United States General Accounting Office

GAO

Report to Congressional Requesters

November 1994

NATIONAL LABORATORIES

Are Their R&D Activities Related to Commercial Product Development?

GAO/PEMD-95-2

GAO

United States
General Accounting Office
Washington, D.C. 20548

Program Evaluation and
Methodology Division

B-256574

November 25, 1994

The Honorable Marilyn Lloyd
Chairman, Subcommittee on Energy

The Honorable Tim Valentine
Chairman, Subcommittee on Technology,
Environment, and Aviation

The Honorable Tom Lewis
Ranking Minority Member, Subcommittee
on Technology, Environment, and Aviation
Committee on Science, Space, and Technology
House of Representatives

You asked us to consider how the national laboratories of the U.S. Department of Energy (DOE) can best be focused to help solve the problems our nation faces during the current decade. As a beginning, we have developed an inventory of the human and capital resources housed in the national laboratories that will provide baseline data for future reports on a number of DOE laboratory policy issues. This report addresses the Committee's interest in the current balance of the research effort in the 10 laboratories' research programs. It examines the extent to which the national laboratories are engaged now in basic and applied research or in research related to commercial product development.

Background

The Department of Energy's multiprogram laboratories have had missions that are national in scope since their inception during World War II. The original laboratories—Lawrence Berkeley (Calif.), Los Alamos (N. Mex.), and Oak Ridge (Tenn.)—were established as government-owned, contractor-operated institutions to apply the productive capability of private industry to the development of atomic weapons.[1] The weapons-development mission continued during the cold war, and six additional laboratories—Argonne (Ill.), Brookhaven (N.Y.), Sandia (N. Mex. and Calif.), Idaho Engineering (Idaho), Lawrence Livermore (Calif.) and Pacific Northwest (Wash.)—were created between 1946 and 1965 to

[1]Ernest Orlando Lawrence founded the Radiation Laboratory for basic scientific research on the University of California at Berkeley campus in 1931. It was funded under government contract in 1942. The laboratory was renamed Lawrence Radiation Laboratory after his death in 1958 and later called Lawrence Berkeley.

foster civilian applications of nuclear technology.[2] A 10th laboratory, the Solar Energy Research Institute, was designated a national laboratory in 1991 to expand federal energy research and development (R&D) capability in alternative energy sources, and it was renamed the National Renewable Energy Laboratory (Colo.).[3] As a group, the 10 laboratories are known as the national laboratories.

As the laboratories' experience and research capability evolved, mission emphases shifted among them. Sandia, Los Alamos, and Lawrence Livermore acquired primary responsibility for nuclear weapons research and development and the largest share of the laboratories' funds. Responsibility for research in the environmental and biological, energy, and national security areas was distributed among all 10 laboratories to varying degrees.[4] However, the Congress and DOE are reassessing this mission configuration.

Since 1980, the Congress has had an active interest, expressed in a series of laws, in seeing that more of the national laboratories' outputs be put to commercial uses.[5] Changing needs for defense technology resulting from the end of the cold war and concern with maintaining U.S industry's competitiveness in global markets have led several members of Congress to open a public debate and propose new legislation that addresses the

[2]The Atomic Energy Act of 1946 delegated responsibility for nuclear weapons research, development, and manufacture as well as civilian uses of nuclear energy to a civilian agency, the Atomic Energy Commission. Historically, civilian agencies have held this responsibility in the United States and most other countries.

[3]The National Renewable Energy Laboratory was established in 1977 as the Solar Energy Research Institute. One of DOE's program-directed laboratories, its R&D activities focus on developing competitive renewable energy and related technologies for the nation and on facilitating their commercialization.

[4]A brief description of the 10 national laboratories' missions is provided in appendix I.

[5]See Technology Transfer: Implementation Status of the Federal Technology Transfer Act of 1986 (GAO/RCED-89-154, May 30, 1989), Implementation of the Technology Transfer Act: A Preliminary Assessment (GAO/T-PEMD-90-4, May 3, 1990), and Diffusing Innovations: Implementing the Technology Transfer Act of 1986 (GAO/PEMD-91-23, May 29, 1991) for a discussion of congressional interest in technology transfer from the national laboratories, as expressed in the Stevenson-Wydler Technology Innovation Act of 1980 (P.L. 96-480) and the Federal Technology Transfer Act of 1986 (P.L. 99-502). The implementation of Executive Order No. 12591, "Facilitating Access to Science and Technology," which ordered executive departments and agencies to facilitate collaboration between federal laboratories and other public and private sector organizations, also is considered in Diffusing Innovations.

Note that this legislation and our reports concern all laboratories owned, leased, or otherwise used by a federal agency. The 10 national laboratories are a subset of this population, which covers at least 10 executive branch departments and 297 laboratories. See also the National Competitiveness Technology Transfer Act (P.L. 101-189), which in 1989 authorized DOE to establish technology transfer as a mission of government-owned, contractor-operated laboratories, such as the national laboratories, and to approve formation of cooperative research and development agreements (CRADAs) between these laboratories and industry.

national laboratories' missions, structure, and cooperation with industry.[6] Among the alternatives being considered in the public debate are reducing all the laboratories' budgets, consolidating or closing some of them, and redirecting their weapons development mission toward commercial product-related R&D in such areas as technology development for environmental restoration, energy, and high-performance computing.

Underlying these discussions are questions about the type of R&D activities the national laboratories are performing now, the nature and scope of their outputs, and their potential for assisting industry in bringing technology to the marketplace. This report is an effort to inform the debate by providing an empirical base for these questions, as a starting point for addressing the broader issues. It examines whether the balance of laboratories' effort is in basic and applied research or research related to commercial product development, the distribution of the laboratories' research outputs, and their potential for commercial application. Findings were based on a cross-section of the laboratories' R&D activities for the period 1989-92. However, the objectives for most of the programs in the study population were initiated before the national laboratories' legislative mandate for technology transfer in the National Competitiveness Technology Transfer Act took effect in late 1989. In most fields of R&D, more than 4 years are required for outputs to evolve after objectives have been established. Therefore, the commercial product-related effort we found is to be considered a baseline against which future activities and outputs can be measured.

Methodology

We began our work by developing a comprehensive description of current research activities in the 10 laboratories. We chose to survey the laboratories directly because we could find no sufficiently comprehensive existing documentation. We collected our data through a survey of the 10 laboratories' research programs and the facilities and equipment that support them. The survey scope consisted of all major research programs and facilities with costs of at least $10 million, as well as special

[6]See U.S. Congress, "Department of Energy Laboratory Technology Act of 1993," H.R.1432, sections 2, 4, 5, and 9.

nominations by the laboratories themselves of other less costly programs and facilities.[7]

These two criteria were designed to ensure that all large subprograms and smaller subprograms that were important to the laboratories' missions would be included in our sample. This allowed us to describe the laboratories' major research efforts. However, findings based on these criteria should not be considered representative of a laboratory's entire research effort since the proportion of programs budgeted at less than $10 million can vary from one laboratory to another.

DOE's Budget and Reporting System categories provided a common classification scheme for the laboratories' 12 research programs, which permitted cross-laboratory comparisons of program characteristics. Research program and subprogram names are shown in table 1. The data we collected on these programs covered fiscal years 1989-92.

We conducted pilot tests of the survey methodology and data collection instruments at Brookhaven and the National Renewable Energy Laboratory. We then revised the instrument and administered one version to the remaining eight laboratories.[8] After we processed the survey responses, we asked each laboratory to confirm by letter that our list of research programs and facilities was, in fact, complete.

[7]A **research program** in the survey population is one of several broad areas of research activity taking place within a laboratory that had a total annual budget equal to or exceeding $10 million, was funded in fiscal year 1992, and was planned to continue in fiscal year 1993. A program that did not meet these criteria could be nominated by the laboratory for inclusion in the survey on the basis of its uniqueness or contribution to science and technology development. Each laboratory could nominate up to 10 programs in this category. A **facility** in the survey population is an entity that houses and comprises the equipment used in conducting R&D. A facility could be a building or defined structure, some area within a structure, or a defined area not confined to a structure (for example, a testing area). An acquisition cost of $10 million or nomination by the laboratory for its uniqueness, world-class quality, synergistic effect when combined with other facilities, or contribution to a given research program or project qualified a facility for inclusion in the survey. Each laboratory could nominate up to 15 facilities that did not meet the $10-million acquisition cost criterion.

[8]The national laboratory inventory data collection instrument has two parts—part I concerns the laboratory's research programs; part II requests information about a laboratory's major research facilities. This report contains data for eight of the 10 laboratories from part I of the revised data collection instrument, which is reproduced in appendix II. Data reported for Brookhaven and the National Renewable Energy Laboratory were collected with the pilot-test versions of the data collection instrument, which were somewhat different from the instrument in appendix II.

Table 1: Classification for National Laboratory Research Programs

Program	Subprogram category[a]
Energy Research	Magnetic fusion (AT) High-energy physics (KA) Superconducting supercollider (KS) Nuclear physics (KB) Basic energy sciences (KC) Biological and environmental (KP)
Conservation and Renewable Energy	Electric energy systems (AK) Geothermal (AM) Solar energy (EB) Building and community systems (EC) Industrial Energy Conservation (ED) Transportation (EE) State and local programs (EF)
Environment, Safety and Health	Environment, safety, and health (HA)
Nuclear Energy	Nuclear energy R&D (AF) Uranium enrichment (CD)
Defense Programs	Weapons activities (GB) Verification and control technologies (GC) Nuclear safeguards and security (GD) Production and surveillance support to the nuclear weapons complex (NM)
New Production Reactors	New production reactors (NP)
Environmental Restoration and Waste Management	Environmental restoration and waste management—defense (EW, EM) Environmental restoration and waste management—nondefense (EX)
Fossil Energy	Coal (AA) Petroleum (AC) Strategic petroleum reserve (SA)
Civilian Radioactive Waste Management	Nuclear waste fund (DB)
Policy Planning and Analysis	Policy, analysis, and systems studies (PE)
Intelligence	Intelligence (NT)
Work for others	Work for others (WFO)

[a]DOE's Budget and Reporting System subprogram category codes are in parentheses. For purposes of this project, we have used the code "WFO" to identify work for others programs.

Source: National laboratories' institutional plans for fiscal years 1991-96.

The national laboratories engage in a wide range of defense and nondefense R&D-related activities. These range from generating hypotheses and testing fundamental science principles to assisting a potential user in adapting laboratory outputs to a production or service delivery system. To analyze the extent to which the laboratories are engaged in basic and applied research or research related to commercial product development, we divided their activities into five categories: basic research, applied research, development, technology transfer, and technical assistance.

Basic research is research undertaken primarily to gain fuller knowledge or understanding of a subject and to contribute to the knowledge base in the field of investigation. **Applied research** is research directed toward the practical use of knowledge or understanding of a subject to meet a recognized need. **Development** is research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes or processes. Development has some type of product as the output goal, but may conclude with a prototype rather than a usable good. Additional time, research, and testing are usually required to convert the prototype to a weapon or commercially viable product.

Because the national laboratories perform R&D only through the development stage, additional mechanisms and arrangements are required to achieve application of the laboratories' outputs in the public or private sector. These activities are technology transfer and technical assistance. **Technology transfer** is the process that fosters the use of devices, processes, "know-how," or scientific and technical information produced in a national laboratory by universities, private industry, or government agencies. It includes making potential users aware of the laboratories' research outputs, assisting in their selection or use, and collaborating with representatives of private industry and public or nonprofit institutions to ensure that some of the laboratories' outputs will have commercial or public applications. **Technical assistance** applies the laboratory's expertise to practical problems but does not involve the use of a laboratory's outputs. It is any form of assistance, other than financial, to a state or local government or a business, including publications, workshops, conferences, studies, or telephone consultation.

Development, technical assistance, and technology transfer are the three national laboratory research activities related to commercial product development. All five categories, already used by the laboratories but specially grouped for our analysis, constitute a natural framework that, together with DOE's program classification scheme, allowed us to look at R&D-related activity across all 10 laboratories, using expenditures as a measure of activity.

Recognizing that the laboratories do not maintain records of their R&D expenditures in terms of our five categories, we asked managers of the subprograms in our study population to estimate, for each subprogram they managed, the proportion of funds expended in each of the five areas. Our analysis of R&D activity is therefore presented as percentages, not actual dollar values. To provide a context for considering our findings, we present in table 2 the fiscal year 1992 budgets for subprograms in the study population that were included in our analysis and the laboratories' total budgets in fiscal year 1992.

Table 2: National Laboratory Budgets for Fiscal Year 1992

National laboratory	R&D budget[a]	Total budget[b]
Argonnne	$357.8	$577.8
Lawrence Berkeley	193.3	270.6
Oak Ridge	346.6	726.9
Pacific Northwest	340.4	417.0
Idaho National Engineering[c]	98.7	931.5
Lawrence Livermore	727.6	1395.5
Los Alamos	710.9	1239.6
Sandia	722.1	1389.6
Brookhaven	253.1	472.6
National Renewable Energy	113.4	131.2
Total	**$3,863.9**	**$7,552.3**

[a]In millions of dollars; includes salaries and wages, overhead, expendables, capital equipment, and other factors for a laboratory's subprograms in the study population. Construction costs are not included. Dollar values are the total of a laboratory's research subprograms' budgets reported by program managers.

[b]In millions of dollars; includes salaries and wages, expendables, overhead, capital equipment, general purpose equipment, construction, and all other factors for all of a laboratory's research, educational, administrative, and other activities. Dollar values are the estimated budget authorization reported in the laboratory 5-year institutional plan.

[c]Idaho National Engineering Laboratory conducts energy, defense, environmental, and nuclear reactor research; provides scientific training in nuclear reactors and waste management; and designs, constructs, and operates defense production facilities. Idaho laboratory representatives determined that much of their work in the environmental, nuclear energy, and defense areas did not meet criteria for inclusion in the inventory. In addition, the total laboratory budget estimate in the fiscal year 1992 institutional plan included $250 million for construction, which was not included in the R&D budget for the study population.

We also examined the laboratories' outputs. As output measures, we selected products of laboratory R&D that were clearly identifiable to our respondents and for which they were likely to maintain records. Since our study objective was to examine the balance among laboratory activities rather than their impact, we focused on outputs of R&D activity that occurred within the laboratories rather than their efforts at job creation or increased sales. Because of great variation in the size, scope, field of investigation and funding level of the subprograms in the study population, both within and among laboratories, we presented our findings as simple tabulations, rather than as standardized units. Use of a single measure for standardizing the outputs, such as dollar of funding per output, would have failed to account for variations among the subprograms on other dimensions. Moreover, because of the institutional complexity this variation represents, we interpreted our output findings very conservatively, treating them as measures of activity rather than indicators of performance. We looked at the outputs in two broad categories: (1) publications and reports and (2) outputs related to commercial product development. The outputs attributed to each category are described in the Principal Findings section.

Finally, we looked at three other indicators—the formation of cooperative R&D agreements, R&D effort devoted to critical technologies, and program managers' assessment of their on-going research—to gauge the laboratories' potential for commercial product development.

We conducted our review in accordance with generally accepted government auditing standards.[9]

Results in Brief

The national laboratories devoted slightly more than half (52.4 percent) of their R&D funds to research related to commercial product development during fiscal year 1992. This includes 30.9 percent for development, 14.4 percent for technical assistance, and 7 percent for technology transfer. However, most of the 10 laboratories' development work (56.7 percent) was devoted to defense (which may have more limited market opportunities) rather than nondefense research. Less than half (44.6 percent) of the laboratories' effort was spent on basic and applied research: 17.4 percent on basic research and 27.2 percent on applied research.

The 10 laboratories produced many more publications and reports (21,593) than they did outputs related to commercial product development (2,510) in fiscal year 1992. We expected this finding because publications and reports are the primary mechanism for disseminating the results of all types of R&D-related activities. Further, we found that the defense program

[9]See appendix III for a more detailed discussion of survey methodology.

supported most of the commercial product-related outputs, and that Sandia, Los Alamos, and Lawrence Livermore—which are known as weapons laboratories—produced most of these outputs. However, because we asked the laboratories to classify these outputs—prototype devices and materials, algorithms, software, and other commercial products or processes that have an identified commercial use—at a time that is still several years away from market entry, whether or to what degree they will actually achieve commercial application is unknown.

With regard to the laboratories' potential for commercial product development, we found that such potential exists, based on the three indicators we examined. Activity is increasing in the formation of cooperative R&D agreements between the laboratories and industry. These agreements increased from 17 in fiscal year 1989 to 196 in fiscal year 1992. Of course, they ensure only that the laboratories and industry will collaborate on R&D; a commercial innovation may or may not be produced. With respect to the research emphasis selected, about three-fourths (74.1 percent) of the 10 laboratories' R&D expenditures were focused on those technologies the National Critical Technologies Panel had identified as vital to national needs.[10] Here again, the potential for commercial product development exists, but the actual outcome will not be known for several years. Finally, over half (57.5 percent) of the managers of programs with commercial product potential expected clear evidence of that potential to emerge within 5 years or less from fiscal year 1992.

Principal Findings

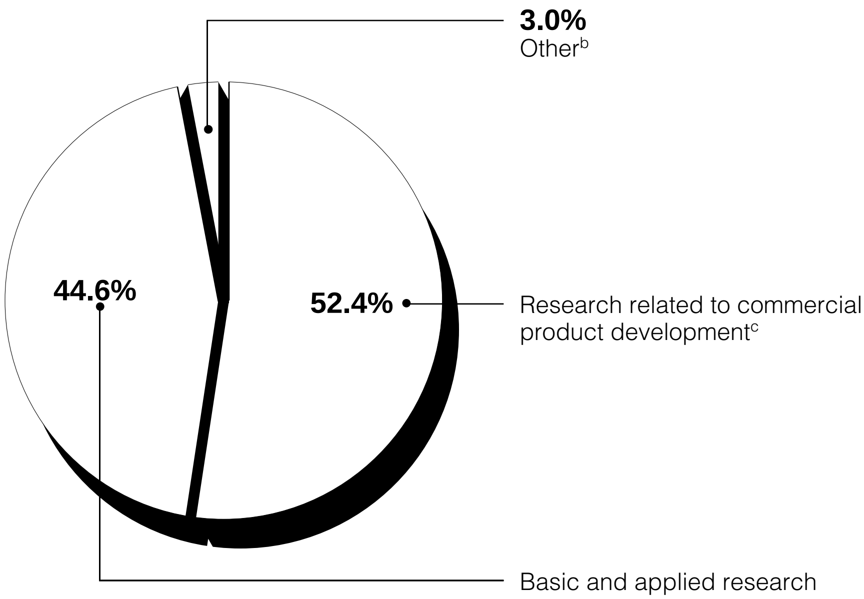
Balance Among R&D-Related Activities

To examine the balance of the national laboratories' current R&D-related activities, we analyzed the distribution of laboratory expenditures for R&D within and among laboratories and research programs. For the 10 laboratories overall, R&D-related activity was almost evenly divided between basic and applied research on the one hand, and research related to commercial product development on the other. Approximately 8 percent more of the effort was devoted to R&D activities related to commercial product development, as shown in figure 1. More applied

[10]The Congress established the National Critical Technologies Panel through the Fiscal Year 1990 Defense Authorization Act (P.L. 101-189), an amendment to the National Science and Technology Policy, Organization, and Priorities Act of 1976. Congress asked the Panel to identify up to 30 areas of technological development they consider essential for the nation's long-term security and economic prosperity. The Panel reports to the Congress and the President on the critical technologies biennially through the year 2000.

research than basic research was conducted: 27.2 percent versus 17.4 percent. Among research activities related to commercial product development, most (30.9 percent) was development, but more activity was devoted to technical assistance (14.4 percent) than technology transfer (7 percent). Thus, R&D-related activity directly targeted on potential commercial applications of the laboratories' outputs currently constitutes the smallest proportion of the laboratories' R&D-related effort. Despite its small size, however, this level of effort exceeds the laboratories' minimum statutory requirement for technology transfer activity.[11]

Figure 1: National Laboratory Mean Percent Expenditures for R&D-Related Activities[a]



[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than basic and applied research or research related to commercial product development, such as training graduate students and postdoctoral fellows or safety procedures.

[c]Development, technical assistance, and technology transfer.

[11]The Stevenson-Wydler Act requires that each federal agency with one laboratory or more make available at least one-half of 1 percent of its R&D budget for technology transfer activities and that laboratories having 200 or more scientific, engineering, and technical full-time-equivalent (FTE) staff assign at least one FTE to an Office of Research and Technology Applications, which has formal responsibility for the laboratory's technology transfer activities.

These overall percentages, however, mask major differences among the laboratories with regard to R&D funding distribution. (See table IV.1 in appendix IV.) Four laboratories—Argonne, Lawrence Berkeley, Oak Ridge, and Brookhaven—spent 25 percent or more of their research funds on basic research. These laboratories account for over half (59.3 percent) of the total national laboratory research budget that is spent on basic research. (See table IV.2.) Los Alamos spent 19.4 percent of its R&D funds to support its mission to perform "basic research in selected disciplines that help maintain an outstanding science and technology base." Only about 10 percent or less of the laboratory research budget was spent on basic research at the other laboratories. The energy research program accounted for the greatest proportion of funds spent on basic research, both within and among research program areas. (See tables IV.3 and IV.4.)

As table IV.1 shows, four laboratories—Oak Ridge, Pacific Northwest, Lawrence Livermore, and Los Alamos—spent 29 percent or more of their research funds on applied research. Among the 10 laboratories, Lawrence Livermore and Los Alamos accounted for almost half (47.9 percent) of applied research expenditures. (See table IV.2.) Most applied research was supported by programs in the areas of defense, energy research, and work for others. (See table IV.4.)

As noted earlier, most of the laboratories' development work, the most product-oriented of R&D activities, was devoted to defense, rather than nondefense, research. Almost three-quarters (71.5 percent) of all the laboratories' development research was conducted at Lawrence Livermore, Los Alamos, and Sandia. (See table IV.2.)[12] In turn, the largest share of development research was performed in the defense and nuclear energy programs. (See tables IV.3 and IV.4.) Therefore, while it is true that across the 10 laboratories, a greater proportion of research funding was devoted to activities more closely related to commercial product development than to basic and applied research, most of these funds currently support defense research. To determine whether this research will have commercial opportunities for use, we examined the national laboratories' outputs.

[12]Pacific Northwest and the National Renewable Energy Laboratory each spend almost one-third of their research funds on development. However, these laboratories are funded at a substantially lower level than the weapons laboratories.

National Laboratories' R&D Outputs

A second measure of the type of effort in which the national laboratories are engaged—as between basic and applied research or research related to commercial product development—is output. The laboratories produce two major types of outputs: (1) publications and reports, and (2) outputs related to commercial product development.[13] Table 3 shows that, across a 4-year period, most of the laboratories' outputs were publications and reports. This finding was expected because reports and publications are the primary mechanisms for diffusion of R&D findings, and they are prepared at all stages of the R&D process. Reports, conference papers, and published articles, which can be produced more quickly than books and book chapters, substantially outnumber the latter.

As we discussed above, a slightly higher percentage of the laboratories' expenditures was devoted to R&D activities related to commercial product development than to basic and applied research; nevertheless, few of their outputs were commercial product-related.[14] Prototype devices and materials, algorithms, and software are the largest number of outputs in this group. These outputs tend to arise from the development stage of the R&D process, which often occurs several years before production of a marketable or usable good. Not all outputs of the development stage will, of course, achieve commercial application.

Most of the prototype devices and materials, algorithms, and software, as indicated in tables V.1 and V.2 in appendix V, were produced at the weapons laboratories, and most were funded by DOE's defense program. Other outputs laboratory managers identified as commercial products or commercial processes also tend to arise from the development stage. Although they will require a substantial additional investment before they are ready to market, these products or processes will more likely result in actual commercial applications because a potential commercial use has already been identified. Most of these outputs were produced by Los Alamos, Sandia, and Pacific Northwest, and the defense program supports most of the research that has led to these outputs. The point here is that although defense-funded R&D has produced more outputs that could lead to commercial products, whether these outputs will achieve commercial application is still unknown.

[13]A third set of outputs, which are not related to these categories, is designated as "other."

[14]Prototype devices and materials, algorithms, software, patents, licenses, commercial products, commercial processes, and spin-off companies are defined as laboratory outputs related to commercial product development. The research program managers have identified a potential commercial use for commercial products and commercial processes, but these outputs have achieved at most a precompetitive stage of development. We view patents, licenses, and spin-off companies as evidence of intent to pursue a marketing strategy for a research output.

Table 3: National Laboratories' Research Program Outputs for Fiscal Years 1989-92

	1992		1991		1990		1989		Total	
Outputs	**All 4 years[a]**	**Any 4 years[b]**	**All 4 years[a]**	**Any 4 years[b]**	**All 4 years[a]**	**Any 4 years[b]**	**All 4 years[a]**	**Any 4 years[b]**	**All 4 years[a]**	**Any 4 years[b]**
Publications and reports										
Books	88	94	120	121	181	181	120	120	509	516
Articles	6,153	6,471	6,330	6,387	5,612	5,652	5,959	5,970	24,054	24,480
Book chapters[c]	355	371	269	271	321	322	280	280	1,225	1,244
Reports	6,245	6,802	5,416	5,542	4,761	4,851	4,497	4,533	20,919	21,728
Conference papers	7,237	7,855	6,812	6,931	6,498	6,572	6,421	6,449	26,968	27,807
Subtotal	**20,078**	**21,593**	**18,947**	**19,252**	**17,373**	**17,578**	**17,277**	**17,352**	**73,675**	**75,775**
Outputs related to commercial product development										
Prototypes	501	566	485	490	497	500	492	492	1,975	2,048
Algorithms	732	778	713	715	632	634	552	552	2,629	2,679
Software	508	554	417	422	350	381	314	315	1,589	1,669
Patents[c]	159	237	139	199	145	203	148	166	591	805
Licenses	210	303	128	149	42	60	39	47	419	559
Commercial products	28	36	17	24	19	26	17	21	81	107
Commercial processes	22	29	13	20	11	18	14	18	60	86
Spin-off company[c]	6	7	2	3	8	11	11	12	27	33
Subtotal	**2,166**	**2,510**	**1,914**	**2,022**	**1,704**	**1,833**	**1,587**	**1,623**	**7,371**	**7,988**
Other										
New programs[c]	153	159	142	146	137	139	98	100	530	544
Invention disclosures[c]	320	617	336	618	247	481	232	341	1,135	2,057
Other[d]	510	523	472	483	412	421	404	414	1,798	1,841
Subtotal	**983**	**1,299**	**950**	**1,247**	**796**	**1,041**	**734**	**855**	**3,463**	**4,442**

[a]These are outputs for subprograms that were in operation every year during fiscal years 1989-92.

[b]These are outputs for subprograms that were initiated in any year during fiscal years 1989-92.

[c]Responses were not collected from Brookhaven National Laboratory and National Renewable Energy Laboratory.

[d]Research subprogram outputs other than those listed above, such as technical abstracts, workshops for laboratory users, and an electronic bulletin board service.

Patent applications may be submitted for inventions throughout the entire R&D process, but a license is usually acquired only when a decision to market a technology has been made. The number of licenses awarded, therefore, is a stronger measure of output activity related to commercial product development than the number of patents. A trend in the data indicative of the laboratories' production of outputs related to commercial product development is the increase in the number of licenses awarded during fiscal years 1989 through 1992. (See table 3.) In fiscal year 1992, Sandia and Pacific Northwest awarded the most licenses, and most licensed outputs were supported by defense program research. (See tables V.1 and V.2.)

We expected to find that most commercial product-related outputs were supported by research programs that spent most of their R&D funds for development. However, the R&D expenditures of those programs that supported the most outputs related to commercial product development covered the range of R&D activities. We found that in fiscal year 1992, four research programs—energy research, conservation and renewable energy, defense, and work for others—supported most of the commercial product-related outputs of all types and that, over 4 years, commercial product-related output production had been increasing each year in three of the programs, as shown in figure V.1. We also found that in fiscal year 1992, the largest proportion of expenditures in the defense and conservation and renewable energy programs was for development.

As expected, the defense and conservation and renewable energy programs supported more of the outputs specifically designated as commercial products and processes than any of the 10 other research programs. However, in looking more closely at these four programs, we found some interesting differences. Work for others, which supports more commercial product and process-type outputs than eight other programs, devoted a slightly higher proportion of R&D expenditures to applied research than to development. But in energy research, which supports more commercial product- and process-related outputs than nine other programs, the largest proportion of expenditures was for basic research. (See table V.3.)

Laboratories' Potential for Commercial Product Development

We looked at three indicators of the national laboratories' potential for commercial product development: (1) formation of cooperative research and development agreements; (2) proportion of R&D expenditures in critical technology areas; and (3) research program managers' judgments about their programs' outputs. Of these three, the most frequently used indicator of the national laboratories' potential for commercial product development is the **formation of CRADAS**.[15] Here we found a major increase in activity. The national laboratories reported that from fiscal year 1989 through 1992, they entered into 196 CRADAS. Among programs in the study population in operation all 4 years, the number of new CRADAS formed increased from 17 in fiscal 1989 to 130 in fiscal 1992.

Sandia and Oak Ridge laboratories were most active in entering into CRADAS. (See table VI.1. in appendix VI.) Most were formed for research sponsored by programs in the defense and conservation and renewable energy areas. (See table VI.2.) The greatest increase in CRADA formation occurred at Sandia, where 74 CRADAS were in effect in fiscal year 1992. Fifty-three of the CRADAS effective in fiscal year 1992 were sponsored by the defense program technology transfer initiative at Sandia. This subprogram was initiated in June 1990 to identify opportunities for commercializing technologies produced by DOE-funded defense research activities in such areas as advanced manufacturing and precision engineering, materials and processes, advanced microelectronics and photonics, and computer architecture and applications.

Although the national laboratories do not yet have a legislative mandate or mission for research in the **critical technologies**, their research program managers reported that 74.1 percent of R&D expenditures are devoted to work in critical technology areas. This research was distributed over the 22 areas identified by the National Critical Technologies Panel, with the greatest concentration in energy technologies (13.6 percent); pollution minimization, remediation, and waste management (8.8 percent); computer simulation and modeling (6.7 percent); and materials synthesis and processing (6.2 percent). (See table VI.3.)

Work in these critical technology areas was distributed broadly among the laboratories and research programs. Five laboratories—Argonne, Lawrence Berkeley, Oak Ridge, Idaho, and Lawrence Livermore—devoted approximately 20-30 percent of their research funds to energy technologies. (See table VI.3.) Pacific Northwest expended the greatest proportion of R&D funds (41.3 percent) on pollution minimization

[15]A CRADA is a contractual provision created to foster technology transfer from federal laboratories to the private sector. Agreements can be formed with businesses as well as nonprofit organizations and state and local government agencies. The National Competitiveness Technology Transfer Act of 1989 authorized government-owned, contractor-operated laboratories, such as the national laboratories, to enter into CRADAs.

CRADA formation represents commercial product potential because it establishes the process uniquely for conducting research related to commercial product development. The conclusion of the period of performance does not guarantee that the research will have been completed or that a market-ready product will have been developed.

technologies. Idaho and Lawrence Livermore were most active in computer simulation and modeling. Oak Ridge and Los Alamos devoted the greatest percentage of effort to materials synthesis and processing. As a group, the laboratories devoted approximately three-fourths of their R&D expenditures to research in critical technology areas, but Sandia and Los Alamos expended only about half of their resources on critical technologies research. All of the research programs sponsored research in critical technologies to some degree, with the least effort expended by environment, safety, and health. (See table VI.4.)

Finally, laboratory research program managers' judgments about their research programs' **potential for commercial product development** were optimistic. Among the subset of all national laboratory programs with a potential for commercial product development, almost 58 percent of the program managers expected that development to occur within 5 years of fiscal 1992. (See figure VI.1.) An additional 27.6 percent reported that their program has the potential for commercial product development within 5-10 years.

Conclusions

As of 1992, the national laboratories spent slightly more than half of their R&D funds on research related to commercial product development. However, most of this R&D was performed at the weapons laboratories and was supported by the defense and nuclear energy programs. Analysis of the outputs produced by the national laboratories indicated that defense-funded research produced more outputs—prototype devices and materials, algorithms, software, and other products and processes that have an identified commercial application—that are precursors to marketable goods, but at this point, whether they will achieve commercial application is not known.

Moreover, three indicators of the laboratories' potential for commercial product development—CRADA formation, critical technology research, and program managers' expectations for commercial potential—showed that some activity was occurring. CRADA formation was increasing, but these arrangements ensure only that collaboration between the laboratories and industry will occur, not that a commercial product will be generated. Almost three-fourths of the laboratories' effort was devoted to research in critical technology areas, but achievement of commercial application will not be known for several years. Over half of the managers of research subprograms that have commercial product potential expected innovations to arise within 5 years, but these expectations must be considered “best educated guesses.” While we can conclude, therefore, that the national laboratories’ were engaged in slightly more research related to commercial product development than basic and applied research, it is too early to determine whether this activity will produce technologies with commercial uses.

Agency Comments

We requested comments on a draft report and received a response from DOE and the 10 national laboratories. DOE questioned the definitions and categories we defined to analyze the laboratories’ R&D-related activities and our finding that the laboratories perform slightly more research related to commercial product development than basic and applied research. DOE also thought that this study should have examined additional institutional factors, including the R&D activities of other agencies, and should have used data maintained by DOE headquarters rather than surveyed the laboratories for data.

We note that the definitions for R&D-related activities we employed are derived from a Congressional Budget Office study of the federal R&D enterprise, our study of the Technology Transfer Act of 1986, and expert opinion. We also disagree with DOE’s proposed broader scope for this study because it exceeds our study objective and would have required additional data collection and analyses that are beyond the study scope. Furthermore, our exploration of data available at DOE headquarters found that it was not adequate to satisfy our information needs.

Eight laboratories agreed with the report’s objective, analyses, and conclusions. However, one of this group, Lawrence Berkeley, thought that the relationship of commercial product development to the broader needs of industry and the nation should have been addressed in the study. Two of the laboratories raised issues about study methodology. Idaho believed that a greater proportion of the budget for its subprograms should have been included in the study sample. Oak Ridge questioned the effect of the study’s sampling methodology on output findings for the laboratory and the definition of the category called outputs related to commercial product development.

Lawrence Berkeley said that we had overlooked an important issue. The laboratory thought that the study should have included an examination of the relationship of the national laboratories’ role in commercial product development to the broader needs of industry and the nation. We agree that this issue is important to address as part of the public debate about the laboratories' missions and structure. However, we disagree that it should have been examined in this report, which focuses on establishing an empirical baseline of national laboratories' activities.

DOE's Idaho Operations Office responded for Idaho National Engineering Laboratory. The Idaho Operations Office said that the budget figure reported for Idaho subprograms included in the study sample should have been higher. We did not agree to revise Idaho's budget figure, because to do so would have violated the study methodology used to sample programs at other laboratories.

Oak Ridge took the position that most of its commercial product-related outputs were produced by subprograms that were not selected in the study sample because they were funded at less than $10 million. The laboratory expressed concern that the subprograms we sampled produced only 7 percent of its commercial product-related outputs while representing 73 percent of its overall budget. Oak Ridge based this position on summary output data for the entire laboratory and sampled subprograms that laboratory representatives had tabulated. Again, we could not include the output data for Oak Ridge's unsampled programs in our analyses without violating the sampling methodology. We also had some questions about the large number of outputs the Oak Ridge analysis ascribed to unsampled programs.

Oak Ridge also thought that our definitions for these outputs equated the laboratories' development work with commercial product development. We disagree. The definitions we used make it clear that the laboratories were not expected to produce commercial products. Our conclusion reiterates that the laboratories' outputs related to commercial product development are "precursors to marketable goods" and that "whether they will achieve commercial application is not known."

We provide a more detailed discussion of all these comments and our response in appendixes VII through XVII.

As agreed with your offices, we plan no further distribution of this report until 30 days from its date of issue, unless you publicly announce its contents earlier. We will then send copies to interested parties, and we will also make copies available to others upon request.

If you have any questions or would like additional information, please call me at (202) 512-3092. Other major contributors to this report are listed in appendix XVIII.

Kwai-Cheung Chan
Director of Program Evaluation in
Physical Systems Areas

Contents

Letter	1
Appendix I Description of the National Laboratories	24
Appendix II National Laboratory Inventory Research Program Data Collection Instrument	29
Appendix III Survey Methodology	48
Appendix IV Balance Among the National Laboratories' R&D Activities	50
Appendix V National Laboratories' R&D Outputs	54
Appendix VI National Laboratories' Potential for Commercial Product Development	60

Appendix VII Comments From the Department of Energy 67

Appendix VIII Comments From Argonne National Laboratory 75

Appendix IX Comments From Brookhaven National Laboratory 76

Appendix X Comments From DOE's Idaho Operations Office 79

Appendix XI Comments From Lawrence Berkeley Laboratory 81

Appendix XII Comments From Lawrence Livermore National Laboratory 85

Appendix XIII Comments From Los Alamos National Laboratory 87

Appendix XIV Comments From National Renewable Energy Laboratory 89

Appendix XV Comments From Oak Ridge National Laboratory 91

Appendix XVI Comments From Pacific Northwest Laboratory 94

Appendix XVII Comments From Sandia National Laboratories 95

Appendix XVIII Major Contributors to This Report 97

Tables

Table 1: Classification for National Laboratory Research Programs 5

Table 2: National Laboratory Budgets for Fiscal Year 1992 7

Table 3: National Laboratories' Research Program Outputs for Fiscal Years 1989-92 13
Table IV.1: Mean Percent Expenditures for R&D-Related Activities Within Laboratories 50
Table IV.2: Mean Percent Expenditures for R&D-Related Activities Among Laboratories 51
Table IV.3: Mean Percent Expenditures for R&D-Related Activities Within Programs 52
Table IV.4: Mean Percent Expenditures for R&D-Related Activities Among Programs 53
Table V.1: National Laboratories' Research Program Outputs by Laboratory 55
Table V.2: National Laboratories' Research Program Outputs by Program 56
Table V.3: Proportion of Funds Spent by Programs With More Than 100 Outputs Related to Commercial Product Development 58
Table VI.1: CRADAs in Effect at the National Laboratories 60
Table VI.2: CRADAs in Effect Within the National Laboratories by Research Program 61
Table VI.3: Mean Percent Expenditures for Critical Technologies Within Laboratories 62
Table VI.4: Mean Percent Expenditures for Critical Technologies Within Programs 64

Figures

Figure 1: National Laboratory Mean Percent Expenditures for R&D-Related Activities 10
Figure V.1: Trends in Outputs Related to Commercial Product Development 59
Figure VI.1: Program Managers' Views of Programs' Commercial Product Potential 66

Abbreviations

AMTEX	American Textile Partnership
AT&T	American Telephone and Telegraph
CRADA	Cooperative research and development agreement
DOE	Department of Energy
FTE	Full-time-equivalent
OSTP	Office of Science and Technology Policy
PNGV	Partnership for a New Generation of Vehicles
R&D	Research and development

Description of the National Laboratories

The descriptions of the national laboratories are adapted from the 5-year institutional plans that the laboratories update and issue annually and from U.S. Department of Energy, Multiprogram Laboratories, 1979 to 1988, A Decade of Change (Washington, D.C.: Apr. 1990).

Argonne National Laboratory

Argonne was established in 1946. The University of Chicago operates the laboratory, which develops and operates national facilities for use by university, industry, and national laboratory groups; performs basic research, technology-directed research and technology evaluations; and conducts technology transfer through cooperative research, and development agreements, sponsored research, staff exchanges, and licensing of intellectual property or through the formation of new firms by the laboratory's Arch Development Corporation.

The laboratory's basic research effort includes experimental and theoretical research on fundamental problems in the physical, life, and environmental sciences to advance scientific understanding and support energy technology development. Argonne's technology-directed research includes conceptualization, design, and testing of advanced fission reactors and other technologies for power applications in both the civilian and defense sectors and investigations of strategies for overcoming materials, chemical, and electrochemical barriers to the development of these technologies. Argonne also supports DOE and, where appropriate, other federal agencies in characterizing and evaluating nationally important projects and technology options in terms of their environmental cost or other implications.

Lawrence Berkeley Laboratory

Lawrence Berkeley, founded in 1931 as the Radiation Laboratory by Ernest Orlando Lawrence of the University of California at Berkeley, was one of the original national laboratories. It was funded under government contract in 1942. The University of California, which operates the laboratory, renamed it the Lawrence Radiation Laboratory after his death in 1958, and later called it Lawrence Berkeley. The laboratory conducts a wide range of interdisciplinary research with core competencies in biosciences and biotechnology; particle and photon beams; advanced detector systems; characterization and synthesis of materials; chemical dynamics, catalysis, and surface sciences; advanced techniques for energy supply and energy efficiency; and environmental assessment and remediation. It performs research in the energy, physical, and life sciences; develops and operates national experimental facilities; fosters industry's interactions with the laboratory's research programs; and offers scientific and engineering education programs.

The laboratory's work in the energy sciences includes applied science, such as the energy efficiency of buildings; chemical sciences, such as the structure and reactivity of transient species; earth sciences, including geophysical imaging methods, isotopic geochemistry and physicochemical process investigation; and materials sciences, such as advanced ceramic, metallic, and polymeric materials for electronic, magnetic, catalytic, and structural applications. Accelerator and fusion research, nuclear science, and physics are pursued in the general science area. Lawrence Berkeley's work in the life sciences includes cellular and molecular biology, chemical biodynamics, and research medicine and radiation biophysics. This work is supported by the laboratory's scientific and technical resources in the areas of engineering, information and computing sciences, and occupational health.

Oak Ridge National Laboratory

Oak Ridge was one of the original national laboratories. Now operated by Martin Marietta Energy Systems, Oak Ridge was established in 1943. The laboratory's R&D activities are focused on basic and applied research, technology development, and other technological challenges in areas that include energy production and conservation technologies; experimental and theoretical research in physical, chemical, materials, computational, biomedical, earth, environmental, and social sciences; the design, building, and operation of unique research facilities for the benefit of university, industrial, and other federal agency and national laboratory researchers; and the development of environmental protection and waste management technologies. Oak Ridge also performs technology transfer and offers educational services from the preschool through the postdoctoral level.

Pacific Northwest Laboratory

Pacific Northwest was established in 1965. Battelle Memorial Institute now operates the laboratory, which performs scientific research and rapid technology development and deployment to meet national needs. Laboratory efforts include molecular science, hazardous waste characterization, global environmental studies, subsurface science, biological systems, technical support for environmental policies and procedures, federal infrastructure modernization, national security technology, energy-efficient methods, advanced analytical methods, materials research, magnetic fusion research, civilian nuclear waste management, technical support for nuclear power plant operation, space exploration technology, fossil fuel technology, renewable energy sources, energy policy analysis, and surveillance and oversight of operations at its Hanford site.

Idaho National Engineering Laboratory

This laboratory was established in 1949. Three contractors operated the laboratory during the time period of our study: Westinghouse Idaho Nuclear Co., Rockwell-INEL, and EG&G Idaho. The laboratory's areas of primary emphasis are nuclear reactor technology R&D, defense production-related support, waste management and environmental restoration analysis, advanced energy production technology development, and research and development on energy and environmental issues, including performance testing of industry-developed electric vehicles, small hydropower and geothermal power production, and fossil energy research. Idaho also offers educational activities and performs technology transfer.

Lawrence Livermore National Laboratory

Lawrence Livermore was established in 1952. The University of California operates the laboratory, which serves as a national resource in science and engineering, focused on national security, energy, environment, biomedicine, economic competitiveness, and science and mathematics education, with a special responsibility for nuclear weapons. National security has traditionally been a special focus of the laboratory's research and development effort. Lawrence Livermore's major areas of activity have included research, development, and testing for all phases of the nuclear weapons life cycle; strategic defense research; arms control and treaty verification technology; inertial confinement fusion; atomic vapor laser isotope separation; magnetic fusion; other energy research; research in biological, ecological, atmospheric, and geophysical sciences; charged-particle beam and free-electron laser research; advanced laser and optical technology applications; technology transfer; and science education. The laboratory also participates in human genome research as part of a nationally directed initiative.

Los Alamos National Laboratory

Los Alamos, one of the original national laboratories, was established in 1943 and is operated by the University of California. Ensuring the nation's deterrence capability through nuclear weapons technology is the laboratory's primary focus. Los Alamos' major R&D activities include research, design, development, engineering, and testing of nuclear warheads; maintenance and enhancement of the weapons technology base and warhead stockpile management; research, development, and testing support for advanced nuclear directed-energy concepts; nuclear materials R&D for the nuclear weapons program; nonnuclear strategic defense R&D activities; advanced conventional munitions development and simulation; verification and safeguards R&D; vulnerability, lethality, effects, and countermeasures research; advanced defense technologies; intelligence activities involving hardware analysis and technology security; weapons and energy technology systems studies; and R&D in nonnuclear energy and technology areas. The laboratory's basic research activities in defense and energy areas include atomic and molecular physics, bioscience, chemistry, computational science and applied mathematics, geoscience, space science, astrophysics, materials science, nuclear and particle physics, plasma physics, fluids, and particle beams. Los Alamos also performs technology transfer and offers science and engineering education programs.

Sandia National Laboratories

Sandia was established in 1949 under an agreement with AT&T to operate the laboratory for the government as a public service on a nonprofit basis. AT&T stepped out of this role in 1993. A contract was recently awarded to Martin Marietta Corporation to operate the laboratories. Sandia's major areas of effort are nuclear weapons, arms control and treaty verification, environmental restoration and waste management, energy supply and conservation, advanced conventional military technologies, and other programs in the national interest. The laboratories' R&D activities in these areas include research, development, and engineering associated with advancing nuclear explosives to integrated, functional weapons for Department of Defense weapon delivery systems; other defense programs, including development of verification and control technologies to support arms reduction and concepts and systems for the safeguarding and security of nuclear materials; research, development, and engineering for hazardous waste removal, minimization, and remediation; and nonnuclear energy research in energy efficiency, recovery techniques, conversion technologies, alternative energy sources, characterization of environmental change phenomena, environmental restoration technologies, and basic energy sciences. Sandia also conducts technology transfer and offers mathematics and science education opportunities.

Brookhaven National Laboratory

Brookhaven was established in 1947 by a group of nine universities to facilitate their mutual access to large-scale research facilities, particularly in nuclear science. The laboratory is operated by Associated Universities, a corporation governed by a board of trustees representing the original nine universities as well as other universities, research institutions, and industrial organizations. Brookhaven's primary role is to conceive, design, build, and operate large-scale, complex facilities for scientific research and to conduct basic and applied research in energy-related physical, life, and environmental sciences. When feasible, Brookhaven makes its laboratory facilities available to state and federal agencies, universities, and private industry. The laboratory's major areas of R&D are high-energy and nuclear physics; basic energy sciences emphasizing research on biological, chemical, and physical phenomena underlying energy-related transfer, conversion, and storage systems; life sciences, nuclear medicine, and medical applications of nuclear techniques; and a broad span of applied programs that draw on the laboratory's unique capabilities. Brookhaven makes all useful results and knowledge obtained from its research activities available to private industry. Brookhaven also performs technology transfer and offers science and engineering education programs.

National Renewable Energy Laboratory

The former Solar Energy Research Institute was designated a DOE national laboratory in 1991 and renamed the National Renewable Energy Laboratory. The focus of the laboratory's effort is on developing competitive renewable energy and related technologies and facilitating their commercialization. The laboratory's R&D activities include basic and applied research, exploratory and advanced development and other activities in renewable energy and related technologies; analytic studies and technology evaluations; and collaborative R&D with universities and industry. The laboratory also manages subcontracted R&D on behalf of DOE and serves as a source of scientific and technical information on renewable energy.

National Laboratory Inventory Research Program Data Collection Instrument

United States General Accounting Office

NATIONAL LABORATORY INVENTORY

PART I: RESEARCH PROGRAMS

PURPOSE OF THE SURVEY

The Congress has asked the U.S. General Accounting Office to develop an inventory of the funding and personnel for the 10 U.S. Department of Energy national laboratories' research programs as well as the facilities and equipment that support them. The purpose of this survey is to collect detailed information for the laboratory inventory as well as preliminary information about technology transfer activities. We will conduct follow-up interviews with each laboratory's representatives in order to establish the laboratory's perspective on its research mission and the potential for cooperative efforts with industry.

HOW TO COMPLETE THIS QUESTIONNAIRE

The questionnaire is divided into two parts--part I concerns the laboratory's research programs; part II requests information about the laboratory's major research facilities. Parts I and II are being sent to laboratory officials designated by laboratory management as knowledgeable in those areas. This is part I and should be completed by research program directors or the eqivalent. It contains questions about the laboratory's research programs. Many of the questions, particularly those concerning equipment, expenditures, and personnel, will require a search of the laboratory's records to complete. It may help to read the questionnaire through quickly first so that you will know what information you may have to look up before you start to answer individual questions.

If you have any questions while completing your responses, please contact Nancy Briggs, on (202) 275-1703 or Sara Edmondson, on (202) 275-8516 in the Program Evaluation and Methodology Division, U.S. General Accounting Office.

Please provide the name, title, telephone number and FAX number of the person who may be contacted concerning the responses to this questionnaire:

Contact person's name: ______________________

Title: ______________________

Telephone Number: ______________________

FAX Number: ______________________

Please return the completed questionnaire in the enclosed envelope within 10 working days of receipt. In the event that the enclosed envelope is misplaced, please mail the questionnaire to:

Nancy Briggs, Ph.D
Project Manager
U.S. General Accounting Office
Program Evaluation and Methodology Division
Room 5853
441 G Street St., N.W.
Washington, DC 20548

Thank you in advance for your cooperation and assistance in addressing an issue of such critical importance to the nation. We will send a report on the analysis of the information to the Congress and you.

I-2

DEFINITIONS

The definitions listed below are included to provide a common frame of reference for responding to the survey.

Applied Research: A study directed toward the practical use of knowledge or understanding of a subject to meet a recognized need.

Basic Research: A study undertaken primarily to gain fuller knowledge or understanding of a subject and to contribute to the knowledge base in the field of investigation.

Capital Equipment Budget: For a national laboratory, this includes the budget for both research equipment and general purpose equipment.

Cooperative Research and Development Agreement (CRDA): A contractual form created for the express purpose of fostering technology transfer from the federal domain to the private sector.

Development: Research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

Facility: An entity that comprises the equipment used for research programs. A facility may include a building or defined structure, some area within a structure, or a defined area not confined to a structure (for example, a testing area).

Laboratory: A group of facilities owned, leased, or otherwise used by the U.S. Department of Energy to perform research and development. A laboratory consists of land (including, but not limited to, remote testing areas), buildings, human resources, research programs, and equipment.

Mission: The primary scientific and technical research programs that a laboratory pursues.

Operating Budget: For a national laboratory this comprises research and development program costs, including salaries and wages, expendables and overhead.

Research and Development: Intensive, systematic study directed toward fuller scientific knowledge or understanding of the subject under investigation; practical use of knowledge; or the production of materials, devices, systems, or methods. Research and development includes basic research, applied research, and development.

Research Program: One of several broad areas of research activity within a laboratory's mission.

Technology: Devices, processes, "know how," or scientific and technical information produced through the research and development process.

Technology Transfer: The process that fosters the use of devices, processes, "know how," or scientific and technical information produced in a federal laboratory by universities, private industry, or government agencies, whether national (federal, state, or local) or foreign.

Total Budget: For a national laboratory, this includes operating, capital equipment, and construction costs.

User Facility: A federal laboratory facility available for use either free of charge or on a cost-reimbursed basis by investigators from private industry, academic institutions, or state and local government agencies.

PROGRAM AND SUBPROGRAM DESCRIPTION

1. Please identify the defense subprogram for which you are reporting. Report only for a subprogram funded by the laboratory's operating budget during fiscal year 1992 and which is on-going for fiscal year 1993. (Check only one.)

Defense

a. ☐ GB-01[1] Weapons RD&T

b. ☐ GB-02 Inertial Confinement Fusion (Guidance)

c. ☐ GB-02 Inertial Confinement Fusion (Required)

d. ☐ GB-05 Program Direction

e. ☐ GC Verification and Control Total

f. ☐ Other (Please specify)
____

[1]U.S. Department of Energy Budget and Reporting and System code.

I-4

2. Please describe the subprogram's research objectives and the major scientific and technical areas the subprogram addresses.

I-5

3. What is the time period of performance for this subprogram? (Write in the subprogram start date and end-date below).

Subprogram start date ________________/_________________/__________________
(month) (Day) (Year)

Subprogram end date _______________/__________________/___________________
(month) (Day) (Year)

I-6

4. How important, if at all, is each of the research and development-related activities listed below to your subprogram objectives? (Check the relevant space.)

Research and development-related activity	Importance					
	Little importance (1)	Somewhat important (2)	Moderately important (3)	Very important (4)	Essential (5)	Not part of mission (6)
a. Basic research[1]						
b. Applied research[2]						
c. Development[3]						
d. Providing technical assistance to government agencies						
e. Providing technical assistance to universities						
f. Providing technical assistance to private firms or industrial organizations						
g. Transfer technology from this laboratory to U.S. government organizations						
h. Transfer technology from this laboratory to foreign government organizations						
i. Transfer technology from this laboratory to U.S.[4] firms or industrial organizations						
j. Transfer technology from this laboratory to foreign[5] firms or industrial organizations						
k. Other (Please specify) ________ ________ ________ ________ ________						

[1]Basic Research: A study undertaken primarily to gain fuller knowledge or understanding of a subject and to contribute to the knowledge base in the field of investigation.

[2]Applied Research: A study directed toward the practical use of knowledge or understanding of a subject to meet a recognized need.

[3]Development: Research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

[4]Majority-owned by U.S. citizens

[5]Majority-owned by non-U.S. citizens

I-7

5. In your estimation, what percent, if any, of your total research subprogram budget was expended each year during fiscal years 1989-92 for each of the research and development-related activities listed below? (Annual total should equal 100 percent. Write "N/A" if the program was not in operation in given year.)

Research and development-related activity	1992	1991	1990	1989
a. Basic research[1]				
b. Applied research[2]				
c. Development[3]				
d. Providing technical assistance to government agencies				
e. Providing technical assistance to universities				
f. Providing technical assistance to private firms or industrial organizations				
g. Transfer technology from this laboratory to U.S. government organizations				
h. Transfer technology from this laboratory to foreign government organizations				
i. Transfer technology from this laboratory to U.S.[4] firms or industrial organizations				
j. Transfer technology from this laboratory to foreign[5] firms or industrial organizations				
k. Other (Please specify) ____________________________ ____________________________ ____________________________ ____________________________				
l. Total	100%	100%	100%	100%

[1]Basic Research: A study undertaken primarily to gain fuller knowledge or understanding of a subject and to contribute to the knowledge base in the field of investigation.

[2]Applied Research: A study directed toward the practical use of knowledge or understanding of a subject to meet a recognized need.

[3]Development: Research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes.

[4]Majority-owned by U.S. citizens

[5]Majority-owned by non-U.S. citizens

I-8

6. We identified the technologies listed below using the Report of the National Critical Technologies Panel. During fiscal years 1989-92, which of these technologies did the research of this subprogram support? In your estimation what percentage of the research subprograms budget was spent each year for research about these technologies? (Check all that apply. Write in the estimated percentage for activities checked.)

		1992	1991	1990	1989
a.	☐ Materials synthesis and processing	______	______	______	______
b.	☐ Electronic and photonic materials	______	______	______	______
c.	☐ Ceramics	______	______	______	______
d.	☐ Composites	______	______	______	______
e.	☐ High-performance metals and alloys	______	______	______	______
f.	☐ Flexible computer integrated manufacturing	______	______	______	______
g.	☐ Intelligent processing equipment	______	______	______	______
h.	☐ Micro - and nanofabrication	______	______	______	______
i.	☐ System management technologies	______	______	______	______
j.	☐ Software	______	______	______	______
k.	☐ Microelectronics and optoelectronics	______	______	______	______
l.	☐ High-performance computing and networking	______	______	______	______
m.	☐ High definition imaging and displays	______	______	______	______
n.	☐ Sensors and signal processing	______	______	______	______
o.	☐ Data storage and peripherals	______	______	______	______
p.	☐ Computer simulation and modeling	______	______	______	______

I-9

q.	☐	Applied molecular biology	____	____	____	____
r.	☐	Medical technology	____	____	____	____
s.	☐	Aeronautics	____	____	____	____
t.	☐	Surface transportation technologies	____	____	____	____
u.	☐	Energy technologies	____	____	____	____
v.	☐	Pollution minimization, remediation, and waste management	____	____	____	____
w.	☐	Other (Please specify) ____	____	____	____	____

I-10

7. How many of the research and development-related outputs listed below did your subprogram produce each year from fiscal year 1989 to 1992? Write "N/A" if the program was not in operation in a given year.)

	1992	1991	1990	1989
a. Published books	______	______	______	______
b. Published articles	______	______	______	______
c. Published book chapters	______	______	______	______
d. Technical and scientific reports/monographs for internal use only	______	______	______	______
e. Technical and scientific reports/monographs for release to others outside the laboratory	______	______	______	______
f. Prototype devices and materials	______	______	______	______
g. Papers for presentation at professional conferences	______	______	______	______
h. New program	______	______	______	______
i. Algorithms	______	______	______	______
j. Software	______	______	______	______
k. Invention disclosures	______	______	______	______
l. Patents	______	______	______	______
m. Licenses	______	______	______	______
n. Commercial products	______	______	______	______
o. Commercial processes	______	______	______	______
p. Spin-off company	______	______	______	______
q. Other (Please specify) ______________	______	______	______	______

I-11

8. How much royalty income was earned each year during fiscal years 1989-92 by technologies supported by this subprogram? Show dollars in millions. (Write "N/A" if the program was not in operation in a given year.)

	1992	1991	1990	1989
Royalty income earned	$______	______	______	______

9. What was the total number of CRDAs and "Work for Others" contracts in effect for this subprogram each year during fiscal years 1989-92?

	1992	1991	1990	1989
a. CRDAs	______	______	______	______
Work for others				
b. Federal agency other than DOE	______	______	______	______
c. Industry	______	______	______	______
d. Foreign governments	______	______	______	______
e. Other sources	______	______	______	______

I-12

10. During what time period, if at all, does this research subprogram have the potential for industrial application or commercial product development (Check only one).

a. ☐ Immediate future (Less than 5 years)

b. ☐ Short-term future (Next 5-10 years)

c. ☐ Long-term future (Over 10-20 years)

d. ☐ Very long-term future (Over 20 years)

11. Is any university or private industry working in cooperation with your research subprogram?

a. ☐ Yes

b. ☐ No

If yes, please provide the following information:

c. Organization name: ____

d. Address: ____

e. Contact person: ____

f. Telephone number: ____

g. Research topic of cooperative effort: ____

Please also indicate if this is a U.S. or foreign government, university or firm. (Check the relevant space.)

	Organization		
Country	Government Agency (1)	University (2)	Firm or Company (3)
h. U.S.			
i. Foreign			

If there is more than one organization working in cooperation with your subprogram, please photocopy this page and provide this information for all organizations.

I-14

12. If possible, please identify up to three other U.S. or foreign government, university, or industrial research institutions that in your view are working on scientific and technical problems similar to those addressed by this research subprogram.

Name of scientific and technical problem	Name of other government, university or industrial R&D institution	Contact person's name and telephone number
a. ____________	a.	a.
	b.	b.
	c.	c.
b. ____________	a.	a.
	b.	b.
	c.	c.
c. ____________	a.	a.
	b.	b.
	c.	c.

I-15

13. If possible please identify one or two administrators of research programs in U.S. government, university, or industrial research institutions who are familiar with the scientific and technical aspects of your research subprogram as well as the facilities and equipment that support it. Please do not list anyone who is affiliated with programs in the U.S. Department of Energy.

a. Research administrator's name and title

Name: ____

Title: ____

Organization name, address and phone number

Name: ____

Address: ____

Telephone no: _____________________________________

FAX no: ____

b. Research administrator's name and title

Name: ____

Title: ____

Organization name, address, and phone number

Name: ____

Address: ____

Telephone no: _____________________________________

FAX no: ____

I-16

PROGRAM BUDGET

14. What was your research subprogram's total annual budget during fiscal years 1989-92? Show dollars in millions. (Write the dollar amount in each column. Write "N/A" if the subprogram was not in operation in a given year.)

(Dollars in millions)

	1992	1991	1990	1989
Operating				
a. Salaries and wages	________	________	________	________
b. All other	________	________	________	________
c. Capital equipment	________	________	________	________
d. Construction	________	________	________	________
e. Other (Please specify)				
______________________________				
______________________________				
______________________________	________	________	________	________

15. What percentage of the research subprogram's total annual budget was contributed by each of the following sources during fiscal years 1989-92? (Write "N/A" if the subprogram was not in operation in a given year. Annual total should equal 100 percent.)

	1992	1991	1990	1989
a. Contracts from DOE	_______	_______	_______	_______
Work for Others				
b. Federal agencies other than DOE	_______	_______	_______	_______
c. U.S. industries	_______	_______	_______	_______
d. Foreign industry	_______	_______	_______	_______

I-17

15. (Continued) What percentage of the research subprogram's total annual budget was contributed by each of the following sources during fiscal years 1989-92 (Annual total should equal 100 percent.)

e. Foreign government	_______	_______	_______	_______
f. Other sources	_______	_______	_______	_______
Total	100%	100%	100%	100%

I-18

PERSONNEL

16. How many workers are employed annually by your research subprogram in each of the following job categories and what is the total employment? Please provide both the number of full-time personnel and the number of full-time equivalent (FTE) staff years for each year during fiscal years 1989-92.

Job category	1992		1991		1990		1989	
	Number of personnel	FTEs	Number of personnel	FTEs	Number of personnel	FTEs	Number of personnel	FTEs
a. Administrators (not involved in research)								
b. Scientists, engineers, and other researchers (including research administrators directly involved in research)								
c. Technicians supporting research (through testing, inspection, maintenance, or construction of research equipment, computer programming)								
d. Clerical maintenance and other support personnel								
e. Other (Please specify) ________ ________ ________ ________ ________ ________								
f. Total employees								

THANK YOU FOR YOUR PARTICIPATION

I-19

Survey Methodology

Survey Response

The research program survey population was enumerated by applying selection criteria to each laboratory's research programs. After processing the surveys, we sent the laboratories a letter requesting confirmation that our list of research programs and subprograms was complete. In response to our letter, the laboratories confirmed a total of 252 research subprograms. The laboratories returned a total of 247 data collection instruments, for a survey response rate of 98 percent.

Data Quality Issues

The data contained in this report are results of analyses of national laboratory program managers' responses to questions 5, 6, 7, 9, and 10 in part I of the national laboratory inventory. These responses represent program managers' judgments or self-reports about question elements, as follows. We made no attempt to validate these responses through independent sources.

Question 5

Responses are research program managers' best estimates of the proportion of the total program budget expended for each R&D-related activity. Although they had our definitions for key R&D-related activities listed in the data collection instrument, their responses also may reflect their own understanding of terms such as basic research, applied research, or technical assistance.

Question 6

Responses are research program managers' best estimates of the proportion of the total program budget expended for research in critical technology areas. The response categories in the question are the critical technologies identified by the National Critical Technologies Panel. Some overlap may exist among these categories because they were not identified for research measurement purposes. The Panel's critical technology categories were used in this question to determine the congruence between research already being conducted at the national laboratories and the research needs articulated by a congressionally mandated body.

A few responses submitted for this question summed to more than 100 percent. These responses were prorated to include them in the calculation of mean percent expenditures for R&D in critical technologies.

Question 7

Responses are research program managers' reports of research program outputs. The responses concerning commercial products and commercial processes are judgments made about research outputs that have reached only the precompetitive stage of the R&D process.

Question 9

Responses are research program managers' reports about CRADAS in effect through the end of fiscal year 1992.

Question 10

Responses are research program managers' judgments about potential industrial application or commercial product development for outputs of their research program over a 20-year planning horizon. The size of research subprograms in the study population varied; thus, managers were considering outputs of one or more research activities in making their assessments.

Balance Among the National Laboratories' R&D Activities

Data concerning the distribution of the national laboratories' expenditures among R&D-related activities, by laboratory and by program, are presented below.

Table IV.1: Mean Percent Expenditures for R&D-Related Activities Within Laboratories[a]

R&D-related activity	ANL	LBL	ORNL	PNL	INEL	LLNL	LANL	SNL	BNL	NREL	All labs
Basic research	29.9	39.7	25.1	9.8	2.2	7.6	19.4	4.9	53.6	6.9	17.4
Applied research	22.5	15.9	29.1	29.7	20.6	36.2	33.1	23.5	7.5	24.3	27.2
Development	17.4	7.4	17.9	31.8	25.5	43.6	25.9	47.7	13.9	31.9	30.9
Technical assistance to											
Government agencies	10.8	4.3	5.9	21.9	15.8	6.2	8.6	11.9	7.8	4.5	9.7
Universities	3.5	11.0	6.2	1.0	1.6	0.6	1.4	0.9	5.7	3.3	2.5
Private firms or industrial organizations	1.6	3.5	5.0	1.2	1.4	0.8	1.7	2.0	2.9	7.9	2.2
Technology transfer to											
Government agencies	4.0	10.4	4.5	2.4	7.0	1.9	2.5	3.1	1.6	1.7	3.2
Private firms or industrial organizations	6.2	1.7	6.1	2.1	4.6	2.1	3.3	3.9	0.9	18.1	3.8
Other[b]	4.1	6.1	0.2	0	21.3	1.0	4.1	2.1	6.2	1.5	3.0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Legend

ANL = Argonne National Laboratory
LBL = Lawrence Berkeley Laboratory
ORNL = Oak Ridge National Laboratory
PNL = Pacific Northwest Laboratory
INEL = Idaho National Engineering Laboratory
LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
SNL = Sandia National Laboratories
BNL = Brookhaven National Laboratory
NREL = National Renewable Energy Laboratory

[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than those listed above, such as training graduate students and postdoctoral fellows or safety procedures.

Table IV.2: Mean Percent Expenditures for R&D-Related Activities Among Laboratories[a]

R&D-related activity	ANL	LBL	ORNL	PNL	INEL	LLNL	LANL	SNL	BNL	NREL	Total
Basic research	14.9	10.9	13.1	5.0	0.3	8.3	20.7	5.3	20.4	1.2	100
Applied research	7.2	2.8	9.7	9.6	2.0	25.3	22.6	16.3	1.8	2.7	100
Development	5.0	1.1	5.2	9.1	2.2	26.8	15.6	29.1	3.0	3.1	100
Technical assistance to											
Government agencies	9.7	2.1	5.6	20.0	4.2	12.1	16.5	23.2	5.3	1.4	100
Universities	12.1	20.9	22.2	3.3	1.6	4.3	10.2	6.9	14.8	3.9	100
Private firms or industrial organizations	6.4	7.6	20.8	4.8	1.7	7.3	14.7	17.1	9.0	10.7	100
Technology transfer to											
Government agencies	10.8	15.4	12.6	6.7	5.6	11.4	14.5	18.2	3.3	1.6	100
Private firms or industrial organizations	14.2	2.2	14.5	4.8	3.1	10.4	16.0	19.3	1.6	14.0	100
Other[b]	11.9	9.6	0.7	0.0	18.1	6.4	25.2	13.1	13.6	1.5	100
All activity	**8.7**	**4.8**	**9.1**	**8.8**	**2.6**	**19.0**	**18.6**	**18.9**	**6.6**	**3.0**	**100**

Legend

ANL = Argonne National Laboratory
LBL = Lawrence Berkeley Laboratory
ORNL = Oak Ridge National Laboratory
PNL = Pacific Northwest Laboratory
INEL = Idaho National Engineering Laboratory
LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
SNL = Sandia National Laboratories
BNL = Brookhaven National Laboratory
NREL = National Renewable Energy Laboratory

[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than those listed above, such as training graduate students and postdoctoral fellows or safety procedures.

Table IV.3: Mean Percent Expenditures for R&D-Related Activities Within Programs[a]

R&D-related activity	ER	CE	ES&H	NE	DP	NPR	ERWM	FE	CRWM	PPA	INT	WFO	All programs
Basic research	53.1	4.4	0	7.6	7.2	0	0.3	14.1	8.2	3.3	2.0	11.5	17.4
Applied research	15.2	25.9	8.8	29.4	32.5	7.6	32.4	31.5	52.8	43.3	50.0	26.1	27.2
Development	10.1	28.6	9.8	51.7	40.9	27.7	37.3	15.8	17.3	6.7	15.0	23.4	30.9
Technical assistance to													
Government agencies	4.0	5.9	71.8	1.6	9.7	0	10.1	10.3	11.6	46.7	25.0	25.1	9.7
Universities	6.5	4.0	2.7	0.6	0.7	0	1.2	2.9	0.4	0	0	2.8	2.5
Private firms or industrial organizations	2.8	11.6	0.1	0.6	0.9	0	0.7	5.8	0	0	0	2.2	2.2
Technology transfer to													
Government agencies	4.1	3.1	2.4	2.0	2.8	0	3.3	7.7	1.7	0	8.0	4.3	3.2
Private firms or industrial organizations	2.5	15.7	0.7	6.5	2.5	0	2.8	7.1	0	0	0	4.4	3.8
Other[b]	1.7	0.7	3.7	0	2.8	64.7	11.8	4.9	8.0	0	0	0.4	3.0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Legend

ER = Energy Research
CE = Conservation and Renewable Energy
ES&H = Environment, Safety and Health
NE = Nuclear Energy
DP = Defense Programs
NPR = New Production Reactors
ERWM = Environmental Restoration and Waste Management
FE = Fossil Energy
CRWM = Civilian Radioactive Waste Management
PPA = Policy Planning and Analysis
INT = Intelligence
WFO = Work for Others

[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than those listed above, such as training graduate students and postdoctoral fellows or safety procedures.

Table IV.4: Mean Percent Expenditures for R&D-Related Activities Among Programs[a]

R&D-related activity	ER	CE	ES&H	NE	DP	NPR	ERWM	FE	CRWM	PPA	INT	WFO	Total
Basic research	68.7	1.7	0	3.0	17.8	0	0.1	0.2	0.6	0	0	7.7	100
Applied research	12.6	6.4	0.1	7.3	51.3	0.2	7.9	0.3	2.4	0.1	0.1	11.2	100
Development	7.3	6.2	0.1	11.3	56.7	0.6	8.0	0.1	0.7	0	0	8.9	100
Technical assistance to													
Government agencies	9.4	4.1	3.0	1.1	43.1	0	6.9	0.3	1.5	0.3	0.1	30.3	100
Universities	57.9	10.8	0.4	1.6	12.5	0	3.2	0.3	0.2	0	0	12.8	100
Private firms or industrial organizations	29.1	36.3	0	1.9	17.6	0	2.3	0.7	0	0	0	12.0	100
Technology transfer to													
Government agencies	28.4	6.4	0.3	4.1	36.9	0	6.9	0.6	0.6	0	0.1	15.5	100
Private firms or industrial organizations	14.5	27.8	0.1	11.5	27.5	0	4.8	0.5	0	0	0	13.4	100
Other[b]	13.0	1.6	0.5	0	39.2	14.6	25.9	0.4	3.3	0	0	1.4	100
All activity	**22.5**	**6.8**	**0.4**	**6.8**	**42.9**	**0.7**	**6.6**	**0.3**	**1.2**	**0.1**	**0**	**11.7**	**100**

Legend

ER = Energy Research
CE = Conservation and Renewable Energy
ES&H = Environment, Safety and Health
NE = Nuclear Energy
DP = Defense Programs
NPR = New Production Reactors
ERWM = Environmental Restoration and Waste Management
FE = Fossil Energy
CRWM = Civilian Radioactive Waste Management
PPA = Policy Planning and Analysis
INT = Intelligence
WFO = Work for Others

[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than those listed above, such as training graduate students and postdoctoral fellows or safety procedures.

National Laboratories' R&D Outputs

Data concerning outputs of the national laboratories' R&D-related activities, by laboratory and by program, are presented below.

Table V.1: National Laboratories' Research Program Outputs by Laboratory[a]

Outputs	ANL	LBL	ORNL	PNL	INEL	LLNL	LANL	SNL	BNL	NREL	Total
Publications and reports											
Books	8	2	16	1	3	17	14	10	14	9	94
Articles	738	1,634	955	210	79	461	1,134	534	634	92	6,471
Book chapters	71	35	154	11	5	51	25	19	[b]	[b]	371
Reports	540	620	1,200	170	335	1,405	828	1,009	515	180	6,802
Conference papers	662	1,027	1,437	369	245	747	1,619	968	534	247	7,855
Subtotal	**2,019**	**3,318**	**3,762**	**761**	**667**	**2,681**	**3,620**	**2,540**	**1,697**	**528**	**21,593**
Outputs related to commercial product development Prototypes	28	14	27	31	28	68	75	233	50	12	566
Algorithms	11	6	6	10	1	21	52	646	17	8	778
Software	36	11	7	3	120	57	96	193	23	8	554
Patents	14	12	12	38	14	37	33	77	[b]	[b]	237
Licenses	2	3	4	83	16	8	5	145	35	2	303
Commercial products	3	2	1	7	0	1	7	8	5	2	36
Commercial processes	3	1	2	6	0	1	3	12	1	0	29
Spin-off company	1	0	0	1	1	0	2	2	[b]	[b]	7
Subtotal	**98**	**49**	**59**	**179**	**180**	**193**	**273**	**1,316**	**131**	**32**	**2,510**
Other											
New program	20	8	3	0	2	6	29	91	[b]	[b]	159
Invention disclosures	43	32	54	122	54	89	11	212	[b]	[b]	617
Other[c]	141	0	4	0	1	96	15	0	101	165	523
Subtotal	**204**	**40**	**61**	**122**	**57**	**191**	**55**	**303**	**101**	**165**	**1,299**
Total	**2,321**	**3,407**	**3,882**	**1,062**	**904**	**3,065**	**3,948**	**4,159**	**1,929**	**725**	**25,402**

Legend

ANL = Argonne National Laboratory
LBL = Lawrence Berkeley Laboratory
ORNL = Oak Ridge National Laboratory
PNL = Pacific Northwest Laboratory
INEL = Idaho National Engineering Laboratory
LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
SNL = Sandia National Laboratories
BNL = Brookhaven National Laboratory
NREL = National Renewable Energy Laboratory

[a]Fiscal year 1992.

[b]Responses were not collected from Brookhaven National Laboratory and National Renewable Energy Laboratory.

[c]Research subprogram outputs other than those listed above, such as technical abstracts, workshops for laboratory users, and an electronic bulletin board service.

Table V.2: National Laboratories' Research Program Outputs by Program[a]

Outputs[b]	ER	CE	ES&H	NE	DP	NPR	ERWM	FE	CRWM	PPA	INT	WFO	Total
Publications and reports													
Books	46	12	0	3	23	0	1	0	0	0	0	8	93
Articles	3,951	475	5	33	1,040	0	45	12	32	2	0	666	6,261
Book chapters[c]	257	35	0	2	39	0	4	5	1	0	0	17	360
Reports	1,692	582	20	393	2,407	80	296	50	84	16	0	1,012	6,632
Conference papers	3,463	663	6	219	2,022	9	215	44	70	2	0	773	7,486
Subtotal	**9,409**	**1,767**	**31**	**650**	**5,531**	**89**	**561**	**111**	**187**	**20**	**0**	**2,476**	**20,832**
Outputs related to commercial product development													
Prototypes	85	39	0	20	309	0	18	1	0	0	0	63	535
Algorithms	43	16	0	10	671	0	6	1	2	0	0	19	768
Software	49	17	0	29	233	0	17	3	0	3	0	200	551
Patents[c]	52	18	0	5	111	0	6	0	0	0	0	7	199
Licenses	41	22	0	0	152	0	1	0	0	0	0	4	220
Commercial products	3	7	0	1	13	0	1	0	0	0	0	4	29
Commercial processes	3	4	0	1	13	0	1	0	0	0	0	1	23
Spin-off company[c]	3	0	0	0	3	0	0	0	0	0	0	0	6
Subtotal	**279**	**123**	**0**	**66**	**1,505**	**0**	**50**	**5**	**2**	**3**	**0**	**298**	**2,331**
Other													
New program[c]	25	12	0	2	97	0	5	2	0	0	0	16	159
Invention disclosures[c]	80	58	0	28	270	0	40	0	0	0	0	19	495
Other[d]	139	168	90	0	108	0	11	6	0	0	0	1	523
Subtotal	**244**	**238**	**90**	**30**	**475**	**0**	**56**	**8**	**0**	**0**	**0**	**36**	**1,177**
Total	**9,932**	**2,128**	**121**	**746**	**7,511**	**89**	**667**	**124**	**189**	**23**	**0**	**2,810**	**24,340**

(Table notes on next page)

Legend

ER = Energy Research
CE = Conservation and Renewable Energy
ES&H = Environment, Safety and Health
NE = Nuclear Energy
DP = Defense Programs
NPR = New Production Reactors
ERWM = Environmental Restoration and Waste Management
FE = Fossil Energy
CRWM = Civilian Radioactive Waste Management
PPA = Policy Planning and Analysis
INT = Intelligence
WFO = Work for Others

[a]Fiscal year 1992.

[b]Pacific Northwest Laboratory provided information about all outputs for the laboratory as a whole that are not included in the data presented here.

[c]Responses were not collected from Brookhaven National Laboratory and National Renewable Energy Laboratory.

[d]Research subprogram outputs other than those listed above, such as technical abstracts, workshops for laboratory users, and an electronic bulletin board service.

Table V.3: Proportion of Funds Spent by Programs With More Than 100 Outputs Related to Commercial Product Development[a]

R&D-related activity	ER	CE	DP	WFO
Basic research	53.1	4.4	7.2	11.5
Applied research	15.2	25.9	32.5	26.1
Development	10.1	28.6	40.9	23.4
Technical assistance to				
Government agencies	4.0	5.9	9.7	25.1
Universities	6.5	4.0	0.7	2.8
Private firms or industrial organizations	2.8	11.6	0.9	2.2
Technology transfer to				
Government agencies	4.1	3.1	2.8	4.3
Private firms or industrial organizations	2.5	15.7	2.5	4.4
Other[b]	1.7	0.7	2.8	0.4
Total	**100**	**100**	**100**	**100**

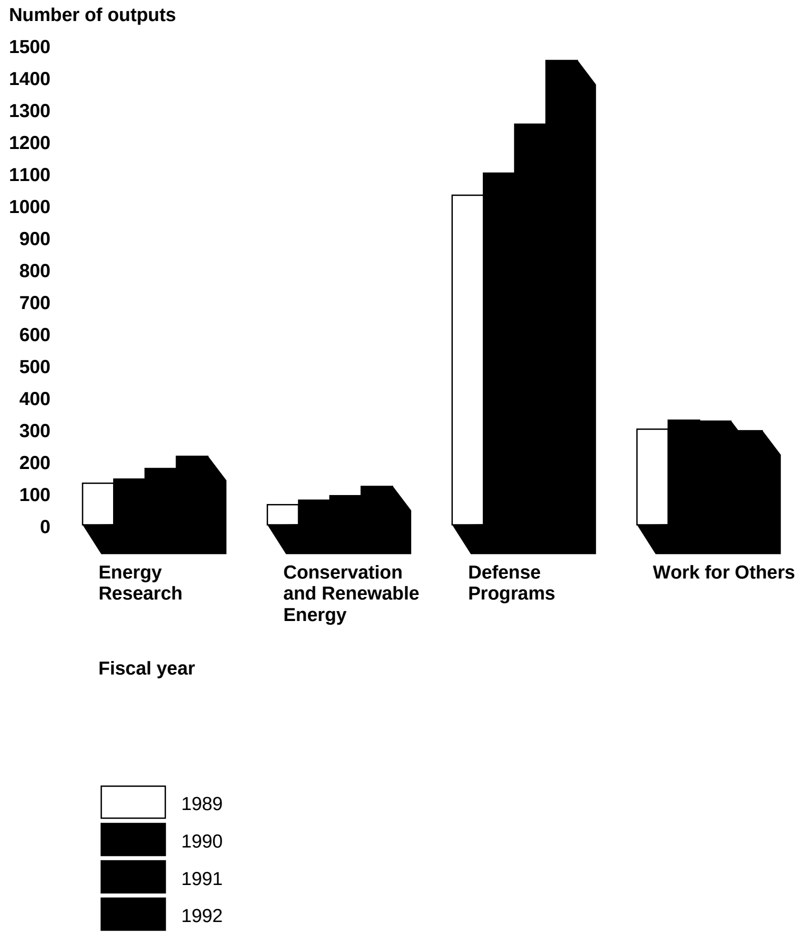
Legend

ER = Energy Research
CE = Conservation and Renewable Energy
DP = Defense Programs
WFO = Work for Others

[a]Fiscal year 1992.

[b]Subprogram expenditures for activities other than those listed above, such as training graduate students and postdoctoral fellows or safety procedures.

Figure V.1: Trends in Outputs Related to Commercial Product Development[a]



[a]The number of outputs is shown only for research subprograms in the study population that were in operation all 4 years (fiscal years 1989-92).

National Laboratories' Potential for Commercial Product Development

Data concerning the formation of cooperative research and development agreements, expenditures for R&D in critical technologies, and the views of national laboratory program managers on their programs' potential for commercial product development are presented below.

Table VI.1: CRADAs in Effect at the National Laboratories[a]

National laboratory[b]	1992		1991		1990		1989	
	All 4 years[c]	Any 4 years[d]	All 4 years[c]	Any 4 years[d]	All 4 years[c]	Any 4 years[d]	All 4 years[c]	Any 4 years[d]
Argonne	7	7	2	2	0	0	0	0
Brookhaven	4	4	0	0	0	0	0	0
Lawrence Berkeley	4	4	0	0	0	0	0	0
Oak Ridge	55	55	38	38	20	20	9	9
Pacific Northwest	4	9	0	0	0	0	0	0
Idaho	12	12	9	9	4	4	1	1
Lawrence Livermore	13	13	3	3	1	1	1	1
Los Alamos	18	18	8	8	6	6	6	6
Sandia	13	74[e]	4	11	0	0	0	0
Total	**130**	**196**	**64**	**71**	**31**	**31**	**17**	**17**

[a]Fiscal years 1989-92.

[b]Responses on CRADA formation were not collected from National Renewable Energy Laboratory.

[c]These are CRADAs formed for research sponsored by subprograms that were in operation every year during fiscal years 1989-92.

[d]These are CRADAs formed for research sponsored by subprograms that were initiated in any year during fiscal years 1989-92.

[e]Most of the CRADAs formed in fiscal year 1992 were sponsored by the DOE defense program technology transfer initiative at Sandia. This subprogram was initiated in June 1990 to identify opportunities for commercializing technologies produced by DOE-funded defense research activities.

Table VI.2: CRADAs in Effect Within the National Laboratories by Research Program[a]

	1992		1991		1990		1989	
Research program[b]	**All 4 years[c]**	**Any 4 years[d]**	**All 4 years[c]**	**Any 4 years[d]**	**All 4 years[c]**	**Any 4 years[d]**	**All 4 years[c]**	**Any 4 years[d]**
Energy Research	41	41	13	13	4	4	1	1
Conservation and Renewable Energy	52	52	41	41	26	26	15	15
Environment, Safety and Health	0	0	0	0	0	0	0	0
Nuclear Energy	0	0	1	1	0	0	0	0
Defense Programs	26	79[e]	7	13	1	1	1	1
New Production Reactors	0	0	0	0	0	0	0	0
Environmental Restoration and Waste Management	1	14	1	2	0	0	0	0
Fossil Energy	3	3	0	0	0	0	0	0
Civilian Radioactive Waste Management	0	0	0	0	0	0	0	0
Policy Planning and Analysis	0	0	0	0	0	0	0	0
Intelligence	0	0	0	0	0	0	0	0
Work for Others	7	7	1	1	0	0	0	0
Total	**130**	**196**	**64**	**71**	**31**	**31**	**17**	**17**

[a]Fiscal years 1989-92.

[b]Responses were not collected from National Renewable Energy Laboratory.

[c]These are CRADAs formed for research sponsored by subprograms that were in operation every year during fiscal years 1989-92.

[d]These are CRADAs formed for research sponsored by subprograms that were initiated in any year during fiscal years 1989-92.

[e]Most of the CRADAs formed in fiscal year 1992 were sponsored by the DOE defense program technology transfer initiative at Sandia. This subprogram was initiated in June 1990 to identify opportunities for commercializing technologies produced by DOE-funded defense research activities.

Table VI.3: Mean Percent Expenditures for Critical Technologies Within Laboratories[a]

Critical technology[b]	ANL	LBL	ORNL	PNL	INEL	LLNL	LANL	SNL	All labs
Material synthesis and processing	4.3	5.5	11.8	4.3	4.6	3.6	13.0	1.9	6.2
Electronic and photonic materials	1.1	4.4	1.7	0.2	0	1.9	1.4	2.1	1.7
Ceramics	2.2	2.2	9.8	0.5	0.8	0.7	0.7	0.4	1.8
Composites	0.2	0.4	4.0	0.6	6.9	0.4	0.9	0.2	1.0
High-performance metals and alloys	3.0	1.5	8.9	0	1.9	1.6	1.2	1.4	2.2
Flexible computer integrated manufacturing	0.2	0	1.6	0.7	1.3	0	0.6	0.9	0.6
Intelligent processing equipment	0.2	0	0.3	1.1	3.7	0.3	1.1	0.8	0.7
Micro- and nanofabrication	0.2	0.4	1.5	0.1	0.5	0.4	1.2	0.7	0.7
System management technologies	0	0.2	0.6	5.0	0.8	0.8	0.7	1.4	1.2
Software	2.2	0.7	0.4	2.4	12.0	6.1	3.5	5.6	4.0
Microelectronics and optoelectronics	0.6	1.1	0.5	2.3	0.3	2.1	2.3	11.5	3.7
High-performance computing and networking	1.9	0.5	3.3	0.2	3.4	5.0	2.0	1.2	2.4
High-definition imaging and displays	0.4	1.0	0.2	1.1	1.2	0.3	0.5	0.1	0.4
Sensors and signal processing	0.8	0.2	1.5	3.5	7.1	5.1	4.2	9.0	4.6
Data storage and peripherals	0.1	0.2	0	0.8	0	0.4	1.1	1.9	0.8
Computer simulation and modeling	5.7	1.4	5.0	5.4	14.6	12.7	4.5	5.0	6.7
Applied molecular biology	0.2	8.6	4.6	0.7	1.4	2.4	1.6	0	1.9
Medical technology	0.8	4.7	0.6	0.3	0.1	0.3	0.4	0	0.6
Aeronautics	0	0	0.3	1.0	0.5	0	0	0	0.2
Surface transportation technologies	1.9	0	1.2	0	2.2	0	0	0.4	0.5
Energy technologies	32.0	24.2	19.7	7.6	24.8	18.7	4.5	3.5	13.6
Pollution minimization, remediation, and waste management	18.8	9.1	1.9	41.3	7.5	3.8	3.8	1.9	8.8
Other[c]	5.3	0.1	6.6	15.3	4.3	32.9	2.1	0.4	10.2
Research funds not expended on critical technologies	18.0	33.3	14.1	5.6	0	0.5	48.5	49.9	25.9
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(Table notes on next page)

LEGEND

ANL = Argonne National Laboratory
LBL = Lawrence Berkeley Laboratory
ORNL = Oak Ridge National Laboratory
PNL = Pacific Northwest Laboratory
INEL = Idaho National Engineering Laboratory
LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
SNL = Sandia National Laboratories

[a]Fiscal year 1992.

[b]Responses were not collected from Brookhaven National and National Renewable Energy Laboratory.

[c]Subprogram expenditures for activities other than those listed above, such as robotics, special nuclear materials, environmental R&D, and detector technology.

Table VI.4: Mean Percent Expenditures for Critical Technologies Within Programs[a]

Critical technology[b]	ER	CE	ES&H[c]	NE	DP	NPR	ERWM	FE	CRWM	PPA	INT	WFO	All programs
Material synthesis and processing	7.0	9.6	0	6.1	7.3	0	1.6	8.5	4.4	0	0	3.1	6.2
Electronic and photonic materials	3.1	0.6	0	0.7	1.9	0	0	5.3	0	0	0	0.5	1.7
Ceramics	3.5	12.5	0	2.4	0.5	3.1	0.1	9.8	0	0	0	0.6	1.8
Composites	2.3	2.7	0	0.4	0.3	0	0.5	3.9	0	0	0	1.7	1.0
High-performance metals and alloys	4.0	2.5	0	6.2	1.2	4.6	0.2	3.8	1.8	0	0	1.4	2.2
Flexible computer integrated manufacturing	0.4	0	0	0.3	0.6	0	0	0	0	0	0	1.8	0.6
Intelligent processing equipment	0.5	0.3	0	0.3	0.8	0	0.1	0	0	0	0	1.6	0.7
Micro- and nanofabrication	0.6	0.4	0	0	1.0	0	0	0.6	0	0	0	0.7	0.7
System management technologies	0.1	0.3	0	0.7	0.9	0	3.4	0	7.1	0	0	2.9	1.2
Software	2.8	0.9	0	2.3	5.3	0	0.3	7.6	5.6	5.0	0	5.6	4.0
Microelectronics and optoelectronics	1.0	0.6	0	0.7	6.7	0	0	0	0	0	0	2.4	3.7
High-performance computing and networking	7.1	0	0	2.0	1.2	0	0	0	0.3	0	0	1.6	2.4
High-definition imaging and displays	0.4	0.1	0	0.3	0.4	4.6	0	0	0	0	0	1.0	0.4
Sensors and signal processing	0.9	0.7	5.0	3.6	7.4	0	2.9	2.4	0	0	10.0	3.3	4.6
Data storage and peripherals	0.7	0	0	0	1.2	0	1.1	0	0	0	0	0	0.8
Computer simulation and modeling	6.5	2.1	10.0	4.0	7.4	4.6	3.9	8.5	12.2	5.0	0	8.4	6.7
Applied molecular biology	8.8	0.3	0	0	0.1	0	0.6	0	0	0	0	0	1.9
Medical technology	2.2	0	0	0	0	0	0	0	0	0	0	1.0	0.6
Aeronautics	0	0	0	0	0	0	0	0	0	0	0	1.3	0.2
Surface transportation technologies	0	4.2	0	0	0.2	0	1.2	0	0	0	0	1.0	0.5
Energy technologies	12.6	39.7	0	68.6	3.6	83.1	1.0	41.3	25.8	90.0	0	12.5	13.6
Pollution minimization, remediation, and waste management	2.3	1.7	10.0	1.3	2.5	0	77.6	0.3	9.5	0	0	11.1	8.8
Other[d]	10.5	0.4	0	0	14.5	0	0.5	8.1	3.6	0	90.0	9.3	10.2

(continued)

Critical technology[b]	ER	CE	ES&H[c]	NE	DP	NPR	ERWM	FE	CRWM	PPA	INT	WFO	All programs
Research funds not expended on critical technologies	22.7	20.3	75.0	0	34.9	0	4.8	0	29.6	0	0	27.1	25.9
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Legend

ER = Energy Research
CE = Conservation and Renewable Energy
ES&H = Environment, Safety and Health
NE = Nuclear Energy
DP = Defense Programs
NPR = New Production Reactors
ERWM = Environmental Restoration and Waste Management
FE = Fossil Energy
CRWM = Civilian Radioactive Waste Management
PPA = Policy Planning and Analysis
INT = Intelligence
WFO = Work for Others

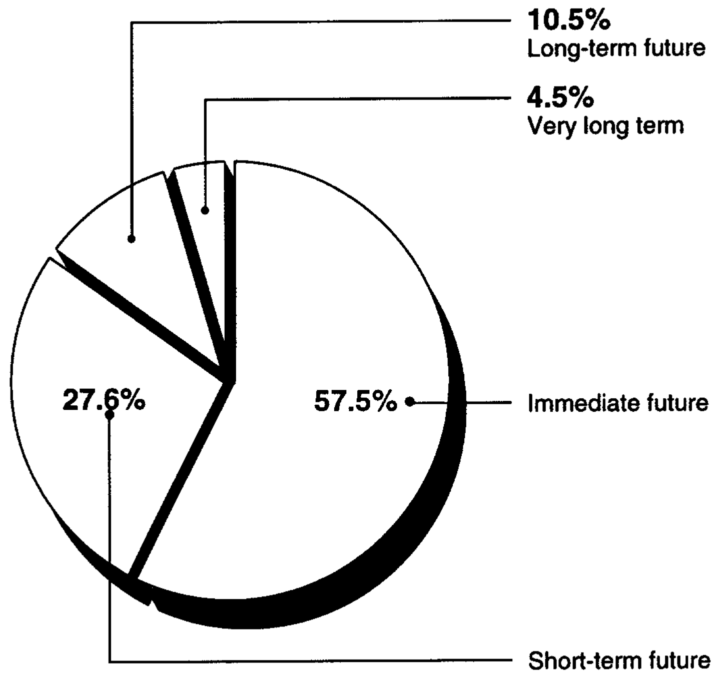
[a]Fiscal year 1992.

[b]Responses were not collected from Brookhaven National and National Renewable Energy Laboratory.

[c]Only one laboratory provided complete information for the ES&H program. ES&H activity at this laboratory provides support for environmental protection at DOE sites in several areas, ensuring safe facility management practices, developing and recommending radiation and chemical protection policies and practices, and evaluating the health of DOE personnel and the public. R&D to improve dosimetry and measurement techniques also is undertaken.

[d]Subprogram expenditures for activities other than those listed above, such as robotics, special nuclear materials, environmental R&D, and detector technology.

Figure VI.1: Program Managers' Views of Programs' Commercial Product Potential[a]



[a]Total exceeds 100 owing to rounding.

Comments From the Department of Energy

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Department of Energy
Washington, DC 20585

September 14, 1994

Mr. Kwai-Cheung Chan
Director, Program Evaluation in Physical
Systems Areas
Program Evaluation and Methodology
Division
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Chan:

The Department of Energy appreciates the opportunity to review and comment on the General Accounting Office's draft report entitled "National Laboratories: Research and Development Activities."

Minor editorial changes have been provided to the General Accounting Office under separate cover.

See comment 1.

Our major concern is that the data base, definitions of research and development, and conclusions based on the data do not provide an accurate picture of the current efforts of the Department of Energy laboratories and do not contribute to the debate on the role of the laboratories in helping to address the Nation's security, environmental, energy, scientific and economic needs of the future. The report reflects a lack of understanding relating to the phases of research and development, the basic and applied research and development activities of the laboratories, and the Department's technology transfer program.

For example, the report combines "development" with technology transfer and technical assistance and defines it as research related to "commercial product development." This leads to the erroneous conclusion that laboratory research and development is evenly divided between basic and applied research, and research related to commercial product development. The report notes, however, most of the development work was devoted to defense research "which may have more limited market opportunities, rather than nondefense research."

See comment 2.

Moreover, additional data is necessary to help Congress consider how the National Laboratories of the Department of Energy can best be focused to help solve the problems our Nation faces during the current decade. That data could include quantitative trends on how the missions of the Department and its laboratories evolved, information on the core competencies developed at the laboratories and dollars invested in the extensive science base. Budget data on current missions of the laboratories in support of critical technologies, and data on all of the laboratory collaborations with industry that contribute to the Nation's economic growth would also be useful. Also the report should include more detailed information leading to a better understanding of work carried out by the laboratories for other agencies and the private sector, and their impact on the economy.

Printed with soy ink on recycled paper

See comment 3.

It is misleading to say that the National Laboratories do product development work. What they typically do is work with partners so that the partners can then carry out the product or process development work. The statements made in the draft about product development do not seem to be based on a firm understanding of the product development process. This is further revealed in the draft report statement about lack of outcomes for the "development" work done at the laboratories. It typically will take years from the conclusion of a Cooperative Research and Development Agreement (CRADA) and the transfer of a technology to a partner, to the commercialization of a product. Incremental product and process improvements will proceed faster. The draft does not recognize this.

See comment 4.

See comment 5.

See comment 6.

See comment 7.

See comment 8.

The report states that the General Accounting Office could find no existing documentation to develop a comprehensive description of current research activities in the ten laboratories, and therefore, collected the data through a survey of the laboratories. The institutional plans and research and development data base for all of the laboratories contain data comparable to and more up to date than the data in the report and is readily available in the Department of Energy Headquarters. One example of the report's inaccurate data is that Department of Energy now has more than 1,000 CRADAs rather than the 183 cited. The absence of the General Accounting Office's interaction with Headquarters also has resulted in a lack of understanding of the missions of the Department and the roles of the laboratories in carrying them out. The report does not clearly state that funds are distributed among the laboratories based on program needs, laboratory expertise, and peer review mechanisms. The report also suffers from an over-emphasis on the number of CRADAs at the laboratories and a lack of discussion of other mechanisms, such as cost-shared cooperative agreements, scientific user facilities, licensing agreements, and personnel exchange agreements. The report's attempt to quantify and compare outputs from the laboratories is not a valid method for assessing the impact of these institutions. In this regard, the General Accounting Office's finding that the laboratories have produced more publications and reports than they did commercial products is a fallacious comparison that implies an unwarranted criticism of the research enterprise.

See comment 9.

Also, the report does not contain human resources data, as requested. The numbers of scientists, engineers and skilled technicians could be compared with the research and development resources of other agencies and the private sector. In addition, the use of percentages to describe laboratory research and development expenditures does not give a true picture of the dollar magnitude of the investment in the research and development areas discussed, nor can they be compared to the investments of others. A comparison of the research and development activities of the laboratories of other agencies to the Department's laboratories would also be useful in determining whether the enormous technical capabilities and experimental facilities will, perhaps, become the best means of enabling new national research and development missions. It will be very difficult, if not impossible, to make such comparisons with the General Accounting Office data base.

While the report attempts to present complex data, without further refinement, it is difficult to see how this data, as reported, and the General Accounting Office's conclusions will be useful to Congress.

Sincerely,

Joseph F. Vivona
Chief Financial Officer

The following are GAO's comments on the September 14, 1994, letter from DOE.

GAO Comments

1. The definitions for basic research, applied research, and development that our study employs are derived from a Congressional Budget Office study of the federal R&D enterprise. The definition of technology transfer is the one used in our study of the Technology Transfer Act of 1986 and the definition of technical assistance is based on expert opinion. Our analysis examined the laboratories' effort in each type of activity separately, and grouped, in two major categories, in order to address the study objective: to provide an empirical base for examining the extent to which the laboratories are engaged in basic and applied research or research related to commercial product development. Figure 1 and tables IV.1-IV.4 allow the reader to view our findings in both the two major categories and as separate R&D-related activities. The finding for each major category presented in figure 1 is the sum of the findings for the corresponding separate R&D-related activities presented in the last column of table IV.1.

DOE disagrees with the category we established for "research related to commercial product development"—that is, that development, technical assistance, and technology transfer are all laboratory activities related to commercial product development—but does not question our definitions or findings for each separate activity. We agree that DOE may decline to accept our definition for research related to commercial product development, but we do not agree that our finding for the sum of the three separate activities is erroneous. This finding is based on laboratory research managers' estimates of the distribution of their subprograms' expenditures that were collected, verified, and analyzed according to generally accepted government auditing standards. We consider these estimates, made by research managers who are closely involved with the R&D, more accurate than estimates that may be obtained by other methods.

2. The analyses we produced were intended to establish baseline data for addressing empirical questions underlying the public debate, rather than to serve as a comprehensive analysis of the laboratories' roles. To address the study objective, we focused on the 10 laboratories as a set of institutions, on comparing the distribution of expenditures for five types of R&D-related activities both within and among the 10 laboratories, on the nature and scope of their outputs, and on their potential for working with industry to bring commercial products to market. Given this approach, with the exception of expenditures for critical technologies and

collaboration with industry, which we do examine, the other factors DOE suggests for analysis are beyond the scope of this study. However, we anticipate that our study might stimulate another party to undertake the type of institutional, comparative analysis that DOE suggests.

3. We agree with DOE that the laboratories collaborate in R&D with industry partners who then perform the additional testing and research activities required for commercial application. We also agree that "it typically should take years from the conclusion of a CRADA and the transfer of a technology to a partner, to the commercialization of a product." The explicit definitions of terms and the discussion of CRADAs in the report make this clear. (See pp. 6, 12, and 15.) However, we disagree that the report attributes commercial product development work to the national laboratories.

4. We state in the section on Methodology that we began our work with a survey of the laboratories' R&D activities because we could find no **sufficiently comprehensive** (emphasis added) existing documentation. To confirm that we had not overlooked an important information source when we designed and implemented our data collection strategy, we made inquiries about DOE's institutional plan and research and development databases. We found that DOE headquarters maintains only the institutional plan database and that it includes only one of the data items, research program budget, that we used in our report. This budget information was available for fiscal years 1989-91 when we implemented our survey but would not have been useful for our analyses because it is not compiled at the same level of detail as our data.

We also found that the research and development database is not one of DOE's databases. It is being developed by the Critical Technologies Institute for the Office of Science and Technology Policy (OSTP) in the Executive Office of the President. When it is complete, it will have five data items analogous to our data. However, this database was not available when we developed our national laboratory inventory and is not now available to users other than OSTP. Forty-one of the items in our report are not included in either the institutional plan or research and development databases.

The Laboratory Management Division in DOE's Office of Energy Research maintains the institutional plan database. It has research program budget data for fiscal years 1979 to the present at the program level for 9 of the 10 national laboratories, and it has subprogram budget data for selected programs, such as energy research, defense programs, civilian radioactive waste management, and work for others. Because they are incomplete at the subprogram level, these data would not have been useful for our R&D-related activities and critical technologies analyses, which required budget data for all subprograms in our sample. Further, none of the budget data for the National Renewable Energy Laboratory are included in the institutional plan database. These data must be obtained from NREL's hardcopy institutional plan, which is available from the Office of Energy Efficiency and Renewable Energy at headquarters.

The Critical Technologies Institute's research and development database will have information on laboratory expenditures for basic research, applied research, development, and technology transfer for research subprogram categories analogous, but not identical, to those we used, and on CRADAS—for the national laboratories as well as for the laboratories of several other federal agencies—when it is available to organizations other than OSTP. The Critical Technologies Institute representative to whom we spoke could not specify when the database will be available. However, the research and development database will not have information comparable to the 16 research subprogram outputs we collected from the laboratories nor on the proportion of subprogram expenditures for the 22 critical technologies and the proportion of expenditures for technical assistance.

We are also aware that abstracts of CRADA agreements can be obtained through DOE headquarters from the Office of Scientific and Technical Information, which is based in Oak Ridge, Tennessee. However, we also found these data to be incomplete. In August 1992, we requested these data through DOE's Office of Technology Utilization at headquarters and received 147 abstracts for the nine laboratories from which we collected CRADA information—49 fewer than the total the laboratories reported to us. Since the fiscal year was not then complete, we assumed that all CRADA information had not yet been reported to DOE or entered into the database.

Our experience developing the survey frame, moreover, suggested that the laboratories' institutional plan data needed modification to address our study requirements and that the information available from DOE was not consistent with information available from the laboratories. We used the list of research programs included in the institutional plans as a preliminary frame for part I of the survey. Recognizing that the laboratories are dynamic institutions, we asked each laboratory to confirm the list before survey implementation. Most of the laboratories made both deletions and additions to the list to meet our survey selection criteria.

(See p. 4.) We used the lists of facilities reported in the DOE report, Capsule Review of DOE Research and Development Laboratories and Field Facilities, as a preliminary frame for part II of the survey. The laboratories made deletions and additions to these lists as well and in two cases almost completely replaced them. Changes of this magnitude confirmed the strategy of collecting data directly from the laboratories to address our study's information requirements.

5. During the agency review of our draft report, two laboratories provided us with additional CRADA information, bringing the total number of CRADAS in effect among all programs in operation in any year from fiscal year 1989 to 1992 to 196. (See table VI.1.) This total is the number of CRADAS in effect in fiscal year 1992, rather than "now," to which DOE refers and which we assume is fiscal year 1994. Moreover, we found a substantial increase in CRADA formation in fiscal year 1992, sponsored by DOE's defense program technology transfer initiative at Sandia. (See tables VI.1 and VI.2.) It is possible that the increase we found persisted and included more laboratories, bringing the total to 1,000 in fiscal year 1994. However, such a change would not render our finding for fiscal year 1992 inaccurate.

6. Brookhaven brought it to our attention that the number of CRADAS formed is limited by the amount of money allocated to a laboratory and that this amount varies widely from laboratory to laboratory. We agree with Brookhaven that characterizing CRADA formation as the "strongest" indicator of a laboratory's commercial product potential is misleading for this reason, and we have modified our discussion of CRADA findings.

Scientific user facilities and personnel exchanges will be examined in a separate study. Licensing is described in the section on Principal Findings of this report. (See pp. 13-14.) CRADAS are cost-shared cooperative agreements targeted to a commercial innovation.

7. We treat laboratory outputs as measures of activity, not as measures of impact or productivity. (See pp. 7-8.)

8. We found that the 10 laboratories produced many more publications and reports (21,593) than they did outputs related to commercial product development (2,510) in fiscal year 1992. This is a statement of fact, tabulated from reports to us by the laboratories' research managers. It describes the laboratories' activity. It is not intended as a criticism of the research enterprise.

9. The purpose of this report was to examine the balance of R&D-related activity across the laboratories, rather than to examine the magnitude of the R&D investment. We used the proportion of funds expended for each type of R&D-related activity as a measure of activity, not as a measure of investment. (See pp. 6-7.) An examination of human resources and a comparison of DOE's national laboratories to those of other agencies was beyond the scope of this study, given its focus on laboratory R&D-related activity.

Comments From Argonne National Laboratory

A representative of Argonne, Internal Audit, called us on July 5, 1994, to report that the laboratory had no substantive comments on the report draft.

Comments From Brookhaven National Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

P.O. Box 5000
Upton, New York 11973-5000

TEL (516) 282- 2772
FAX (516) 282 5803
E MAIL

Office of the Director

June 27, 1994

Mr. Kwai-Cheung Chan, Director
Program Evaluation in Physical Systems Area
U. S. General Accounting Office
Washington, DC 20548

Dear Mr. Chan:

This is in response to your letter dated June 2, 1994 in which you request comments to the draft report entitled "National Laboratories: Research and Development Activities". Based upon discussions between Ms. Sara Edmondson of your office and Mr. Anthony Romano of my office, most of our initial questions about the report have been resolved. We believe that your consideration of these suggestions will more accurately reflect the Brookhaven National Laboratory contribution to your report.

The following comments have been discussed with Sara:

Now p. 4.
See comment 1.

1. p. 5. We believe the report should emphasize the fact that the BNL and NREL data in the report are based upon the earlier survey instrument which is somewhat different from the one included in the report.

Now p. 7.
See comment 2.

2. p. 10, Table 2. It is our understanding that the value for "Total Budget" of $472.6M is from our Institutional Plan dated November 1990. That plan shows a combined value of $365.7M for DOE Effort, WFO and Capital Equipment (Table IX, p. 99). As discussed with Mr. Romano an alternate acceptable value could be derived by adding the individual B&R budgets in the survey instrument supplied to GAO ($289.1M) adjusted to include the appropriate capital equipment budgets from Table A.1 attached to this letter and by subtracting the budgets of those programs which you have determined do not fit your R&D program definition. The work papers backing up this request are attached as Exhibit A.

Now table IV.1, p. 50.
See comment 3.

3. p16, Table 3. We now believe the value for BNL in this table was highly skewed by an erroneous interpretation on the part of one of our program managers. He assumed operation of the NSLS should be categorized as "other" whereas it should have been basic research. Our new interpretation is attached as Exhibit B.

TELEX 6852516 BNL DOE   CABLE BROOKHAVEN UPTONNY

Mr. Kwai-Cheung Chan - 2 - June 27, 1994

Now p. 14.
See comment 4.

4. p. 24. We question the statement regarding the importance of the formation of CRADAs as the strongest indicator of potential for commercial product development. The number of CRADAs formed is limited by the amount of money allocated to a laboratory not by the number of good CRADA proposals. The amount of funds available for CRADA's varies widely from laboratory to laboratory. The number of good proposals greatly exceeds the existing funding levels. Certainly the formation of CRADAs should be one of the three indicators of the national laboratories' potential for commercial product development, but the conclusion that it is the "strongest" indicator is misleading since it is dependent upon the funds provided by DOE.

See comment 5.

Now p. 28.

5. Table VI.1. BNL had 4 CRADAs formed in F which are not reflected this table. The data had been provided to GAO in the survey instrument, a copy of which is attached as part of Exhibit C. We also believe this should be reflected in Appendix I, Description of the National Laboratories, Brookhaven National Laboratory, p. 6. We suggest adding the following sentence "Brookhaven also performs technology transfer and offers science and engineering education programs."

Thank you for the opportunity to review and comment on the report. If you require any additional information or assistance, please call Mr. A. Romano, 516-282-4024. We look forward to receiving the final report.

Very truly yours,

Mark Sakitt

N. P. Samios
Director

for N.P. Samios

/gm

Enclosures

cc: A. Romano
H. Grahn, w/o attach.

The following are GAO's comments on the June 27, 1994, letter from Brookhaven National Laboratory.

GAO Comments

1. We have added a statement to the report clarifying this difference.

2. We have evaluated the data Brookhaven submitted and, after making the appropriate changes, added it to the database. These data have been incorporated into the tables included in the report letter and appendixes.

3. We agree with Brookhaven's evaluation of this response and have made the change they requested to the database and report tables.

4. We agree with Brookhaven and have modified the discussion of CRADA findings.

5. The information on CRADA formation Brookhaven submitted in the pilot version of the data collection instrument has been added to the database and the tables in appendix VI. We also have added the sentence Brookhaven suggests to appendix I.

Comments From DOE's Idaho Operations Office

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

United States Government **Department of Energy**

memorandum

Idaho Operations Office

DATE: June 29, 1994

SUBJECT: Comments of GAO Draft Report - (CFO-PAD-THR-94-013)

TO: Kwai-Cheung Chan
Director, Program Evaluation
in Physical Systems Areas
General Accounting Office

REFERENCE: Letter, K. C. Chan to A. A. Pitrolo, Subject: Draft Report - National Laboratories: Research and Development Activities (973356)

ID has reviewed the draft copy of the GAO report prepared from responses of DOE's 10 national laboratories. It is our observation that interpretation of "R&D" is subjective at best. Because of this subjectivity, the responses from the 10 national laboratories with respect to FY 1992 INEL R&D budgets (Table 2) should not be utilized for purposes of comparison. ID's interpretation of HQ definitions/criteria for research programs resulted in our not reflecting the entire FY 1992 INEL R&D budget on Table 2. Approximately $176M of the $275M FY 1992 INEL R&D budget was not shown.

See comment 1.
See comment 2.

Please direct any questions which you may have regarding this observation and comment to Richard Burger (208-526-0536) or Jack Reed (208-526-0013).

J. M. Wilcynski
Acting Manager

The following are GAO's comments on the June 29, 1994, memorandum from DOE's Idaho Operations Office.

GAO Comments

General Comments

DOE's Idaho Operations Office representative, who responded for Idaho, observed that the value in the "R&D Budget" column of table 2 for Idaho should be $275 million, rather than $98.7 million and that the Idaho Operations Office made this determination by applying DOE headquarters' definitions for research programs to Idaho's research programs. The list of Idaho research programs to which the Idaho Operations Office applied DOE headquarters' definitions is unspecified. We disagree with this determination, because it violated the study methodology.

Specific Comments

1. The R&D budgets of the 10 national laboratories in table 2 were not compared.

2. We coordinated data collection from the laboratories with DOE's operations office representatives, but none of them participated in any of the technical activities involving survey implementation. Therefore, the Idaho Operations Office representative may not have been aware that GAO program selection criteria should have been employed to assess the "R&D Budget" column value for Idaho in table 2 to be consistent with the methodology employed for the other nine laboratories. The use of DOE headquarters' definitions for research programs to make this determination would result in a list of subprograms that differs substantially from the one jointly developed by GAO and Idaho.

Subprograms included in the survey population were identified by laboratory representatives who applied the selection criteria we specified (see p. 4) to a preliminary subprogram list we compiled from the institutional plans and sent to the laboratories. This approach was followed by Idaho's representatives, who identified 10 subprograms. We reduced the number of Idaho subprograms to nine during the editing and coding process. The $98.7-million value in the "R&D Budget" column is the total of nine research subprogram budgets reported by Idaho program managers on part I of the national laboratory inventory data collection instrument.

Comments From Lawrence Berkeley Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Lawrence Berkeley Laboratory
University of California Berkeley, California 94720
Office for Planning & Development
(510) 486-4361

June 17 1994

Kwai-Cheung Chan
Director, Program Evaluation in Physical Systems Areas
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Chan:

We appreciate the opportunity to comment on the GAO Draft Report on "National Laboratories: Research and Development Activities". We would like to respond both with some general comments on the role of basic research in commercial product development and specific suggestions on particular portions of the document.

The general comment we would like you to consider relates to the relationship of basic and applied research to commercial development. The report is a thoughtful assessment of commercial product development in the research and development activities of the National Laboratories. What is not clear is the relationship of commercial product development to the broader needs of industry or the nation. These broad needs include the scientific and technological infrastructure required as a precursor to any industrial technology and the development of final products. As one example, no industrial development would be possible without the training of scientists and engineers as supported by universities and the national laboratories, yet clearly such training is not directed toward a particular commercial output.

See comment 1.

The opening paragraph does seem to raise this more general topic by addressing "...interest in the current balance of the research effort in the 10 laboratories research programs... (and) the extent to which the national laboratories are engaged now in basic and applied research or in research related to commercial product development." This rightly implies that commercial product development is a subset of the broader research and development role of the national laboratories. The conclusion, however, deals only with this subset. Not even the non-commercial product output of nuclear weapons research is discussed despite being one of the major activities. In short, we believe the report is far more focused than what is implied in the current introduction so clarification and discussion of this point would be valuable to all parties.

See comment 2.

See comment 3.

In addition, some of the criteria used throughout the tables for the analysis are the more easily measurable indicators (e.g. number of licenses, patents, etc.) of commercial product development, while there are other relevant areas which are not included in the analysis and perhaps hard to measure. Two in particular are "impacts" and "public domain transfers." Economic impact might be under- or over-stated by these indicators. A product, software for instance, might have lots of licensing activity but a low impact in its economic contribution to the society. Even more important is that laboratories participate in public domain transfers which have had a major economic impact, but for which no licenses, fees, or other indicators in this analysis are attributable. An example from LBL is its development of low-emissivity windows which is in the public domain, for which we receive no fees or licenses, yet can be attributed to a energy savings for the nation of over $250 million per year. A discussion somewhere of these limitations would make the analysis more insightful.

Along more positive lines, the five categories of laboratory activities on page 7 and 8 (basic research, applied research, development, technology transfer, and technical assistance) are a useful identification of different aspects of research and development. We also believe it is important to recognize, as the report does in various places, that commercial product development does not insure that commercial application will be achieved. Even industrial R&D labs have a low rate of successful commercial application.

The document as a whole is a very interesting presentation and use of complex data. We certainly support the need for such analysis for the policy makers of the U.S., and believe this is a worthy step in evaluating the relationship and role of government and industry in research and development. We applaud your effort in addressing this difficult task.

Sincerely,

Todd Hansen for

Michael Chartock
Acting Head

Enclosure

cc: C. Shank
P. Oddone
S. Samuelson, Berkeley Site Office
Eileen Rountree-McLennan, DOE/OAK
S. Buswell, LM-10

The following are GAO's comments on the June 17, 1994, letter from Lawrence Berkeley Laboratory.

GAO Comments

Although Lawrence Berkeley agreed with the study's analytic framework and with the need for studies of this type to inform congressional policymakers, the laboratory raised an issue about the relationship of the national laboratories' role in commercial product development to the broader needs of industry or the nation, which was not addressed in the report. This omission warrants clarification.

General Comments

The relationship of the national laboratories' role in commercial product development to the broader needs of industry is an issue being discussed in the public debate about the laboratories' missions and structure, but one that falls outside of the study scope. The purpose of this study was to examine the extent to which the national laboratories are engaged in basic and applied research or research related to commercial product development. Scientific and technical infrastructure, which Lawrence Berkeley gives as an example of industry need, while important to the considerations of laboratory mission and structure that serve as the study's policy context, was not addressed. It was our expectation that the findings of this study would serve as an empirical base for designing a study to address this and other institutional issues.

Specific Comments

1. The statement "interest in the current balance of the research effort in the 10 laboratories' research programs . . . . (and) the extent to which the national laboratories are engaged now in basic and applied research or in research related to commercial product development. . . ." implies that commercial product development is an indirect consequence of laboratory R&D-related activities, rather than a subset of the broader research and development role of the national laboratories. That is the meaning of the phrase "research related to (emphasis added) commercial product development," and the use of the phrase "outputs related to (emphasis added) commercial product development" elsewhere in the report. The explicit definitions and discussions of CRADAs in the report make it clear that the laboratories' involvement in commercial product development is limited to collaboration with industry partners in R&D-related activities that produce innovations with market potential and that move these technologies beyond the laboratories' walls. These definitions assume that the industry partner performs the subsequent research, testing, and

marketing activity that accomplish commercial application. (See pp. 6, 12, and 15.)

2. This study was not designed as a broad assessment of the national laboratories' roles, but to examine the balance of the laboratories' R&D-related activities in two major areas: basic and applied research and research related to commercial product development. We looked at these activities with three types of measures, and our conclusions interpret our findings for each type. The conclusion focuses on research related to commercial product development because we found slightly more activity in this area. We amplified this conclusion with an interpretation of findings for the other two types of measures. A discussion of the noncommercial product output of nuclear weapons research was not relevant.

3. We have added a discussion of these limitations to the Methodology section. (See pp. 7-8.)

Comments From Lawrence Livermore National Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Lawrence Livermore National Laboratory

OFFICE OF MANAGEMENT REVIEW

July 6, 1994

Mr. Kwai-Cheung Chan,
Director, Program Evaluation in Physical Systems Areas
U.S. General Accounting Office, PEMD Room 5844
441 G Street, NW.
Washington, DC 20548

Re: GAO Draft Report - National Laboratories: Research and Development Activities

Dear Mr. Chan:

Thank you for the opportunity to review and comment on the subject draft report.

Now page 26.

In reference to Appendix I, page 4, **Lawrence Livermore National Laboratory,** we request that you consider including the following revised description of the Lawrence Livermore National Laboratory (revisions are shown in italics).

> Lawrence Livermore was established in 1952. *The University of California operates the laboratory which serves as a national resource in science and engineering, focused on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education, with a special responsibility for nuclear weapons.* National security *has traditionally been a* special focus of the laboratory's research and development effort. Lawrence Livermore's major areas of activity *have included* research, development, and testing for all phases of the nuclear weapons life cycle; strategic defense research; arms control and treaty verification technology; inertial confinement fusion; other energy research; research in biological, ecological atmospheric and geophysical sciences; charged particle beam and free-electron laser research; advanced laser and optical technology applications; technology transfer; and science education. The laboratory also participates in human genome research as part of a nationally directed initiative.

The above revision provides a balanced description of the Laboratory's current mission and its major activities during the period encompassed by the study (fiscal year 1989-92).

We appreciate your consideration of our comments and those provided by Lawrence Berkeley and Los Alamos National Laboratories in finalizing your report on research and development activities at the national laboratories. If you have any questions or require any additional information, please contact Mr. John Keane at 510-422-5381.

Sincerely

Charles A. Dobson

Charles A. Dobson, Manager
Office of Management Review

cc: R. W. Cochran
W. A. Lokke
P. T. Schafer
C. B. Tarter
E. Rountree-McLennan DOE/OAK

115/CAD:yw

An Equal Opportunity Employer • University of California • P.O. Box

The following are GAO's comments on the July 6, 1994, letter from Lawrence Livermore National Laboratory.

GAO Comments

We have added the revised text describing Lawrence Livermore Laboratory to appendix I.

Comments From Los Alamos National Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Los Alamos
NATIONAL LABORATORY

Audits and Assessments Office
Mail Stop A115
Los Alamos, New Mexico 87545
(505) 665-3104, FAX 667-7340

Date: June 23, 1994
Refer to: DAA-94-149

Mr. Kwai-Cheung Chan, Director
Program Evaluation in Physical Systems Areas, PEMD
U. S. General Accounting Office
441 G Street N.W.
Washington, D.C. 20548

Dear Mr. Chan:

GAO DRAFT REPORT: NATIONAL LABORATORIES RESEARCH AND DEVELOPMENT ACTIVITIES (973356)

Thank you for the opportunity to review and comment on the subject draft report.

The only comments the Laboratory has are the following:

BACKGROUND

The formal recognition of the legal division of DoD and Civilian control regarding nuclear weapons research and development and manufacture seem a glaring omission in the context of the historical role of the nuclear weapons labs visa statutory responsibility. Also, we would suggest that the middle paragraph on page 2 be modified to include the words "nuclear weapons research and development". This will allow the prose to be consistent with the definitions of research and development that are defined elsewhere in the document.

If you would like to discuss this matter further, please feel free to call me at (505) 665-3104. Once again, let me thank you for the opportunity to comment on this draft audit report.

Sincerely,

MRPatterson

Margaret R. Patterson, Director
Audits and Assessments Office

MRP:mcm

An Equal Opportunity Employer/Operated by the University of California

The following are GAO's comments on the June 23, 1994, letter from Los Alamos National Laboratory.

GAO Comments

We have added a footnote to the Background section discussing the legal division of Department of Defense and civilian responsibility for nuclear weapons research and development. We also expanded the phrase on page 2 from “weapons development” to “nuclear weapons research and development.”

Comments From National Renewable Energy Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393
(303) 231-1000

NREL

June 22, 1994

Kwai-Cheung Chan
Director, Program Evaluation in Physical Systems Areas
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Chan:

After reviewing the draft report, National Laboratories: Research and Development Activities, I have the following comments.

See comment 1.

Pg. 1: Refers "to baseline data for reports on a number of DOE laboratory policy issues." It would be nice to present some of the topics that these reports might cover in the future.

Now p. 2.
See comment 2.

Pg. 1,2: Alludes that NREL is a multi-program laboratory, which it is not; it is a "Program-directed Laboratory." You might consider describing briefly some pre-NREL/SERI background. This report tends to give the impression that NREL sprung up out of no where.

Now p. 8.
See comment 3.

Pg. 11: A simple table, supplemented by some text, might better convey the overall information on different types of R&D activities by all of the national labs.

Now p. 10.
See comment 4.

Pg. 14: Table 1. Split out the three categories in the graph under commercial product development: development, technical assistance, and technology transfer in order to better portray these categories.

Now p. 15.
See comment 5.

Pg. 26: A table that shows the percent of critical technologies for each lab would be useful.

Now p. 28.
See comment 6.

Appendix 1, Pg. 7: NREL was not authorized as a DOE multi-program laboratory in 1991. President Bush designated it a national laboratory.

If you have any questions or would like to discuss this material further, my phone number is 303-275-3027.

Sincerely,

J. Sherman Feher

J. Sherman Feher
Senior Planner

cc. Duane Sunderman

A Division of Midwest Research Institute

The following are GAO's comments on the June 22, 1994, letter from National Renewable Energy Laboratory.

GAO Comments

1. One future report will provide a descriptive statistical analysis of the technical and operating characteristics of the national laboratories' major research facilities. Other topics are yet to be determined.

2. We have made this correction to the text.

3. Graphs and tables are presented in the section on Principal Findings.

4. The aggregation in figure 1 is intentional. The graph is designed to illustrate the balance between the two major areas of R&D-related activity we examined. The last column of table IV.1, labeled "All Labs," presents percentages for development, technical assistance, and technology transfer for the 10 laboratories.

5. See table VI.3 in appendix VI. Table VI.4 presents these percentages by program area.

6. We have made this correction to the text.

Comments From Oak Ridge National Laboratory

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

OAK RIDGE NATIONAL LABORATORY
MANAGED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE U. S. DEPARTMENT OF ENERGY

POST OFFICE BOX 2008
OAK RIDGE, TENNESSEE 37831

June 21, 1994

Dr. Kwai-Cheung Chan
Director, Program Evaluation in Physical
Systems Areas
United States
General Accounting Office
Washington, D.C. 20548

Dear Dr. Chan:

Thank you for the opportunity to comment on the draft GAO report "National Laboratories: Research And Development Activities."

We have been requested by the Department of Energy's, Oak Ridge Operations Office to send our comments through them to the Department for coordinating and transmission to you.

Sincerely,

Alvin W. Trivelpiece
Director

cc: File - RC

We did not receive Oak Ridge's written comments from DOE. We did discuss Oak Ridge's views with laboratory representatives by telephone on June 22 and July 13 and 19, 1994, and we spoke with a representative of DOE's Oak Ridge Operations Office on July 7, 1994. We also received new output data for Oak Ridge's subprograms by facsimile from representatives of both organizations. A summary of their comments and our response follows.

GAO Comments

Oak Ridge raised two general issues. One was the effect of the study sampling methodology on findings for the laboratory's outputs related to commercial product development. Oak Ridge took the position that most of the laboratory's outputs related to commercial product development were produced by subprograms not selected in the study sample and, consequently, expressed the concern that GAO's findings for outputs related to commercial product development based on the sampled subprograms may not be representative because of this distribution of outputs among all laboratory subprograms. Most of these outputs, they explained, are produced by programs that fall below the $10-million threshold for inclusion in the survey. In fact, according to tabulations they had performed, the sampled programs, while representing 73 percent of the overall budget, produce only 7 percent of the outputs in question.

Secondly, Oak Ridge thought that the report's definitions and analyses equate development work with commercial product development and that the conclusion based on this definition is not supported by the data. We address these issues separately.

First, Oak Ridge actually had identified two sources of potential underreporting: (1) data for outputs of sampled subprograms that were not available at the time of the survey and (2) data for outputs of unsampled programs. We agreed that additional data for sampled subprograms should be added to findings for Oak Ridge. We requested and received from Oak Ridge the new data for the sampled subprograms, and we added them to our database and report tables.

We did not add to our database and report tables the summary data Oak Ridge tabulated as total outputs (including unsampled subprograms) for the entire laboratory. To have incorporated these data would have violated the sampling methodology. Moreover, without more detailed information at the subprogram level, we could not judge to what extent these totals represented outputs of research and development programs. This was a matter of some concern to us, particularly in light of the large number of outputs Oak Ridge ascribed to the unsampled programs.

Second, we disagreed that the report definitions and analyses equate development work with commercial product development. Our definitions, analyses, and conclusions make it clear that the laboratories were not expected to produce commercial products. We defined development as having "some type of product as the output **goal** (emphasis added)," but concluding "with a prototype rather than a usable good." Further, we point out that "Additional time, research, and testing are required to convert the prototype to a weapon or commercially viable product." The definitions of outputs related to commercial product development, including those for precompetitive commercial products and processes, state that these outputs **tend** (emphasis added) to arise from development work, but that "they will require a substantial additional investment before they are ready to market." The conclusion, moreover, reiterates that these outputs are "precursors to marketable goods," and that, for this reason, "it is too early to determine whether this activity will produce technologies with commercial uses."

We also examined the assumption that R&D is a linear process, with all commercial product-related outputs arising from development, and found that our data did not support it. We included this segment of the analysis to emphasize the uncertainty associated with current understanding of the operation of the R&D process, and the origin of technologies with commercial potential. The conclusion we reached concerning the uncertain prospects of the laboratories' commercial product-related outputs is an interpretation of this finding as well as our definitions for outputs related to commercial product development.

Comments From Pacific Northwest Laboratory

A representative of Pacific Northwest, called us on June 22, 1994, to comment on the draft report by telephone. A summary of the laboratory's comments is included in our response, which follows.

GAO Comments

Pacific Northwest offered one general comment and several comments and questions about specific items in the text. We address the general comment first and then the specific comments.

General Comment

Pacific Northwest suggested that a section be added to the report describing the major commercial product-related initiatives the national laboratories have undertaken since the end of fiscal year 1992. Partnership for a New Generation of Vehicles (PNGV) and American Textile Partnership (AMTEX), two consortia for R&D targeted on commercial applications in which several laboratories are participating, were mentioned as examples.

We are aware that the laboratories have been active in technology transfer activities of many types since the end of fiscal year 1992. This activity will be captured in any follow-up study that is performed in the next few years to determine if progress has been made since fiscal years 1989-92, the time period measured in this report.

Specific Comments

1. Pacific Northwest thought that the word "primarily" in the sentence beginning on draft line 10, page 4 (now line 12, p. 3), should be deleted because it implies that the laboratories have only one primary mission. We have modified this sentence.

2. Pacific Northwest said that the output data in table 5 (now table V.1) not reported for the laboratory are available and will be submitted to us. We received and reviewed the data, and we added it to table V.1.

3. Pacific Northwest said that information on CRADA formation for the laboratory as a whole was submitted to us during survey implementation. We confirmed that this information had been received and added it to table VI.1.

Comments From Sandia National Laboratories

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Sandia National Laboratories

P. O. Box 5800
Albuquerque, New Mexico 87185-0123

Managed and Operated by Sandia Corporation
a subsidiary of Martin Marietta Corporation

William W. Hollis
Director
Audit Center

July 1, 1994

Kwai-Cheung Chan
Director
Program Evaluation in Physical Systems Areas
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Chan

On behalf of Dr. Al Narath, thank you for the opportunity to comment about GAO's draft report on *National Laboratories: Research and Development Activities*. The report accurately depicts the contribution that DOE's Weapons Program R&D activities have made to the national security mission, as well as the commercialization process and technology transfer.

We believe the concept of creating this document is worthwhile, the methodologies for collecting the data are appropriate, and we suggest further updating the report's contents to include the national laboratories' FY 1994 activities. Since creation of the draft report's FY 1992 baseline statistics, DOE's National Laboratories have significantly expanded their technology transfer expertise, and reporting that progress could further enhance the document's potential for addressing that issue.

During our review of the report, we particularly noticed Table VI.3—"Distribution of Expenditures for Critical Technologies Within Laboratories: Mean Percent." Our experience indicates that data ranges this broad within the weapons laboratories are unusual. We suggest an additional review of these data.

The attached addendum to this letter contains additional editing suggestions for the report. If you have any further questions, please contact A. T. Schwyzer, (505) 844-2403.

Sincerely,

WW Hollis

Exceptional Service in the National Interest

The following are GAO's comments on the July 1, 1994, letter from Sandia National Laboratories.

GAO Comments

Sandia agreed with the report's objective, methodology, and conclusion, but made two general comments. First, Sandia suggested that the report include a description of the national laboratories' expanded efforts in technology transfer during fiscal years 1993-94. Second, Sandia suggested that we review the substantial variation in the percentage of laboratory funds not expended for critical technologies reported for Lawrence Livermore, Los Alamos, and Sandia in table VI.3. Sandia expected this percentage to be very similar for all three laboratories.

We are aware that the national laboratories have been active in technology transfer activities of many types during fiscal years 1993-94, including participation in large-scale R&D consortia such as PNGV and AMTEX. These activities will be captured in any follow-up study that is performed during the next few years to determine if progress has been made since fiscal years 1989-92, the time period measured in this report.

We reviewed all responses by Lawrence Livermore, Los Alamos, and Sandia concerning percent of expenditures for critical technologies and funds not expended for R&D in these areas. We found that Lawrence Livermore program managers allocated a percentage of funds expended to the "other" category to a much greater extent than did program managers at Sandia or Los Alamos. We also found considerable variation among all laboratories in the proportion of expenditures allocated to this category. R&D activities specified in the "other" category included items such as robotics, special nuclear materials, environmental R&D, and detector technology. Allocations to this category, and to the energy technologies category, accounted for most of the difference in proportion of funds not expended for critical technologies by Lawrence Livermore, Los Alamos, and Sandia.

Major Contributors to This Report

Program Evaluation and Methodology Division

Robert E. White, Assistant Director
Sara E. Edmondson, Project Manager
Dale W. Harrison, Computer Analyst
Venkareddy Chennareddy, Referencer
Richard R. Scott, Project Adviser
Gerald L. Dillingham, Project Adviser
Eric M. Larson, Project Adviser
Nancy A. Briggs, Project Adviser

Denver Regional Office

Miguel A. Lujan, Project Adviser

Ordering Information

The first copy of each GAO report and testimony is free. Additional copies are $2 each. Orders should be sent to the following address, accompanied by a check or money order made out to the Superintendent of Documents, when necessary. Orders for 100 or more copies to be mailed to a single address are discounted 25 percent.

Orders by mail:

U.S. General Accounting Office
P.O. Box 6015
Gaithersburg, MD 20884-6015

or visit:

Room 1100
700 4th St. NW (corner of 4th and G Sts. NW)
U.S. General Accounting Office
Washington, DC

Orders may also be placed by calling (202) 512-6000
or by using fax number (301) 258-4066.

Each day, GAO issues a list of newly available reports and testimony. To receive facsimile copies of the daily list or any list from the past 30 days, please call (301) 258-4097 using a touchtone phone. A recorded menu will provide information on how to obtain these lists.

PRINTED ON RECYCLED PAPER

United States
General Accounting Office
Washington, D.C. 20548-0001

Bulk Mail
Postage & Fees Paid
GAO
Permit No. G100

Official Business
Penalty for Private Use $300

Address Correction Requested