long-range future. There is, of course, no obvious reason why both strategies should not be continued, but they may involve very different evaluation approaches, different implementation approaches, and even targeting of different labs.

Another important strategic issue is the role of basic research in commercialization. It is easy to argue that the labs, many of which have strong basic research capabilities, should play a role as basic research provider (or partner) to companies. But it is also plausible that commercialization efforts are more likely to pay off when they are centered on product development. Actually, our results seem to support both views. Activities focused on product development are likely to provide substantial benefits. Basic research does not enhance the likelihood of commercial payoff from interactions. But those projects that are "big winners," the ones with huge returns, are disproportionately basic research projects—indicating that just as basic research itself is a high-risk, high-payoff activity, basic research aimed at commercialization seems to have the same character.

Finally, while we learned a good deal from this phase of the NCRDP about the value of interactions between federal laboratories and industry, many pieces of the puzzle are still missing. In the first place, this is a study of companies that have interacted with federal laboratories, and it would be useful to examine some that have not done so. To what extent is the lack of interest in working with federal labs due to self-conscious avoidance decisions and to what extent is it due to lack of exposure to the labs or to other such nonsystematic factors? Second, what are the opportunity costs of laboratories' involvement in commercial activity? When labs are working with companies there are other activities that could be pursued but are not. What is the value of industry-federal lab interaction *compared to* other lab activities? Any comprehensive analysis of the "competitiveness potential" of the laboratories will need to take such factors into account.

The bottom line for this preliminary assessment of the cooperative technology paradigm is that partnerships between federal labs and industry *can* work and often *do* work, but their success is far from being uniform.

CHAPTER SEVEN

Redesigning Federal Laboratories

Twenty Years of Study Panels and Their Recommendations

With $25 billion on the table annually, and with facilities the size of small cities, it is little wonder that the U.S. has struggled with what to do with its federal laboratories. For example, how do you direct the future of labs devoted for 50 years to the making of weapons of mass destruction? Since 1978, more than 20 major commissions or task force groups (see appendix 2 for complete list) have been chartered to help address some version of this question. Chartered by the president, secretary of defense, secretary of energy, congress or others, each group has posed essentially the same question: How can the various federal laboratories be enhanced to be of greater value to national purpose and, especially, economic development? The targets in these reviews have often been the major multiprogram labs of the Department of Energy and the labs of the Department of Defense. Given both the magnitude of activity in the leading DOE and DOD labs and the changes in national priority associated with their historic mission, it is little wonder that there exists concern about the deployment of this multibillion dollar asset and its multibillion dollar annual budget.

The findings of these various commissions and task forces were based on many of the assumptions associated with the general movement toward the cooperative research paradigm that were detailed in earlier chapters. These findings were also based on anecdotal evidence about how to increase the effectiveness and efficiency of the federal laboratories. A summary of the findings of several representative efforts is presented below. In each case, we assess the findings and recommendations of the panels, in many cases relying on our institutional design framework and NCRDP research findings.

1993 Council on Competitiveness: "Industry as a Customer of the Federal Laboratories"

With the election of Bill Clinton as president in 1992 and with the development of a new national technology policy as a stated objective of the new

administration, a number of groups stepped up to develop their concepts. Prominent among these groups was the blue-ribbon panel established by the Council on Competitiveness. The council was established in the early 1990s as a forum and interest group for those companies and universities interested in the development of policies intended to maintain national technological competitiveness. While pursuing a number of issues and working Capitol Hill on a number of fronts, the council took it upon itself to attempt to deal with what was a major question of the day, namely, what to do with the federal labs. Dominated by industrial representation, the council formed a working group focused on designing a future role for federal labs. This working group and ultimately the entire council reported a number of specific recommendations on how to enhance the technology transfer process between government and industry. These recommendations were built on the assumption that federal R&D labs were untapped, underutilized sources of new technology. Further, it was assumed that there existed a need for clear action intended to "make the labs more responsive to industry's needs (i.e., more customer-driven)." This basic assumption is derived from the belief that the labs are a dormant source of new technology and that all that is needed to enhance U.S. competitiveness is to provide the mechanisms for the labs to release this latent source of technology. In that context the council recommended the following:

- Congress and the executive agencies should assign 10% of the budget of DOE and NASA labs to technology transfer programs.

There is a general assumption on which this recommendation is based, namely, that there is insufficient spending on technology transfer and that this is the key factor in linking with industry. There is no evidence that lack of government funding is the problem. Some labs as a result of size, breadth of mission, and culture are equipped to work with industry in the technology transfer process; others are not. Some laboratories' basic science mission limits their ability to contribute to a technology transfer program. They make contributions to the basic stock of knowledge, which can have dramatic effects on overall technology patterns but have less potential for one-to-one technology transfer.

It is an aggravating problem in most federal labs, that they are not funded as units. Most federal labs are funded via individual program managers who are attempting to attain various mission objectives through research groups located at the various labs. Outside of the USDA, there is little meaningful institutional-level planning for labs in agencies with multiple labs under their jurisdiction. Therefore, the result is that even with a 10% commitment to directors, systematic technology transfer will remain problematic.

Most important, many groups within federal labs have nothing significant

to offer as technology seeds or development opportunities. Labs focusing predominantly on either fundamental research results, technical service in support of industry, technical service in support of the government, or classified military research generally offer little commercial technology. Indeed, what some of these labs offer is more important for the NIS than a set of commercial technology opportunities. Assigning 10% of all lab budgets for technology transfer programs would, without discretion, weaken or destroy programs of the type listed above. A universal technology transfer mandate fails to recognize the variation and uniqueness that exists in the federal R&D lab community. Let us remember the comparative advantage principle.

- Increase laboratory directors' discretionary spending to 5–10% of their annual budgets

We know that laboratory directors are positively influenced by an economic development mission. We also know that the lack of flexible dollars is a critical weakness in the design of federal labs. If we assume that each laboratory would be defined around a specific mission and that this specific mission statement included a definition of its role within industry, then a federal laboratory could, with such discretionary funds, potentially increase its effectiveness with industry significantly. Often, a laboratory works in realms where close collaboration with industry is desired as a precursor to successful technology transfer. As indicated by our research, this is an important factor. In this situation, lab directors might use such discretionary funding to cofund centers for joint technology development and transfer. Such center settings have proven most effective in stimulating traditional technology transfer.

At the same time, it must be remembered that many federal labs have little technology to offer industry. What they have is basic knowledge, technical insight, and know-how. In these cases, such discretionary dollars could be used to build enhanced two-way information linkages with industry and to tackle small know-how problems for small and medium-sized companies. This type of knowledge transfer, as evidenced in the findings in chapter 5, can be of tremendous value to industry, but it would not fall under the general rubric of technology transfer. In fact, because labs generally lack organizations connecting their useful knowledge and industry, the transaction cost for acquiring such knowledge is so high that our findings show that industry views most information of this type as a negative input to the technology development process. Discretionary spending could be used to establish a bridge between the labs and industry in industry-relevant ways.

- National technology infrastructure projects should be launched so as to strengthen U.S. industrial competitiveness and foster cooperation between industry and federal labs

Here it is assumed that critical areas such as telecommunications or the environment can be identified as national projects and that federal labs can be directed to cooperate by focusing their energies on these national projects.

Our empirical evidence suggests that the diversity among federal labs, in terms of mission, skills, and design, is so great that any across-the-board effort to link these labs with national projects will be problematic (Crow and Bozeman, 1991; Bozeman and Crow, 1995). Our findings regarding industry's evaluation of its technology transfer interactions with federal labs indicate that working with industry is not a simple process of redirecting a lab's energies (Bozeman, Papadakis, and Coker, 1995). A key factor is whether or not the research group based at the federal laboratory has anything to offer, either knowledge or technology, to a market-driven company trying to develop or improve a product or process.

We must also remember that evidence suggests that some labs are equipped to interact with industry very effectively, while others, because of their focus on the long term, their particular culture, or their problem set, should be viewed as building blocks for national technology projects (Bozeman, 1994a; Bozeman and Coker, 1992). There is a need for a highly detailed mission definition and the building of a team of labs that link basic and applied research capability in areas related to particular national technology infrastructure projects.

- Federal laboratory directors should have full legal authority to negotiate, sign, and execute cooperative R&D ventures with industry.

Our research indicates that not only is government red tape significant in general, but the red tape within federal labs stands out (Bozeman, Reed, and Scott, 1992; Crow and Bozeman, 1989a). Our findings indicate that all decisions are slower in general and that the release of research findings is, except for basic research, slower than in all other lab types (Crow and Bozeman, 1991). Therefore, granting lab directors authority to enter into such agreements without providing for some level of overall autonomy for the lab would not result in a great improvement with regard to cooperative R&D ventures.

- DOD should establish an outreach program to make R&D and technical expertise in DOD labs more accessible to civilian industry.

The development and use of bridging organizations for the purpose of industry outreach and as a means of cooperating with industry has proven to be a particularly successful arena for activities related to technology transfer (Crow and Bozeman, 1989a). It is likely that research centers organized to act as a bridge between industry and DOD labs could prove effective as transfer enhancement tools.

- Federal laboratories (non-DOD) should establish industrial advisory committees to assist in the planning and execution of programs related to technology transfer.

Many labs have already established industrial advisory groups. Our findings indicate that such groups, if organized into collectives with a research center orientation, could have a positive effect on the process of technology transfer (Bozeman and Crow, 1991a; Bozeman and Coker, 1992). While we did not look at these advisory groups as committees, we did view them as a form of enhanced research coordination offering immense value from the industrial perspective.

1978 The Multiprogram Laboratories (A Report of the DOE before the Current Laboratory Reevaluation): A National Resource for Nonnuclear Energy Research, Development, and Demonstration

Shortly before intense reevaluation of federal labs got underway in the early 1980s, Congress inquired of the DOE to define how the national labs under its jurisdiction could be harnessed toward the development of nonnuclear energy technologies. This request came in the first full year of the operation of the newly formed Department of Energy and was the result of a number of concerns about how the old labs of the Atomic Energy Commission could best be applied in the context of a civilian energy development agency. The questions of the day evolved around the general concern of how to increase the return to the government from its investment, but also considered defense and civilian deployment of lab capacity. This precursor analysis and set of recommendations from nearly 20 years ago asked the same essential questions that are being asked today. How can federal laboratories be redirected toward new national missions and purposes? Twenty years ago the U.S. established a national priority, nonnuclear energy technology development. The nation attempted to focus its most significant federal lab asset, the DOE multiprogram labs, on that problem. Much like the Council on Competitiveness' recommendation of 1993, the thought was that nonnuclear energy technology would spur cooperation and technological success. The specific 1978 recommendations included:

- Organize the national labs for national focus rather than programmatic focus.

The thought here is that the labs are controlled by the various DOE program offices, such as defense or nuclear programs or basic energy science programs, and that this mission control limits the flexibility of the deployment of the

asset. Our research indicates that the most successful labs are larger and have multiple missions (Bozeman and Crow, 1988, 1995). Thus, it seems sensible to raise the labs to a higher organizational level and detrimental to narrow the mission of the labs.

This historic recommendation reveals also that in the years since 1978 the status of the labs at DOE has not changed. Our findings from a detailed 1984 analysis of DOE labs indicates that DOE laboratories were not significantly changed between 1978 and 1984 (Crow, 1985; Crow and Bozeman, 1987b). Our later work between 1984 and 1996 confirmed once again that this basic design feature (program-level control) has been maintained and has, generally, had negative consequences (Bozeman and Crow, 1992, 1995).

- Develop coordinated laboratory missions maximizing individual and lab group competencies

In the 1980s and 1990s the federal R&D laboratories demonstrated a high level of cooperation and linkage among themselves. This is less the case among the DOE labs discussed circa 1978.

Interestingly, the 1978 report by the GAO was clearly based on the market failure model for federal labs, finding that it was proper for federal labs to move in when and where there are insufficient incentives for private sector research. But in all of the recommendations there was only one mention of industry. Even in this one instance, industry was mentioned only as a subcontractor helping to fulfill national energy research objectives in coordination with the national labs.

1994 Changes and Challenges at the DOE Laboratories (The Galvin Commission)

Two years into the Clinton administration the issue of what to do with the national labs remained unresolved (as it still does). Just the DOE labs alone were costing billions of dollars per year, and their energy and defense missions were both being questioned. The secretary of energy turned to Robert Galvin, the former chairman of Motorola, and an industry-dominated panel to map out some alternative futures for the DOE national labs. The report, which got broad exposure through the press, concluded that fundamental changes were required. The report recommended that the government carry out of a number of steps intended to enhance performance and return on national investment. These steps include the following:

- Develop new management systems based on quality principles

Most federal R&D labs already have strong notions about quality. When asked to rank various labs or to list the highest quality research labs, lab directors

have little difficulty responding. Regarding new management, we do know that R&D labs are particularly sensitive to external instability and political and managerial uncertainty. New management system designs must consider the differences among the labs, the comparative advantage principle. Moreover, the organizational structure and internal management of the labs have much less impact on performance than external factors affecting laboratory management. Yes, management changes are badly needed, but at levels outside the laboratory.

- Develop mission to emphasize the use of federal lab core competencies as a national resource in collaboration with the private sector and other federal agencies.

Complex federal laboratory missions have evolved, in most cases, over several decades. Our research indicates that R&D labs have evolved to perform particular, although often broad missions (Bozeman and Crow, 1990). Public science labs focus on basic science and precompetitive applied research with little direct government intervention into their particular research agendas. These public science labs have evolved into organizations whose effectiveness could be inhibited through the introduction of market factors. One might wish to have public science labs coordinate with industry in carefully defined ways. Collaboration might be limited to enhanced information flow to targeted industries, industrial-government scientist exchange, bridging centers that build on basic research findings, and enhanced patenting and licensing efforts.

On the other hand, a public technology lab could serve as a key technology developer for enabling technologies in a particular sector. For instance, Agricultural Research Service labs involved in new product development from agricultural feedstocks could be clustered in collaborative teams with industry based on a research agenda developed in conjunction with industry. In this case, the federal labs could tackle those elements of a technology development problem that benefit all private developers or those problems that the federal lab is best equipped to address on its own.

- Focus laboratories on long-term R&D as a supplement to address the decline in American industrial investment in long-term R&D

Laboratories already have foci that are difficult to change. Early results from the NCRDP indicate that efforts to alter missions often have net negative effects (Bozeman and Crow, 1990; Crow and Bozeman, 1991). Many federal laboratories are already focused on long-term R&D. Enhancing their linkages to support U.S. industry would require whole new strategies for R&D project formulation and agenda-setting.

At present, the dominant forces affecting federal R&D labs and their agenda-setting process include:

- Federal appropriations
- Missions defined by the parent agency
- Political environment of parent agency mission
- Degree of laboratory autonomy

Laboratory missions have typically been focused on service to the parent agency. Unless there is dramatic change in the core mission of the agencies themselves, the laboratories have limited ability to independently alter long-standing research patterns.

- Expand all laboratory missions to provide industrial, educational resource and environmental assistance to the region in which it is located.

Our findings indicate that labs already perform this type of mission to a significant extent, but they receive few resources for such activity (Bozeman, Papadakis, and Coker, 1995). Present barriers to expansion are bureaucratic and financial. This is particularly true with extensive technical service activities. Increased technical assistance will, for most federal laboratories (the great majority of which now perform only limited technical assistance), lead to reduced overall effectiveness. The comparative advantage principle tells us that only selected laboratories should have significant technical assistance roles.

- Develop more partnerships with industry

Industrially active technology development organizations in the U.S. are typically small emerging science or engineering groups. These organizations have few if any linkages with federal labs. On a larger corporate scale, the research products from federal labs are perceived, at best, as a neutral and often as a negative factor in the process of developing corporate technology strategies (Bozeman and Crow, 1991a). Simply building more partnerships is at best problematic and at worst not likely to occur without substantially rethinking how small and medium-sized companies interact with the labs. It is not the *number* of partnerships that is important but their *quality* (Bozeman, Papadakis and Coker, 1995b).

1993 Defense Conversion: Redirecting R&D, Office of Technology Assessment

Although eliminated in 1996, the Office of Technology Assessment (OTA) for nearly 25 years had an active policy analysis function in the area of science and technology policy. In 1993 OTA was asked to review the issues surrounding R&D as affected by the effort at the time to link military research more closely with civilian needs, an effort known as "defense conversion." At the time Congress was interested in the overall issue of how best to link the attainment of military objectives with the possible secondary benefits to the civilian sector. The assumption was that investments in military R&D, which at the time totaled more than 55% of the entire federal R&D investment, might through careful planning be parlayed into specific civilian applications for industry. As a result of this general thrust a number of new programs where developed. Although shortened by the 104th Congress in 1995, this effort did involve a rethinking of the design of defense R&D labs. Specific OTA recommendations included:

- Speed up cooperative R&D agreements (CRADAs)

Here it is assumed that CRADAs are the means by which technology transfer can be best accomplished. However, our research indicates that CRADAs are not always the best path to successful technology transfer (Bozeman and Coker, 1992; Bozeman, Papadakis, and Coker, 1995). CRADAs came to be little more than a popular symbol for an incoherent jumble of laboratory activities. By becoming everything, they became nothing—at least nothing distinct. This OTA recommendation focuses on numerical assessments of one ambiguous technology transfer vehicle.

- Enhance local autonomy of labs

Again, the OTA focus is on CRADAs. This focus fails to recognize those areas in which labs either address market failure research needs or focus on research transfer where CRADAs would be inappropriate. The emphasis of these recommendations reflects a narrow nonsystem approach to thinking about the labs. At the same time, a more general recommendation for increased local autonomy matches well with our findings that laboratories that set their own technical agenda are the most effective.

- Create a lab rationalization commission

According to this recommendation, a commission would be established to determine which DOE & DOD labs remain as critical assets of the nation. Such a commission would necessarily need to consider the design and structure of all federal labs and not just the DOE/DOD laboratory community. Focusing such efforts only on DOD and DOE labs would fail to recognize what our findings reveal, namely, that the government R&D laboratory community and the university community are highly interwoven (Bozeman and Crow, 1990, 1991a). We also know that within individual labs, particularly large federal labs, there are multiple missions and multiple linkages. Therefore, a lab-scale review would be unable to accurately analyze the scope of lab variability and interorganizational relations. Such a commission would

need to map and understand the complex interorganizational relationships among federal laboratories as well as those between federal laboratories and other laboratories. An effective assessment must consider more than DOD and DOE laboratories alone.

- Establish stronger incentives for technology transfer.

Our findings (Bozeman, 1994a; Bozeman and Coker, 1992) indicate that the strongest incentives for laboratory involvement in technology transfer are:

- economic development mission
- collaborative centers
- new national missions

It is likely that the behavior of federal labs will be altered by the improvement of institutional incentives, flexible dollars, lab autonomy, royalty income return, and personal incentives. Consider the case of universities. Since 1981 universities have been marketing their patents on an exclusive basis with substantial economic incentives. As a result of these efforts, the patents issued to the universities in 1992 alone equaled the total of the previous ten years. Licensing income and therefore new product sales have shown the same responsiveness.

1983 Report of the White House Science Council: Federal Laboratory Review Panel

In 1982 and 1983, in the middle of the first term of the Reagan administration, the economic stability of the nation seemed uncertain. While the economic downturn of the period was a function of a number of factors, it was well understood that one issue of importance to national economic health was the structure and performance of the NIS. There was recognition of the need for greater attention to the federal R&D investment and the U.S. R&D system. At the same time there was a massive increase in spending related to national defense, a major factor in the doubling of the national debt between 1981 and 1989. The process of increasing this spending in 1981–1985 put tremendous stress on the rest of the federal budget forcing new scrutiny of the expensive, uncertain investments in federal R&D labs. This complex set of motivations led to the development of a White House panel on the future of the national labs.

This 1983 report, known popularly as the Packard Report (after the panel chair, David Packard), was perhaps the most profound and far-reaching of all of the studies of the 1980s and 1990s. It took the first radical departure from the party line (science is inherently good, labs are national treasures) in

the then 40-year history of major investments in federal research. The report was a scathing attack on the federal research laboratory establishment. The Packard report's recommendations included:

- Laboratories should be given specific missions from which their performance could be measured

In many cases, particularly among the larger federal labs, the laboratory is more a community of loosely attached research units than a tightly coordinated, centrally managed organization. For example, at Oak Ridge National Laboratory, there are groups producing critical materials for DOE Defense Programs, new materials being developed for DOE/Basic Energy Sciences, and social science studies funded by DOE and other agencies. Each of these groups follows its Washington-based program leaders, and on occasion they are subject to the administrative leadership of the laboratory director. Our research has not found federal laboratories to be missionless, but "mission-full" (Bozeman and Crow, 1995). Multiple missions, sometimes conflicting, are the norm at the larger laboratories.

Among smaller federal labs there are much more specific and focused missions. The National Animal Disease Center of the USDA is an example of a smaller lab that clearly knows its mission. The Naval Civil Engineering Laboratory has no confusion about its mission. What many of these labs do not know is whether or not their mission also includes diverting time, energy, and resources toward working with industry. Individual laboratories with self-defined research agendas fitting clear missions do appear to be the most effective.

- Size of federal laboratories should be determined by their missions and quality

Both mission diversity and research niche are the principal determinants of size. It is important to understand, in addition, that the research component of some federal labs is smaller than the technical support, material manufacturing, and service components. A significant difference exists between a research group using parallel processors to develop new algorithms for the purpose of solving geophysical problems and a group using the same computer technology to optimize a tactical nuclear counterattack scenario. Yes, size should be determined by mission and quality. Missions, however, must first be carefully understood.

- Develop a scientific/technical personnel system independent of civil service

All laboratories operating outside of the civil service have lower levels of red tape and, as a result, respond more quickly and are quicker in almost every

way. They can hire or fire, acquire new equipment, change structure, and move into new directions more rapidly and with greater ease (Crow and Bozeman, 1989a; Bozeman and Crow, 1991a). Dependence on the civil service structure is seen by a majority of federal lab directors as a barrier to successful science and successful technology transfer (Bozeman and Crow, 1988, 1995).

- Federal laboratories should open up their facilities to industry and universities

In general, facility use by industry remains a minor factor in the success of technology development or technology transfer (Bozeman, 1994a). There are, of course, unique facilities that have, for the most part, been open and available since the early 1980s. Some of these facilities are important in advancing industrial technology, but many more are important in advancing fundamental science.

- R&D interactions between federal laboratories and industry should be increased by more exchange of knowledge and personnel as collaborative projects and by industry funding of laboratory work.

Our evidence indicates that rapid movement toward this recommendation could lead to a significant decrease in effectiveness, high levels of instability, and a general decline in the overall quality of federal labs so affected (Bozeman and Crow, 1995). However, those having a long history of working closely with industry and, especially, those designed for this type of mission are an exception. If there is an interest in enhancing laboratory-industry collaboration, a better approach is to create laboratories with this specific mission, rather than appending it, as an afterthought, to long-standing, successful missions.

During the past two decades, major reports and task force statements concerning federal labs have been issued at a rate exceeding one per year. Without exception, the principal recommendations of these key studies are weakened by the fact that there is insufficient recognition of the system-level variables and institutional factors that govern laboratory behavior. As a result, the implementation of many of these recommendations (including some already being undertaken) could lead to a diminution of the contribution of the 700 federal laboratories operating the U.S. NSI and an inefficient match of the federal labs to the other labs among the 16,000.