Policy Issues and Options 2

The end of the Cold War and the accompanying cuts in defense budgets give the United States an opportunity for abroad reexamination of national priorities. Throughout the past five decades, the United States has concentrated most of its public research and development (R&D) in military security, with health a distant second. While military needs will continue to consume significant R&D resources, the largest R&D institutions contributing to national security—Department of Energy (DOE) weapons laboratories—are expected to face serious budget cuts in nuclear weapons development programs. These cuts could amount to several hundred million to over a billion dollars, a number that could be regarded as significant if, as many have proposed, the money is applied to one or two new national technology initiatives. For comparison, the National Aeronautics and Space Administration (NASA) spends upwards of $800 million annually on aeronautics R&D and facilities, and the eight-agency High Performance Computing and Communications Initiative also receives over $800 million. NASA programs are acknowledged to have made significant contributions to technology, and less directly, to competitiveness; HPCCI, which is still in progress, is expected to improve high performance computing technologies.

The potential savings from the DOE labs' nuclear weapons development and other defense program budgets are, however, small compared with many people's expectations and with the Federal budget deficit. Many who talk about redeployment of defense R&D funds speak of the $25 billion spent on federally owned or funded laboratories. Only about half, however, goes to defense; while a significant chunk of this may eventually be available for deficit reduction or other missions, the amount available from curtailing nuclear weapons research, development, testing, and evaluation (RDT&E) at DOE labs is a much smaller slice—only about 8 percent of the $25 billion. Moreover, the savings are unlikely to be realized all at once; it may take 2 or more years for the full extent of savings to be made available.

Money not spent on nuclear weapons RDT&E could go toward a number of other purposes. One obvious candidate is deficit reduction. In the long run, smaller deficits could contribute significantly to the health and growth prospects of the American economy, and a realistic plan for deficit reduction will probably be a priority for both Congress and the Administration over the next few years.

However, deficit reduction is not the only claim on resources ''saved' at DOE weapons labs. There is a broad array of social programs and federal outlays that might wish to make a claim on the money. Some possibilities could include health care, environmental investments, infrastructure, and increased assistance to the struggling new democracies of Eastern Europe. The list of worthy causes is long, but it would be incomplete without some consideration of shifting the money to other types and performers of R&D, including universities, private research laboratories, and nondefense government labs.

Research and development is an important part of the foundation on which competitiveness is built,[1] and while it has always been considered healthy in the United States, there are some ominous signs. Total U.S. R&D spending, while far higher than R&D spending in any other nation, is a smaller percentage of our gross domestic product (GDP) than in Japan and Germany, the best of the international competition. Japan spends 3.1 percent of its GDP on R&D, and Germany spends 2.8 percent. U.S. R&D funding tilts much more heavily toward defense than in most other developed nations. Military R&D spending was 24 percent of American R&D spending in 1990, less than 1 percent of Japan's and about 5 percent of Germany's.

Analysts can muster logical arguments supporting the proposition that absolute spending is more important than percentage of GDP, and vice versa; lacking a definitive test, the question will remain unsettled. However, the fact that R&D--both civilian and military-is shrinking as a proportion of U.S. GDP, is reason for concern. This is particularly so in light of other indicators that show American companies still struggling to compete with their best foreign counterparts in a variety of fields, including high-tech industries.

In the past, R&D has been considered one of the strengths of the United States. Other factors—such as access to patient capital, well-educated and trained workers, and institutions to help diffuse new technology—are much more at the heart of the Nation's competitiveness problems. However, this is not an argument against ensuring that R&D remains healthy. Both public and private R&D are under strain. Private R&D is difficult to fund in times of shrinking or nonexistent profits and heavy competition. The recession increased the burden on R&D managers to justify projects, and unless the recovery and subsequent growth greatly exceed all expectation, private R&D funds may remain scarce.

The pressures on publicly funded R&D are also heavy. Financing the Nation's 1991 debt of more than $4.4 trillion consumes a growing share of Federal revenue, and the consequent pressure to cut all optional spending is increasing. Continued funding for defense-related activities will demand exacting justification.

More specifically, nuclear weapons development in the post-Cold War era will not be

1 Many other things affect competitiveness as well. For a thorough analysis of America's manufacturing competitiveness, see U.S. Congress, Office of Technology Assessment, *Making Things Better: Competing in Manufacturing,* OTA-ITE-443 (Washington, DC: U.S. Government Printing Office, February 1990), passim; and 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, November 1991), passim.

supported at the levels of the recent past. Although budgets of the DOE weapons laboratories had hardly shrunk by 1993, it was highly likely that they would in the near future. To many, that is appropriate; the people and facilities at DOE weapons labs, they argue, have little adaptability to the needs of commercially-oriented R&D and the DOE bureaucracy makes the technologies of the laboratories difficult to access anyway, The advisory board of the Secretary of Energy recommended that the weapons labs adopt no new missions, and that their funding be cut to the point where they can adequately fulfill their nuclear weapons missions.[2]

A contrary argument is that now is not the time to cut billions from national R&D budgets, unless it is impossible to use the formerly military resources in ways that will contribute more directly to civilian technologies. There have been several attempts to make the Federal laboratories more accessible to U.S. industry, and to give them missions that contribute more directly to the overall economy, but generally the results have been seen as disappointing, A few laboratories in the Federal system have developed good working relationships with companies, but DOE's largest labs (the nine multiprogram labs, and more particularly the three weapons labs) did not develop technology transfer activities to the point where their contributions to economic goals were clear. That may be changing. Industry interest in forming cooperative R&D partnerships with Federal labs, and particularly with DOE multiprogram laboratories, has been unexpectedly strong since the beginning of the National Technology Initiative in February 1992. While there is still no real consensus, increasing numbers of people from the private sector are coming to view the national laboratories as sources for development of advanced technology.

Despite the weapons labs' greater accessibility to industry and interest in technology transfer, working out cooperative R&D agreements (CRADAs) with them has been anything but easy. Unless better ways can be found to make the abilities of the labs serve potential codevelopers of civilian technologies, interest in finding new ways to use the weapons labs will wane. The immediate task, unless the labs are simply cut to the size needed for post-Cold War nuclear defense, is to make the CRADA process easier, faster, and more transparent.

In the longer term, there are other considerations. First among them is the idea that the dividend from a shrinking nuclear weapons development mission could be reallocated to other R&D performers, With some justification, researchers at universities, private research labs, and civilian-oriented government R&D labs feel as though they have been increasingly short of funds while defense labs and defense companies have had generous budgets. Many of them see the shrinking of the weapons labs as their chance to capture a larger share of Federally funded R&D.

Another idea is that, rather than trying to settle how to redeploy R&D funding first, the Nation ought to set new R&D priorities, and allocate the funding based on the abilities and cost structures of all the different performers, public or private. There are already a few Federal R&D initiatives, such as the High Performance Computing and Communications Program, aimed at dual-use goals, that coordinate public and private technology development efforts. One notion is that more such initiatives could be adopted, to develop new technologies that are somewhat broadly defined. Finding ideas for new national initiatives is easy; for example, environmental and transportation initiatives generally rank high.

2 Secretary of Energy Advisory Board Task Force on the Department of Energy National Laboratories, ‘‘A Report to the Secretary on the Department of Energy National Laboratories, ’ July 1992, mimeo, p. 10. The nuclear weapons missions of the labs include verification, non-proliferation, and arms control technologies; restructuring of the weapons production complex; and environmental restoration and waste management.

Some analysts have suggested that government play a larger role in cooperative development of high-risk, high-payoff commercial technologies; the defense labs have considerable expertise in some, though not all, of these fields. DOE weapons labs are big and full of talent, but their abilities are not suited to all problems, nor is the mandate of their parent agency. Several of the new national initiatives suggested would fit easily within the purview of DOE; others would not. More importantly, conflicts or overlaps with the work of other R&D institutions will come up.

For example, many in universities and private companies fear that their potential contributions might not be weighted as heavily as those of the national labs in contributing to new R&D initiatives. These analysts often advocate some sort of competition, adjusting for necessary differences between public and private institutions (e.g., the need to build in a margin for profit), to decide how to allocate responsibilities and funding among the various R&D performers in pursuing new national missions.

Another set of ideas aims more directly at coordination among existing institutions-either creating a civilian technology agency to coordinate Federal technology development efforts, or increasing the scope and responsibilities of existing agencies, like the National Institute of Standards and Technology (NIST) of the Department of Commerce and the Advanced Research Projects Agency (ARPA; until recently the Defense Advanced Research Projects Agency), that have done a good job of supporting commercially relevant R&D. Finally, some have suggested creating new institutions with cultures and purposes more compatible with those of civilian industry, perhaps modeled on institutions in foreign countries. A leading candidate for a model institution that uses public and private money to contribute to civilian technology development is the Fraunhofer Gesellschaft of Germany.

A summary of policy options is in Box 2-A.

OPTIONS TO REDUCE THE SIZE OF DOE WEAPONS LABS

The burgeoning enthusiasm for CRADAs does not obscure the conviction of many analysts—including many potential CRADA partners-that the weapons complex is too large for the post-Cold War era, and that budget cuts are necessary and appropriate. This argument has been fueled by the difficulties and delays involved in negotiating and initiating CRADAs with the DOE GOCO (government-owned, contractor-operated) labs, especially early in the process. Frustrations have not yet overwhelmed interest in joint research, and in fact, the CRADA process has become more predictable. However, DP labs (Defense Programs), many argue, are still too big to fit their remaining missions. In 1993, combined funding for the three weapons labs was $3.4 billion.

The report of the Secretary of Energy Advisory Board (SEAB) summed up the argument for cutting the weapons complex in a paragraph, saying the most appropriate strategy is to scale the labs appropriately to meet the Nation's diminished nuclear defense needs.[3] The SEAB went on to say that DOE should devise a plan to rationalize the labs, taking care to maintain their excellence during the adjustment.

A common assumption among those who espouse the view that the labs should be smaller is that reduced nuclear weapons missions will result in large savings. This is almost assuredly true, but the size of the dividend may disappoint those who envision billions of dollars in savings.

[3] Ibid., p. 10. The report is not entirely consistent on the topic of the defense laboratories, it should be noted; on page 8, the report recommends that DOE designate several labs, ". . . for example, Sandia and Oak Ridge National Laboratories . . . to become technology partnership 'centers of excellence.' " There is some inconsistency in recommending that the Department consider Sandia as a candidate for a center of excellence in technology partnership, and recommending that it maintain its devotion to nuclear weapons missions, and be sized accordingly.

Box 2-A-Summary List of Policy Options

1. Cut the DOE weapons laboratories' budgets to fit the scope of scaled-back nuclear weapons functions.
2. Establish a Laboratory Rationalization Commission to review thoroughly laboratories' funding and missions.
3. Shorten the process of cooperative research and development agreement (CRADA) initiation.
   a. Direct that the Defense Programs proposal screening process be shortened or dropped.
   b. Shorten the times allotted for the approval of joint work statements and CRADAs; make the approval a shorter, one-step process; eliminate the extra 30-day approval process for CRADAs that follow the DOE model.
   c. Make the period for approval of joint work statements continuous, from the time the lab submits a JWS to the field office to approval.
   d. Provide DOE headquarters with an exemption from the Freedom of Information Act covering proposals for cooperative R&D.
   e. Provide DOE headquarters with an exemption from FOIA covering proposals for CRADAs.
4. Reallocate authority for CRADA signoff.
   a. Give lab directors greater discretion in allocating budgets to technology transfer.
   b. **Give** government-owned, contractor-operated (GOCO) lab directors full legal authority to negotiate, sign, execute, and fund CRADAs.
   c. Give lab directors the authority to complete the process for CRADAs up to a certain limit, e.g., half a million or a million dollars.
   d. Give lab directors authority to execute CRADAs unless the parent agency objects within 30 days, the same terms as for many GOGO laboratories.
5. Allocate a certain percentage of DOE labs' R&D budgets to technology transfer or to direct DOE to do so.
6. Direct DOE and lab staff to establish stronger incentives for technology transfer.
   a. Encourage DOE to develop stronger incentives for technology transfer.
   b. Establish a governmentwide set of awards for effective technology transfer from Federal laboratories.
   c. Earmark money for activities that support proposal development at the labs.
   d. Encourage DOE to allocate sufficient funds for proposal development; direct DOE to build in the budgets and authority necessary for proposal development in its yearly planning process with the laboratories.
7. Reassess definitions of national interest within the technology transfer process.
   a. Establish a U.S. Preference Review Board, and to make determinations on companies' contributions to the U.S. economy as a condition for CRADA approval, and to screen participation in many federally funded programs by American affiliates of foreign companies.
   b. Establish guidance on disposition of intellectual property among companies, labs, and DOE.
   c. Encourage and guide the labs to harmonize intellectual property provisions.
8. Measuring the value of cooperative R&D
   a. Direct the Secretary of Energy to develop an evaluation procedure for cooperative R&D.
   b. Direct OSTP to develop a generic evaluation procedure for all cost-shared R&D that involves government and private funds.

SOURCE: Office of Technology Assessment, 1993.

The end of the Cold War indeed means, almost assuredly, cuts in nuclear weapons RD&T, but it has also expanded nuclear weapons decommissioning and dismantling functions. It is increasingly clear that the weapons complex, along with the rest of the DOE labs, has a burgeoning responsibility for environmental restoration and waste management, much of which is associated with past nuclear weapons activities. While the three nuclear weapons labs' budgets are still close to their peaks (in constant dollars) of the past two decades, spending priorities within Defense Programs and related nuclear weapons offices have shifted in accord with the reduced emphasis on weapons development and increased needs for other nuclear-weapons-related functions.

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

This option probably is not much different than the exercise currently ongoing within DOE, the Administration, the Office of Management and Budget (OMB), and Congress. It probably means more than simply following routine budget procedures in an agency whose missions are shifting. There may be pressure within DOE or the labs to keep the institutions at or close to their current size, since most organizations resist downsizing if they can. There maybe some pressure to expand other weapons-related missions to take up the slack left by reducing nuclear weapons RD&T, rather than doing a thorough review and overhaul of existing programs.

A point to consider in scaling back is that all three weapons labs also have nondefense missions as well. Altogether, the weapons labs spend nearly $570 million on energy programs in fiscal year 1991. The continuation and health of energy research at the weapons labs should be considered in the process of scaling them back.

Policy **Option 2: Establish a Laboratory Rationalization Commission to review thoroughly laboratories' funding and missions.**

Should Congress cut the labs' budgets, it might also wish to establish a Laboratory Rationalization Commission, composed of experts from Department of Defense (DoD), DOE, the private sector, and other institutions as appropriate, to recommend how to manage the cuts and reorganize the remaining work. The outcome of such a reorganization might even mean no budget cuts at all, if, for example, the Commission finds that there are legitimate reasons to expand funding for missions whose importance is growing. The Commission, if it is to exercise the "care and forethought" the SEAB recommended, would be of little help in 1993 when the fiscal year 1994 budget is under consideration, but its findings could be valuable the following year. This, in turn, is an argument for postponing deep cuts and major reorganizations for 1 more year, which might be time well spent. **While significant changes in the labs' funding and organizations might be desirable, they will inevitably cause disorder and chaos; if steps are not taken to keep the disorder to a minimum we could well lose the ability to establish an effective program of technology transfer (particularly CRADAs) for many years to come.**

OPTIONS TO IMPROVE TECHNOLOGY TRANSFER FROM THE DOE WEAPONS LABS

Another approach (not necessarily incompatible with reduced funding for the weapons labs) is to find ways to make the talents and resources of the labs available to private firms and universities as part of an effort to improve technology development and diffusion nationwide. Congress's several efforts since 1980 to improve technology transfer from Federal labs aimed in this direction (see ch. 4). A notable expansion of the labs' authority to conduct technology transfer was the ability to enter into CRADAs with private institutions (mainly businesses and universities). Government-owned, government-operated (GOGO) labs gained this authority in 1986, and GOCOs in

1989.[4] Unlike many other forms of technology transfer, CRADAs not only permit but require extensive face-to-face contact between researchers. This contact is almost always necessary for effective technology transfer.

Past efforts to make lab resources more generally available have had disappointing results, particularly when it comes to DOE weapons labs. The CRADA process in particular was slow getting off the ground at the agency and its GOCOs.[5] In well-publicized cases, some of DOE's initial model CRADAs took many months to over a year to put in place; and even with models in place, many industry representatives complain that individual CRADAs using those models take well over 8 months to negotiate, starting with the submission of a proposal.[6] Many in industry compare DOE's delays and bureaucracy to the relative swiftness and simplicity of the CRADA procedure at NIST, where lab directors have broad authority to initiate and authorize cooperative R&D, and the process can take as little as a few weeks, starting with the submission of a proposal.

Delays have happened at many points in the DOE system, not all of which result in frustration. One step that appropriately consumes a fair amount of time (at any lab, not just DOE's) is the first, when lab and outside researchers discuss their respective research and explore areas where they might cooperate. The culmination of this phase is the construction of a research proposal. In the case of a Defense programs CRADA, the labs and their outside partners submit research proposals when DOE initiates a call for proposals. The proposals then go through two review-and-ranking sieves, and the winnowed list of fundable proposals is sent to the responsible official in DOE Defense Programs for authorization to proceed with CRADAs. This authorization signals that DOE is willing to fund the proposal once a CRADA is in place; negotiation of the actual agreement can then begin. This step still takes several months. The agency aims for a 4-month turnaround from proposal submission to CRADA signing, but so far the process has taken longer than that in every call for proposals. Delays can also occur in the lab. At times individual researchers report that they cannot get their superiors' approval to spend the time they need to develop proposals. Moreover, negotiation of the CRADA agreement, once the proposal is approved, still takes months. These negotiations involve the lab and the DOE field office. DOE headquarters has also taken extra time to approve funding for CRADAs.[7] Finally, company legal counsels have also been named as sources of delays in CRADA negotiation. The CRADA process is reportedly working much more smoothly as of early 1993, although less than half the CRADA proposals

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[4] Other mechanisms for technology transfer include technology licensing, work for others (WFO), personnel exchanges, publications, user facilities, consulting arrangements, university interactions, and cooperative arrangements (besides CRADAs).

[5] Some dispute this. DOE representatives point out that, considering the agency's total unfamiliarity with the CRADA process when it was given the authority 10 enter thcm at the end of 1989, it had a fairly good process up and running as of early 1993 (some maintain that the process was working well in mid-1992). This, they say, is a fast learning curve. It is true that the agency deserves credit for ironing out many of the more serious bugs in the CRADA process since the passage of the National Competitiveness Technology Transfer Act of 1989, and that the process is working much more expeditiously now than it was in early 1992. However, outside DOE, few would describe the agency's learning process as fast.

[6] Development of the proposal itself can take months. Some lab researchers complain that their time accounting system makes it difficult for them to spend the needed time talking to industry contacts about their research programs and joint interests, but even if it were easy, the process of learning about mutual research interests and devising a proposal for joint development would be a many-month process. What rankles industry and lab representatives is not so much the time taken to develop the proposal as the time it takes to get a research proposal through the CRADA system.

[7] In the June 1992 call for proposals, according to onc lab official, DOE headquarters got the winnowed list of proposals from the reviewers by the beginning of September, and didn't announce which proposals could be funded until the end of October. None of the proposals approved in October could have been funded before the beginning of fiscal year 1993. The June 1992 call was the most expeditious ever at DOE, however, and it might not have caused a stir had there not been far more lengthy delays before mid-1992.

submitted in June 1992 were executed by the beginning of March 1993.

This is longer than the 6 months that NASA officials report that it takes to sign a Space Act Agreement, or that NIST takes to evaluate, select and fund proposals under the Advanced Technology Program, but DOE has less experience with the process than NIST or NASA. Moreover, once NIST's ATP awards are made, work can begin; MST labs take no part in R&D, and no CRADA is necessary. Even so, DOE's CRADAs are probably more comparable to NIST's ATP program than to NIST's CRADAs, for several reasons. For one thing, NIST labs are GOGOs, which reduces the perceived need for agency oversight. More important, however, is the size of the programs. NIST is far smaller than any one of the DOE weapons labs, and while it has many CRADAs (131 were active in January 1992) they are smaller than DOE's. The average NIST CRADA is valued at $200,000, compared with over $800,000 for DOE CRADAs. ATP, on the other hand, has $68 million in fiscal year 1993, and was under consideration for a supplemental appropriation of $103 million as of April 1993; the Administration plans for ATP to grow to $750 million by 1996, In size and importance, ATP is far more like the DOE CRADA program than NIST's CRADAs.

Launch delays are understandable, to some extent. Because DOE labs are GOCOs, many in Congress and the Executive branch consider lab directors and researchers to be less concerned with the public mission of the labs than the government employees who staff GOGOs. This may justify heavier headquarters involvement in the CRADA process, and headquarters involvement itself accounts for a significant share of the delay in signing a CRADA with a DOE defense lab. Another consideration is that DOE multiprogram labs' ability to do CRADAs only began in 1989, while other government labs (all GOGOs) have had the authority to do so since 1986, and therefore have more experience making the process work.

Finally, technology transfer is notoriously difficult, even within large organizations. Company representatives often make the point that it takes real work to transfer know-how and technology between groups within the company. Transfers from outside organizations are, *ceteris paribus,* even harder. DOE's task in devising a process to make labs accessible to outsiders is therefore extremely challenging. In addition, however, there are pressures to do more than just develop a CRADA process. Because of the multibillion-dollar size of the agency's R&D establishment, it also makes some sense to design a strategic approach to lab/industry/university partnerships that concentrates resources on critical problems and minimizes overlaps. Tens or hundreds of millions of dollars spent on technology development could, according to one school of thought, accomplish more for the welfare of the Nation if some of it were spent on critical technologies than if it were simply allocated on a first-come, first-served basis. A strategic approach calls for much heavier headquarters involvement than would be needed simply to design an acceptable model CRADA and oversee the process. DOE is trying to do both.

There is no simple answer to speeding up and simplifying the process. There is very little consensus on what makes the CRADA process cumbersome or how to fix it. Lab staff and many industry sources would like to see lab directors given more authority to initiate CRADAs; they believe, probably correctly, that this would speed up the process, particularly if the labs also had the power to allocate designated CRADA funds as well. As it is, DOE headquarters is now closely involved in the approval process for work state-

[6] One caveat pertains. CRADAs can be funded from so-called program money, or money the labs spend on their own missions according to the work plan they negotiate with DOE. In order to use program money, however, the proposed cooperative work must fit almost completely with an ongoing project, requiring little or no change.

ments, and controls all the money for CRADAs.[8] The view from headquarters and observers of various affiliations is that directors of these GOCO labs, especially during times of uncertain budgets and changing missions, might be somewhat too willing to compromise the national interest in order to find industry partners, so as to prove to the agency and Congress that they should not be cut back too far. Others hold that there are problems within the labs—that some researchers, interested in seeing their work used broadly, are enthusiastic and entrepreneurial about technology transfer, while others see it as a sideshow. The cooperation of this latter group-often referred to as middle managers—is essential in designing joint work, Lab culture, especially in the defense areas that have been ''behind the fence' for decades, is sometimes raised as an impediment.

Congress comes in for a share of the blame too. Congressional oversight covering details of lab operations is seen as responsible in part for some of DOE headquarters' zealous management of lab operations, including CRADAs.[9] Along the same track, some believe that if lab directors are given greater authority to initiate cooperative R&D, fear of Congressional investigations could prompt labs or headquarters to micromanage the process. Finally, the division of authority over DOE authorizations (energy and natural resources committees authorize energy programs, and armed services committees are responsible for defense programs) complicates legislative guidance on funding and managing technology transfer.

The lack of broad agreement on the source of the problems with DOE CRADAs makes it difficult to specify solutions with any confidence. Consequently, the policy options identified here should be regarded as experiments, which also means that results ought to be monitored. It does *not* mean that any experiments should be undertaken tentatively, or that the monitoring function should devolve to micromanagement. If Congress chooses to implement any of the options suggested below, it should recognize that positive outcomes will be hard to come by if the subsequent oversight of the DOE CRADA process, by Congress or by designated monitors, interferes with the implementation.

Policy Option 3: Shorten the process of CRADA initiation.

This option is an umbrella for a number of possible actions. The National Competitiveness Technology Transfer Act of 1989 specifically directs the parent agency of GOCOs to sign off on both the joint work statement of a CRADA and the legal agreement that is the CRADA itself, requiring a two-step approval that does not pertain at the parent agencies of GOGOs.

DOE has delegated to its field offices the authority to sign off on Joint Work Statements (JWSs), which lay out what the proposed R&D entails and the roles of the lab and the outside partner, and the CRADA, or the legal agreement required before work can begin. The field office has 90 days to approve the JWS, and 30 days to approve the CRADA. Whether or not the clock ticks continuously following the lab's submission of a JWS or CRADA to the field office, or only begins after the details are worked out, is a matter of dispute; the labs maintain that the clock should tick constantly and the field offices take the other view. In practice, some labs submit JWSs and CRADAs simultaneously. The time allotted for field office review of these is also a matter of dispute; the field offices maintain that they have 120 days in such cases, while the labs feel that time should be saved by submitting the two documents simultaneously.

However, many potential CRADAs have another hurdle to clear, even before the submission of a joint work statement to the DOE field office. This frost hurdle is at DOE headquarters, and all

[9] Much of the congressional interest in the labs over the past decade has been in lab management issues, defined much more broadly than simply management of the technology transfer process. This study does not go into lab management questions, beyond this examination of the CRADA process.

CRADAs funded by Defense Programs (which has far more money to spend on CRADAs than any other DOE program) must pass it. Several times a year, DP issues a call for proposals. The labs, together with their potential outside partners, submit CRADA proposals to DP,[10] and DP reviews these proposals in two steps, operating in parallel.[11] This review process has the understandable objective of minimizing overlap and assuring complementarily to the extent possible between individual CRADAs. DP aims to keep this process to no more than 6 months, with the eventual goal of reducing it to 4. Once this process is finished, the field offices, labs, and outside partners are notified which projects DP is prepared to fund, and the work on the JWS can begin.

In short, if all steps take the time they are allocated and no more, the upshot is that initiating a CRADA may take 8 months.[12] For the past couple of years (1990-92), the process has taken longer on average; as of early 1993 it's probably still close to 8 months. The CRADA-processing time has shrunk as everyone becomes more familiar with the exercise, In addition, it may be possible for the lab/field office process of approving JWSs and CRADAs to be compressed to less than 120 days, at least for CRADAs whose language is the same as or very similar to the agency model CRADA.

Many actions could shorten the process. Congress could direct that the DP proposal screening process be shortened or dropped. Congress might consider shortening the times allotted for the two-step approval process of JWSs and CRADAs, making the approval a shorter, one-step process, or eliminating the extra 30-day approval process for CRADAs that follow the DOE model.[13] Congress could also consider stipulating that the period for approval of joint work statements is to be continuous, from the time the lab submits a JWS to the field office to approval.

Another issue that came up in the evaluation of proposals submitted in the November 1992 call is protection of the proprietary information contained in the proposal itself. In describing proposed research projects, companies often include information in proposals that they would not wish to fall into the hands of competitors. The labs are protected from Freedom of Information Act (FOIA) requests to see proposals, but DOE headquarters is not.[14] Fearing that competitors could access proprietary information in the proposals, the labs refused in February 1993 to send DOE headquarters proposals to review after the Technology Area Coordinating Teams (TACTs) and Laboratory Technology Transfer Coordination Board (LCB) had finished their two-step screening of proposals to DP. The same worry arose in 1992, but it was resolved when DOE headquarters promised the labs that each DP proposal would be screened by only a few people at headquarters.

Since 1992, however, concerns within DOE and in Congress prompted DOE to widen the headquarters proposal review process to include

10 These proposals require no small amount of work to put together; they are not sketches. They require a work plan, estimates of costs and benefits to the government and to industry, and commercialization plans.

11 This process is described in ch. 4.

12 This assumes that the DP review process takes no more or less than 4 months, and that the field office takes 120 days to approve the JWS and the CRADA, with the clock ticking. Currently, however, field offices are spending considerably less than the 120 days they are allotted to approve JWSs and CRADAs. The average in early 1993 is probably less than 4 weeks for both documents.

13 One bill currently before the Senate, "Department of Energy National Competitiveness Technology Partnership Act of 1993," would reduce to 30 days the time allocated to headquarters to approve, request modifications to, or disapprove a CRADA. If modifications are required, the agency is required to approve or disapprove resubmissions within 15 days. The Act does preserve the agency's mandate to approve both the JWS and the CRADA.

14 Personal communication with Roger Lewis, Director, Office of Technology Utilization, and Warren Chernock, Deputy Science and Technology Advisor, Defense programs, DOE, February 12, 1993.

other divisions of DOE (e.g., Conservation and Renewable Energy, Energy Research), which manage the other 6 multiprogram labs. With the expanded review process, lab staff feared that there would be too much access to proprietary information contained in proposals. The situation was resolved, but only after a substantial delay while the labs, in consultation with the industry partners, removed or marked passages in proposals that contained proprietary information. LCB's prioritized list of proposals was due at DOE headquarters by March 18, but because of the FOIA problems, were submitted on May 6, 1992.[15] DOE headquarters staff object to reviewing proposals at the labs, because it means a great deal of travel and extra time; labs dislike sending proposals to Washington, where they could be subject to FOIA requests. This is not an idle fear; NIST officials report that their FOIA exemption for Advanced Technology Program (ATP) proposals is necessary to fend off requests, many of them by foreign corporations. To expedite and protect the review process, Congress could provide DOE headquarters with an exemption from FOIA covering proposals for cooperative R&D.

Policy Option 4: Reallocate authority for CRADA signoff.

This option, like the first, could be enacted in several ways. Currently, the National Competitiveness and Technology Transfer Act (NCTTA) requires lab directors and staff to have DOE approvals of both the JWS and the CRADA. Many suggest that if lab directors had the authority to approve CRADAs, the process could be considerably shortened. A recent report of the Council on Competitiveness included two variants of this option; one suggested that lab directors be given greater discretion in allocating budgets to technology transfer, and another stated that Congress and executive agencies ought to give GOCO lab directors ''full legal authority to negotiate, sign, execute, and fund" CRADAs.[16] Another way to configure this option is for Congress to give the lab directors the authority to complete the process for CRADAs of a certain size (up to, say, half a million or a million dollars).[17] Or they might be authorized to execute CRADAs on the same terms as do many of the GOGO laboratories, including NIST's; the lab director negotiates CRADAs, which take effect within 30 days unless the parent agency objects. For example, Albert Narath, the President of Sandia National Laboratories, suggests:

> About eight percent of the government agency's operating budget should be set aside for technology transfer initiatives. These should be market-driven, cost-shared programs that are national in scope. The national labs should compete for these funds to provide the best technology solution . . . [In addition, approximately eight percent of each Lab's base program funds should be made available to encourage Lab/industry partnerships to address significant technological challenges faced by industry. These efforts should be managed at the Labs.[18]

Narath, in the same document, supports DOE's role in approving CRADAs (while making a case for greatly streamlining the process), but other lab directors have argued for their being given the full authority to approve at least some CRADAs. In combination, these variants add up to the option of giving lab directors the authority to initiate

15 Personal communication with Charles Fowler, Technology Transfer Specialist, Defense Programs, and James van Fleet, Ac@ Director, Technology Transfer Division, Defense Programs, DOE, May 7, 1996.

16 Council on Competitiveness, *Industry as a Customer of the Federal Laboratories* (Washington, DC: Cour September 1992, p. 1.

17 The average Federal contribution to a CRADA, as of the end of calendar year 1992, was just over $860,000.

18 Statement of Albert Narath, President of Sandia National Laboratories, U.S. House of Representatives, Committee On Small Business, Subcommittee on Regulation, Business Opportunities, and Energy, Dec. 4, 1992, ''Reducing the Cycle Time in Lab/Industry Partnerships, ' p. 3.

some CRADAs, while retaining agency oversight and approval of others.

Any of these permutations would require a change in NCTTA. The act states clearly that the parent agency of any GOCO must review and approve each joint work statement and CRADA.[19]

Policy Option 5: **Allocate a percentage of DOE labs R&D budgets to technology transfer.**

Yet another option, alluded to briefly above, is to allocate a certain percentage of DOE labs' R&D budgets (or to direct the agency to do so) to technology transfer. In their February 1993 statement of technology policy, President Bill Clinton and Vice-President Albert 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.[20] Similar proposals have come from several other quarters as well.[21] The Council on Competitiveness suggests, as do many others, that 10 percent of the budget of DOE labs be assigned to joint civilian technology programs with industry immediately, with a target of 20 percent (or possibly more) in a few years. This could prove somewhat tricky, since DOE's authorizations are handled by two committees in the Senate and four in the House of Representatives (see ch. 4). Appropriations are somewhat simpler, with defense appropriations and all other appropriations being separated into different subcommittees in both houses. Coordination between the authorizing committees and appropriations subcommittees may be necessary to assure that any overall spending target for technology transfer or CRADAs is feasible.

Policy Option 6: Direct DOE and lab **staff to establish stronger incentives for technology transfer.**

In their annual planning process, DOE and the multiprogram labs establish projects for the labs. After these plans are agreed to, some lab researchers report that it is difficult to devote more than a few days of project time (possibly a couple of weeks) to working out a plan of joint work with an outside partner. Lab researchers must account for their time on a strict basis, and their ability to charge to ongoing projects the time they spend with industry or university researchers planning joint R&D is quite limited. This constraint, combined with the lukewarm enthusiasm for technology transfer on the part of some middle managers at the labs, can slow or even abort potential CRADAs. Both lab staff and DOE headquarters staff acknowledge that, partly because of the prestige attached to weapons work over the past decade, and partly because DP budgets were quite generous throughout the 1980s and into the 1990s, many DP researchers

19 103 Stat. 1363, Public Law 101-189, "National Defense Authorization Act for Fiscal Years 1990 and 1991," Sec. 3133(a)(6)(C)(i), states, "Any agency which has contracted with a non-Federal entity to operate a laboratory shall review and approve, request specific modifications to, or disapprove a joint work statement that is submitted by the director of such laboratory within 90 days after such submission. In any case where an agency has requested specific modifications to a joint work statement, the agency shall approve or disapprove any resubmission of such joint work statement within 30 days after such resubmission, or 90 days after the original submission, whichever occurs later. No *agreement may be entered into by a Government-owned, contractor-operated laboratory under this section before both approval of the agreement under clause (iv) and approval under this clause of a joint work statement. . . .* **(iv) An** agency which has contracted with a non-Federal entity to operate a laboratory shall review each agreement under this section. Within 30 days after the presentation, by the director of the laboratory, of such agreement, the agency shall, on the basis of such review, approve or request specific modification to such agreement. Sue\ *agreement shall not take effect before approval under this clause.* " [emphasis added]

20 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.

21 For example, The Department of Energy National Competitiveness Technology Partnership Act of 1993, S. 473, directs that at least 10 percent of the annual budget of each multiprogram departmental lab be devoted to cost-shared partnerships with U.S. industry. See also Council on Competitiveness, op. cit., footnote 16.

are reluctant to commit more than the minimum required effort to technology transfer.

While there is little Congress could do to change the sentiments of lab researchers who are skeptical of the value of technology transfer, it could encourage greater support by directing DOE to develop stronger incentives. Already, the law encourages researchers to engage in technology transfer by providing that 15 percent of the royalties of any patent licenses may accrue to the developers—that is, individual lab scientists and engineers. However, this incentive may seem distant to many researchers; technologies must be developed, patented and licensed before there is any hope of royalties.

More immediate incentives might help effect a change in lab culture. According to a representative of the Sandia Office of Research and Technology Applications (ORTA), such incentives need not be directly monetary. They might include rewards such as additional staff positions,[22] access to a capital equipment fund, or increasing the prominence of technology transfer as a factor in employees' performance ratings. None of these require legislative action; Congress could encourage DOE to direct the labs to take such actions through oversight or a nonbinding resolution.

Another kind of nonmonetary incentive is recognition. It is easy to overuse this kind of option, but there are examples of how prominent awards have had real impacts, such as the Malcolm Baldridge National Quality Award, created by Congress in 1987. Congress might consider establishing a governmentwide set of awards for effective technology transfer from Federal labs, possibly with separate categories for GOGOs and GOCOs. If such an option is adopted, it might be worthwhile to direct the agencies managing labs to study and adopt many of the procedures of the Baldridge Award.

Congress could also facilitate technology transfer by setting aside, or directing DOE to set aside, part of the labs' appropriation for pre-CRADA development of proposals for joint work. While Congress does not now allocate part of DOE's appropriation for CRADAs, it may be worthwhile to earmark money for activities that support the CRADA process on a one-time basis, to jump-start the process. After the first year, Congress could encourage the agency to allocate sufficient funds for the purpose. Congress did something similar in 1991, designating $20 million for CRADAs at DOE, because many members felt that the agency needed the lure of an explicit appropriation. DOE could itself, allocate more funds as needed to the activities of the labs' ORTAs.

How much money would this option take? It depends on how much money could usefully be spent on CRADAs. If, for the sake of argument, we assume that the objective is to use 10 percent of the labs' budgets for CRADAs, the target would then be $250 million.[23] If the cost of preparing proposals is around $5,000 in the time and travel of lab researchers (a conservative estimate), this would mean that, to start 50 to 100 CRADAs, each weapons lab would need approximately $250,000 to $500,000.[24] The only other lab that has generated interest in cooperative research comparable to that of the weapons labs is Oak Ridge, which could also probably make

22 Sandia representatives pointed out that, at the end of 1992, SNL was constrained by its personnel ceiling (which self-imposed).

23 The combined budget of the three weapons labs in 1992 was $3,4 billion, but about one-fourth of that was Work For Others, mainly DoD. It probably is not reasonable to expect that 10 percent of the work DoD asks the labs to do should consist of CRADAs, so the 10 percent figure was based on 75 percent of $3.4 billion.

24 However, the CRADA process has been functioning on anything approaching a volume basis for only a year—calendar year 1 992—and is still not routine. As of December 1992, Sandia had initiated 69 CRADAs, Los Alamos 35, and Livermore 33. While there is probably not enough FY 1993 funding to continue signing agreements at the pace of late 1992 and early 1993, it is conceivable that the three weapons labs could average 50 to 75 CRADAs apiece in FY 1993, by the time all the agreements that are in the pipeline have been initiated and those that came in as a result of the November 1992 call are awarded.

good use of a similar amount of money. These four labs accounted for about 60 percent of all the CRADA activity in DOE facilities at the end of 1992. All told, then, to sustain the activity levels of 1993, DOE labs might need a set-aside of $1.7 to $3.4 million for pre-CRADA activity.

Another possibility is for Congress to direct DOE to build in the budgets and authority necessary for pre-CRADA development in its yearly planning process with the laboratories.

DEFINITIONS OF NATIONAL INTEREST WITHIN THE TECHNOLOGY TRANSFER PROCESS

Many of the options described above aim at facilitating tech transfer with 'volunteers' (mostly companies and private sector consortia, and a few universities) from outside. They presume that facilitating these volunteers' agendas in the CRADA process is in the national interest, and indeed it is. Private industry accounts for the majority of the Nation's job creation, value added, and technology development; it is clearly in the national interest for firms, American or foreign, that make and sell products and/or do R&D here to prosper.

However, the match between national interest and corporate objectives is not perfect. There will always be tension between public and private interests in technology diffusion. The agency's interest in assuring that technologies the labs develop (in partnerships or alone) are diffused and applied widely; companies participating in CRADAs, and to an extent the lab operators, want as much control over intellectual property as possible. So, for example, industry might support an option to specify that private sector partners retain more control over intellectual property rights developed in CRADAs, while some in DOE would prefer to strengthen the agency's right to restrict companies' proprietary rights to certain applications, or expand march-in rights.[25]

U.S. preference is another thorny issue. Increasingly, companies of all nationalities are knitted together in a complex fabric of cross-border investments and alliances. In some industries, successful competition is not possible without international partnerships. During its CRADA negotiation, for example, the Computer Systems Policy Project (CSPP) rejected a stipulation in the agreement obliging companies to manufacture in the United States any products resulting from technologies developed in partnership with labs.

Systems companies, CSPP argued justifiably, are obliged to operate globally by innumerable factors. Government procurement regulations and habits often oblige computer and telecommunications equipment makers to manufacture goods in the purchasing country; private sector purchasing and other business arrangements likewise argue for a local presence in many markets. Trade restrictions have led many systems companies to set up manufacturing and marketing subsidiaries or agents in many Nations. Finally, the costs of technology development are increasingly beyond the reach of individual firms, even the largest; development costs running in the billions of dollars have encouraged (even driven) companies into partnerships. Under such conditions, requiring U.S. manufacture would discourage such companies from taking advantage of CRADAs.

There are some who would pay that price. R&D financed by U.S. taxpayers, according to this point of view, ought to be used to create American jobs and value added, not just to improve the fortunes of companies operating overseas. Already, DOE has compromised on the provision of an earlier model CRADA that stipulated that manufacture of all products based on technologies developed jointly with labs take place in the

25 "March-in rights" refers to a situation in which a firm has exclusive rights to technology developed with government funding, but is taking too long to commercialize the technology and to make it widely available. In some cases, the government has the right to "march in" and take back the exclusive rights, and to license other firms to commercialize the technology. In the case of patents, march-in rights are required by law (35 U.S.C. 203), though the specific procedures are set by agency regulations.

United States. The CSPP CRADA, after hard negotiation, ended up as a compromise, with the requirement that the CRADA R&D take place in the United States, There are some in DOE, and certainly in Congress (which strongly encouraged U.S. preference in the first place), who would be disappointed or at least concerned if the CSPP CRADA's provision on U.S. preference became the convention rather than the exception, and their fears may become reality. Officials of DOE's Defense Programs Technology Transfer office report that more companies are asking for the same compromise CSPP got, and DOE's new CRADA guidelines now requires only that CRADA partners contribute significant benefits to the U.S. economy (although substantial U.S. manufacture is still the preferred option).

There may be no comfortable resolution of this issue. Stricter requirements for U.S. R&D and manufacturing could well drive potential R&D partners away from the DOE labs. Under this circumstance, it is possible that the only companies willing to work with labs on CRADAs would be smaller, with few or no ties to companies in other countries, and typically with less money to spend on R&D. Moreover, even requiring U.S. manufacturing is not a guarantee that American companies will have the best shot at commercializing or applying technologies developed in CRADAs. Companies with international cross-licensing agreements may put part or all of their portfolio of technology before other companies in exchange for the same rights to their partner's technology; any technologies developed and patented in a CRADA might automatically become part of those portfolios.

On the other hand, both manufacturing and R&D jobs are important to America, and it makes sense to discriminate between companies, given limited money for CRADAs, on the basis of the size of the contribution they can or might be willing to make to U.S. national interests. Allowing offshore manufacture on a routine basis could become a much more serious public policy issue in the event that a company decided to manufacture offshore all or substantial parts of products based on technology developed in CRADAs.

Policy **Option 7a: Establish a U.S. Preference Review board.**

Policy options at either end of the argument outlined above are almost guaranteed to alienate someone. One possible compromise would be to set up a review board to decide, on a case-by-case basis, whether companies may manufacture products based on cooperative work with the government offshore. For this to be a better alternative than simply insisting on U.S. manufacture, the board would have to operate in such a way that approvals could be gained expeditiously. In order to avoid becoming a rubber stamp that allowed companies to manufacture offshore at will, the board would have to be objective and analytical. Congress might consider empowering the White House Office of Science and Technology Policy (OSTP) or the Department of Commerce to fulfill this function, or create a small independent agency along the lines of the International Trade Commission, to consider U.S.-preference issues on a governmentwide basis.

DOE is not the only agency struggling to maintain a domestic preference in R&D and technology transfer activities; NASA, too, has come under scrutiny for offshore transfer of technology, and there are many agencies vulnerable to criticism if the point is pressed. Perhaps the context in which a Preference Review Board makes the most sense is as a governmentwide advisory body, handling questions and contracts involving foreign firms and their U.S. affiliates, and the location of U.S. firms' activities, insofar as Federal funding is involved. The board might also help to expedite the process of review. After ascending the learning curve, the agency might have enough information and experience to make decisions on U.S. preferences and eligibility more expeditiously than any agency acting alone, with a smaller caseload.

The other possibility, though, is that such a board might, no matter how constituted, simply

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be more time-consuming for everyone. A preference review board is a compromise between competing interests (attracting many firms to cooperative R&D vs. assuring that the benefits of cooperative agreements remain in the United States). But this issue may be too contentious for such a compromise to work. It may simply prove that making decisions on a case-by-case or company-by-company basis will prove infeasible or obstructive. Certainly, the level and extent of dissatisfaction with the Coordinating Committee for Multilateral Export Controls (CoCom), which controlled exports of technology and high-tech products with the aim of preventing enemies from obtaining them, is ample proof that well-intentioned policies can be implemented in ways that please no one. If this is the case, then Congress's options are simple, if uncomfortable: choose something and accept the less-than-optimal outcome. One possibility is to choose to maintain a U.S. preference that is stricter than many companies are prepared to accept, and live with the consequences. That could lead to increased pressure to close or cut the budgets of Federal laboratories, as potential CRADA partners opt out. The other option[26] is to permit a form of U.S. preference that companies are more comfortable with, such as the clause in the CSPP CRADA requiring the R&D to take place in the United States, and live with those consequences, which might mean that the United States ends up importing a product whose soul was invented here.

Policy Option 7b: Establish guidance on disposition of intellectual property.

Another issue that comes under the heading of national interest is the disposition of intellectual property. Like U.S. preference, this issue is unlikely to be resolved in a way that completely satisfies either public or private interests; rather, the solutions are compromises. Under their operating contracts with DOE, the contractors often are allowed to take title to intellectual property developed there. In the case of patents or other intellectual property developed with funding from DP, the labs must apply for a waiver from DOE in order to retain title to the patent; it is usual for the agency to grant these waivers, and DOE retains a fully paid license in perpetuity.[27] In fact, in 1992, DOE delegated the responsibility for handling waivers to operations (field) offices to make the process more efficient. Because the labs have so much control over the intellectual property generated within their walls, DOE has delegated to them responsibility for negotiating with CRADA partners the disposition of intellectual property within a CRADA, provided that the intellectual property belongs to the contractor and not DOE. However, in the CRADA negotiation process, it is still common for intellectual property rights to consume a disproportionate share of the time, for there are still conflicts between different interests in the disposition of intellectual property.

The government's preferred option is to assure wide dissemination of the technologies developed at taxpayer expense, for two reasons. First, wider dissemination of technologies has greater potential to raise standards of practice, productivity, and the other benefits that new technology confers broadly throughout the Nation, which in turn helps raise living standards. Second, broad dissemination helps to avoid the appearance or reality of government benefiting specific firms at the expense of competitors. In fact, many in DOE

26 There is another course, and that is to make the United States an attractive enough place to do R&D and manufacturing that most firms would choose, without additional pressure, to locate the vast majority of their R&D and manufacturing here. This course involves a number of actions, some of them representing major changes in the course of U.S. policy. Options to make the United States a more attractive location for investment in R&D, manufacturing, worker training, and the like are described in U.S. Congress, OTA, *Making Things Better: Competing in Manufacturing,* op. cit., footnote 1; and *Competing Economies: America, Europe, and the Pacific Rim,* op. cit., footnote 1.

27 In cases where technology development is funded by energy programs, which includes most of the work at the Other six multiprogram labs, DOE allows the labs to take title to the intellectual property immediately, with no waiver required.

would prefer to work with consortia rather than individual fins, for the simple reason that such arrangements make it more difficult to accuse the agency of playing favorites.

Intellectual property developed within CRADAs may be held by the industrial partner, the contractor (operator of the lab), or both, depending on who was primarily responsible for the invention. By law, CRADA participants are free to agree on any allocation of intellectual property developed within the agreement, subject only to Government's retention of a royalty-free license. As a rule, the government would prefer that the contractors (labs) retain title to the patents developed within CRADAs (except, of course, when the technology was developed by the company), to grant nonexclusive licenses to the intellectual property, or to limit the field of use (breadth of application) under exclusive licenses. Companies, on the other hand, are not anxious to see technologies that they have partly funded licensed by another party. Having put up half the money for developing intellectual property, companies want to be able to have first crack at practicing the technologies, or to have control over licenses.

Exclusive rights need not be all or nothing. For example, a firm might get exclusive rights only to specific fields of use, or only for a few years duration. Still, the issues are divisive enough to prolong negotiation. Here, too, the option for Congress, if it wants to change the status quo, comes down to picking one side or the other and living with the consequences. Put simply, if Congress chooses to strengthen support for the public purpose of wider diffusion, fewer companies may be interested in partnerships; if it chooses to give companies more protection, the taxpayers' immediate return on their investment may be more limited. Congress may wish to provide some guidance, in the form of a resolution or a law, that would eliminate the source of many disagreements during negotiations over intellectual property, and thus help to shorten the negotiations. One route is to discourage exclusive licenses that have broad field of use, or limit the time during which the exclusive license prevails; the other is to encourage DOE and its contractors to accommodate companies' desires for broader intellectual property rights.

A final consideration is that of signing a CRADA with several laboratories. Different contractors have different preferences on intellectual property, and companies that devise multilab CRADAs complain that it takes a separate negotiation with each of them to work out intellectual property rights. DOE could encourage and guide the labs to harmonize intellectual property provisions; Congress could encourage this through oversight or a resolution.

Product **Liability.** A final national-interest issue is liability. In contrast with the other two, there is more here for the labs, the agencies, and companies to agree upon. Currently, the outside institution that signs a CRADA is liable for any damages or penalties except the labs' own negligence. This is more acceptable than DOE's original position, which was that the outside partner was required to indemnify DOE completely; however, it is still riskier than companies would like. DOE, and presumably, other government agencies, are nervous with any liability, because it raises the likelihood of having to pay for damages. The perception of both government and industry representatives is that liability claims are becoming larger, and damages more expensive to pay; they also see that large companies or government agencies with deep coffers are more vulnerable to costly litigation and possible heavy damages. As long as product liability law remains as it *is*, both the agencies and the companies would like to shift as much liability as possible onto other parties; both, however, would welcome some limitation of liability. No policy option is proposed here, however, for the Office of Technology Assessment (OTA) has not done an extensive analysis of product liability in this or other contexts.

MEASURING THE VALUE OF COOPERATIVE R&D

Even if the process of initiating CRADAs can be made to work more efficiently, longer-term questions of how to measure the value of the agreements remains. This point is particularly stressed by R&D providers other than National labs, who view the labs as having more or less carte-blanche funding without the accountability built into other institutions-for example, the peer review system or the competition for National Science Foundation (NSF) grants among universities, and the necessity of satisfying paying clients among privately-funded R&D institutions.

Ideally, we could develop measures of the efficacy of R&D that could gauge the performance of any institution. However, R&D is notoriously difficult to measure adequately. Standard economic measures used to rate the performance of policies or businesses can be applied to R&D, but with so little precision and accuracy as to render them nearly meaningless. For example, we can measure the performance of the economy in terms of value added and numbers of jobs created (among other things). But when we try to use these to compare various R&D projects, the range of interpretation is vast. Public investments. many decades ago, formed an essential part of the development of the American semiconductor and computer industry. Without the military's support of early efforts to design and build integrated circuits and electronic computers, it is likely that the industries would look very different today, but it is impossible to tell how different. We might, for example, be one to several generations farther behind in technologies essential to the industries, or technologies may have taken a different turn altogether. Probably the least likely scenario is that things would be pretty much as they are. Yet it is clearly incorrect to count the entire volume of sales or numbers of jobs involved in these industries as benefits of the original public R&D, not to mention the jobs and value added in industries downstream, that depend on modern computation and circuitry. R&D is only the initial link in a long chain of activities and investments that end up creating value and employment; without it, the entire chain might disappear, yet it is by no means the only critical link.

Other problems abound. Private R&D institutions point out, probably correctly, that R&D at the National labs costs roughly twice what it costs at private institutions, on a per-researcher basis. This is an important consideration, but it does not mean that anything that could be done at a National lab could be done for half the cost at another institution. Different performers have different strengths, and different facilities. It is hard to generalize about these different abilities, but a few (possibly overstated) may be valid. It may be the case, for example, that DOE weapons labs are uniquely suited to carrying out R&D that demands the sophisticated facilities and computational power they possess, especially if the problems are long-term in nature and highly complex. Private R&D labs, either stand-alone or within companies, are usually regarded as better at doing R&D that is more tightly focused on commercial products or processes and bringing the results in at a time when they can be useful in production. Universities are often regarded as having particular value in pursuing things more at the research than the development end of the spectrum-investigating new approaches to problems, exploring the scientific bases for technologies. These are, as stated above, generalizations; universities have contributed to near-term technological problems, for example.

Perhaps the best measures of performance are less quantitative and more judgmental. Some in industry have suggested that the ultimate yardstick of CRADAs is whether companies are willing, after 5 years or so[28] of experience, to continue to put in significant amounts of money to cooperative R&D with the labs, and whether key company researchers are encouraged to spend significant amounts of time participating in the projects. In the short run, the fact that industry is willing to put up money to fund many more CRADAs than DOE has money for can be interpreted as a measure of faith that cooperative arrangements can be made to work, perhaps tempered by the experience of a few companies with longer-standing cooperative arrangements (like the Specialty Metals Processing Consortium at Sandia—see ch. 4 for details).

Policy Option 8: Develop Ways to Evaluate Cooperative R&D

The fact that the best measures of CRADA performance are somewhat judgmental and may be several years coming is not an admonition against attempting evaluation. R&D money is precious, and scarce. If the labs prove to be inefficient or slow R&D providers for the private sector, shifting money to other providers (after a fair trial period) is prudent. Congress could direct the Secretary of Energy to develop an evaluation procedure for cooperative R&D. Another option is to direct OSTP to develop a more generic evaluation procedure for all cost-shared R&D that involves government and private funds.

STRATEGIC DIRECTION OF COOPERATIVE TECHNOLOGY DEVELOPMENT

The options laid out above aim mostly at streamlining the process of developing and initiating CRADAs. In a few cases, that streamlining comes as a direct result of downplaying or eliminating agencywide strategic direction, which is now provided by the LCB process in Defense Programs. The LCB process, described in greater detail in chapter 4, consists of reviews of each proposal by two groups of lab staff (one technical experts and one composed of the heads of the Offices of Research and Technology Application at each of the sites in the DP research complex) and, eventually, in parallel, an industry advisory board.[29] The prioritized list of fundable research projects that results is both a form of peer review of research and a safeguard against unnecessary redundancy (some being desirable) among research projects.

Within limits, the LCB review process also gives DOE's DP staff some ability to allocate its CRADA funds to strategic industries or critical technologies, either in accord with agencywide plans or with broader, multiagency technology policies. For example, Warren Chernock, the Deputy Science and Technology Advisor of Defense Programs, had developed tentative plans in mid-1992 to allocate $75 million over 5 years to semiconductor lithography, and $10 million in fiscal year 1993 money to a program to develop better flat-panel display technologies. Chernock also had plans to allocate CRADA money (ranging from a few million to over $20 million) to programs in advanced materials and ceramics, manufacturing, and transportation technologies. Many of these technologies were identified by Congress, DoD, and the OSTP as critical to both military and economic security of the United States.

28 Five years was not picked at random. Most of the participants agree that it took Sematech a couple of years to get On the right track, and then another couple to start making real progress. By the end of *5 years,* Sematech's members are in agreement that the consortium has contributed substantially in tangible and intangible ways to their competitiveness. Sematech is credited by members and observers with revitalizing the American semiconductor production equipment industry, and a few insiders speculate that if it hadn't, some of the semiconductor companies might not be in business at all now, It has also contributed to lowered costs per wafer, another boost to competitiveness. Finally, it has significantly improved communication and coordination within the industry, vertically and horizontally. Now, in its sixth year of operation, Sematech continues to contribute substantially to American semiconductor manufacture, and member companies are willing to dedicate substantial amounts of money and the time of important company representatives to Sematech.

29 So far, the industry advisory board is not part of the review process. Officials in Dp had initially planned to gather an industry bored to advise the LCB, but by April 1993, the group did not yet exist.

The purpose of the LCB process is clear and logical. Some kind of internal screening will be necessary should DOE participate in governmentwide initiatives to advance specific technologies, and the process makes sense even if it is only applied within the agency, given the large size and scope of DOE's R&D program. The downside is that this level of internal screening prolongs the CRADA process by several months, trading expedition for oversight. In the short run, in order to streamline CRADA initiation, it might be worth sacrificing some control over the portfolio of research covered by cooperative R&D. Otherwise, the lively interest industry has recently shown in R&D partnerships with the labs could evaporate. In the longer run, once DOE and its field offices and labs become more accustomed to CRADAs, it might be desirable to rank CRADA activities to fit within strategic initiatives to develop specified technologies, without delays of months for proposal selection. For example, proposals for joint R&D superconductivity are processed much more rapidly than CRADAs. Perhaps other technology initiatives could be identified, allowing the agency to process pertinent proposals on a faster track.

Interest is growing in allocating at least some money and effort to specific technologies or industry sectors on the basis of their contributions to economic well-being or National security. The competitive position of many of America's high-tech industries is too precarious for comfort, even though private and public efforts have improved competitiveness in many sectors over the past decade. Critical industries and technologies make disproportionately large contributions to National well-being through creation of larger than average numbers of highly skilled, well-paid jobs; the promise of productivity or product improvement in many industries; and, in many cases, fast-growing markets here and abroad. Yet many fear that, without new initiatives to advance critical industries and technologies, market signals and current government programs alone are insufficient to assure that American companies maintain prominent places among the world's best competitors.

While the pressures for both economywide and sector-specific policies to improve competitiveness have grown, the American approach toward such policies has been mostly not to adopt them, except where military security is concerned. Over the past decade, the United States has embarked on a few initiatives aimed at improving the performance of sectors whose contributions to defense needs were irreplaceable, but whose ability to make those contributions depended mainly on performance in primarily civilian competition. Sematech was one such initiative; ARPA's work in semiconductor manufacture and flat panel displays also count.

The High Performance Computing and Communications Program

An example of a different approach to sector-specific technology policy is the High Performance Computing and Communications Program, or HPCCP. The program's goal is "to accelerate significantly the commercial availability and utilization of the next generation of high performance computers and networks."[30] HPCCP has four component programs.

1. High Performance Computing Systems (HPCS), aimed at developing innovative systems to provide a 100- to 1,000-fold increase in sustained computational capability over conventional designs;
2. Advanced Software Technology and Algorithms (ASTA), whose objective is to match hardware improvements with new and innovative software and algorithms;

30 Federal Coordinating Council fo, 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, no date, p. 2.

3. The National Research and Education Network (NREN), which aims to expand interconnected computer networks in the United States, and greatly enhance the capabilities of the network; and
4. Basic Research and Human Resources (BRHR), aimed at meeting long-term National needs for educated and trained people capable of sustaining greatly expanded high performance computing.[31]

Many of the activities of HPCCP began as efforts on the part of individual agencies in the early 1980s. For example, NSF established several National Supercomputer Centers to serve the science and engineering community, and connected them with the research community on a net work called NSFNET. ARPA funding spawned the first generation of commercial, scalable parallel computer systems. DOE expanded an existing computer network of the National Magnetic Fusion Computer Center to serve users of energy research in National laboratories, universities, and industries; several DOE labs also formed computational groups to experiment with high performance computing and develop advanced algorithms. NASA established a National data network to link researchers in computational aerodynamics through the Numerical Aerodynamics Simulation facility at its Ames research laboratory .32

In 1986, Congress directed that OSTP study the problems and options for communication networks supporting high performance computing. The charter of the the Federal Coordinating Council for Science, Engineering, and Technology (FCCSET) Committee on Computer Research and Applications was broadened to accommodate the study. The Committee's report, *High Performance Computing Strategy,* formed the basis for the four components of today's HPCC. Congress put its imprimatur on the program with the High Performance Computing Act of 1991, which now has an overall budget of $805 million.

While the program has been criticized on a few counts, HPCCP enjoys widespread approval and support, both among the agencies that are part of it and among industry observers. According to one source at DOE, the program increased the emphasis given to high-performance computing within the agency, while also helping to eliminate needless redundancies among agencies. In addition, it has several attributes that could guide Congress as it considers the longer-term future of the DOE labs. There are doubtless several technologies to which many Federal agencies and several institutions in the R&D infrastructure could contribute, including many of the technologies on the DOE headquarters list. While lab/industry partnerships enacted on a first-come-first-served basis would doubtless end up concentrating on many critical technologies simply because they are of great interest to both the public and private partners, uncoordinated funding of individual partnerships is not so likely to advance critical technologies as a well-designed multiagency strategic program.

The key phrase is "well-designed." While good planning will probably mean that the shape of the initiative depends on the characteristics of the industry, technology, and competitive position, several generalizations are possible. One is that the core competencies of all the participating Federal R&D performers are exploited appropriately. Hastily planned programs sometimes err in the direction of adding too many new missions to existing agencies, and even competent institutions are rarely capable of a dramatic change. Another characteristic of a good critical-technology initiative is that it builds in significant and ongoing roles for private companies and other institutions. Initiatives with the sole or primary

31 Ibid., pp. 12 to 21.

32 Executive Office of the President, *The Federal High Performance Computing Program,* Office of Science and Technology Policy, SePt-8, 1989, p. 9.

mission of boosting competitiveness need substantial and continuing guidance and participation from industry. Industry is usually the end user of technology generated with Federal spending, and must be involved at all stages in order to increase the chances for success.

Critical technology initiatives are also likely to work better if they have clear, concrete goals, milestones, and performance metrics. They must be given time to work—and not evaluated too soon after birth-and they must have the freedom to take risks. This, in turn, means that they must possess the ability to sustain failures from time to time, without necessarily risking immediate cancellation. However, the ability to cancel an initiative when it has failed too many times, or when it has succeeded to the point where it is no longer needed, must exist in reality, not just on paper. This principle may be especially important for OSTP, which has emerged as a more important player in initiating and coordinating Federal technology initiatives, and which has had more difficulty than other agencies in obtaining advice from industry.

In isolation, these guidelines are mere platitudes; they will mean different things in different initiatives. It might be wise to examine the conduct and structure of past technology initiatives, particularly successful ones, for some guidance in the preparation of new ones. HPCCP, while not a completed success story, is worth examining, as are Sematech and NASA's aeronautics research program (stretching back many decades, including the work of NASA's predecessor, the National Advisory Committee on Aircraft).

Based on the analysis conducted for this assessment, OTA is not prepared to suggest which of the many possibilities for new national R&D initiatives that have been proposed are the best candidates for Congressional consideration. The following policy-related discussion should serve as a general guide to selection and construction of broad critical-technology issues, using a few examples for clarity; it is not a recipe for initiatives in the technologies used as illustrations.

NEW NATIONAL INITIATIVES

The "peace dividend" that accompanies the end of the Cold War will not be hard to spend; in fact, quite the opposite. Defense cuts are already spoken for by a growing list of petitioners. While a high priority for any Administration has to be deficit reduction, the powerful arguments for finding new investments to repair national problems and mitigate the economic impact of the defense cuts have also had an effect. Even after winnowing away the half-baked ideas, proposals for new national initiatives outnumber the resources that could be dedicated to them, without a major overhaul of the Nation's fiscal policies and priorities. Intelligent development of new initiatives will depend on our ability to select a few, based on their potential for conferring broad public benefits.

One factor in selecting the initiatives is their ability to match the things the Nation values most in its shrinking defense establishment (excepting, of course, its ability to defend the Nation). For example, the defense complex supported a disproportionate share of the Nation's R&D, some of which was applied broadly; advanced technologies in many civilian industries can be traced to DoD support. Defense was also a large provider of relatively well-paid, high-quality jobs, and many of the proposed new initiatives have been or should be held up to the employment yardstick. DoD also provided a large market for goods and services; the size of the market for products of a new national initiative will also be a consideration. The smaller the eventual market, the less the opportunity to mitigate the damage done by defense cuts. Finally, as conversion opportunities, the extent to which existing defense-related institutions like DOE weapons labs can contribute to new national initiatives could be important, though it ought not be the highest priority. Whether all of these can or should be used as a sieve for selecting new national initiatives is a question. The best way to understand how such criteria might work is through the use of some examples.

One obvious choice is environmental restoration and waste management. It is a frontrunner because, in a sense, it is already a $200 billion enterprise. A number of programs, run by different agencies and governmental units, are already in place, though they could hardly be called coordinated. Cleanup as a national initiative has many of the attributes of a good replacement for defense: the government has a great need for environmental remediation technologies, products, and services and is expected to continue providing a multibillion dollar market; the output is a public good; there are many possibilities for spillovers to other sectors.

U.S. employment in a range of environmental jobs was about 970,000 in 1991, and was expected to rise to nearly 1.5 million within 5 years. U.S. sales of environmental goods and services were about $120 billion in 1991 and rising at the rate of 7 percent a year.[33] The world market is estimated at $200 billion and growing at an annual pace of 5 to 6 percent, faster than the expected average growth of any advanced national economy.[34] Environmental cleanup (along with other environmental concerns) is high on the agenda of public policymakers all over the globe, so both growth prospects and opportunities to develop and test new technologies should be outstanding for the foreseeable future.

Finally, environmental restoration is a large and growing focus of activity at DOE. All nine of the multiprogram labs are working on environmental remediation and waste management (EM). DOE's interest in the problem stems largely from the fact that the agency's weapons complex (not just the labs, but the weapons manufacturing and nuclear waste management facilities) is a big part of the hazardous waste problem. Over 3,700 sites, covering 26,000 acres, are contaminated. Four sites—Hanford, Washington; Rocky Flats, Colorado; Fernald, Ohio; and the Idaho National Engineering Laboratory (one of the nine multiprogram laboratories)--present particularly nasty radioactive and hazardous waste problems. The three weapons labs all have special expertise to devote to improving traditional cleanup methods and developing new restoration technologies.

If environmental remediation is an obvious choice for a national initiative, then companion pieces might be considered as well. That we need to cleanup the waste of the past decades is crystal clear, but cleanup, as currently conceived, is an after-the-fact approach. In the future, demand for technologies that create less or, if possible, no pollution is expected to increase. Pollution prevention is, however, an umbrella; the technologies for pollution prevention are probably more numerous and more varied than for cleanup, since pollution prevention can mean many different things even within even one industry. For example, in motor vehicles it could encompass projects aimed at creating cars with completely recyclable parts, eliminating greenhouse gases and other polluting emissions through new propulsion technologies, and several changes in manufacturing methods to reduce or eliminate the pollution and waste heat generated there. How good a candidate pollution prevention makes depends heavily on what projects are included; without greater specificity, this option is hard to compare with other, more concrete, proposals.

Another theme that has often been raised for new national initiatives is transportation. Ideas for new transportation initiatives are varied—some propose new infrastructure projects; others focus on high-speed ground transportation, super-

33 Data provided to OTA by *the* Environmental Business Journal.

34 Dr. Clyde W. Frank, Deputy Assistant Secretary for Technology Development, Offive of Environmental Restoration and Waste Management, DOE, statement at the conference, Environmental Technology Transfer from the DOE National Labs, Washington, DC, Nov. 11, 1992.

sonic commercial air travel, or nonpolluting cars. All of these may have merit in meeting transportation goals; OTA has not evaluated them on that basis for this report. As defense conversion initiatives, some look better than others.

One of them, nonpolluting cars (and other motor vehicles), is already in the works, in a small way. Most developed nations, particularly those with automobile industries, have invested in alternative fuel-alternative vehicle programs, especially in ones to develop technologies for electric or hybrid vehicles whose propulsion systems have few emissions. In the United States, several defense firms are interested in using their experience with electric propulsion systems to build powertrains for electric vehicles; Westinghouse Electric's electronic systems group, for instance, is cooperating with Chrysler in such a program. Many DOE labs could make contributions, based on ongoing research programs, to electric vehicle technologies. In fact, DOE's Conservation and Renewable Energy Program has a fiscal year 1993 budget of nearly $60 million for electric and hybrid vehicle research, most of which is being spent on the U.S. Advanced Battery Consortium (USABC), formed in 1991 as a collaborative effort among the Big Three automakers and DOE.

For several reasons, electric vehicles (EVs), which depend completely or substantially on batteries for propulsion, are unlikely to replace internal-combustion vehicles in all market segments, although there are niches (such as vehicles for in-town mail delivery) for which EVs could be eminently suitable. In addition, EVs are likely to have some near-term market potential in meeting stiffer air-quality statutes, beginning with California's Clean Air Act Amendments of 1990, which requires that 2 percent of the vehicles sold in California by 1998 have zero emissions, with the percentage increasing to 10 percent by 2008. USABC is aimed only at developing battery technology, which will be necessary for electric vehicles, but could contribute to an effort to develop hybrid vehicles[35] as well. Should the United States opt to extend its effort to contribute to electric vehicle technologies, it could build on the experience and contributions of USABC in crafting a program aimed at developing the technologies needed for hybrid vehicles. As a defense conversion initiative, such a program has several attractions: the expertise of several defense contractors and Federal labs can already make a contribution, offering those that are interested some relatively straightforward opportunities for conversion; and the potential market is enormous, both in the United States and offshore. The R&D investment needed to overcome the rather formidable technical challenges is substantial, which probably means that a vehicle initiative would offer the promise of many of quite highly paid and high-value-added R&D jobs over the next several years. There are many legitimate public goals that could be fulfilled if the program is successful. It could help eliminate America's dependence on imported oil and contribute to environmental goals, as well as provide opportunities to companies, labs, and workers hurt by defense cutbacks (though the latter is, as stated before, not the highest priority).

High speed surface transportation-in particular, maglev trains-is also often proposed as a new initiative, but here there may be fewer attractions, at least as far as defense conversion opportunities are concerned. Maglev or high-speed rail systems could contribute to many transportation goals, but most analysts agree that potential applications are limited to a few heavily traveled corridors like the Eastern seaboard, parts of the West Coast, and a portion of Texas, at least if the system is to be liberated from continued heavy public subsidy. There may be other growth opportunities abroad, but several foreign companies are already better positioned to take advantage of them than American companies, several of which are struggling just to survive startup. There

35 In this report, the term hybrid vehicle refers to vehicles that use, for example, a battery and a fuel cell, for propulsion.

are, however, many ways that national labs and probably several defense companies could bring relevant expertise to bear on the problems of maglev systems, should such an initiative be adopted. In particular, high speed systems need vehicles made of strong, lightweight materials, an area in which the defense sector is a leader. Also, maglev systems might become a market for high temperature superconducting magnets; three DOE multiprogram labs (Los Alamos, Argonne, and Oak Ridge) have ongoing cost-shared projects with industry on commercial applications of high temperature superconductivity.

New Missions, New Institutions

Whatever initiatives are chosen, it seems clear that they will involve many agencies and hundreds, maybe thousands, of private companies. It is also quite likely that many of the initiatives now under discussion are broader than the mission of any single government institution or agency, which brings up the question of who should manage such initiatives, and how. The immediate problem may be how to deal with changing size and missions of DOE labs (and likely DoD labs and test facilities as well), but the long-term solution is probably *not* **to try to** give DOE, DoD, or any of their labs the primary mission of managing new national initiatives. Indeed, some of the institutions formerly devoted wholly or mostly to defense technology development may be unable to adapt well enough to civilian market conditions to play major roles in civilian technology development, despite current hopes. Some, anticipating this development, have suggested that this is the time to consider new national technology-development institutions to help the U.S. economy adapt to the post-Cold War world. Another approach is to assign new, broader missions to existing institutions that already have responsibility for technology development.

One suggestion that has been raised a few times is to make one or more of the DOE multiprogram labs into centers of excellence for technology transfer. The Secretary of Energy Advisory Board's July 1992 report, for example, says:

> The Task Force recommends that the Department designate several National Laboratories, for example, Sandia and Oak Ridge national labs which are considered to have successful technology transfer programs, to become technology partnership "centers of excellence. " These centers could lead the DOE Complex and other Federal R&D centers in developing the most effective processes for including the private sector in the planning and developing of technology projects, and making technology available for private sector use. The Department should target roughly twenty percent of the base funding for technology R&D programs to be committed to long-term, large-scale partnerships with the private sector at these experimental centers.[36]

Others have proposed larger-scale reorganizations along similar lines. One suggestion, for example, was to turn one of the weapons labs into a civilian technology development center. One difficulty with suggestions of this kind is that they beg the question of what technologies the labs will have to transfer, assuming significant shrinkage of their defense missions. One reason for the avid interest in CRADAs that many companies have shown is the repository of technologies available, and that repository, in turn, is a result of years of generously funded work in nuclear weapons development and management. Without some new mission or missions, interest in partnerships might decline after the initial few years, after industry discovers the research that has long been inaccessible to it, at least in the weapons labs. There is a great deal of interest in finding new missions for DOE labs, but only as part of larger, national missions to do things like cleanup the environment, develop nonpolluting transpor-

36 **SEAB, op. cit.,** footnote 3, p. 8.

tation systems, and the like. DOE labs have a great deal to contribute to some new national initiatives, but few can envision them taking the major responsibility for research or management of a new set of national R&D goals.

This is not meant as a condemnation of DOE or its labs; there is currently no agency or laboratory with the charter of performing research or leadership functions for broad national technology initiatives that span jurisdictions of existing agencies. Institutions of this sort do exist in other nations, but usually under the auspices of a Federal agency for science and technology. Agencies like the Federal Ministry for Research and Technology (BMFT) in Germany or Japan's Ministry of International Trade and Industry (which contains Japan's science and technology agency) have many technology-policy responsibilities, including funding R&D labs that contribute to civilian technology development, often with substantial private matching funding.

BMFT, for example, had a budget of $4.4 billion in 1992, more than half the money the German Government spent on R&D.[37] Its missions are: to contribute to innovation supporting Germany's environmental and economic goals; to pursue a variety of long-term scientific and technological developments such as space exploration, nuclear fusion, and advanced transportation; to increase the pool of human knowledge; and to expand knowledge about environmental threats in order to contribute to policy decisions. BMFT funds R&D at four kinds of institutions, including national labs that resemble DOE labs in many ways. Another, the Fraunhofer Society (or Fraunhofer Gesellschaft, FhG) consists of 47 R&D institutions, funded at nearly $453 million in 1992, that aim to promote innovation in civilian technologies and transfer research results to practical use in industry. About 30 percent of FhG's funds come from industry contracts to develop specified technologies; the rest comes from Federal and state governments. FhG are considered quite successful in accomplishing their goals, though institutes that concentrate on longer-term, riskier technologies have more trouble attracting industrial support than those whose work focuses on technologies with a more immediate payoff. Broadly speaking, the FhG resemble some of the proposals made for DOE labs' metamorphosis, or alternatively, for some newly-created institution in the United States. For a variety of reasons, it is hard to see DOE labs performing like FhG institutes-the greatest difficulty, of course, being that the DOE has a far different charter than BMFT.

Another idea is to transfer some DOE labs (and possibly other Federal laboratories) to a different, or new, agency with responsibility for implementing national technology policies. For example, if the United States created a Department of Industry and Technology, or a National Technology Foundation, it is possible to imagine such an agency taking on the administration of some parts of the Federal R&D infrastructure, or at least contributing heavily to the missions and funding of labs belonging to other agencies under the auspices of national technology initiatives. There have been several bills in past Congresses to create a new Cabinet-level or other executive agency for technology policy,

Without an agency whose marching orders include technology development in pursuit of national goals, those seeking a home for the management of national technology initiatives may continue to focus on reconfiguring existing agencies whose missions are somewhat similar. NIST is sometimes raised as a possibility for the Nation's technology agency, and it has been given several new programs to manage in the last few years. These include the Advanced Technology Program, Manufacturing Technology Centers, and the Baldridge Award. In addition, NIST runs four labs that, though modest in size, have good reputations for cooperative technology development with industry.

37 See the Appendix to Part One for a discussion of German R&D institutions.

ARPA has attracted even more attention.[38] ARPA is responsible for most of what DoD does in advancing high-risk, high-payoff technologies. Increasingly, DoD is interested in technology advances made in civilian markets that are applicable to military needs-and are often cheaper and more advanced. ARPA portfolio of research projects is now about two-thirds dual-use.[39] On the dual-use side, ARPA managers often prefer working with civilian companies or civilian divisions of companies that do defense work, so as to help assure wide diffusion of the technologies that are developed. ARPA is not a research performer, but instead uses a variety of mechanisms-including contracts under which ARPA pays for all research, and cooperative agreements in which ARPA shares funding with companies and universities-to advance technology both in military systems and throughout the community of companies and other institutions on which DoD depends.

ARPA is considered very successful in supporting long-range, relatively speculative technologies that private companies (whether or not they depend mainly on DoD for business) would invest little or no money on their own. It has had failures, but it could not fulfill its mission properly without taking risks, and there is no reasonable expectation that every risk could pay off. In fact, ARPA is so often touted as a success in technology development that, even while the rest of the defense establishment is in the midst of shrinking missions and budgets, ARPA's budget has been augmented far above its request, and its missions have been broadened to include activities with which it has no experience. ARPA's 1993 budget of $2.25 billion is more than 50 percent above its 1992 budget, and it has been given responsibility for managing several new programs for defense conversion. The largest of these new responsibilities are the Defense Dual-Use Extension Assistance program, aimed at helping defense companies develop dual-use capabilities ($95.4 million in fiscal year 1993); Regional Technology Alliances, which would fund regional centers to apply and commercialize dual-use technologies ($95.4 million); and the Defense Manufacturing Extension program, to share the costs of supporting State and regional manufacturing extension programs to aid small manufacturing companies to convert to civilian markets (also $95.4 million). These extension programs are very different from anything ARPA has done. ARPA has also been given four other new conversion programs aimed at codeveloping dual-use technologies and supporting manufacturing process technologies and education, with funding that totals $128.8 million. Other dual-use programs were continued and given additional funding.

These new programs effectively broaden ARPA's mission, just as earlier proposals to turn the agency into the National Advanced Research Projects Agency (NARPA) would have. A NARPA, according to one report, could support dual-use technologies; fund long-range, high-risk, high-payoff technologies; and advance technologies that would help other government agencies fulfill their missions.[40] Turning the agency into NARPA would, argued proponents, give it a permanent mission to advance dual-use technologies, considering the effect such technological advance would have on both military and economic security.

Whether or not ARPA, or NARPA, could function as the implementation agency of the Nation's technology policies and initiatives is unknown. It does a good job of advancing more speculative technologies of interest to the military, Many of the needs that drive the military's

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38 See ch. 5 for a more detailed discussion of ARPA.

39 See ch. 5 for details.

40 Technology and Economic *Performance: Organizing the Executive Branch for a Stronger National Technology Base* (New *York:* Carnegie Commission on Science, Technology, and Government, September 1991, p. 7.

need for goods and services also propel competition in civilian markets, and vice versa; to some extent, ARPA can be said to have experience in managing national technology initiatives. Yet unless it is removed from DoD--in which case DoD would be worse off, in the eyes of many analysts-it is possible that military needs might still dominate ARPA's agenda, especially if there is a resurgence of concern for military security in the future. It is also uncertain that ARPA, with no additional staff, can cope adequately with its various new missions, or that its particular expertise will equip it to manage things like technology extension.

In short, there is no perfect home for management of new national initiatives in the executive branch. Many agencies might be made to function adequately, if the initiative chosen fits largely (if not completely) within its existing charter and experience. Initiatives that span multiple departments and agencies, and cannot be mostly contained within any one, might prove difficult to coordinate in the continued absence of an executive agency charged with implementing national technology policies and initiatives.