluting personal vehicles look promising as an area of industrial growth, a driver of advanced technologies, a potential provider of good jobs, and a user of technologies and skills no longer needed for Cold War purposes. Americans have historically chosen the automobile as their means of transport, and much in this country (e.g., the interstate highway system, cities that sprawl out into suburbs) favors its use. Electric vehicles (EVs), which depend completely or substantially on batteries for propulsion, could have some near-term market potential in meeting stiffer air-quality standards. California has mandated that 2 percent of vehicles sold in the State by 1998, and 10 percent by 2008, must have zero emissions, and some other States (New York, Massachusetts) are following suit. EVs are at present the only cars able to meet that standard.

Battery EVs will probably fill most of the early demand for ultra-clean cars, and they are eminently suitable for some niches (e.g., Postal Service or other in-town delivery vehicles); however the market for them may turn out to be limited. Vehicles powered by a combination of fuel cells and batteries are currently less advanced than battery EVs, but in the long run could be the more successful technology if they are more easily able to provide the range and quick refueling that battery EVs are struggling to achieve. Still, fuel cell technology for automobiles is immature and unproved; whether affordable cost and reliability can be achieved is not yet known. Both battery and fuel cell EVs face competition from other kinds of less polluting vehicles, many of which are better developed, are continuously improving, and require much less new infrastructure. Alternative less polluting fuels for vehicles using the time-tested internation combustion engine include methanol and ethanol, natural gas, and reformulated gasoline. Moreover, although battery and fuel cell EVs are themselves without emissions and do not cause local pollution, the energy source used to generate electricity for them may be polluting.

U.S. Government support for the development of nonpolluting cars was already underway in early 1993, but in a limited and uncoordinated way. The Clean Air Act of 1990 and the stricter California standards have provided strong impetus for industry to develop clean cars, and there is some very modest support for purchase of nonpolluting or less polluting vehicles for government fleets. However, the main encouragement on the part of government is, first, in the field of regulation, and second, in research, development, and demonstration (RD&D). DOE and the Department of Transportation (DOT) both have scattered RD&D projects underway. The biggest of these is in DOE's Conservation and Renewable Energy program, which had a fiscal year 1993 budget of $60.8 million for electric and hybrid vehicle research, of which more than half ($31.5 million) was for battery EVs.[54] DOT has a $12-million project for cost-shared funding of consortia to develop EVs and advanced transit

54 Fuel cell R&D got $12 million, and hybrid vehicles, defined as those powered by electricity combined with a small internal Combustion engine, got $16.8 million.

systems, related equipment, and production processes.

The U.S. Advanced Battery Consortium (USABC), formed in 1991 as a collaborative effort between DOE and the Big Three American automakers, is the largest government-supported R&D project for EVs. It is funded at $260 million over its frost 4 years, 1992-96 (there are plans to continue it for 12 years); of this, each auto company is providing $36 to $40 million, the Electric Power Research Institute is contributing $11 million, and DOE is picking up the rest, which amounts to $130 million or one-half. USABC has set development and performance goals for mid- and long-term batteries, on a timetable shaped in part by the coming requirements of the California emissions law.

So far, defense conversion (i.e., the use of defense talents and resources for new civilian purposes) has played little part in USABC. It is largely a civilian enterprise, with the Big Three automakers running the show from the private sector side. Sandia is the only weapons lab involved, but other DOE labs—Argonne, the National Renewable Energy Lab, Lawrence Berkeley, and the Idaho National Engineering Lab-are participants. Outside USABC, several defense firms are using their experience with electric propulsion systems in building power trains for electric vehicles. Westinghouse Electric's electronic systems group, for instance, is cooperating with Chrysler in such a program. The DOT program for EVs has explicitly tried to enlist defense resources in some cases. One of its four 1992 awards was a $4-million grant to California's Calstart project, a consortium that aims to create a new industry providing transportation technologies and systems. It includes in its members aerospace companies, utilities, universities, small high tech companies, transit agencies, and representatives of environmental and labor interests.

Key areas in the development of both battery-powered EVs and the fuel cell-battery alternative overlap with many technologies developed for military purposes both by industry and government labs. These include the handling and use of new fuels such as hydrogen; the application of advanced materials such as ceramics, plastics, alloys, and ultra-light composites; the use of computers to model manufacturing processes and performance and thus improve design; the development of fuel cells, batteries, and ultracapacitors; and the use of electronic controls and sensors. The demands of space flight, stealth, undersea operation, strategic defense, and other military and aerospace programs have pushed forward work on these technologies.

Most of the government's efforts for EVs have so far been directed toward developing and showcasing battery EVs in the near future. The fuel cell-battery alternative has received less attention. The R&D investment needed for a concerted, integrated program to overcome the formidable technical challenge is substantial, and would seem to offer the promise of highly paid scientific and engineering jobs over the next few years. If the efforts are successful, they might eventually support the creation of a new kind of auto industry with substantial numbers of production jobs and the advance of many new technologies.

High-speed ground transportation systems (HSGT)---in particular magnetically levitated trains-are also often proposed as new initiatives, but here there may be fewer attractions in the way of new technologies, new jobs, and defense conversion. These systems may fill the bill for many transportation policy objectives, including less pollution and less dependence on foreign oil, and they have the additional attraction of less impact than highways on the use of land. However, most analysts agree that maglev or high speed rail systems are probably limited to a few heavily traveled corridors like the route from San Francisco to San Diego, the Eastern seaboard, and parts of Texas, at least if the system is not to rely on ongoing heavy public subsidy. There may be other growth opportunities abroad, but several foreign companies, having long experience in the field and historic, generous government subsidies, are much better positioned to take advantage of them than fledgling U.S. companies.

Whether HSGT could spur the advance of highly innovative, broadly applicable technologies is questionable. There are no breakthrough technologies in high speed steel-wheel-on-rail systems, such as France's Train a Grande Vitesse (TGV) and Japan's Shinkansen; rather they embody incremental advances over rail systems that have evolved over nearly 200 years. Even maglev trains, long the favorite technology of the future for engineering optimists, are not necessarily held back by technological problems that the ingenuity of the aerospace and defense industries could solve so much as the tremendous expense of the systems, the difficulty of acquiring rights of way, and the tough competition of air and auto travel in a big country with widely separated cities and relatively low population density. Maglev might contribute to the advance of some technologies, such as strong lightweight composite materials, an area in which the defense sector is a leader, but overall the effects would probably be helpful rather than crucial. Still, it is unwise to be too dismissive about the technological possibilities. The Japanese maglev system uses low-temperature superconducting magnets, and work for the system has contributed to cryogenic technologies with applications in other fields. Possibly, high-temperature superconductivity (HTS) will get a boost from maglev, though this is by no means certain since the magnets are a very small part of this large system and may not offer enough advantages to offset their development cost and technological uncertainties. One DOE weapons lab, Los Alamos, and two multiprogram energy labs, Oak Ridge and Argonne, have ongoing cost-shared projects with industry on commercial applications of high-temperature superconductivity. The application nearest fruition is energy storage devices for electric utilities, to help solve the problems of peak use.

The hope for large numbers of manufacturing jobs from HSGT initiatives is probably misplaced. Japan is a premier producer, consumer, and exporter of passenger train cars, but the industry there (finished cars, freight and passenger, and parts) employed fewer than 15,000 people in 1990, of whom about 3,000 were employed in building 288 cars for the Shinkansen. Similarly, about 100 train sets (including 200 locomotives and 800 cars) were built over a 3-year period for France TGV with a manufacturing workforce for the rolling stock and parts of about 4,000. Most of the jobs involved in building a HSGT system are in construction; many of these are skilled high-wage jobs, but they are temporary and often create boom-and-bust effects in local economies. There may be excellent transportation policy reasons for building HSGT systems in parts of the United States, but on the basis of the preliminary analysis in this report, they do not look like a very promising replacement for the civil benefits of defense.

Indeed, there is no one new national initiative that fills that bill. For example, in the long run, nonpolluting cars might form the basis for a new industry that would foster technology advance and create large numbers of productive well-paid jobs (perhaps only replacing jobs lost in the conventional auto industry, but possibly creating new ones, if the world market for ‘‘green’ cars expands). However, such anew industry will take years to grow. Eventually, a combination of new public and private investments can provide benefits that formerly came from defense, and do it in ways more directly rewarding to the civilian economy and US. competitiveness. Meanwhile, measures that help U.S. workers and firms do their jobs more productively and spur local and national economic growth are the best bet for defense conversion.