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The future of the national laboratories

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ABSTRACT The end of the Cold War has called into question the activities of the national laboratories and, more generally, the level of support now given to federal intramural research in the United States. This paper seeks to analyze the potential role of the laboratories, with particular attention to the possibility, on the one hand, of integrating private technology development into the laboratory's menu of activities and, on the other hand, of outsourcing traditional mission activities. We review the economic efficiency arguments for intramural research and the political conditions that are likely to constrain the activities of the laboratories, and analyze the early history of programs intended to promote new technology via cooperative agreements between the laboratories and private industry. Our analysis suggests that the laboratories are likely to shrink considerably in size, and that the federal government faces a significant problem in deciding how to organize a downsizing of the federal research establishment.

The federal government directly supports nearly half of the research and development (R&D) performed in the United States. Of this, about a third is for intramural research (research performed by agencies or in federal laboratories), while the remainder is performed extramurally by industry, universities, and nonprofit organizations under grants or contracts with the federal government. In fiscal year 1994, federal obligations for all laboratories amounted to nearly 23 billion dollars. In constant dollars, the federal R&D budget has been shrinking since fiscal year 1989, and the laboratory budget has followed suit (see Fig. 1).‡

Intramural research includes a range of activities. Much of it is in support of agency activities and contributes to technology that is purchased by the government. Examples include weapons technology in Department of Defense laboratories and research that supports the regulatory activities of the Environmental Protection Agency and the Nuclear Regulatory Commission. (The distribution of intramural and extramural research by agency is shown in Table 1.) A relatively small but important activity is the collection and analysis of statistics by the Department of Commerce, the Bureau of Labor Statistics, and the National Science Foundation. A significant share of the intramural R&D budget goes for basic and applied science in areas where the government has determined that there is a public interest: National Institutes of Health (NIH) in the biomedical field; National Institute of Standards and Technology in metrology; Department of Energy (DOE) in the basic physics; and agricultural research at the Agricultural Research Stations. Finally, the laboratories support commercial activities of firms. The final category has been growing in recent years and is usually distinguished from all the previous categories (although the distinction is blurred in some agencies) in that the former are called "mission" research and the latter "technology transfer" or "cooperative research with industry."

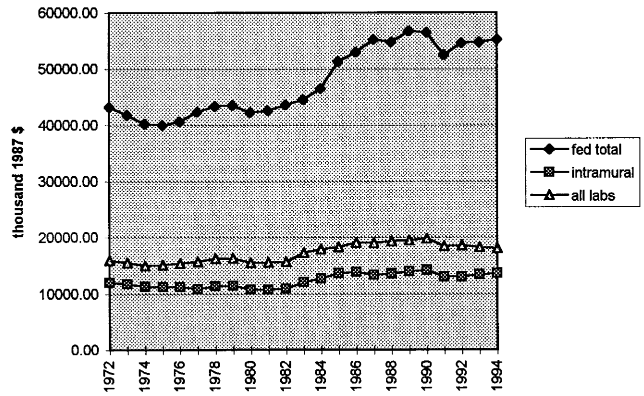

FIG. 1. Federal obligations for R&D.

An important distinction between the categories lies in the treatment of intellectual property rights. Whereas the government has pursued strategies to diffuse the results of mission activities, the cooperative programs contain arrangements that allocate property rights to private participants. This distinction is not sharp: results of defense-related work, of course, have been tightly controlled. However, the government retains for itself property rights for intramural defense R&D, and where feasible, licenses the patents to more than one company. Alternatively, the new programs have used assignment of property rights as a tool to raise profits to firms and thereby encourage private technology adoption, through exclusive licensing arrangements (particularly for those technologies developed primarily by the laboratories) or assignment of patents (for cooperative projects). In their intellectual property rights policy, the latter set of programs mirror the policies employed for extramural research. Thus to some extent, private firms effectively retain residual rights in inventions. For these programs, the laboratories can be characterized in part as subcontractors to industry.

Recently, the role of the federal laboratories in the national research effort has come under serious reexamination. At the core of the question about the future of the national laboratories is the importance of national security missions in justifying their budgets. The end of the Cold War has called into question the missions of the Department of Defense laboratories and the weapons laboratories run by the DOE and its contractors. In addition, the end of the Cold War has weakened the political coalition that supports public R&D

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Abbreviations: R&D, research and development; NIH, National Institutes of Health; DOE, Department of Energy; CRADAs, cooperative research and development agreements.
‡Statistical information about R&D spending in the United States reported here comes from refs. 1 and 2, and the National Science Foundation web site: www.nsf.gov.

Table 1. Federal obligations for total R&D, selected agencies and performers, fiscal year 1994

	Total	Labs-total	Intramural	FFRDC	Share of total R&D, %	Share of lab R&D, %	Share of intramural, %	Share of FFRDC, %
All agencies	71,244	22,966	17,542	5424				
Defense, development	33,107	8,613	7,651	962	46.5	37.5	43.6	17.7
Defense, research	4,416	1,634	1,515	119	6.2	7.1	8.6	2.2
DHHS	10,722	2,285	2,213	72	15.0	9.9	12.6	1.3
NIH	10,075	1,980	1,908	72	14.1	8.6	10.9	1.3
NASA	8,637	3,356	2,653	703	12.1	14.6	15.1	13.0
Energy	6,582	3,822*	500	3322	9.2	16.6	2.9	61.2
NSF	2,217	148	17	131	3.1	0.6	0.1	2.4
Agriculture	1,368	901	901	0	1.9	3.9	5.1	0.0
ARS	640	609	609	0	0.9	2.7	3.5	0.0
Forest Service	215	180	180	0	0.3	0.8	1.0	0.0
Commerce	897	655	654	1	1.3	2.9	3.7	0.0
NIST	382	244	244	0	0.5	1.1	1.4	0.0
NOAA	504	400	399	1	0.7	1.7	2.3	0.0
Transportation	688	280	253	27	1.0	1.2	1.4	0.5
EPA	656	135	135	0	0.9	0.6	0.8	0.0
Interior	588	517	517	0	0.8	2.3	2.9	0.0
USGS	362	332	332	0	0.5	1.4	1.9	0.0
All other	1,366	620	533	87	1.9	2.7	3.0	1.6

Data are from ref. 3, table 9, pp. 26–28. DHHS, Department of Health and Human Services; NIH, National Institutes of Health; NASA, National Aeronautics and Space Administration; NSF, National Science Foundation; ARS, Agricultural Experiment Station; NIST, National Institute of Standards and Technology; NOAA, National Oceanic and Atmospheric Administration; USGS, U.S. Geological Survey; federally funded research and development corporations (FFRDCs).
*Not including Bettis, Hanford, and Knolls, former FFRDCs, which were decertified in 1992.
Obligations for these facilities are now reported as obligations to industrial firms.

activities in the United States more generally. Furthermore, increased expenditures on entitlement programs for the elderly and resistance to further tax increases has placed further pressure on budget levels at the laboratories. The budgets of most federal laboratories have been constant or declining in recent years, and expectations are that reductions will continue.

In contrast to these trends, in the early 1980s the federal laboratories were called on to expand their activities. Responding to the perceived productivity slow-down in the 1970s, and later, the increased competition of foreign firms in high-tech industries, efforts were undertaken by the laboratories to improve the technology employed by U.S. firms. The Stevenson–Wydler Act of 1980 established "technology transfer" as a role of all federal laboratories. Whereas the original Stevenson–Wydler Act had few teeth, it ushered in a decade of legislative activity designed to expand laboratory activities in promoting private technology development. The primary innovation in laboratory activities has been the development of cooperative research and development agreements, or CRADAs, which provide a mechanism for industry to enter into cooperative, cost-shared research with government laboratories. In 1993, the Clinton Administration proposed that these activities would not only be pursued, but would substitute for the decline in traditional activities at the national laboratories (4, 5). President Clinton proposed devoting 10–20% of the federal laboratory budgets to these programs. That number has not been reached, although CRADA activity has been impressive. The President's 1996 Budget claims that 6093 CRADA partnerships had been entered into by fiscal year 1995, with a value (including cash and noncash contributions of public and private entities) of over $5 billion (6). Some estimates of the size and distribution of CRADAs are provided in Table 2.

The past 2 years have witnessed a retreat from the policy of promoting commercial technology development at the labo-

Table 2. Number and industry of CRADAs by agency, 1993

		Distribution of 1993 CRADAs by industrial technology									
		Biological		Manufacturing							
Agency	Total	Medical	Other	Aerospace	Automobile	Chemical	Other	Information technology	Computer software	Energy	Other
Agriculture	103	1	47	1	0	12	31	0	1	2	8
Commerce	144	1	2	17	1	21	33	44	7	8	10
Defense											
Air	73	1	2	7	1	2	2	33	16	3	6
Army	87	19	6	2	4	3	27	9	3	0	14
Navy	46	9	0	4	2	1	10	13	5	0	2
Total	206	29	8	13	7	6	39	55	24	3	22
Energy	368	14	10	21	20	35	86	86	18	61	17
EPA	5	1	2	0	0	0	0	0	0	1	1
HHS	25	25	0	0	0	0	0	0	0	0	0
Interior	15	0	1	0	0	3	8	0	0	0	3
Transportation	14	0	0	12	0	1	0	0	0	1	0
Total	880	71	70	64	28	78	189	185	50	76	61

Data from ref. 7.

ratories. During 1995, the Clinton Administration undertook a major review of the national laboratory structure in the United States (8). Both its reports (9–13) and additional analyses from the science policy community (14–16) have recommended that the laboratories deemphasize industry technology efforts, outsource some R&D activities, and concentrate on missions, narrowly defined. Although the cooperative programs continued to expand, their future is now problematic.

This paper seeks to analyze the potential role of the laboratories, with particular attention to the possibility, on the one hand, of integrating private technology development into the laboratory's menu of activities and, on the other hand, of outsourcing traditional mission activities. The next section reviews the economic efficiency arguments for intramural research and the political conditions that are likely to constrain the activities of the laboratories. The third section considers cooperative agreements between the laboratories and industry in somewhat more detail, and reviews some of the early history with these programs. Our discussion suggests that the laboratories are likely to shrink considerably in size, and that the federal government faces a significant problem in deciding how to organize a downsizing of the federal research establishment. In the last section, we examine this issue, and conclude that without some advance planning about how to downsize, the process is likely to be costly and inefficient. In particular, downsizing cannot be addressed sensibly without two prior actions: a reprioritization of the relative effort devoted to different fields of R&D, and a commitment to minimize the extent to which short-term political considerations affect the allocation of cuts across programs and laboratories. Thus, to rationalize this process, we propose the creation of a National Laboratories Assessment and Restructuring Commission, fashioned after the Military Base Closing Commission.

Economics, Politics, and Intramural Research

The economic rationale for government support of R&D has two distinct components. The first relates to the fact that the product of R&D activity is information, which is a form of public good. The second relates to problems arising in industries in which the federal government has market power in its procurement.

The public good aspect of R&D underpins the empirical finding that, left to its own devices, the private sector will underinvest in at least some kinds of R&D. To the extent that the new information produced by an R&D project leaks out to and is put to use by organizations other than the performer of the project, R&D creates a positive externality: some of the benefits accrue to those who do not pay for it. To the extent that the R&D performer can protect the new information against such uses unless the user pays for it, the realized social benefits of R&D are less than is feasible. (See ref. 17 for an excellent discussion of these issues.)

Keeping R&D proprietary has two potential inefficiencies. First, once the information has been produced, charging for its use by others is inefficient because the charge precludes some beneficial uses. Second, an organization that stumbles upon new information that is useful in another organization with a completely different purpose may not recognize the full array of its possible applications. Hence, even if it could charge for its use, neither the prospective buyer nor the potential seller may possess sufficient knowledge to know that a mutually beneficial transaction is possible.

The potential spillovers of R&D usually are not free; typically, one firm must do additional work to apply knowledge discovered elsewhere for its own activities. Hence spillovers generate complementarities across categories of R&D. More R&D in one area, when it becomes available to those working in another area, increases the productivity of the latter's research. This complementarity can be both horizontal (from one industry, technology, or discipline to another) or vertical (between basic and applied areas) (19).

The public goods argument leads to a richer conclusion than simply that government should support R&D. In particular, it says that government should support R&D when a project is likely to have especially large spillover benefits, and that when government does support R&D, the results should be disseminated as widely as possible. One area where this is likely to be true is in basic research: projects that are designed to produce new information about physical reality that, once discovered, is likely to be difficult to keep secret and/or that is likely to have many applications in a variety of industries. Here the term "basic" diverges from the way that term is used among researchers in that it refers primarily to the output of a project, rather than its motivation. A project that is very focused and applied may come upon and solve new questions about the fundamental scientific and engineering principles that underpin an entire industry and so have many potential uses and refinements.

The public goods argument also applies to industries in which R&D is not profitable simply because it is difficult to keep new discoveries secret. If products are easily reverse engineered, intellectual property rights are not very secure, and innovators are unable to secure a "first-in" advantage, private industry is likely to underinvest in R&D, so that the government potentially can improve economic welfare by supporting applied research and development.

Finally, the complementarities among categories of R&D indicate still another feature of an economically optimal program: increases in support in one area may make support for another area more attractive. Thus, if for exogenous reasons a particular area of technical knowledge is perceived to become more valuable, putting more funds into it may cause other areas to become more attractive, and so increase overall R&D effort by more than the increase in the area of heightened interest.

If the purpose of government R&D is to add to total R&D effort in areas where private incentives for R&D are weak and where extensive dissemination is valuable, a government laboratory is a potentially attractive means for undertaking the work. A private contractor will not have an incentive to disseminate information widely and will have an incentive to try to redirect R&D effort in favor of projects that are likely to give the firm an advantage over competitors. For basic research, another attractive institution in the United States is the research universities, which garner the lion's share of the extramural basic research budget.

The second rationale for publicly supported R&D arises when the government is the principal consumer of a product. The problem that arises here is that once a new product has been created, the government, acting as a monopolist, can force the producer to set the price for the product too low for the producer to recover its R&D investment. If a private producer fears that the government will behave in this way, the producer will underinvest in R&D.

Whereas this problem can arise in any circumstance in which a market is monopsonized, the problem is especially severe when the monopsonist is the government. The root of the problem is the greater susceptibility of government procurement to inefficient and even corrupt practices, and, consequently, the more elaborate safeguards that government puts in place to protect against corruption. The objectives of government procurement are more complex and less well defined than is the case in the private sector, where profit maximization is the overriding objective. In government, end products do not face a market test. Hence, in evaluating whether a particular product (including its technical characteristics) is efficiently produced and worth the cost, one does not have the benefit of established market prices. In addition,

Table 3. Basic research share of federal R&D expenditures by performing sector and function

	1982	1984	1989	1990	1992	1993	1995
Basic share of total federal R&D	0.150	0.145	0.170	0.177	0.188	0.203	0.200
Basic share of DoD R&D	0.050	0.029	0.025	0.025	0.029	0.032	0.034
Basic share of DoD intramural R&D	0.043	0.035	0.027	0.028	0.030	0.036	0.033
Basic share of DoD extramural R&D	0.030	0.027	0.025	0.024	0.028	0.031	0.035
Basic share of federal civilian R&D	0.303	0.365	0.410	0.392	0.379	0.388	0.390
Basic share of federal civilian intramural R&D	0.252	0.298	0.320	0.314	0.310	0.318	0.380
Basic share of federal civilian extramural R&D	0.347	0.427	0.480	0.449	0.428	0.435	0.440

DoD, Department of Defense.

the relevant test for procurement is political success, which involves more than producing a good product at reasonable cost. Such factors as the identity of the contractor and geographic location of production also enter into the assessment.

Because of the complexity and vagueness of objectives, procurement is susceptible to inattentiveness or even self-serving manipulation by whomever in the government—an agency official or a congressional overseer—has authority for negotiating a contract. To protect against inefficiency and corruption, the government has adopted extremely complex procurement rules, basing product procurement on audited production costs when competitive bidding is not feasible. In such a system, recovering the costs associated with financial risk and exploratory R&D in the procurement price is uncertain at best. Thus, the firm that produces for the government faces another form of a public goods problem in undertaking R&D: even if the knowledge can be kept within the firm, the firm still may not benefit from it because of the government's procurement rules. Hence, the government usually deals with the problem of inducing adequate R&D in markets where it is a monopsonist by undertaking the R&D in a separate, subsidized project.

Unfortunately, the procurement problem is even more severe for research projects. Because of the problems associated with contracting for research, in the private sector firms perform almost all of their research in house. Only about 2% of industrial R&D is procured from another organization. Monitoring whether a contractor is actually undertaking best efforts—or even doing the most appropriate research—is more difficult than monitoring whether a final product satisfies procurement specifications. Likewise, a firm is likely to find it easier to prevent diffusion of new information to its competitors if it does its own work, rather than contracts for it from someone else. For the government, the analogous problem is to prevent other countries from gaining access to military secrets or even commercially valuable knowledge that the government wants U.S. firms to use to gain a competitive advantage internationally. Thus, it is not surprising that the public sector has national laboratories: research organizations that are dedicated to the mission of the supporting agency, even if organizationally separated, over which the agency can exercise strong managerial control. Indeed, a primary rationale in the initial organization of the national laboratories that were established during the second world war and shortly thereafter was to avoid the complexities of contractual relationships that would be necessary were the activities to be performed by the private sector.[§]

Table 3 shows the distribution by character of R&D supported by industry, by government through intramural programs, and by government through extramural programs. The distribution bears a rough relationship to the principles discussed here. Government support for basic research greatly exceeds that of industry, with the differential magnified when the activities of the Department of Defense (which invests heavily in weapons development activities) is excluded. Outside of the Department of Defense, the basic research component of extramural research is significantly higher than for intramural research, although the differential narrows in recent years. Thus, the budget levels are consistent with extramural support for activities undersupported by the private sector (i.e., basic research) and intramural support that includes mission-oriented development work as well as basic research.

The preceding economic rationales for government R&D and national laboratories do not necessarily correspond to an effective political rationale for a program. Public policies emerge because there is a political demand for them among constituents. Organizations that undertake research have an interest in obtaining federal subsidies regardless of the strength of the economic rationale behind them. And, national laboratories, once created, can become a political force for their continuation, especially large laboratories that become politically significant within a congressional district.

In most cases, areas of R&D are not of widespread political concern. Instead, the advocates consist of some people who seek to attain the objectives of the R&D project and some others who will undertake the work. In principle, an area of R&D could enjoy widespread political support, but as a practical matter almost all R&D projects have relatively narrow constituencies. Even in defense, which until the demise of the former Soviet Union enjoyed broad-based political support, controversies emerged out of disagreements about the priorities to be assigned to different types of weapons systems: nuclear versus conventional weapons, aircraft versus missiles versus naval ships, etc.

The standard conceptual model of understanding the evolution of public policy involves the formation of support coalitions, each member of which agrees to support all of the projects favored by the coalition, not just the ones personally favored. Applied to R&D, the coalition model implies that public support for a broad menu of R&D programs arose as something of a logroll among groups of constituents and their representatives, with each group supporting some programs that it regarded as having lower value in return for the security of having stable support for its own pet projects. The members of this support coalition included various interested in defense-related activities, but was not confined to them.

The coalitional basis of political support suggests another form of complementarity among programs. If, for exogenous reasons, the proponents of research in one area perceive an increase in the value of their pet programs, they will be willing to support an increase in other R&D programs to obtain more funds for their own. Hence, coalitional politics can be expected to cause the budgets for different kinds of research to go up and down together, even across areas that do not have technical complementarities.

In other work, we have tested the hypothesis that real federal R&D expenditures by broad categories are complements, and are complementary with defense procurement. In this work, we use two-stage least squares to estimate simultaneously

[§]This point was made in the report prepared for the White House Science Council by the Federal Laboratory Review Panel (the "Packard Report") in 1983. For a discussion of this report (considered the "grand-daddy" of federal laboratory reviews), see ref. 19.

annual expenditures on defense R&D, civilian R&D, and defense procurement for the period 1962–1994.

One major finding is that defense and civilian R&D are strong complements, that defense procurement and defense R&D are complements, and that defense procurement and civilian R&D are substitutes. Quantitatively, however, the last effect is sufficiently small so that an exogenous shock that increases procurement has a net positive effect on civilian R&D as well as defense R&D. Logically, the system works as follows: if defense procurement becomes more attractive, it causes a small reduction in civilian R&D and a large increase in defense R&D; however, due to the combination of political and economic complementarities between defense R&D and civilian R&D, the increase in defense R&D leads to an increase in civilian R&D that more than offsets the initial reduction.

The other major finding is that basic and applied research are also strongly complementary, with analogous relationships with procurement. Whereas defense procurement and basic research are substitutes, quantitatively this relationship is smaller than the complementarities between procurement and applied research and between applied research and basic. Hence, an exogenous shock that increases procurement has a net positive effect on both basic and applied R&D.

These results have important implications for the national laboratories. Many have observed the obvious fact that the reductions in defense expenditures associated with the end of the Cold War have led to reductions in defense-related R&D, including support for defense-related national laboratories. About the time that the end of the Cold War was in sight, federal officials and the national laboratories placed new emphasis on commercially relevant R&D. At the national laboratories, this emphasis took the form of participation by the laboratories in large industrial research consortia (such as SEMATECH, a consortium concerned with semiconductor manufacturing technology) and in CRADAs with individual firms to apply in-house expertise to commercial R&D problems. Simultaneously, the Department of Defense developed its "dual use" concept: supporting the development of new technology that could be used simultaneously for military and civilian purposes. The theme running through these programs was that a new emphasis on commercially relevant activity could substitute for the drop in demand for national security brought on by the end of the Cold War.

In principle, this strategy could have worked—but only if a genuine exogenous shock took place that increased politically effective demand for nondefense R&D. If a counterpart to the Soviet Union in defense after World War II arose in commercial activities around the middle of the 1980s, the complementarities among categories of research could have worked not only to maintain the overall R&D effort, but, through complementarities between defense and civilian R&D, actually softened the blow to defense R&D. For a while, through the economic stagnation of the late 1970s and early 1980s, the declining relative economic position of the United States in comparison to Japan and the European Economic Community (EEC) was a possible candidate; however, as the decade of the 1980s progressed, and the economic performance of other advanced industrialized nations deteriorated relative to the United States, it became clear that no such exogenous change was taking place. Regardless of the conceptual merits of civilian R&D, whether basic or applied, no fundamental change had taken place in the political attractiveness of such work.

If this line of reasoning is correct, there is no "peace dividend" for civilian R&D, whether basic or applied. To the extent that there are technical complementarities between defense and civilian R&D, the reduction in the former reduces the attractiveness of the latter, all else equal. And, because one member of the R&D coalition—the defense establishment—has experienced an exogenous shock that reduces demand for national security, the willingness of this group to support other areas of R&D has concomitantly shrunk.

The preceding argument abstracts from partisanship and ideology in politics. The November 1994 elections increased the relative power of defense-oriented interests compared with those who support civilian R&D. To the extent that the relative influence of these groups has shifted, a given level of economic attractiveness of defense and civilian R&D will produce more of the former and less of the latter. But the forces we identify here are separate from these short-term political shifts. Here a reference to the mid-1970s and early 1980s is instructive.

In the mid-1970s, in the wake of Viet Nam and Watergate, the Congress became substantially more liberal. Not only did defense expenditures fall, but so did almost all components of R&D, civilian and defense, basic and applied. In the late 1970s, under President Carter and with a liberal Democratic Congress, defense procurement and all categories of R&D began to recover. The election of 1980 brought Republic control of the Senate and the Presidency, and a more defense-oriented government; however, after much criticism of federally subsidized commercial R&D, again all categories of R&D expanded until the end of the Cold War. Now, once again, all categories are declining. Expenditures in the national laboratories followed the same pattern.

Cooperative Research Activities at the Federal Laboratories

The purpose of this section is to examine in more detail the set of cooperative research activities that the federal laboratories have been engaged in during the recent past. CRADAs seek to advance technology that will be used by private industry, and in particular industries that compete with foreign firms. Expanding such activities is the primary proposal for maintaining historic levels of support at the federal laboratories.

The economic justification for the programs is not frivolous. In part, the case rests on the considerable expertise of the federal laboratory establishment. The contributions of the laboratories to commercial technology has, in the past, been substantial, and provides a basis for the belief that considerable technology exists at the laboratories whose "transfer" to industry would be beneficial. Detailed studies of the R&D process suggest that transferring technology is far from a straightforward process, and can be substantially facilitated by close interaction, ideally through joint activities of personnel from the transferring and receiving entities. Thus, cooperative projects are seen as a mechanism to increase the extant and efficiency of technology transfer.

Second, the laboratories and private firms can bring different areas of expertise to the research project, so that complementarities may exist between the two types of entities. As a result, cooperative R&D may yield interesting new technologies that go beyond transfers from the laboratories to industry. Both arguments apply to private firms, in addition to firms and the laboratories, and provide economic justification for the government's preference for working with private consortia, and with consortia that include university members as well as commercial firms.

Instituting the policy has required legislation that departs significantly from some past practices. One set of laws has dealt with the conflict between promoting joint research and antitrust policies. Relaxed antitrust enforcement was established for research joint ventures in 1984, and extended in 1993 to joint production undertaken by firms to commercialize the products of joint research.¶

¶The National Cooperative Research and Development Act of 1984 and The National Cooperative Research and Production Act of 1993.

Table 4. Number of CRADAs in the Department of Health and Human Services

Fiscal year	No. new CRADAs
1987	98
1988	145
1989	225
1990	239
1991	261
1992	63
1993	25
1994	19*

Data are from G. Stockdale (personal communication).
*Estimated.

The thornier legislative problem involves intellectual property rights. Historically, results of publicly supported research (both intramural and research supported by grants and contracts) were not patented. The policy was consistent with the philosophy that the results were public goods, and hence social benefits would be maximized by wide dissemination, constrained only by the requirements of national security. However, this philosophy was manifestly at odds with the new programs. Implementing new technology typically requires large investments that constitute sunk costs of development. As with other R&D expenditures, firms may not, absent some form of patent protection, be able to recover these expenditures if the products are sold in competitive markets. Moreover, if the purpose of the programs is to advantage U.S. manufacturers over foreign competitors, widely disseminating the laboratories' research results is (in the short-run) counterproductive: the government needs to erect barriers that prevent the diffusion of technology to foreign firms. Thus, the policies have required the government to rethink its policies on intellectual property rights.

Congress has reconsidered intellectual property rights policies in nearly every legislative session for the past 15 years. Currently firms and universities are, with numerous caveats, allowed to patent inventions arising from federal contract work and to obtain exclusive licenses for application of inventions to specific fields of use for inventions arising from cooperative work with the federal laboratories. Government-owned, government-operated laboratories (GOGOs, or the intramural category of activities) obtained this authority in 1986; government-owned, contractor-operated laboratories (GOCOs, including the federally funded research and development corporations) were given the authority in 1989.[‖] Chief caveats include (*i*) small business preferences in the assignment of exclusive licenses; (*ii*) requirements (with exceptions) for domestic manufacturing; and (*iii*) limited government march-in rights.[**] Disposition of intellectual property rights have become increasingly complicated with the laboratories' increased emphasis on cooperative research, as opposed to technology transfer, and with their preference for working with consortia, wherein arrangements are needed to allocate, specify and protect the rights of each participant.

The initial legislation for these policies enjoyed broad non-partisan support; indeed, Congress passed the major bills by voice vote rather than conducting rollcalls. More recent efforts to modify and clarify patent policies have not been successful. Similarly, CRADAs have enjoyed wide support from both industry and politicians. Until last year, agency heads were regularly exhorted in hearings before Congress to speed up and expand their cooperative activities. The number of CRADAs executed by agencies has grown enormously overall (see Table 2 for recent statistics), and agencies have received far more requests from private firms for cooperative research than they are able to accommodate. However, enthusiasm for the policies appears to be waning. Reports from the Office of Technology Assessment and DOE Advisory Committees have recommended that DOE focus more narrowly on agency missions; the current Congress is likely to slash budgets for the extramural programs in fiscal 1996. In part, the turnaround reflects the partisan shift in Congress. But more importantly, both it and the difficulty congress has had in resolving intellectual property rights issues reflects more fundamental political and economic problems with the policies.

The potential problems in these programs are illustrated by the history of CRADAs at NIH. Table 2 reveals a rather puzzling statistic. NIH is the primary provider of biomedical research in the United States. Moreover, the biomedical industry is extraordinarily research intensive and opportunities for new products and processes are rife. Yet NIH is now involved in a very modest number of CRADAs. This was not always the case (see Table 4). However, CRADAs at NIH have suffered from previous technological successes. In the past, some projects created especially valuable property rights, which were conferred on private partners. As a result, some firms enjoyed apparently exorbitant profits, and direct competitors were excluded from what could be presented as a government-sponsored windfall—two conditions that created political firestorms.

The first firestorm arose in 1989 over 3′-azido-3′-doexythymidine (AZT), a drug for treating patients infected by HIV, which was developed in a CRADA with Burroughs Wellcome Company.[††] Members of Congress were outraged at the price set by Burroughs Wellcome for the drug; in response, NIH adopted a "fair pricing" clause for future CRADAs. The clause did not resolve the controversy, for to institute it, NIH would have to undertake a broad examination of the economics of the pharmaceutical industry—in effect, an effort tantamount to that required for traditional economic regulation. Then-Director of NIH Bernadine Healy appointed a panel to study the issue, but ultimately concluded that NIH was unable to undertake the type of economic regulation of pharmaceutical prices that would be necessary to enforce it. Furthermore, NIH lacks any statutory basis for obtaining the necessary information. An additional problem was identified in 1994 by a New York patent attorney who served on the NIH panel, and claimed that the U.S. Department of Justice had decided not to enforce drug patents issued to firms participating in CRADAs. Industry officials claim that the political problems and legal uncertainties about the ultimate disposition of property rights have made them reluctant to engage in CRADAs with NIH. The statistics bear out their claim.

The high profits of drug companies for particular products developed under CRADAs may have engendered a particularly fast response from Congress since it is also the public sector that pays a large share of the costs of medical care. But the apparent inequity—public support for companies who are then in a position to extract large profits from consumers—could easily arise in other cooperative research activities. As yet, complaints of either upstream suppliers or downstream customers have not focused on the products of CRADA consortia, but if the projects are successful, the modifications in antitrust policies as well as patent policies are likely to cause controversy.

‖Stevenson–Wydler Technology Innovation Act of 1980; Bayh–Dole University and Small Business Patent Act of 1980; Federal Technology Transfer Act of 1986; National Competitiveness Technology Transfer Act of 1989.

**This summary of the patenting situation gives only a general overview of an extremely complicated situation. Additional rules and regulations apply to establishing and protecting proprietary information in cooperative research.

††The AZT congressional response is not unique; a similar firestorm arose over the profitable marketing of a second CRADA-created product, Taxol (see ref. 20).

A second issue that has arisen in successful CRADAs concerns the arrangements for exclusive licensing. Agencies in theory can sign numerous CRADAs, or sign CRADAs with consortia with open membership policies, so that CRADA proponents claim that the policy is free from the possibility that government will create identified "losers" and "winners" among firms. In practice, exclusive licensing excludes firms in competitive industries—sometimes at the choice of the excluded firm, who may not have wished to participate in a consortium, sometimes because firms will agree to CRADAs only if competitors do not participate. Successful projects, or projects that are believed to be likely to succeed, can engender complaints with political, if not legal clout. NIH ran into this problem with Taxol, which it developed with Bristol-Myers (a big multinational) and not with Unimed (a small, inexperienced company). Relying on the small business preferences written into the Bayh–Dole Act, Unimed succeeded in opening up more embarrassing oversight hearings for NIH. The Environmental Protection Agency was sued for executing CRADAs with the competitors of a firm, Chem Services, who had not been also awarded a CRADA. The Environmental Protection Agency prevailed in court, but the politics of "unfair advantage" claims suggests that the agency take care in future agreements. A third example is a $70 million CRADA entered into in 1993 between Cray Research and two national laboratories for supercomputer development. After objections from other supercomputer manufacturers, and pressure from congress, the CRADA was dropped.

The issue revealed by these examples is that CRADAs generate political problems when they create industry winners and losers—or potential losers—and when they succeed and make visibly large profits for private firms. The programs have not been in place long enough to observe how congress will respond if agencies fund—at substantial cost—projects that do not succeed. Given the nature of R&D, potential candidates are likely to arise. The historical record of responses in government procurement suggests that the likely response will be for the government to institute much more elaborate cost accounting and oversight, the traditional baggage of procurement policies that CRADA legislation sought to avoid. Expanded oversight will create conflicts with the confidentiality provisions of CRADAs and the flexibility of laboratories in contracting with firms (a hard-won right), and bodes poorly for private interest in cooperative research.

The fundamental problem with CRADA policy is that the laboratories are expected to fill an institutional role that provides external R&D to firms, which, as detailed in the previous section, presents exceptionally difficult organization and incentive problems, exacerbated by the essentially political problems presented by the potential creation of private winners and losers. As a result, we do not expect that it can provide a long-term rationale for maintaining the level of support at the federal laboratories.

Implications for the Future

Our examination of the state of the national laboratories yields two main conclusions. First, that commercial R&D is unlikely to work as a substitute for national security as a means for keeping the national laboratories at something like their current level of operation. Second, in any event the scope for economically and politically successful collaborations with industry is limited because of the conflicts of interest between the government and the private sector in selecting and managing projects. The good news is that uneconomic commercial collaborations are not likely to command a large share of the budget, but the bad news is that, because of the political complementarities among categories of research, the failure of the commercialization initiative is likely to cause parallel reductions elsewhere in programs that are worthwhile.

The standard approach to budgetary retrenchment is to spread the pain among most categories of effort. In particular, this means roughly equal reductions in the size of each laboratory, rather than consolidation. The early returns on the 1995 budget indicate that a "share the pain" approach is generally being followed by Congress. In the House appropriations bills passed in the summer of 1995, nondefense R&D was cut 5% ($1.7 billion). Most of this was transferred to defense R&D, which grew by 4.2% ($1.6 billion). This represents a real cut in total R&D effort equal to roughly the rate of inflation (about 3%) and a general shift of priorities in favor of defense (about 1% real growth) and against civilian (about 7% real decline).

In the nondefense category, every major category of R&D took a cut except NIH. Real federal expenditures on basic research, even including the NIH increase, will fall by about 1.5%.

If, as we conclude, the next few years are likely to witness a steady decline in real federal R&D expenditures in all categories, including the national laboratories, two major issues arise. The first is prioritization of the cuts among areas of R&D, and the second is how to spread cuts in an area of research among institutions.

With respect to priorities, the logic of our argument is that technical and political complementarities work against substantial differences in cuts from the historical shares of each major area of research. Only changes in political representation, such as took place in the elections of 1994 (and 1974 and 1932 before), are likely to cause a substantial shift in priorities, and these will be based less on the economic and technical characteristics of programs than on their distributive effects and ideological content.

With respect to allocations among institutions, the political process is much more likely to embrace a relatively technical solution. Three issues arise in deciding how to spread cuts among national laboratories within a given category of research, one political and two technical. The political issue is classically distributive: no member of Congress, regardless of party of ideology, is likely to volunteer the local national laboratory as a candidate for closure. And, given the number of national laboratories, a majority of Congress is likely to face strong constituency pressure to save a laboratory, just as they did when facing base closures. Congress has considerable experience in facing a circumstance in which each member has a strong incentive to try to protect a significant local constituency, but collectively the members have an incentive to do some harm. The mechanism is to commit in advance to the policy change, before the targets are identified and without the opportunity for amendment. This action relieves a member of Congress from direct responsibility for the harmful action.

Two recent examples of the use of this mechanism are the "fast track" process for approving trade agreements, and the base closure commission. Under fast track, the Congress commits to vote a trade agreement up or down without amendment on the floor of Congress. This process prevents any single member from trying to assist a local industry by proposing an amendment to increase its protections. Historically, when Congress wrote trade legislation, logrolls among representatives led to the adoption of many such amendments. Under the base closure process, the commission, after listening to recommendations from the Department of Defense, submits a list of targets to the President. The President can propose changes, and then the amended list is sent to Congress—again, without the opportunity to amend the list on the floor. Like the trade procedure, this process prevents a member from trying to remove a local base from the list.

A similar process for the national laboratories would deal with the two relevant technical issues. The first is the value of competition among laboratories in a given area of research, and the second is the importance of scale economies.

R&D competition has two potential benefits. The first is that it provides the supporter of research with performance benchmarks that improves its ability to manage the research organizations, as well as spurs each competitor to be more efficient and so reduces the need for intensive monitoring of performance. The second is that it facilitates parallel R&D projects that take radically different approaches to solving the same problem.

The primary disadvantages of competition are that it can sacrifice economies of scale and scope. If a large physical facility is needed for experiment and testing, duplication can be excessively costly. In addition, if projects have strong complementarities, separating them into competing organizations can increase the difficulty of facilitating spillovers among projects, and cause duplication of effort as each entity separately discovers the same new information. In addition, competition has a political liability: parallel R&D means that some projects must be failures in that they lose the competition. Scandal-seeking political leaders can use these failures as an opportunity to look for scapegoats, falsely equating a bad outcome with a bad decision.

The decision about how to downsize the national laboratory system requires an assessment for each area of work whether competition is, on balance, beneficial or harmful. This issue is fundamentally factual, not theoretical, and constitutes the most difficult question to be answered before a reasonable proposal for downsizing the laboratories can be developed.

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