AN ANALYSIS OF MAJOR FEDERAL LABORATORIES IN CALIFORNIA

VOLUME II: POLICY OPTIONS AND BACKGROUND INFORMATION

A REPORT PREPARED FOR

THE CALIFORNIA COUNCIL ON SCIENCE AND TECHNOLOGY

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ABOUT THE CCST CALIFORNIA REPORT ON THE ENVIRONMENT FOR SCIENCE AND TECHNOLOGY

CCST's California Report on the Environment for Science and Technology (CREST) has analyzed the state's science and technology infrastructure to determine if California has the people, capital investment and necessary state governmental policies to maintain California's leadership in the face of increasing worldwide competition. Through eight individual research projects, CREST analyzes the state's ability to create and use new technology. By facilitating a dialog with policy makers, industry leaders, and academic communities, CCST hopes to enhance economic growth and quality of life for Californians.

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This report examines major Federal laboratories in California and their current and possible future contributions to the state's economy. The report is part of a larger study of the California science and technology infrastructure being conducted by the California Council on Science and Technology (CCST). The report is divided into two parts – an Overview (Volume I) and this second volume, which presents more details on policy options and the laboratories.

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1. Introduction and Options for Expanding the Contributions that Major Federal Laboratories Make to the California Economy

1.1 Introduction to the Report

This report examines major federal laboratories in the State of California and their current and possible future impacts on the California economy. It particularly focuses on three major laboratories with close connections to California industry and universities – the Lawrence Livermore National Laboratory (Lawrence Laboratory or LLNL), the Lawrence Berkeley National Laboratory (Berkeley Lab or LBNL), and the Jet Propulsion Laboratory (JPL). In addition, the report also briefly examines other federal laboratories in the State that conduct research and development (R&D). California has a total of 48 federal R&D laboratories, more than any other state.

This report is part of a larger study of the California science and technology infrastructure being conducted by the California Council on Science and Technology (CCST), with support from the Keck Foundation. The purpose of the overall study is to collect and analyze data regarding science and technology resources in the State of California and to make recommendations on how to improve the performance of this infrastructure and the contributions it makes to the economy and well being of the state.

While these government laboratories in California exist to serve federal missions – defense, energy, space, and so forth – and do not exist primarily to help either industry generally or California industry in particular, the laboratories nonetheless contain great scientific and technological resources which they are increasingly willing to share with companies and universities within the state. This makes them a significant resource for the California economy and one deserving of close attention.

1.2 Five Tasks

This report focuses on five specific tasks, the most important of which is to identify policy options and organizational options for continuing and strengthening the contributions federal laboratories in California make to the state's economy. This chapter presents such a set of policy and organizational options. The same options are also presented in Volume I of this report, the Overview.

This volume's other chapters and its appendices address the other four tasks -- tasks which provide background information on the laboratories and the federal policies which affect them. Those four tasks are:

- Identify the main programs, resources (particularly those relevant for California), and budget trends for LLNL, LBNL, and JPL, as well as briefly discuss the programs of other major federal laboratories in California.
- Analyze how federal policies now affect laboratory interaction with industry and universities.
- Estimate, with appropriate quantitative and qualitative measures, the value to date to California of industry and university interaction with these three laboratories.
- Identify likely future missions and activities for these three laboratories, and the implications of those missions and activities for the California economy.
- Analyze how federal policies regarding laboratory interaction with industry and universities are evolving, and the implications for the California economy.

1.3 Options for Expanding the Contributions that Major Federal Laboratories Make to the California Economy

What can be done at the federal, state, laboratory, university, and industry levels – in terms of both policy and organization – to continue and strengthen the contributions that these federal laboratories make to the California economy? Specifically, who should do what and when? This chapter suggests some possible steps.[1] These options are also presented in Section 4 of the Overview.

1.4 Steps Regarding Federal Policy

California citizens and officials – including the California Congressional delegation – may wish to consider taking the following steps regarding federal policy:

1. *Identify current and potential future laboratory programs valuable to the California economy or other problems important to the state.* Federal laboratories in California are a source of jobs, procurement contracts, valuable technologies and technical expertise, and research opportunities for faculty and students. For example, JPL's work with industry to develop new, less expensive satellite platforms may eventually be of significant value to the state's commercial satellite industry, and the Laboratory's expanding program of research grants to universities is already important to academic researchers

[1] The suggestions offered in this section have not been formally reviewed by the California Council on Science and Technology and do not necessarily reflect its views.

in the state. The Berkeley Lab's work in energy efficiency and alternative energy sources and LLNL's work in lasers, optics, and lithography environmental remediation biotechnology, and materials are likely to continue to be valuable to California companies.

In addition, the laboratories' collection of broad multidisciplinary capabilities has the potential for working with state agencies, industry, and others to help address problems of particular importance to the state, such as environmental remediation and protection, transportation, and seismic studies and hazard reduction.

At the moment, budgets over the next few years for major DOE, NASA, DOD, and USDA laboratories in the state appear stable, but they cannot be taken for granted. Economic recession or competition with other programs or states could lead to cuts in existing programs, and competition among the states for any new projects could be intense. The following specific steps should be considered:

CCST could annually review emerging policy and budget trends that will affect laboratories in California – particularly possible new federal initiatives which, if brought to California, would not only meet national needs but also be particularly helpful to California universities and companies. These are situations in which targeted attention could make a difference in whether these valuable initiatives are funded.

As part of this process, CCST could meet annually with officials of California universities to identify which current or potential future laboratory programs are most important to the state's academic researchers. Laboratory user facilities as well as grant programs would be studied.

Beyond the current budget cycle, it would be helpful for the CCST to identify the potential match between technology advances at the federal laboratories and problems especially important or unique to California. Potential federal policy steps to facilitate practical application of these advances could then be identified. Some such initiatives would require a multi-year focus and thus should be considered strategically.

Related, CCST and the California Trade and Commerce Agency could meet periodically with key industry trade associations to identify which current and possible new federal laboratory R&D activities which, if brought to California, would not only meet national needs but also be particularly helpful to California universities and companies or deal with issues important to the state (e.g., environmental quality, transportation, and seismic safety). As companies increasingly seek new technologies from external sources and not just from their own internal R&D, the importance of federal laboratories to California companies may grow. Trade associations in this process would include the Semiconductor Industry Association, the American Electronics Association, and the Aerospace Industries Association. This approach would work particularly well with industry groups that have technology roadmaps.

To complement these discussions with trade associations, CCST might meet with the National Science Foundation (NSF), which collects data on R&D, to see if additional information is available or could be collected regarding how federal laboratory R&D in California does or does not complement industrial R&D in the state. For example, do the laboratories have real technical strength in specific R&D areas that California companies are now investing heavily in? If so, those laboratory projects could be a real asset to the state economy, and California leaders should know that. Better information on exactly what R&D areas both companies and laboratories are investing in would help this process. (Better information on federally-funded/ industrially-performed R&D in the state would also be useful. There may be technical strengths there that also would be helpful to commercial companies.)

2. Build support. Identifying valuable programs is one thing; alerting potential political supporters is another. This is particularly important because while both the President and Congress appear genuinely supportive of federal R&D budgets, those R&D programs must always compete with other parts of the federal budget. It is important to build solid Congressional support in favor of useful R&D activities – including those of DOE and NASA. Several specific steps might be considered:

After identifying current or proposed laboratory programs of particular value to the California economy, CCST or another group could create a "Technology Watch" unit that would track these laboratory programs and alert industry and the California Congressional delegation when key decisions are being made in Congress that affect these programs. One good way to communicate with the Congressional delegation is through the California Institute.

It would then be up to industry associations to take the lead in working with key California Members of Congress to build Congressional support for specific funding requests. In the case of initiatives oriented toward non-industrial opportunities or problems, it is less clear who would take the lead.

3. Support improvements in DOE technology transfer policies. Related, California officials should stress the importance of DOE clarifying and improvement technology transfer policies for its laboratories. The controversy over the recent Intel-DOE agreement on extreme ultraviolet lithography illustrates the challenges that the Department faces as it addresses policy issues associated with CRADAs. Possible steps include:

CCST could ask the California Congressional delegation to encourage DOE to reestablish within itself an ability to handle policy questions regarding CRADAs and other industrial partnerships and to resolve disputes.

CCST, on its own or in partnership with the National Research Council, could convene a workshop to explore ways of dealing with some of the more vexing issues associated with CRADAs, including the risk of being accused of aiding some companies while ignoring others and the issue of when it is appropriate to transfer taxpayer-supported technology to foreign entities.

4. Support other federal R&D programs valuable to California. California leaders also might complement the contributions of the laboratories by providing more support for other federal programs that aid industrial competitiveness or develop technologies critical to solving important California problems in areas such as disaster management, environmental management, or transportation.

While federal laboratories in the state will continue to provide important technologies and facilities as a by-product of their federal mission activities, in the present policy environment they will not shift major government resources and personnel into explicitly industrially-oriented R&D.

Other federal programs that California organizations might seek to build support for include: NSF funding in engineering and other industrially-relevant areas; the Department of Commerce's Advanced Technology Program (ATP), which provides matching grants to companies conducting long-term R&D with significant economic potential; and the federal research and experimentation tax credit. Federal laboratories participate in some ATP-sponsored projects. California benefits significantly from these other programs, and their continuation or expansion would provide additional benefits to the state – benefits complementing those of the federal laboratories.

1.5 Steps Regarding State Policy

The following are some of the steps the California state government might take to increase the contributions that federal laboratories make to the state's economy:

1. Improve links between the laboratories and California industry. As mentioned earlier, the importance of federal laboratories to California companies may grow as these firms increasingly seek new technologies from external sources and not just from their own internal R&D. Moreover, the laboratories are already a source of new startup firms, another contribution to the state's economy. As a result, it would be in the state's interest to work with the laboratories to increase their economic contributions.

To enable companies to take advantage of expertise in federal laboratories, the state could support (1) incubator programs to encourage spin-off companies from the laboratories; (2) extension programs to link the labs to small and medium-sized business; and (3) personnel exchange programs to move people between the laboratories and companies and universities in California.

In some cases, the state could build on existing programs. For example, NASA's Ames Research Center already has a small incubator program, and soon JPL and NASA's Dryden Flight Research Center will together start a similar facility, using NASA funds. Similarly, LLNL is cooperating with the local community area to establish the Tri-Valley Technology Enterprise Center. In terms of providing technical assistance to small and medium-sized manufacturers, the Trade and Commerce Agency currently supports three California centers that are affiliates of the national Manufacturing Extension Partnership; the Agency could encourage those centers to involve interested federal laboratories, as appropriate, in assistance projects for small manufacturers.

In addition, the state government or universities within California could create a matching-grant program for industry-laboratory partnerships. This program could be modeled on two existing UC activities that support university-industry cooperation – the MICRO Program for Microelectronics and Biotechnology STAR (Strategic Targets for Alliances in Research) Project. Under such a model, seed money would be provided for R&D projects that bring together researchers from the federal laboratories, universities, and California companies. Such projects could be built around either technology licenses or CRADAs. An effort could be made to encourage small high-technology firms to participate in the program.

The California Trade and Commerce Agency and the federal laboratories (perhaps through the Federal Laboratory Consortium) could work with major trade associations in California to publicize research and licensing opportunities at the federal sites. Attention could be paid to industries that might particularly benefit from interactions with the laboratories, ranging from existing industries such as semiconductors and communications satellites to emerging sectors such as biotechnology and commercial space launch vehicle firms.

CCST or the Trade and Commerce Agency could set up workshops in which research leaders and intellectual property managers from key federal laboratories in the state meet with venture capital firms, perhaps leading to a process in which these venture capitalists routinely evaluate laboratory innovations and explore commercialization possibilities.

2. Take steps to help the laboratories meet state government needs. The federal laboratories have technologies and expertise that could help state and local governments in California in such areas as environmental management, information management and systems, seismic safety, and transportation. Clearly, technical needs and opportunities do exist. Federal laboratories in

California might help with some of these needs. Some could be addressed through consulting or technical assistance projects. Other problems could require new R&D, possibly with state sponsorship or federal sponsorship (if the work addressed national needs).

Leaders at several laboratories have expressed an interest in trying to assist state and local officials with these needs, and in a number of cases the laboratories have worked closely and successfully with state agencies. Examples include LLNL's work with the State Water Resources Control Board and LBNL's partnerships with the California Energy Commission. Unfortunately, barriers also exist: state and local agencies have limited R&D resources and personnel; they are reluctant to discuss any resources they do have, for fear that these R&D resources will be easy targets for budget cutters; and federal laboratories, given their high level of expertise, are expensive to work with. For their part, the laboratories cannot afford to provide much *pro bono* assistance. Under these circumstances, policy steps to consider are necessarily modest:

CCST or another state-level organization could serve a liaison role, putting interested state officials into contact with laboratories that could help them address either internal agency needs (such as improving information systems) or pressing state problems (such as environmental remediation or seismic safety).

To help improve public services, state and local governments could allow their agencies to participate in the technology assistance programs already run by several of the federal laboratories – such as JPL's Technology Affiliates Program. While state agencies rarely will have the funds for full-scale work-for-others projects at the laboratories, they might want to take advantage of these existing, lower-cost affiliates programs. Any such initiative would need to focus on projects where the laboratories have unique capabilities, so that neither the state agencies nor the laboratories are vulnerable to accusations that they are competing unfairly with private consultants.

In terms of R&D, CCST could work with the laboratories and state officials to create a state agency equivalent to the MICRO program, with a small pot of new funds set aside to support joint projects between state agencies, laboratory researchers, and perhaps university researchers as well. One would have to think carefully about what kinds of projects make sense both substantively and politically.

The California Trade and Commerce Agency could establish a focal point to help identify technologies of particular value for California foreign trade and facilitate industry-laboratory cooperation in these areas. In certain technology fields a strong foreign market exists substantially before a domestic one develops. Examples could include desalination, fuel efficient/low pollution transportation options, and certain health care technologies. It should be noted, however, that it is not generally advisable for federal laboratories to transfer technology to foreign companies, and therefore caution is required if joint a project with a laboratory involves foreign firms as well as California companies. Exports of California-made goods, on the other hand, would not be problematic.

1.6 Laboratory Actions

Laboratory directors and the university officials who oversee FFRDC laboratories might consider the following steps to strengthen the contributions that these laboratories make to the California economy:

1. Further assist startup companies. In a state where entrepreneurs play an important role in economic growth, one of the most valuable things federal laboratories can do is assist startup companies. These are some key points:

Laboratories already assist startups in several ways: licensing laboratory technology to firms in the state, licensing technology to their own current or former employees or to others who are starting new firms, or by providing technology assistance to small companies (including SBIR winners). More assistance of this type might be very valuable.

Within California, R&D at LLNL appears to have led to the creation of many new firms – some 100 companies have been created over the years, according to the Laboratory. Some of these firms stemmed from laboratory employees who used laboratory-developed know-how as the basis for a new service or manufacture company, some involved licenses to former or current employees, and some involved outside entrepreneurs. LLNL also undertakes CRADAs with small firms and works with SBIR winners who are trying to develop new technologies. Other laboratories in the state might wish to study LLNL's approach.

JPL is grappling with the difficulties that arise when a current employee wishes to license a laboratory technology. Conflict-of-interest questions inevitably arise, as do questions of how such employees are allocating their time because the laboratory duties and their private interests. Other laboratories may wish to learn from JPL on this matter.

NASA's Ames Research Center has an incubator center devoted to helping entrepreneurs turn NASA technologies into successful companies and products. JPL and the Dryden Flight Research Center will soon open a second such NASA facility in the state. LLNL and the Tri-Valley area are establishing a Technology Enterprise Center. Other DOE, DOD, and USDA laboratories should consider similar arrangements, perhaps with local government or private funding.

2. Further improve the CRADA process. With respect to CRADAs, federal laboratories in California are now very willing to work with interested companies. Some difficulties remain, though. Some of these difficulties are inherent in the CRADA process, including the risk that political critics will claim that a CRADA project benefits some companies and not others. Other difficulties deal with the rules and process for negotiating CRADAs. LLNL, LBNL, and the UC Office of the President all have made major improvements in this area, but additional steps could improve the process even more.

First, some California companies complain of having to work first with laboratory lawyers and then with DOE's own government lawyers, who sometimes take different positions. This is a matter DOE should review.

Second, the recent controversy over the Intel-DOE CRADA on extreme ultraviolet lithography shows the importance of setting basic groundrules that the laboratories can use regarding such issues as the participation of foreign companies in CRADAs. While no set of guidelines can cover all future cases, laboratory and DOE officials should continue their efforts to anticipate the types of issues and objections that can arise over high-visibility CRADAs and provide basic guidance to technology transfer officers.

The UC Office of the President should consider holding a follow-on meeting to its 1997 *Retreat on Relationships with Industry and Technology Transfer*. This could be a symposium with laboratory and industry leaders on ways to improve interactions between the two sectors.

3. Continue offering access to user facilities. One of the most valuable services provided by the DOE laboratories remains access to sophisticated facilities that industry could not afford to duplicate. The laboratories have done a good job of opening up their facilities and making them accessible for both proprietary and non-proprietary research. If certain types of future facilities would be particularly valuable to California, state and laboratory officials should identify them and consider trying to locate these facilities in California – much as Tennessee did recently in winning support to build the new Spallation Neutron Source at Oak Ridge.

4. Improve cooperation among the laboratories. When DOE or industry is considering new initiatives, DOE laboratory directors in California could work more closely together to blend talents and create proposals stronger than if the laboratories individually sought projects. The Stanford Linear Accelerator Center (SLAC) B-Factory project demonstrated effective collaboration among SLAC, LLNL, and LBNL. The extreme ultraviolet lithography project with the Intel-led consortium involves LLNL, LBNL, and Sandia working as a single "virtual laboratory."

5. Provide more information on opportunities for graduate students. LLNL, LBNL, and JPL have long had California graduate students working in their facilities. These arrangements are beneficial to both the students and the laboratories. One possible step for the future is:

As these laboratories set R&D priorities for the coming years – such as microelectronics at JPL and advanced computing at LLBL and LLNL – their parent institutions could alert deans and department chairs of the new research directions and the opportunities for students, and ask those deans and chairs to alert faculty about these opportunities.

1.7 University Actions

As mentioned earlier under "Steps regarding federal policy," universities in California should try to identify which current and potential future programs in federal laboratories are most important to them. Two steps in particular might be valuable.

1. Take steps to stay competitive in JPL science grants. As mentioned earlier, JPL has long awarded significant science funding to university researchers, and recently those amounts have increased sharply. This expanded funding is a major opportunity for California universities. However, as seen in the data in this volume's Appendix 5 (JPL section, part 3, "Laboratory contacts with universities"), California universities have competed well in some years in getting JPL funding and poorly in others. The variance is large: in FY 1994, for example, California received 96 percent of JPL university funds, but only 19 percent in FY 1997. The overall average during FY 1993-1998 is 48 percent. Given strong competition from schools in other states, California cannot take its position for granted. Several steps should be considered:

CCST should establish an *ad hoc* committee on the space sciences to review the strengths and weaknesses of California universities in this area and to meet with JPL officials to discuss where their science program is going is coming years, what they will be looking for in university research, and what areas California researchers might focus on. (Note: If JPL hold such a meeting with California universities, it may feel obligated to hold similar informational meetings for universities in other states. Nonetheless, the information provided to California schools could be very useful.)

If and when JPL issues solicitations for large, multidisciplinary research projects, CCST should convene meetings with California space scientists and their home institutions to see explore possible joint proposals, including proposals with universities from other states, that would have an excellent chance of winning.

2. *Inform faculty and graduate students of research opportunities.* University administrators also can take steps to inform faculty, post-doctoral fellows, and graduate students of research opportunities at federal laboratories in California.

1.8 Industry Actions

Since federal laboratories in the state are willing and able to work with interested companies, California companies now have the opportunity to expand their contacts with the laboratories. Here are some relevant points:

1. Procurement opportunities. Because federal laboratories are now contracting-out activities once handled by laboratory personnel, new procurement opportunities exist.

Individual companies and industry trade associations may wish to investigate new procurement opportunities with the laboratories – both through regular procurements and laboratory-funded programmatic CRADAs.

2. Joint research and technical assistance. In terms of joint research and technical assistance, no one can say in advance how useful federal laboratories can be to California companies. On the one hand, some companies will find that they are ahead of the laboratories in certain technologies and thus have little use for laboratory assistance. Moreover, federal processes make the laboratories still relatively expensive and slow to work with. On the other hand, the laboratories remain world leaders in a range of technical areas. And working with the laboratories can be very helpful, given the strong pressures that companies now face to find new external sources of technology and to reduce R&D costs by using outside facilities and experts. The laboratories also can provide very valuable technical advice for small manufacturers, a fact shown, for example, by JPL's Technology Affiliates Program. These are some relevant points:

Industry trade associations can play a valuable role in providing information on laboratory opportunities and brokering services to companies that wish to work with federal facilities. For example, trade shows, technical meetings, and publications can provide information on laboratory programs and capabilities. Technical meetings are particularly valuable because laboratory and company researchers can meet face to face.

Entrepreneurs interested in possibly developing NASA technologies should consider working with the incubator centers at NASA's California facilities – the current incubator at Ames and the JPL/Dryden center that will soon open. Similarly, LLNL industry partners will soon be able to take advantage of the Tri-Valley Technology Enterprise Center.

2. Comparisons Among the Three Major Laboratories

This chapter uses three tables to provide some perspective on how the main three laboratories analyzed in this report – the Livermore Laboratory, Berkeley Lab, and JPL – compare with each other in terms of core competencies, mechanisms for partnering with industry, and their budgets, staffs, and interactions with universities and industry. The information on core competencies and partnership mechanisms is drawn from Appendices 2 and 3. The data on budgets, staffs, and interactions with universities and industry are drawn from Appendix 5, which contains detailed statistics supplied by three laboratories.

2.1 Areas of Core Competency

Table 1 lists the core areas of scientific and technical competency for these three laboratories, areas in which they have world-class capabilities. Many of these areas are relevant to California industry.

2.2 Mechanisms for Partnering with Industry

As discussed in this volume's Chapter 3 and Appendices 3, the three laboratories use a variety of mechanisms for engaging in R&D partnerships with industry and with state and local governments. Table 2 compares these mechanisms. As the table's footnotes explain, in some cases the three laboratories use similar mechanisms with different names. Key Facts on Budgets, Staffs, and Interactions with Universities and Industry

These three federal laboratories exist to serve federal missions. Nonetheless, they have a positive impact on California in several ways -- the number of people they employ, the ties they have with universities in the state, procurements from California companies, and technology partnerships in California. Table 3 provides a brief summary of laboratory budgets and staffs, as well as some of the benefits these laboratories generate for the state. (This table is identical to Table 1 in the report's Overview.) As mentioned above, further details are presented in Appendix 5 of this volume.

Table 1. Areas of Core Competency for LLNL, LBNL, and JPL

	LLNL	LBNL	JPL
Nuclear science and technology	X		
Lasers and electro-optics	X		
Advanced computing	X	X	X
Advanced sensors and instruments	X		X
Bioscience and biotechnology	X	X	
Advanced process and manufacturing technology	X		
Particle and photon beams		X	
Materials		X	
Energy technologies		X	
Chemical sciences		X	
Advanced detector systems		X	
Environmental assessment and remediation		X	
Communications technology			X
Imaging systems and digital imaging processing			X
Microelectronics			X
Intelligent automated systems/robotics			X
Earth and planetary sciences			X
Astrophysics			X

Sources: LLNL, LBNL, and JPL.

Note: Only areas in which a laboratory has a major core competency are listed. In addition, a laboratory may have a significant secondary competence in an unmarked area of this table.

Table 2. LLNL, LBNL, and JPL Mechanisms for R&D Partnerships with Industry and State and Local Governments

	LLNL	LBNL	JPL
Procurements	X	X	X
Licenses of laboratory patents	X	X	X
Information exchange/dissemination	X	X	X
Personnel exchanges		X	
Large-scale technology transfers *	X		X
Agency-funded CRADAs **	X	X	
Lab-funded programmatic CRADAs **	X		
Industry-funded CRADAs or TCAs **	X	X	X
Work-for-others projects ***	X	X	X
Technical assistance projects ***	X	X	X
User facility agreements ***	X	X	
Small Business Innovation Research awards ****	****		X

Sources: LLNL, LBNL, and JPL.

* LLNL has one major large-scale technology transfer, the transfer of the laser uranium enrichment process to the U.S. Enrichment Corporation. JPL has a new Targeted Commercialization Office which aims for million-dollar-level projects, industry-funded, to transfer and commercialize major JPL technologies.

** CRADAs are cooperative research and development agreements. Within DOE, agency-funded ("funded") CRADAs are where dedicated set-aside funds are used to pay the DOE portion of a project of interest to industry; lab-funded CRADAs are where the laboratory uses its own funds because the projects serve mission purposes; and industry-funded ("funds-in") CRADAs are regular CRADAs where companies pay for the projects. TCAs are Technology Cooperation Agreements, CRADA-like agreements used at JPL.

*** The terms "work-for-others projects," "technical assistance projects," and "user facility agreements" overlap. JPL has a major technical assistance program (the Technology Affiliates Program) which it considers a form of work for others. LBNL distinguishes between work-for-others projects (sponsored research) and user facility agreements, while LLNL appears to include facility agreements within the work-for-others category. LLNL and LBNL have separate technical assistance programs, with a particular focus on small businesses.

**** DOE laboratories, including LLNL and LBNL, do not themselves make SBIR awards; JPL does. LLNL does on occasion work with a small business that has won an SBIR award. LLNL also holds workshops to help interested small businesses apply for SBIR awards.

Table 3. LLNL, LBNL, and JPL Interactions with Universities and Industry

	LLNL	LBNL	JPL
BUDGETS AND STAFFS			
Laboratory budget (FY 1997)	$1013M	$ 346M	$1134M
Percent of lab budget spent on partnerships with industry (estimated)	5%	1%	1%
Employees (FTEs) (FY 1997)	6728	2566	5251
On-site contractors (FTEs) (FY 1997)	654	365	849
INTERACTIONS WITH UNIVERSITIES			
Collaborations with university researchers & students (FY 1997)	1575	1153	
(Number of these with CA researchers & students)	(361)	(90% plus)	
Research contracts with universities (FY 1998) *			$372M
(Amount of these with CA universities)			($178M)
INTERACTIONS WITH INDUSTRY **			
Procurements from industry (FY 1997)	$473M	$141M	$679M
(Amount of these with CA companies)	($303M)	(unknown)	($322M)
Total number of licenses issued FY 1993-97	236	92	544
(Number of these issued to CA entities)	(33)	(46)	(unknown)
Agency-funded CRADAs initiated FY 1993-97	84	62	
(Number of these initiated with CA entities)	(29)	(33)	
Lab-funded CRADAs initiated FY 1993-97	46	Not used	
(Number of these initiated with CA entities)	(14)		
Industry-funded CRADAs initiated FY 1993-97	52	55	
(Number of these initiated with CA entities)	(19)	(25)	
TCA projects initiated FY 1993-97			40
(Number of these initiated with CA entities)			(15)
Work-for-others projects initiated FY 1993-97	123	122	79
(Number of these initiated with CA entities)	(48)	(63)	(39)
Number of new SBIR awards lab made FY 1993-97	***	***	316
(Number of these awarded to CA small businesses)			(119)

Sources: LLNL, LBNL, and JPL. These data are excerpted from Appendix 5.

* *Note:* JPL does not count the number of academic researchers it works with. Instead, it counts the dollar value of the contracts it awards to academic researchers.

** *Key terms:* CRADAs are cooperative research and development agreements. Within DOE, agency-funded ("funded") CRADAs are where dedicated set-aside funds are used to pay the DOE portion of a project; lab-funded CRADAs are where the laboratory uses its own funds because the projects serve mission purposes; and industry-funded ("funds-in") CRADAs are regular CRADAs in which companies pay for the projects. TCAs are Technology Cooperation Agreements, CRADA-like agreements used at JPL.

*** *Note regarding Small Business Innovation Research (SBIR) awards:* In DOE, headquarters rather than individual laboratories make SBIR awards, so there are no SBIR awards listed for LLNL and LBNL. However, LLNL does in some cases work with companies that have received DOE SBIR awards. Under authority from NASA, JPL does make SBIR awards.

3. Federal Policy Regarding Laboratory Interaction with Universities and Industry

3.1 Overview

Federal policy allows and encourages federal laboratories to work with universities, private industry, and also state and local governments. This chapter makes the following points:

Federal laws and policies allow laboratories to involve university faculty, post-doctoral fellows, and graduate students in laboratory research. University-operated FFRDC laboratories have particularly close ties with university researchers.

In classified projects at the laboratories, university researchers must have the proper security clearances; but much of the work in even defense-oriented laboratories such as LLNL is unclassified.

Federal laboratories have long bought goods and services from California companies, and these procurements remain important. But under new federal policies from the 1980s, laboratories also can now interact with industry in four additional ways: technology licenses, cooperative research and development (R&D) projects, work for others (including technical assistance projects for companies), and, in a few cases, direct grants under the Small Business Innovation Research Program. These new mechanisms offer California companies the opportunity to take advantage of laboratory inventions, expertise, and facilities.

3.2 Federal Policy Regarding Laboratory Interactions with Universities

Except in the most classified areas, federal agencies have allowed and even encouraged their laboratories to establish good ties to university faculty and students. Not surprisingly, those laboratories operated by universities have particularly close ties to their parent institutions and other academic centers. The Livermore Laboratory, Berkeley Lab, JPL, and the Stanford Linear Accelerator Center (SLAC) are examples of university-operated laboratories in California that work closely with faculty and students from their parent schools and other universities. Even some of the government-operated laboratories in California have historically had close ties to universities: Ames, for example, has long worked with Stanford. Details on these various laboratory-university interactions will be presented in later sections of this report that deal specifically with these laboratories.

Because the Livermore Laboratory has major national security responsibilities, there are certain programs not open to professors or students who lack the required security clearances. However, as will be discussed in the later chapter on LLNL, most of that laboratory's programs are not classified and are quite open. Even in the classified programs, some professors and graduate students do obtain the requisite clearances and participate in the research. Laboratory-university interactions appear to be less frequent in California's DOD laboratories than at LLNL.

One important federal policy affecting laboratory-university interaction comes from NASA and affects JPL. As will be explained in detail in the chapter on JPL, NASA has instructed JPL and other NASA centers throughout the country to reduce their in-house workforces, focus the remaining personnel on what these centers do best, and "contract out" many other functions. As a result, JPL is focusing particularly on the development of advanced technologies for unmanned space probes. One consequence of this policy is that more and more of the science that JPL supports is being performed by outside university professors and students than by in-house laboratory scientists. Of course, JPL has always involved outside professors in the science related to its space missions, but that process has expanded in recent years. As a result, professors and graduate students in California universities have expanded opportunities to work with JPL.

3.3 Overall Federal Policy Regarding Laboratory Interactions with Industry

3.3.1 Federal Technology Transfer Policy Since 1980

Federal laboratories exist to help carry out the missions of their parent agencies. In the case of DOE, those missions historically have been national security, energy, science, and the environment. In the case of NASA, the missions have been space exploration and, in the case of several NASA centers other than JPL, aeronautics. DOD laboratories of course focus on supporting the defense missions of the various services. Historically, it has *not* been a purpose of mission-agency laboratories to conduct research to help either general U.S. industry or civilian companies in particular states – except to the extent that their agency mission responsibilities have led them to work with particular companies in specific mission-related sectors such as energy or aerospace or agriculture.

In the early and mid-1990s, Congress debated whether the DOE labs should shift major resources into directing assisting general civilian industry. That debate is discussed in the next section of this paper; the end result, however, was a decision not to have mission-agency laboratories – particularly DOE laboratories – take on civilian industrial competitiveness as a major new activity with its own budgets and programs. This decision necessarily limits what the laboratories can do to help commercial companies in states such as California.

However, beginning in 1980 Congress passed a series of laws that encourage federal laboratories to share technology and expertise – technology and expertise they develop in pursuit of their federal missions – with private industry, state governments, and others. The idea is that in the course of conducting their federal missions these laboratories may very well generate inventions and expertise or build facilities that would also benefit private companies and others. To get more "bang" out of the taxpayers' money, these laws allow and encourage the laboratories to make those technologies, areas of expertise, and facilities available to industry. This activity is generally called "technology transfer," although some laboratories now prefer the term "industrial partnering." Again, the main idea here is *not* to create new laboratory research programs explicitly to help general industry; instead, it is to share technologies and scientific and technical information developed in course of mission-related research.

The new legislation focuses on licensing and cooperative R&D, while agency regulations under older law deal with two additional subjects, work for others and software.

Licensing of patented inventions. In 1980, Congress passed the Bayh-Dole Act (Public Law 96-517). Bayh-Dole allowed not-for-profit institutions (especially universities) and small businesses to hold title to inventions that they develop with federal funds, to license those inventions to companies and others, and to retain for themselves any royalty income they made from those licenses. Bayh-Dole was a significant departure from previous federal practice: before 1980, the government held title to all federally-funded inventions, on the grounds that the taxpayer had paid for those inventions. The problem was that federal agencies such as DOE or the National Science Foundation (NSF) had little incentive or expertise in licensing those inventions; in the phrase of the time, these inventions "just sat on the shelf" and did little to help U.S. companies or the American economy. Bayh-Dole took the view that allowing universities and small businesses to own and license these inventions would help produce new innovation and serve the public interest more than simply letting federal agencies hold title. Bayh-Dole also allowed government-owned/government-operated (GOGO) laboratories – that is, civil-service-operated laboratories – to grant exclusive licenses to the patents they hold.

In 1984, the Trademark Clarification Act (Public Law 98-620) extended Bayh-Dole to allow government-owned/contractor-operated (GOCO) laboratories operated by nonprofits (including universities) also to hold title to patents for federally-funded inventions and to license them. In short, the universities managing LLNL, LBNL, JPL, and other laboratories could now own and license their inventions to the private sector and receive royalties. This was a major policy change that greatly expanded the ability of these laboratories to transfer valuable technologies to American industry.

In 1998 the House has passed legislation (H.R. 2544) that would amend current rules for licensing federal laboratory inventions. The Senate considered but did not pass a companion bill (S. 2120). The bills would have (1) reduced the requirements for obtaining non-exclusive licenses to laboratory inventions; (2) addressed private industry's concerns about maintaining confidential information accompanying license applications; and (3) clarified the ability of licensing agencies to terminate a license if certain criteria are not met. On January 6, 1999, Representative Morella (R-MD), author of the legislation, reintroduced in the new Congress as H.R. 209.

Cooperative R&D with industry. In 1980 Congress also passed another important technology transfer statute – the Stevenson-Wydler Technology Innovation Act (Public Law 96-480). The law requires all federal laboratories to take an active role in technical cooperation with industry, and requires agencies to establish technology transfer offices (Offices of Research and Technology Applications) at major laboratories, both government-operated and contractor-operated facilities. These offices and the ability, under Bayh-Dole, to license existing federal inventions to industry led to some early technology transfer efforts.

But by the early 1980s it became apparent that successful technology transfer involved more than just licensing existing patents or having technology transfer offices hand out technical documents. Joint research between company scientists and laboratory researchers was often needed – either to refine a licensed invention to the point where it could be introduced into the market or to conduct entirely new research that might led to new inventions useful to industry. However, companies and federal agencies were reluctant to launch new industry-funded research projects at the laboratories until and unless a way was found to work out legal obligations and rights, including the rights to any new technologies that might be invented during the course of joint research.

In 1986, with important input from the Reagan Administration's Department of Commerce (DOC), Congress passed a series of amendments to Stevenson-Wydler. The amendments, known as the Federal Technology Transfer Act (Public Law 99-502), allows agencies to permit their GOGO labs to enter into a new type of legal contract between laboratories and outside partners known as a "cooperative research and development agreements" or CRADA ("CRAY-da"). As will be discussed below, NASA is the one agency that has chosen not to use this CRADA authority; instead, for its partnerships with industry NASA uses CRADA-like authority under the National Aeronautics and Space Act of 1958.

It is important to emphasize that CRADA authority is permissive, not mandatory. No agency is required to enter into CRADAs; whether to enter into CRADAs, how many to sign, and with what specific details are issues all left to the discretion of agency heads and laboratory directors. The 1986 law simply allows agencies to enter into CRADAs. However, it also definitely encourages technology transfer activities, particularly by making technology transfer a responsibility of all federal laboratory scientists and engineers.

Under a CRADA, a laboratory and "collaborating party" (usually a company) agree to undertake joint research in an area in which the laboratory has expertise. Before any joint research is undertaken the parties agree, through the CRADA, on who will own any invention resulting from the research (the federal government may retain title or assign title to the research partner); what license rights that company will have if the laboratory retains title; and what royalties, if any, the company will pay. Under a CRADA, a laboratory may contribute, at its own expense, staff, intellectual property, and equipment and facilities, but it may not give any cash directly to the collaborating party. (This feature is what distinguishes a CRADA from a government research grant or contract.) The collaborating party, in turn, may contribute cash, people, intellectual property, and other resources. Laboratories often ask to retain title to inventions resulting from the joint research, on the grounds that they are supplying the main technology or expertise. They may also ask for royalties. But in turn the companies receive licenses that give any resulting products intellectual property protection. No laboratory is required to enter into a CRADA, but, as will see below, the number of CRADAs have steadily grown since 1986.

The original 1986 law applied only to GOGO laboratories – that is, to laboratories operated by federal civil-service employees. In 1986 debate still continued over how and when contractor-operated laboratories, particularly at DOE, should engage in joint R&D with outside entities. In 1989, however, political agreement was reached, and the National Competitiveness Technology Transfer Act (Public Law 101-189) granted GOCO federal laboratories authority to enter into CRADAs in essentially the same way as GOGOs. The 1989 statute also explicitly makes technology transfer one of the missions of the DOE nuclear weapons laboratories.

A 1996 law, the National Technology Transfer and Advancement Act (Public Law 104-113) has made the CRADA negotiation process easier by stating, that at a minimum, a collaborating party will have the right to an exclusive license in at least one field of use (that is, one application area). Before passage of the 1996 statute, CRADA negotiations sometimes bogged down because of debates over whether companies should be offered only non-exclusive licenses.

Advantages and limitations of CRADAs. The CRADA mechanism has several significant advantages and limitations. Three advantages are particularly important. First, the CRADA approach allows for intellectual property rights and other issues, such as industry funding and royalties, to be negotiated up front, before any joint R&D begins. This gives both the laboratory and the research partner more predictability than would otherwise be the case. Second, because no federal money is given to the research partner, and thus no formal competition must be held as is required in federal grant programs, basic CRADAs often may be negotiated quickly and with a minimum of red tape. Some federal agencies can negotiate basic CRADAs in as little as two weeks. Third, the law allows for proprietary technical data to be protected and kept confidential.

There are also several limitations. With the exception of those few cases in which an agency receives special dedicated funds to undertake new research in areas of interest to industry, companies are limited to working with federal laboratories on technologies and technical areas which the laboratories are already pursuing as a result of their mission activities. If those mission-related technologies fit the needs of companies, then there is a good fit. But that is not always the case. Second, the Federal Technology Transfer Act has some requirements which can be hard to specify in practice, including a provision gives a preference to companies that agree to manufacture a substantial portion of any resulting products in the United States. Third, in agencies with GOCO laboratories, the process of negotiating CRADAs can be a long one. Both contractor and agency lawyers are involved, for example.

Fourth, there are also some important political tensions and limitations inherent in the CRADA model. These tensions and limitations are well described in an article by Linda Cohen and Roger Noll.[2] They note that "CRADAs generate political problems when they create industry winners and losers – or potential losers – and when they succeed and make visibly large profits for private firms." That is, the very nature of CRADAs – a laboratory choosing to work with a company or group of companies – can lead, first, to other firms or political critics claiming that the laboratory is engaging in favoritism ("picking winners and losers") and, second, to criticisms that a company is making "unfair" profits by using technology initially paid for by the taxpayer. The latter charge has most often occurred in the medical area, when pharmaceutical companies sell expensive and profitable drugs developed in part through CRADAs with the National Institutes of Health (NIH). Cohen and Noll go on to add the following:

> The fundamental problem with CRADA policy is that the laboratories are expected to fill an institutional role that provides external R&D to firms, which... presents exceptionally difficult organizational and incentive problems, exacerbated by the essentially political problems presented by the potential creation of private winners and losers.

Most CRADAs are relatively small in terms of the resources involved, the benefits generated, and the potential for political controversy. Moreover, laboratory-funded programmatic CRADAs that serve agency missions as well as help companies generate little criticism. But larger industry-funded CRADAs can generate controversy, causing difficulty for laboratories and causing them to be cautious about working with industry.

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[2] Linda R. Cohen and Roger G. Noll, "The Future of the National Laboratories," *Proceedings of the National Academy of Sciences, USA*, Vol. 93, pages 12678-12685, November 1996. The paper was originally presented at an NAS colloquium entitled "Science, Technology, and the Economy," organized by Ariel Pakes and Kenneth L. Sokoloff.

Work for others. In general, federal laboratories may engage in what the government calls "work for others." This includes both contract work for other federal agencies and work for private companies and other non-federal entities, such as state governments. In general, federal laboratories will only work with private companies when there is no private-sector alternative available – that is, when the laboratory has unique capabilities not available elsewhere. For example, in recent years federal agencies have allowed expanded company access to unique unclassified laboratory facilities, such as specialized reactors and synchrotrons used to study advanced materials. Several agencies have developed regulations that would allow some time on these machines for proprietary industry research. Companies reimburse the laboratories for associated costs.

Software. Under long-standing federal law, no product produced by a government employee may be copyrighted. This policy applies to reports, databases, and computer software. Therefore, GOGO laboratories may not copyright or license software; any software generated is available to everyone. This has advantages, but it also means that few companies are willing to invest in refining and marketing non-copyrighted software developed by government employees for fear that competitors will simply copy it.

Because the employees of GOCO laboratories are not government employees, these laboratories are able to copyright and then license computer software. As will be discussed in later sections, the ability to license software is a valuable policy tool by which LLNL, Berkeley Lab, and JPL can assist the private sector.

3.3.2 Special Rules at DOE Concerning Joint Research

DOE and NASA have some special rules concerning joint research projects with companies and other non-federal entities. In the case of DOE, the Department has used three different types of CRADAs. These three are:

Industrial funds-in CRADAs. A "funds-in CRADA" is the DOE term for regular industry-funded CRADAs. The aim is to transfer existing laboratory technology or expertise – developed for mission purposes – to industry or some other outside partner. Under this arrangement, the laboratory contributes people, technology, etc. but no funds. All funding for the new research comes from the outside partner.

Laboratory-funded CRADAs. This type of agreement is called either a laboratory-funded or programmatically-funded CRADA. As the title suggests, a laboratory will put its own funding into such a CRADA to pay the costs of its own employees engaging in the new R&D. It will do so because the intent of this type of agreement is to help accomplish the laboratory's mission objectives, rather than to help industry *per se*. These are projects where a DOE laboratory believes that industry's technical capabilities can help the laboratory build its technology base and better carry out its federal missions. However, since industry also seeks to benefit from these projects, some observers believe it is appropriate to think of these programmatic CRADAs as true dual-use projects – helpful to both the laboratory, in pursuit of its federal missions, and to industry.[3]

Funded CRADAs. Under this approach, now ending, DOE received special dedicated appropriations from Congress to help pay for new R&D of interest to industry – R&D above and beyond what the laboratory is doing for mission purposes with regular mission funds. As with all CRADAs, no federal money was given directly to the company; the DOE funds were used to pay for laboratory employees to participate in the new R&D, and each company must pay for its part in the project. Several specific DOE programs provided these extra funds. Lawrence Livermore and other laboratories that report primarily to DOE's Office of Defense Programs used the Technology Transfer Initiative (TTI). Berkeley Lab and other facilities that report primarily to the Office of Energy Research received funds primarily from what was once called the Laboratory Technology Transfer (LTT) program and which more recently had the name Laboratory Technology Research Program. There was also at one point a small technology transfer budget line item in DOE's Environmental Management Office. As will be discussed later, in the early and mid-1990s funded CRADAs became a major initiative at DOE, creating many new R&D projects of interest to American industry. But recent Republican Congresses have cut funds for technology partnerships. Most existing projects will close soon, and no funds are available to start new ones.

3.3.3 Special Rules at NASA Concerning Joint Research.

NASA also has some special rules regarding joint research. First, NASA laboratories do not use CRADAs. The reason is that NASA has long had its own separate authority, under the National Aeronautics and Space Act of 1958, to enter into what are called "Space Act agreements with industry." NASA's government-operated research centers, including Ames, use these agreements. Second, however, JPL – as a university-operated NASA laboratory – uses neither CRADAs nor Space Act agreements. Instead, by arrangement with NASA, JPL conducts joint research agreements under Caltech authority. Just as any university may write its own contracts with industrial partners, Caltech/JPL may write its own agreements.

[3] For a good discussion of programmatic CRADAs at Livermore, see Christopher T. Hill and J. David Roessner, "New Directions in Federal Laboratory Partnerships with Industry", a report to the Jet Propulsion Laboratory, June 1997.

3.3.4 Summary

To sum up, federal laws and policies allow the following:

For university-run GOCOs. For any laboratory invention that results from federal funding – that is, for anything invented by a laboratory employee using federal funds – Bayh-Dole allows the university running that GOCO to own all patent rights to that invention and to license the invention as the university sees fit. That is why in the case of LLNL, Berkeley Lab, and JPL, all licenses of laboratory inventions are handled by technology licensing offices at their parent universities. Licenses can be either exclusive or non-exclusive. In many cases, the university will ask for royalties in exchange for a license to a university-owned invention. Technically, the federal agencies funding these university-run laboratories do not have a legal say in how the universities license laboratory inventions – although in practice the agencies sometimes insist on being consulted. In addition to these Bayh-Dole provisions, the 1989 amendments to the Federal Technology Transfer Act allow all GOCO laboratories (including those run by universities) to enter into cost-shared CRADAs with outside parties, including companies. These legal agreements typically include provisions as to who will own and who will have licensing rights to any *new* inventions that might result from collaborative research under the CRADAs. JPL does not use CRADAs or Space Act agreements but with Caltech may enter into its own legal contracts to conduct joint research with industrial partners. GOCOs may also copyright and license software.

For government-operated laboratories. Under Bayh-Dole, inventions developed by civil service employees of GOGO laboratories in California or elsewhere remain the property of the U.S. Government; however, the laboratories have authority to license these inventions to outside parties. Under the Federal Technology Transfer Act, these laboratories also may enter into CRADAs. Government-operated laboratories may not copyright or license software.

4. Appendix 1. Introduction to Federal Laboratories

4.1 Summary

California has 48 of the federal government's approximately 500 research and development (R&D) laboratories – the highest number in any one state.[4] Table 2, starting on page 28, lists the 48 facilities.

California has a high percentage of total nationwide spending on federal laboratories. In federal fiscal year (FY) 1995, these 48 laboratories constituted 17.8 percent of total federal laboratory spending nationwide ($4.7 billion of $26.6 billion). This exceeds California's 1995 share of the nation's population (12.0 percent) and its share of the country's gross domestic product (12.8 percent).

Budgets for federal laboratories nationwide and in California have declined since 1985 – the result of the Cold War's demise and tight federal budgets.

4.2 Federal Laboratories

Overall, the federal government owns some 700 laboratories – some 200 analytical testing facilities and approximately 500 R&D laboratories. The R&D laboratories range in size, with some small and others each having an annual budget of a billion dollars or more. Three sets of definitions are useful in understanding the purposes and organization of these laboratories.

4.2.1 Government-Operated and Contractor-Operated Laboratories

Federal laboratories come in two main types – government-owned/government-operated facilities ("GOGOs") owned by the agencies and operated by civil service personnel and government-owned/contractor-operated facilities ("GOCOs") owned by the agencies but operated by private contractors using non-government personnel.

4.2.2 Federally-Funded Research and Development Centers

"Federally funded research and development centers" (FFRDCs) are organizations operated by contractors and performing research for the government; they operate under special FFRDC contracting rules. The terms GOCO and FFRDC are similar but not identical. Two differences are significant. First, while most federal GOCO laboratories are also FFRDCs, there are a few GOCOs that are not FFRDCs.[5] Second, while most FFRDCs are laboratories, some are not. The federal government formally divides FFRDCs into three categories: R&D laboratories, study and analysis centers, and systems engineering and integration centers.[6] California has several FFRDCs that the government does not always classify as laboratories, including the

[4] Of the 48 federal facilities in California, one – the Aerospace Corporation – is sometimes classified as a laboratory and sometimes as a systems engineering and integration center. This report will follow the standard practice of defining the Aerospace Corporation as a federal laboratory.

[5] Examples of federal GOCOs that are *not* FFRDCs are two DOE naval atomic propulsion laboratories, Bettis Atomic Power Laboratory (in West Mifflin, PA, operated by Westinghouse) and Knowles Atomic Power Laboratory (in New York State, operated by Lockheed Martin).

[6] For a good discussion of what an FFRDC is and for a list of all FFRDCs, see *http://www.nsf.gov/sbe/srs/anno96/start.htm*.

Aerospace Corporation (technically a systems engineering and integration center rather than a laboratory)[7] and three study and analysis centers operated by the RAND Corporation in Santa Monica – the Arroyo Center, funded by the Army; the National Defense Research Institute, funded by the Office of the Secretary of Defense; and Project Air Force, funded by the Air Force.

4.2.3 R&D Laboratories versus Other Types of Federal Laboratories.

A 1996 report by the U.S. General Accounting Office (GAO)[8] makes a distinction between federal laboratories that conduct R&D and other federal laboratories whose sole purpose is to test or analyze samples for chemical, physical, or biological properties. GAO counted 515 federal R&D laboratories[9], with the remainder of the 700 or so total federal laboratories being testing facilities. The distinction is important for understanding which federal laboratories have R&D capabilities that might be useful to industry, universities, or state governments.

Most federal laboratories are GOGOs, including most research facilities operated by the Department of Defense (DOD), the National Aeronautical and Space Administration (NASA), and the Department of Agriculture (USDA). Important GOGO laboratories in California include NASA's Ames Research Center (ARC) and DOD laboratories such as the Flight Test Center at Edwards Air Force Base and the Naval Air Warfare Center facility at China Lake. However, Livermore, Berkeley Lab, and JPL are all GOCOs: each is owned by the federal government but operated by private contractors. JPL is the only GOCO within NASA; federal civil service personnel operate all other NASA centers.

The Livermore Laboratory, the Berkeley Lab, and JPL are FFRDCs. The FFRDC model grew out of World War II. During that war, the government needed new science and weapons laboratories quickly, and turned to universities and companies to manage and staff them. Among the best known examples are the nuclear weapons laboratories of what is now the Department of Energy (DOE) – Los Alamos National Laboratory in New Mexico and Livermore Laboratory in California (both administered by the University of California) and Sandia National Laboratories (now run by Lockheed-Martin Corporation). Other FFRDCs established during and after the World War II era focused on nuclear and energy sciences rather than on weapons development; these science laboratories include the Berkeley Laboratory (also administered by the University of California). Other agencies also established FFRDCs. For example, first the Army and then NASA contracted with the California Institute of Technology to operate JPL. More recent FFRDC laboratories include several university-run facilities funded by the National Science Foundation (NSF). In general, the FFRDC model involves a master contract between an agency and a contractor that allows great flexibility in laboratory operations.

4.3 Federal Laboratories in California

Table 4 contains a list, by agency, of federal laboratories in California that conduct R&D. Laboratories that are also FFRDCs are so noted. A total of 48 R&D laboratories are listed. In FY 1995 (the most recent year for which complete data are available), the operating budgets for these laboratories in totaled just over $4.7 billion.[10] New data for later years may soon be available.

4.4 Further Budget Information on California's Federal Laboratories

Budgets for federal laboratories nationwide and in California have declined since 1985 – the result of the Cold War's demise and tight federal budgets. Figures 1 and 2 present data for the two main types of federal laboratories in California: intramural civil-service-run

[7] While the federal government technically defines the Aerospace Corporation as a systems engineering and integration center rather than a laboratory, most lists of federal laboratories and accompanying budget tables including Aerospace. This report will follow the standard usage and call the Aerospace Corporation a federal laboratory.

[8] U.S. General Accounting Office, *Federal Research Laboratories,* Report GAO/RCED/NSIAD-96-78R, February 29, 1996.

[9] The GAO list of R&D laboratories is somewhat misleading, however, because it includes FFRDC study and analysis centers (such as those at the RAND Corporation) which the Department of Defense does *not* define as laboratories. So the actual number of R&D laboratories would be about 505 instead of 515.

[10] The FY 1995 total is drawn primarily from data in Linda R. Cohen, "California Science and Technology Indicators," a draft report prepared for the California Council on Science and Technology, February 2, 1998, Table a.5. That table lists FY 1995 federal spending on intramural research (GOGO laboratories) in California of $1.848 billion and spending on university-operated FFRDCs of $2.378 billion. To this one must add the FY 1995 federal funding for corporate-managed Sandia/California ($159 million) and the non-profit Aerospace Corporation ($335 million). These figures total $4.720 billion. A separate figure of $4.8 billion for FY 1993 comes from the American Association for the Advancement of Science, using National Science Foundation data. See American Association for the Advancement of Science, *The Future of Science and Technology in California: Trends and Indicators,* May 1996, Table 1 at *http://www.aaas.org/spp/dspp/cstc/catabs.htm#table1*. The previously-mentioned GAO report states, on page 10, an FY 1995 California total of $4.120 billion. After subtracting out FFRDC study and analysis centers that are not in fact laboratories, the figure drops to $4.105 billion. However, the GAO report does not include several major California laboratories that are field installations of research centers with headquarters in other states. It particular, the GAO reports misses Sandia-California and California's two Naval Air Warfare Centers.

Table 4. Federal Research & Development Laboratories in California

Laboratory name and location	Mission and research areas	FY 1995 operating budget (in millions of dollars) *
Department of Agriculture -- Agricultural Research Service		
Western Regional Research Center, Albany, CA	Conduct research on cereal product utilization, crop improvement, food safety, plant protection, process biotechnology, process chemistry and engineering, and plant gene expression.	$ 18.2
Irrigated Desert Research Center, Brawley, CA	Conduct research on irrigated crops in desert environments.	unknown
Aquatic Weeds Control Research Unit and Crops Pathology and Genetics Unit, Davis, CA	Weed unit develops improved methods to control aquatic weeds. Crops Unit develops improve rice germplasm and solves problems facing the U.S. rice industry.	$ 1.7
Horticultural Crops Research Lab and Water Management Research Lab, Fresno, CA	Conduct research on protecting fruits and vegetables from insects and maintaining their postharvest quality; water management; and landscape ecology of rangelands.	$ 6.0
U.S. Salinity Laboratory, Riverside, CA	Assess salt-affected soil-plant-water systems to improve crop production and preserve and distribute clonal germplasm of citrus and dates.	$ 3.8
Crop Improvement and Protection Research Unit, Salinas, CA	Determine the biology of viral diseases of sugar beets and vegetables.	$ 2.1
Western Human Nutrition Research Center, San Francisco, CA	Assess human nutritional requirements and develop methodologies to assess nutritional status, nutrition intake, and the impact of intervention programs.	$ 4.5
U.S. Cotton Research Station, Shafter, CA	Develop sustainable systems for producing cotton and other irrigated crops by integrating remotely sensed information with models.	$ 1.0

* The term "FY 1995 operating budgets" is the amount GAO calculates each laboratory spent performing R&D internally that year. It excludes both non-R&D expenditures and R&D contracts with outside entities, and thus does not necessarily reflect a laboratory's entire FY 1995 budget.

Table 4 (continued). Federal Research & Development Laboratories in California

Laboratory name and location	Mission and research areas	FY 1995 operating budget (in millions of dollars) *
Department of Agriculture -- Forest Service		
Pacific Southwest Research Station (PSRS), Albany, CA	Conduct research on forest genetics, watershed effects and inland fisheries, global climate, chemical ecology, and forest insects.	$ 5.5
Redwood Sciences Laboratory, Arcata, CA (PSRS field lab)	Assess timber management/wildlife interactions and management effects on hillslopes, fisheries, and streams.	$ 2.2
Forestry Sciences Laboratory, Fresno, CA (PSRS field lab)	Evaluate montane ecosystems in the Sierra Nevada Mountains.	$ 1.8
Silviculture Laboratory, Redding, CA (PSRS field lab)	Examine silviculture of California conifers, management of competing vegetation, and ecosystem management.	$ 2.5
Forest Fire Laboratory, Riverside, CA (PSRS field lab)	Assess ecology and fire effects in drought-prone ecosystems, fire meteorology, fire management, air pollution and global change, and wildlife.	$ 4.4
Technology and Development Center, San Dimas, CA	Develops, tests, and applies technologies for fighting forest fires; improving USFS water treatment systems; and meeting other USFS needs.	unknown
Department of Commerce -- NOAA National Marine Fisheries Service		
Southwest Region Science Center and Laboratory, La Jolla, CA	Tuna-dolphin, population dynamics, population biology, protected species, Antarctic ecosystems, fishery economics, fishery oceanography, genetic stock identification, International Whaling Commission activities.	$ 15.6
Pacific Grove, CA	Ecosystem modeling and analysis, fishery environmental linkages, physical oceanography.	$ 0.9
Tiburon, CA	Groundfish ecology, population dynamics/ assessments, population biology, ecosystem dynamics.	$ 1.9
Department of Defense-- Air Force		
Aerospace Corporation (FFRDC), Los Angeles, CA	Systems integration of space and space-related systems.	$ 335.0
Air Force Research Laboratory -- Propulsion Directorate, Edwards AFB, CA	Develops space and missile rocket propulsion technology, including evolved expendable launch vehicles.	unknown
Flight Test Center, Edwards AFB, CA	Test, support, and operations; test pilot school.	$ 329.5
Department of Defense -- Army		
Hydrologic Engineering Center, Davis, CA	Conducts research, training, policy analysis, and technical assistance in hydrologic engineering.	unknown

* The term "FY 1995 operating budgets" is the amount GAO calculates each laboratory spent performing R&D internally that year. It excludes both non-R&D expenditures and R&D contracts with outside entities, and thus does not necessarily reflect a laboratory's entire FY 1995 budget.

Table 4 (continued). Federal Research & Development Laboratories in California

Laboratory name and location	Mission and research areas	FY 1995 operating budget (in millions of dollars) *
Department of Defense -- Navy		
Naval Air Warfare Center Weapons Division (CL), China Lake, CA	Conducts research, development, test, evaluation, and in-service engineering for weapons systems associated with air warfare.	unknown
Naval Air Warfare Center Weapons Division (PM), Point Mugu, CA	Same mission as China Lake.	unknown
Naval Facilities Engineering Service Center, Port Hueneme, CA	Provides engineering and technology support for specialized Navy facilities.	$ 85.6
Naval Health Research Center, San Diego, CA	Conducts research, development, test, and evaluation on the biomedical and psychological aspects of the Navy and Marine Corps.	$ 4.8
Navy Personnel Research and Development Center, San Diego, CA	Conducts R&D on personnel systems, training, and organizational systems.	$ 16.0
Naval Surface Warfare Center, Port Hueneme Division, Port Hueneme, CA	Provides test and evaluation, in-service engineering, and logistics support for surface warfare combat systems and subsystems.	unknown
Navy SPAWAR Systems Center, San Diego, CA	Designs, acquires, and supports integrated information systems for the Navy.	$ 501.7
Department of Defense-- General		
Defense Microelectronics Activity, McClellan AFB, CA	Assists weapons systems managers in inserting and maintaining advanced microelectronics technologies.	unknown
Department of Energy		
Lawrence Berkeley National Laboratory (FFRDC), Berkeley, CA	Conducts R&D in energy research, energy efficiency and renewable energy, environmental management, and other areas.	$ 222.7
Lawrence Livermore National Laboratory (FFRDC), Livermore, CA	Conducts R&D in national security, energy research, nonproliferation, environmental management, nuclear energy, and other areas.	$ 859.2
Sandia National Laboratories/ California (FFRDC), Livermore, CA	Conducts R&D in national security, energy technologies (including advanced energy sources and combustion science and technologies), environment, and manufacturing technologies.	$ 158.5
Stanford Linear Accelerator Center (FFRDC), Stanford, CA	Conducts research in high-energy physics.	$ 124.2
UCLA Laboratory of Structural Biology & Molecular Medicine (Cooperative agreement with UCLA), Los Angeles	Conducts research on proteins in genomes; develops molecular nuclear medicine.	$ 7.4
Note: Energy Technology Engineering Center (FFRDC), Canoga Park, CA, closed out in November 1995		

* The term "FY 1995 operating budgets" is the amount GAO calculates each laboratory spent performing R&D internally that year. It excludes both non-R&D expenditures and R&D contracts with outside entities, and thus does not necessarily reflect a laboratory's entire FY 1995 budget.

Table 4 (continued). Federal Research & Development Laboratories in California

Laboratory name and location	Mission and research areas	FY 1995 operating budget (in millions of dollars) *
Department of the Interior -- Geological Survey		
Western Region Office, Menlo Park, CA	Conducts research in digital cartography and geographic information systems, minerals and land resources, geologic hazards assessment, and water resources.	$ 104.8
Department of Veterans Affairs -- Medical Centers and Clinics Conducting R&D	The purpose of VA research is to contribute to (1) improved medical care for veterans and (2) the nation's knowledge about disease and disability. VA research falls within broad areas of biomedicine, health services, and rehabilitation.	
Fresno, CA		$ 0.2
Loma Linda, CA		$ 1.3
Long Beach, CA		$ 2.9
Los Angeles , CA (clinic)		$ 0.5
Palo Alto, CA (Palo Alto Rehabilitation R&D Center)		$ 10.9
Pleasant Hill, CA (clinic)		$ 1.5
San Diego, CA		$ 8.6
San Francisco, CA		$ 8.8
Sepulveda, CA		$ 5.5
West Los Angeles, CA		$ 8.1
National Aeronautics and Space Administration		
Ames Research Center, Moffett Field, CA	Conducts R&D in aeronautics, information technology, astrobiology, and earth and space sciences.	$ 522.3
Dryden Flight Research Center, Edwards, CA	Conducts flight research.	unknown
Jet Propulsion Laboratory (FFRDC), Pasadena, CA	Conducts space science, particularly robotic space probes; conducts R&D in robotics, microelectronics, imaging, communications, and other areas.	$ 783.7

Sources: U.S. General Accounting Office, Federal Laboratory Consortium for Technology Transfer, and agency and laboratory Web pages

* The term "FY 1995 operating budgets" is the amount GAO calculates each laboratory spent performing R&D internally that year. It excludes both non-R&D expenditures and R&D contracts with outside entities, and thus does not necessarily reflect a laboratory's entire FY 1995 budget.

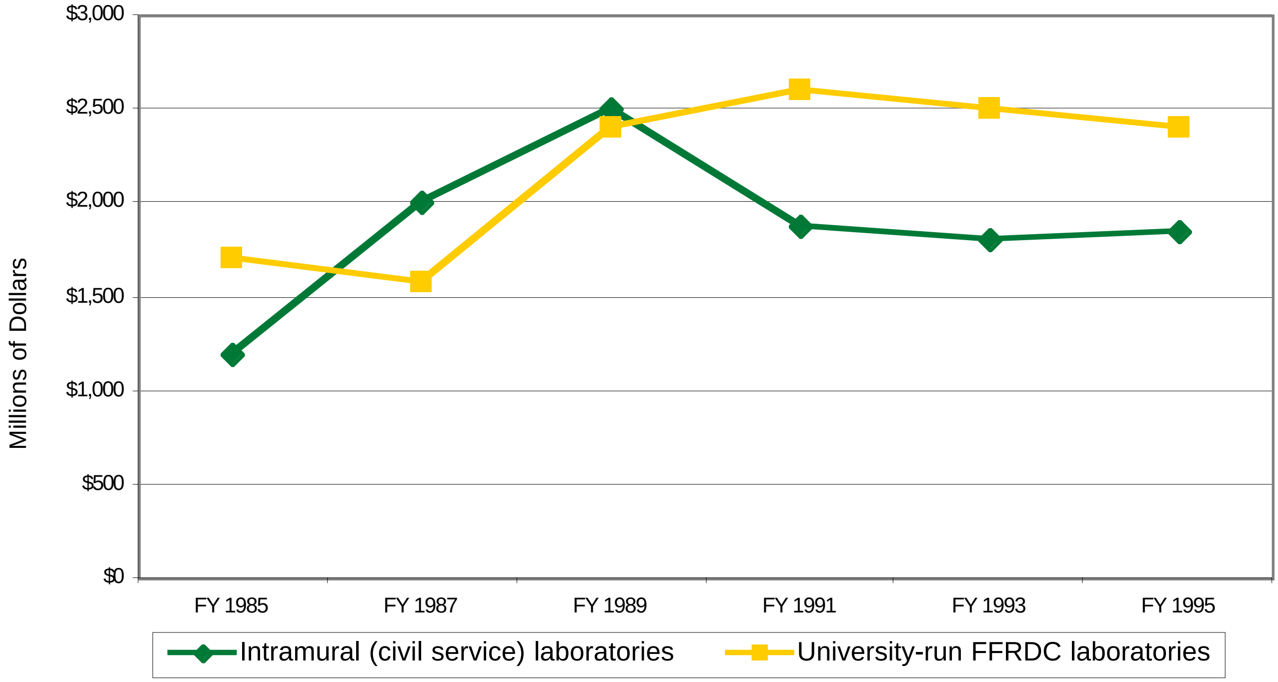

Figure 1. Selected federal laboratory expenditures in California (millions of dollars)
Source: Linda Cohen of UC Irvine, using NSF data

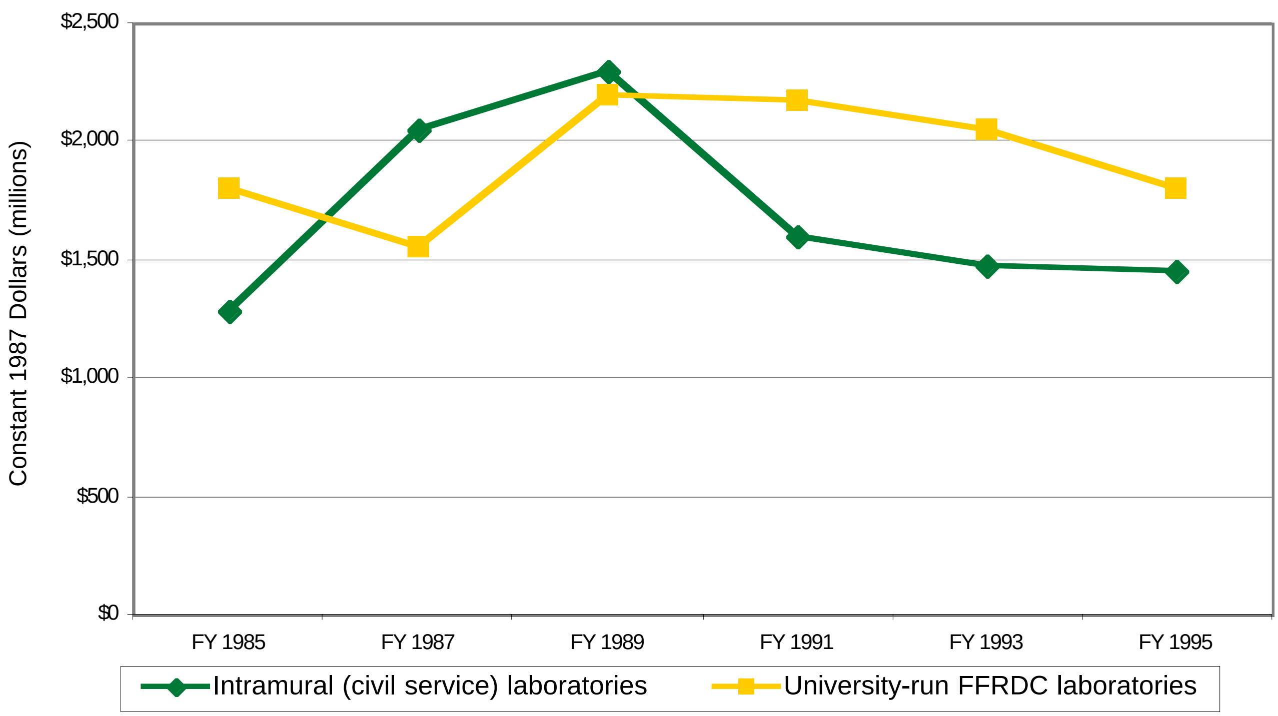

Figure 2. Selected federal laboratory expenditures in California (millions of constant 1987 dollars)
Source: Linda Cohen of UC Irvine, using NSF data

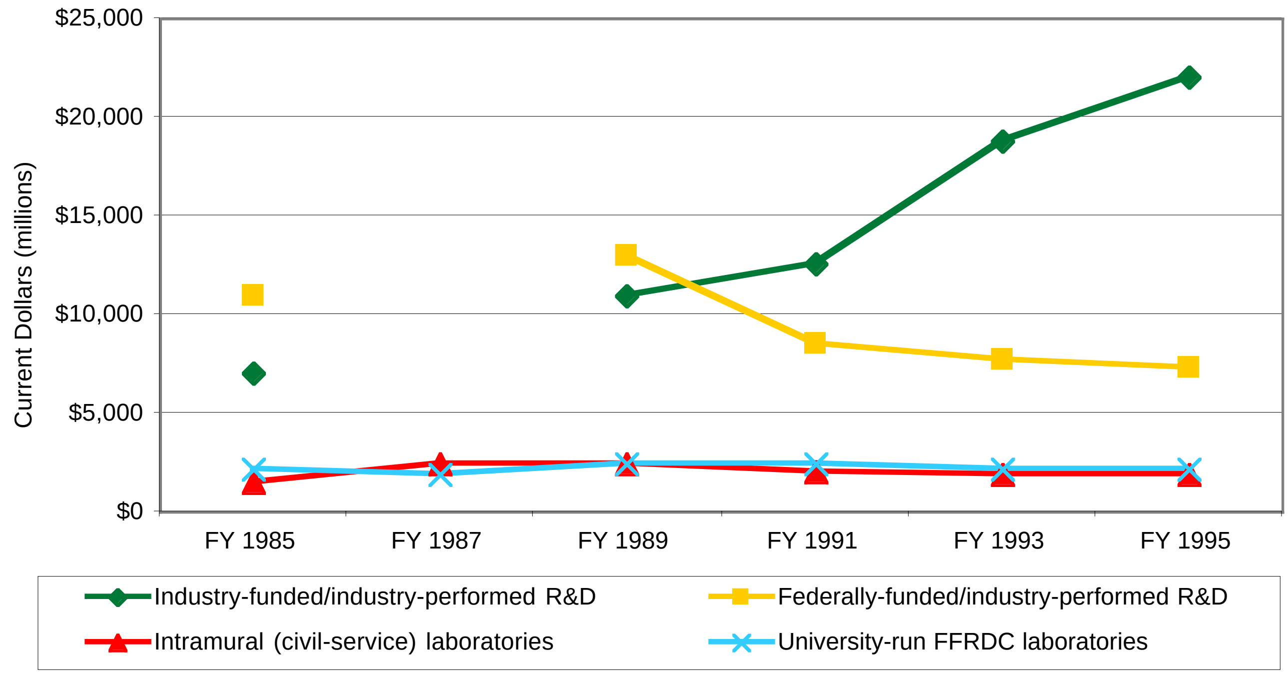

Figure 3. Selected R&D expenditures in California -- FY 1985-1995 (in millions of current dollars)
Source: Linda Cohen of CCST, using NSF data

facilities and federally-funded research and development centers (FFRDCs) run by universities and colleges.[11] The budget cuts have been particularly deep in intramural laboratories.

Even with these reductions, in FY 1995 overall federal laboratory expenditures still totaled 13.1 percentage of total private and government R&D in the state ($4.720 billion out of $36.133 billion). And as Figure 3 shows, the decline in federally-funded/industry-performed R&D in California means that expenditures for intramural and university-run FFRDC laboratories are an increasing percentage of overall federally-supported R&D in the state.

5. Appendix 2. Livermore and Berkeley Laboratories

5.1 Summary

This report now turns to a review of the missions, programs, budgets, and benefits to California of the main federal laboratories in state, starting, in this appendix, with two large multiprogram DOE laboratories – the Livermore Laboratory and Berkeley Lab. This appendix summarizes their missions, programs, and budgets; goes on to discuss their contributions to date to the California economy, particularly interactions with California universities and industry; and concludes with a discussion of current trends in federal budgets and policies and the implications of those trends for state's economy. The information for the two laboratories is drawn from interviews, laboratory Web pages, and other documents and data provided by laboratory officials. These are the main points:

The Lawrence Livermore National Laboratory (the Livermore Laboratory or LLNL) is owned by DOE and operated by the University of California (UC). It has responsibility for nuclear weapons stewardship and a wide range of other missions. It has particular expertise in nuclear science and technology, lasers and opto-electronics, advanced computing, advanced sensors, biotechnology, and process technology. In FY 1997, its budget totaled $1.013 billion.

The Lawrence Berkeley National Laboratory (LBNL or Berkeley Lab) is also owned by DOE and also operated by UC. An energy research facility, it has expertise in particle accelerators, energy technologies, advanced computing, and biotechnology, chemical and materials sciences, and environmental assessment and remediation. It had an FY 1997 budget of $346 million.

[11] The other two types of federal laboratories are industry-operated FFRDCs and FFRDCs operated by nonprofits. California has two such facilities, the industry-run Sandia/California Laboratory and the nonprofit-run Aerospace Corporation.

With regard to LLNL's interactions with universities, the total number nationwide has been growing – although the number collaborations with California partners has stayed relatively constant. The FY 1995 nationwide total was 1225, of which 499 were in California, and the FY 1998 total was 1656, of which 450 were in this state.

Over the years, about 90 percent of the university researchers working with Berkeley Lab have been from the University of California. In addition to hosting university researchers on its site, Berkeley Lab in FY 1997 spent $10.1 million on procurements and contracts with universities.

Of the three major laboratories discussed in this report, to date LLNL has, in dollar terms, the largest set of interactions with industry. Procurements are the most significant interaction, but in addition the Laboratory is active in collaborative research. For example, data in Appendix 5 show that in FY 1997 total DOE and industry spending at LLNL on CRADAs and work-for-others totaled $51.6 million, or five percent of the Laboratory's budget that year of $1.013 billion. The mix of CRADAs has changed in recent years – a decline in the number of agency-funded ("funded") CRADAs, after the Republican Congress cut funds in 1995, but also a steady rise in the number of industry-funded CRADAs.

While considerably smaller than LLNL, Berkeley Lab also has a range of collaborative R&D projects with industry, including California companies. For its size, Berkeley Lab particularly has a significant number of industry-funded CRADAs and work-for-others projects; in part, this reflects the value of user facilities such as the Advanced Light Source.

In the status-quo budget and policy environment that is likely to prevail in Washington, D.C., over the next few years, budgets at LLNL and Berkeley Lab will be essentially flat, with the exception of two major defense-related initiatives at LLNL -- the National Ignition Facility (NIF) and new supercomputer activities under the Accelerated Strategic Computing Initiative (ASCI).

LLNL will continue to use laboratory-funded programmatic CRADAs. As LLNL downsizes and as it seeks to tap expertise and technology in the private sector, these agreements are a useful mechanism. In procurement, LLNL is working more companies in the design of new equipment, rather than simply doing all the specifications and designs in-house.

LLNL and LBNL will not have much dedicated DOE funding to start new CRADAs in areas of interest to industry. For example, today there is relatively little in the dedicated DOE technology transfer account for LLNL and other defense-oriented laboratories – $60 million in FY 1999, up from $56 million in 1998, but far down from the $225 million in FY 1995. LLNL's share is likely to be between one third and one quarter of these funds, or between $15 and $20 million. However, both LLNL and Berkeley Lab will continue to welcome industry-funded CRADAs and work for others.

Both laboratories see their future strengths as lying in areas of great potential value to the California economy, including advanced computing, lasers and inertial fusion, and biotechnology. Both laboratories also have major user facilities open to industry. Berkeley Lab, for example, has the Advanced Light Source, the National Energy Research Supercomputing Center, and the National Center for Electron Microscopy.

5.2 The Department of Energy

5.2.1 Background

This discussion of the Livermore and Berkeley Laboratories begins with a brief review of the Department of Energy.

In the current fiscal year, FY 1999, DOE is a $17.856 billion agency with responsibilities for national security (nuclear weapons), science and technology related to energy, energy resources, and overall energy policy. The Department's origins go back to the immediate period after the end of World War II, when Congress established the Atomic Energy Commission (AEC) to take over nuclear weapon and energy science activities begun under the Manhattan Project. Soon thereafter, the AEC began working with the Navy to develop nuclear propulsion for submarines and ships. Later, under President Eisenhower's Atoms for Peace program, the AEC also began efforts to develop and promote peaceful uses of nuclear power, particularly nuclear power plant technologies.

In 1974, Congress passed legislation that split the AEC into the Nuclear Regulatory Commission (NRC) and an Energy Research and Development Administration (ERDA). During the Carter Administration, ERDA R&D functions were merged with the Federal Energy Administration and other civilian energy activities to form DOE. National security programs remain the largest part of the Department, however ($12.381 billion in FY 1999). DOE's Science account (formerly the Energy Research account) is the primary funder of Berkeley Lab and other DOE energy science laboratories; its budget totals $2.698 billion in FY 1999.

Although Berkeley Lab's origins go back to the early 1930s, the Department's overall system of national laboratories dates back to the Manhattan Project. Los Alamos National Laboratory was established during World War II to design and build the first nuclear weapons. The two other principal nuclear weapons laboratories, Livermore and Sandia, were established after the war, as will be discussed below. A series of energy science laboratories also developed, including Berkeley Lab, Argonne, and Brookhaven and later specialized facilities such as SLAC in California, Fermilab in Illinois, and the National Renewable Energy Laboratory in Colorado. Reactor research continues at the Idaho National Engineering Laboratory. In the past, smaller laboratories also existed at several of the large DOE nuclear-materials production facilities around the country; while some of those facilities are now closed, research continues at the Savannah River Site in South Carolina.

The national laboratories report to the Secretary of Energy, through regional DOE operations offices that handle contracts. Individual activities at the laboratories are funded and supervised by specific programs offices at DOE. As a result, the predominant program office for each laboratory plays a significant role in managing that laboratory. Most but by no means all of the programs at Los Alamos, Livermore, and Sandia are funded by DOE's Defense Programs Office. Most but not all the activities at the energy science laboratories such as Berkeley Lab are funded by DOE's Office of Energy Research. DOE laboratories may accept funding from other federal agencies; and, as discussed above, may enter into CRADAs with private companies and other non-federal entities and may do work for others.

Policies and budgets at DOE during the 1990s. During the 1990s the Department of Energy has been the subject of dramatic swings in federal policy and budgets. The end of the Cold War, the debate over what role if any DOE laboratories should play in industrial competitiveness, and budget ups-and-downs have all made for a tumultuous policy environment. However, many of these fights have now quieted down, and basic trends for FY 1999 and beyond now seem relatively clear.

Cold War followed by the end of U.S.-Soviet rivalry. In 1990, DOE's laboratories were at the end of the large Reagan-era build-up of the Department's nuclear weapons program. Military, not civilian, programs still dominated. The Reagan and Bush Administrations strongly supported the concept of technology transfer – making mission-related technologies more widely available to industry – but technology transfer laws were still new in 1990. The weapons laboratories at DOE were preoccupied with the Cold War and security and not with technology transfer. CRADAs were also new to energy research laboratories such as LBNL. In addition, many of the DOE civilian research programs that might be most useful to industry – in energy efficiency, alternative energy, and environmental protection, for example – had been cut back by these Republican administrations.

Then the political climate changed dramatically. First came arms control agreements, followed by the demise of the Soviet Union at the end of 1991, the decision to stop the design and construction of new nuclear weapons, and a federal budget crunch which put enormous pressure on the White House and Congress to find programs to cut. Suddenly DOE's weapons laboratories, the Livermore Laboratory among them, faced the prospect of major reductions in budgets and staffs. By 1993 LLNL faced even more: as the "second" weapons design laboratory after Los Alamos, there were serious discussions about whether to close it altogether.

Early CRADAs. In the early 1990s, there were many barriers to labs working with industry. Industry complained that the process of signing an agreement with the laboratories took far too long – many CRADAs took a year or more to approve. In the 1992-1995 period, however, the DOE policy was to greatly expand work with industry. The Department and the national laboratories improved the procedures. The number of partnerships grew quickly, from only a few at the beginning of 1992 to over 1,500 by the middle of 1995 and an estimated 3,000 or so by 1998.

The growth in DOE CRADAs was helped by the fact that by the mid-1990s the Department's laboratories were able, as mentioned earlier, to undertake three different types of CRADAs – regular "funds-in" CRADAs, laboratory-funded agreements, and special "funded CRADAs" using dedicated set-aside moneys. Of the DOE programs supporting funded CRADAs, the largest has been the Technology Transfer Initiative (TTI) funded through DOE's Office of Defense Programs. Between 1991 and 1997 this program provided some $232 million in government funding for joint R&D projects at Lawrence Livermore. In the early 1990s the smaller Laboratory Technology Transfer Program in the Office of Energy Research began to provide similar funding for new CRADAs at non-weapons laboratories.

The debate over a DOE role in industrial competitiveness. In this environment, some in DOE, the laboratories, and in Congress sought a major new mission that might retard budget cuts and help meet new national needs. In 1993 they thought they found that new mission in research for industrial competitiveness – a top priority for the new Clinton Administration. Legislation was introduced in Congress in 1993 that would have given DOE's laboratories – particularly the weapons laboratories – a major new competitiveness mission and new money to apply their traditional "core competencies" to helping American industry. Some advocates talked of DOE's facilities becoming the "corporate research laboratories of the United States." While Congress debated this legislation, several pilot efforts occurred, most notably the TTI and related partnership programs and the creation of a high-level technology transfer office within DOE headquarters.

Four factors limited and eventually rolled back most of these efforts. First, even before Republicans won control of Congress in the 1994 elections, DOE's Congressional advocates ran into opposition from those who believed that existing industrial technology programs in other agencies should be used to help American business; the perception was that DOE was trying to muscle in, with an aggressive stance but in many cases little actual experience working with commercial industry. DOE received technology transfer funds during this period, but legislative efforts to expand DOE's formal mission to include industrial competitiveness failed in Congress during 1993 and 1994.

Second, even some of DOE's friends worried that the laboratories might lose focus if they took on large new missions. This view was, in effect, the conclusion of the February 1995 report entitled *Alternative Futures for the Department of Energy National Laboratories* (the Galvin report), prepared by a task force of the Secretary of Energy Advisory Board.[12] The report recommended that the Department, and its laboratories, stay focused on energy issues (including nuclear weapons) and associated science, although the report did not oppose TTI-type partnership efforts.

Third, and most important, was the effort of Republicans, especially House Republicans, during the 104th Congress (1995-1996) not only to curtail technology programs but also to try to eliminate the DOE itself. The new Republican-led Congress strongly opposed all of President Clinton's industrial technology initiatives, including those at DOE. Their effort to close the Department failed, but technology program budgets such as the TTI were cut severely and the Department's high-level technology transfer office was abolished. Some Republicans cited the Galvin report as one argument for cutting the technology programs, although Mr. Galvin wrote to them saying he did not intend for his recommendations to be used to cut the partnership programs. For a while key Republicans even opposed traditional CRADAs – the ones where mission units of the laboratories attempted to transfer mission-developed technology at industry's expense. But that opposition to traditional CRADAs largely subsided by mid-1996. In addition to ideological concerns, Congressional decisions were also influenced by internal resistance in the Department from the people who liked doing traditional mission work and by resistance to the partnership programs from appropriators who felt they did not have as much budget control as they would like and were not sure the funds were well spent. In the tight budget environment, with tradeoffs between the technology partnerships and other programs, partnerships programs did not seem like a good fight.

Fourth and finally, the weapons laboratories, hitherto facing major cutbacks, found a new version of an old mission – the long-term "stewardship" of existing nuclear weapons. The new budgets that came with this mission prevented major cutbacks and reduced the search for a major new mission. These substantial new budgets resulted largely because the Administration was trying to convince conservatives in the Senate to support a comprehensive nuclear test ban treaty.

Current policy. By the middle of 1996, a new basic policy for DOE technology transfer was in place. It looked much like the pre-1993 policy: DOE would continue to fund laboratory research related to its weapons, energy, and science missions; companies interested in this mission research could enter into CRADAs, at company expense; the Department would not fund new programs in general industrial competitiveness; and DOE would cost-share CRADAs that fit DOE mission needs. Individual laboratory researchers certainly remained interested in working with industry, especially if it brought corporate money or funding from other agencies to their research teams. But DOE has not added general industrial competitiveness to its mission.

Since 1996, there has been little explicit DOE policy regarding work with industry. The Department generally encourages partnerships with industry, but today there is little dedicated money for funded CRADAs and DOE is phasing out most projects. At the same time, however, regular "funds-in" CRADAs have been increasing at some laboratories, including LLNL. And laboratory-funded CRADAs have continued, with LLNL again being an example. As mentioned earlier, approximately 3,000 CRADAs have now been entered into at the national laboratories, although precise numbers are hard to come by since Department no longer keeps records of the partnerships.

General budget uncertainties. If technology transfer policy became clearer and more stable beginning in 1996, another major issue was less clear at that point -- overall budgets for DOE laboratories, particularly the non-weapons facilities such as the Berkeley Lab. Budget levels would of course affect which research programs these laboratories would have, thus affecting what programs companies in California and elsewhere could partner with.

When Republicans took control of Congress in January 1995, they pushed very hard spending reductions deep enough not only to balance the federal budget but also to permit tax cuts. Moreover, the new majority made clear that the spending cuts would not come from defense (including DOE weapons activities). Defense might not rise much but it would not be cut. The

[12] Secretary of Energy Advisory Board, Task Force on Alternative Futures for the Department of Energy National Laboratories, *Alternative Futures for the Department of Energy National Laboratories,* February 1995. The report is available on the Web: *http://www.lbl.gov/LBL~PID/Galvin-Report/Galvin-Report.htm).*

proposed reductions would come from civilian programs, some from entitlement programs such as Medicare but much from civilian agency programs (discretionary programs) -- including non-defense research and development (R&D). Based on the budget resolution passed by Congress in 1995, budget analysts at the American Association for the Advancement of Science (AAAS) estimated that non-defense R&D could fall 33 percent within seven years. DOE civilian energy research (along with R&D at NASA and many other agencies) would fall dramatically.

By 1997, the strong U.S. economy and associated growing federal budget revenues changed much of this plan. Under the 1997 balanced budget agreement and associated appropriations acts, DOE research actually received an increase rather than a cut. According to AAAS statistics,[13] total DOE R&D for FY 1998 (much of which goes to the laboratories) was $6.3 billion, a 3.1 percent from the previous year. Within this amount, DOE defense-related R&D increased to $3.0 billion, a 6.4 percent increase. In FY 1999, DOE R&D totaled $7.0 billion, a $714 million or 11.4 percent increase over FY 1998. DOE defense-related R&D rose to $3.3 billion, an increase of 10.5 percent.

5.3 Lawrence Livermore National Laboratory

The contractor for the Livermore Laboratory is the University of California (UC). The laboratory director is Dr. Bruce Tarter.

5.3.1 History

The Livermore Laboratory was established in 1952 to pursue research in thermonuclear physics for weapons and energy; Livermore scientists played an important role in the development of the hydrogen bomb. LLNL is now a multiprogram national laboratory supporting national security, energy, environment, and bioscience. Along with Los Alamos, it was one of DOE's two main laboratories for the design of nuclear weapons (when new nuclear weapons were being designed), and since the end of the Cold War focuses largely on the task of "nuclear stewardship" -- maintaining the safety and effectiveness of those nuclear weapons which remain in the U.S. stockpile. While LLNL receives funds from several divisions of DOE (see below), it remains a nuclear weapons laboratory and receives its principal funding from the Assistant Secretary of Energy for Defense Programs.

As one would expect at a nuclear weapons facility, many of LLNL's programs are highly classified. However, in order to be at the cutting edge of technology the laboratory also maintains extensive research programs in science and engineering, and many of those research programs are unclassified and able to consider partnerships with industry. In addition, as mentioned above the laboratory has built competence in several non-weapons areas, particularly energy, environment, and bioscience. These programs are generally unclassified.

5.3.2 Mission and Major Programs

The mission of the Livermore Laboratory, as stated by DOE, is to serve as a national resource in science and engineering, focused on national security, energy, the environment, and bioscience, with a special responsibility for nuclear weapons. The major program assignments include stewardship of the nuclear weapons stockpile; arms control, nonproliferation, and treaty verification technology; advanced conventional weapons; inertial fusion; operation of Nova, the world's most powerful laser; magnetic fusion and the International Thermonuclear Experimental Reactor; atomic vapor laser isotope separation; nuclear systems safety; advanced process technology; energy research in basic energy sciences, atmospheric and oceanic sciences, fossil energy, conservation, and civilian radioactive waste; Atmospheric Release Advisory Capability; biomedical and environmental research, including a national Genome Research Center; environmental technology; industrial partnering; university research collaborations; and science education.

The major new initiative at the Laboratory is the National Ignition Facility (NIF), a very powerful laser complex that will be used in weapons research. The laboratory also is active in the Accelerated Strategic Computing Initiative (ASCI) and the DOE portion of the human genome project.

Areas of competency. The Laboratory identifies the following as specific areas of competency:

- Nuclear science and technology
- Lasers and electro-optics
- Computer simulation of complex systems
- Advanced sensors and instrumentation
- Biotechnology
- Advanced process and manufacturing technology

5.3.3 Scientific and Technical Achievements

DOE and LLNL list the following as among the laboratory's major achievements. While some of these are primarily of interest to DOE itself, several others illustrate what the laboratory is doing in areas of interest to industry:

On-going non-proliferation assessments of Third World countries; detection and disablement technology being developed.

Assisting in weapons build-down to START II stockpile levels technology for safety and security is highest priority.

[13] See the AAAS Web site, at *www.aaas.org*.

Transferring Atomic Vapor Laser Isotope Separation (AVLIS) technology to the U.S. Enrichment Corporation, the largest technology transfer in DOE history.

Demonstrated steam stripping of volatile soil contaminants, microbial destruction of pollutants and hydrocarbons, mixed waste destruction, and automatic robotic hazardous material sorting and handling.

Covered 95 percent of chromosome 19 with cloned and mapped DNA fragments; identified almost 200 genes so far; co-discovered genetic cause of muscular dystrophy.

Developed the sensors and compact satellite technology for the successful Clementine mission which mapped and mineral inventoried the entire Moon.

5.3.4 Budget, Staffing, and Principal Program Activities

Appendix 2 of this report includes detailed data on all three laboratories, LLNL, Berkeley Lab, and JPL. The appendix includes data on the laboratories' budgets, personnel, and interactions with universities and industry. Here one can briefly mention that in FY 1997, the total budget of LLNL was $1.013 billion, and full-time equivalent staff positions (FTEs) that year numbered 6,728, plus on-site contractors numbering 654 FTEs. Both budgets and staffing have fallen in recent years. In nominal (not inflation-adjusted) dollars, the budget went from $1.049 billion in FY 1993 to $965 million in FY 1994 to the FY 1997 figure of $1.013 billion. Employee FTEs fell from 8,330 in FY 1993 to what will be an estimated 6,565 this current fiscal year (FY 1998), and from 1,867 on-site contractor FTEs in FY 1993 to 654 FTEs in FY 1997 and an estimated 827 FTEs in FY 1998.

Principal program activities, as a percentage of the laboratory's overall FY 1996 budget, are below. The different categories (e.g., Defense Programs) are major program divisions of DOE.

- Defense Programs, 41 percent
- Energy Research, 10 percent
- Nonproliferation and National Security, 8 percent
- Environmental Management, 7 percent
- Nuclear Energy, 2 percent
- Other DOE, 12 percent
- Work for Others (work for other agencies and for industry), 19 percent

Additional information can be found at the Livermore Laboratory's Web site: *http://www.llnl.gov.*

5.4 Livermore Laboratory Interactions to Date with Universities, Industry, and State Government

5.4.1 Universities

LLNL allows university faculty, research staffers such as post-doctoral fellows, and graduate students to have access to unclassified laboratory facilities and work in collaborative projects with laboratory researchers. For example, the Laboratory has long been a leader in advanced computing, especially large supercomputers, and has both shared computing time with university researchers and worked with them on advanced scientific computing. Many of these academic researchers come to the Livermore Laboratory during the summer, but others participate in longer projects. In some cases, LLNL also allows university personnel with required security clearances to participate in classified research projects.

As one would expect at a laboratory managed by the University of California, many of the university researchers who work with LLNL come from UC. Yet many also come from other schools, both within and outside California. LLNL has provided the following data for FY 1995-1998 (Table 5). These data are also presented in Appendix VI.

The key trends here are (1) the steady growth in collaborations with non-UC California personnel and with out-of-state researchers and (2) a recent sharp decline in the number of UC researchers working with the Laboratory. (In FY 1995, UC researchers made up 41 percent of all university personnel working with LLNL; in FY 1998, three years later, they consisted of only 18 percent.)

5.4.2 Industry

The Livermore Laboratory's new era of technology partnerships with industry began in 1990. Although the Laboratory has always had significant interactions with industry through procurements, the passage in 1989 of the National Competitiveness Technology Transfer Act gave national laboratories the opportunity to form CRADAs with U.S. industry. Since then, both CRADAs and other partnerships with industry have grown significantly.

Procurements and large-scale technology transfers are two major ways in which LLNL interacts with companies and helps develop new cutting-edge technologies useful to both the Laboratory and industry.

Table 5. LLNL Interactions with University Researchers (FY 1996)*

	FY 1995	FY 1996	FY 1997	FY 1998
UC faculty	183	174	38	58
UC research staff (including postdocs)	79	61	92	142
UC students	237	173	46	60
Total collaborations with UC personnel	**499**	**408**	**176**	**260**
Other CA faculty			22	22
Other CA research staff			23	27
Other CA students			140	141
Total collaborations with other CA personnel			**185**	**190**
Non-CA faculty	90	54	117	116
Non-CA research staff	369	85	115	156
Non-CA students	267	890	982	934
Total collaborations with non-CA personnel	**726**	**1029**	**1214**	**1206**

Source: LLNL.

* Number of university and college faculty, research staff, and students involved in collaborations with the Laboratory, either at LLNL, their home institutions, or both sites.

High-technology procurements. LLNL invests a great deal each year in procurements, many with California companies. In FY 1997, the Laboratory spent $473 million on procurements from industry, $303 million of which came from California companies. Many of these procurements involve high-technology products. One example is the Accelerated Strategic Computing Initiative. LLNL, Los Alamos, and Sandia are working with computer companies and universities to develop new supercomputers. Those supercomputers will serve DOE needs but also eventually will advance the state of art in commercial computing. In February of this year, DOE announced a major procurement under which IBM will supply LLNL with one of these very advanced supercomputers. Another procurement example is the set of advanced optics for the National Ignition Facility. LLNL developed the technology for advanced optics to accomplish its mission objectives, but rather than manufacture the optics itself the Laboratory has transferred this technology to private firms. Both the Laboratory and the companies will benefit from this arrangement.

Large-scale technology transfers. LLNL developed the Atomic Vapor Laser Isotope Separation process to provide a low-cost, environmentally responsible method for producing fuel for commercial nuclear power plants. The U.S. Enrichment Corporation is now commercializing that technology.

In addition, the Laboratory has four other formal mechanisms for providing technical assistance to industry, as well as some informal processes.[14] [15]

R&D partnerships. This category includes both (1) CRADAs and (2) industrial "work for others," in which an outside entity contracts to use Livermore's unique facilities, services or technical expertise. From 1992 through 1997, Livermore entered into over 175 CRADAs -- including 117 in California. The high number of CRADAs with California companies illustrates the current and potential future value of the Laboratory to the State's economy. In the mid-1990s, the majority of CRADAs were supported by DOE's Technology Transfer Initiative (TTI) funds, with some others being programmatically-funded CRADAs and a few "funds-in" CRADAs without TTI funding. In more recent years, TTI funding from Congress has fallen sharply, which has had a marked effect on the amount of money LLNL has for TTI-supported agreements (see Figure 1). However, the number of funds-in CRADAs is rising, reflecting strong industrial interest in working with the Laboratory. Also rising is the amount of work for others. All of these trends can be seen in Figure 4, below. All told, in FY 1997, even after the decline in TTI funds, funding at the

[14] For a useful summary of Livermore programs, see *Industrial Partnering at LLNL: 1996 Annual Report and Resource Guide,* available from the Laboratory's Industrial Partnerships and Commercialization Office (IPAC). The information presented here is based on that report and additional data from IPAC. The report is available at: *http://www.llnl.gov/IPandC/IPCAnnual/ipacAnn.html.*

[15] The following section and similar sections for LBNL and JPL focus on the number of laboratory-industry projects and the dollar value of those projects. Detailed quantitative data on the economic benefits of those projects (e.g., numbers of resulting new products, amounts of increased sales, improved productivity, jobs created and saved, additional exports) would be valuable but are not presented here because they are hard to collect and generally are not available.

Laboratory for joint research projects constituted some five percent of LLNL's overall budget.

In a March 1998 interview, Laboratory Director Bruce Tarter mentioned that LLNL forms partnerships with a variety of companies in four basic areas.

> No. 1 – and our main focus so far – is the computer industry. For instance, we are now working with IBM to create the world’s largest supercomputer. And we are partnering with an Intel-led consortium to make the next generation computer chip. Second, we also partner with the optics industry. Because of our large lasers, we are a natural to help companies in that industry with projects. Third, we are doing more work in the engineering field, specifically with precision engineering and high-tech engineering. Finally, fourth, we are just starting to get into the biotech industry. For example, we are a partner in the Department of Energy’s Joint Genome Institute, located in Walnut Creek.[16]

Licenses. In 1996, LLNL (working through the UC licensing office) issued 60 patent and copyright licenses. Those licenses in turn brought in $1.1 million in royalties. The Laboratory's most widely licensed technology is the Micropower Impluse Radar, the so-called "radar on a chip." This technology has been licensed to 16 companies in recent years, and over 100 applications have been identified. Overall, many of Livermore's licenses go to startup companies. For example, from FY 1994 through FY 1998, 14 startup companies formed in California based on LLNL licenses.

Small Business Program. This program includes: (1) small-business CRADAs, totaling 49 through the end of FY 1996; (2) through the end of FY 1996, 264 small business technical assistance projects, which usually involves solving a specific, short-term technical problem; (3) work with eight intermediary organizations that link the Laboratory to small businesses; (4) workshops to help interested small businesses understand how to apply to the Small Business Innovation Research and Small Business Technology Transfer Programs; and (5) small business access to unique facilities at the Laboratory, particularly the Livermore Center for Advanced Manufacturing and Productivity, the Livermore User Facility for Inspection and Characterization, and the Virtual Laboratory Testbed.

Technical assistance for businesses of any size. In this program, companies are allowed to contract for up to $25,000 apiece for advice and guidance on technical issues related to existing LLNL technologies. In FY 1996, 12 companies participated in the program.

Informal processes. In some cases, technology transfer that occurs through less formal means has significant benefits. In one of LLNL's most successful transfers of technology, the Laboratory made a three-dimensional dynamic impact software source code broadly available at no charge to all qualified users. The software has been widely used, and the Laboratory in turn has benefited from having access to a wide range of applications.

Beyond the benefits generated by technology partnerships with existing companies, Livermore reports one other important impact on the California economy: the Laboratory estimates that approximately 100 small companies have spun off from its activities over the years, many of them either started by former Laboratory employees or built around technologies licensed from the Laboratory.

5.4.3 State government

The broad multidisciplinary capabilities of Lawrence Livermore and other federal laboratories have the potential for contribution to a variety of important California problems. For example, in 1994 the California State Water Resources Control Board (SWRCB) contracted with LLNL to form a UC team of experts to study leaking underground fuel tanks ("LUFTs") in California. The SWRCB recognized that the demand for reimbursement of cleanup expenses from its cleanup fund outstripped the available revenue, and asked LLNL to examine a risk-based corrective action approach. After examining data from 1,400 LUFT sites, the LLNL/UC team concluded that 90 percent of the dissolved gasoline/benzene plumes were less than 280 feet in length, and most of the plumes were either stable or decreasing from natural bacterial biodegradation. The conclusion was that almost all petroleum fuel releases naturally degrade. Based on these results, the SWRCB promulgated new precedent-setting rules for LUFT cleanup, recognizing the validity of incorporating natural attenuation in LUFT site cleanup action plans, which will save California large cleanup costs.

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[16] “An Interview with Bruce Tarter,” adapted from 680 Business Journal, March 1998. At *http://www.llnl.gov/director/news/680bj.html.*

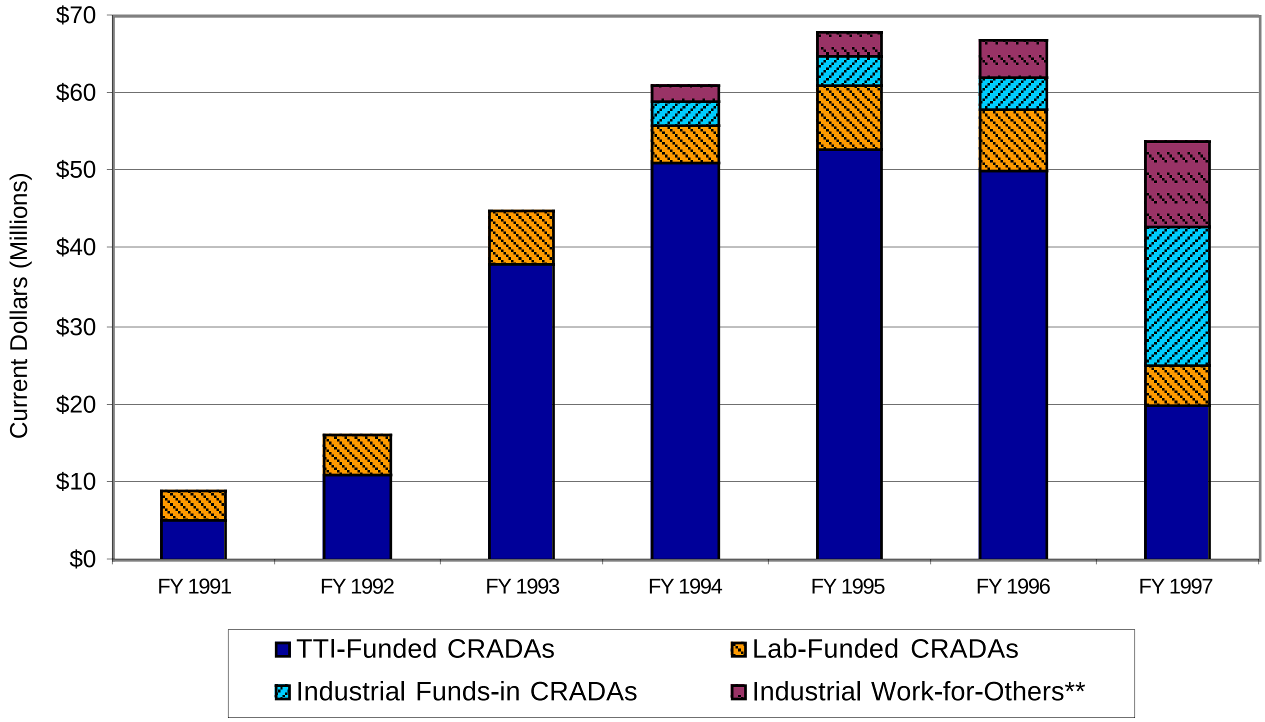

Figure 4. LLNL partnering activities by funding source*

Source: LLNL, Industrial Partnering at LLNL: 1996 Annual Report and Resource Guide, page 19

* Figures for Industrial Work-for-Others and Industrial Funds-In CRADAs are industry dollars. Figures for Lab-funded CRADAs and TTI CRADAs are for DOE funds only; industry matching funds are not included.

** No data available for Work-for-Others prior to FY 1994; amounts were small.

As a result of the LLNL credibility established in the LUFT study, the SWRCB recently asked LLNL to conduct a similar study of the impact of MTBE (methyl tertiary butyl ether) on the state's groundwater. MTBE is a fuel oxygenate added to gasoline to reduce air pollution and increase octane ratings. LLNL found that MTBE is a frequent and widespread contaminant in shallow groundwater in California. There are presently 32,000 LUFT sites in California, and 13,000 have impacted groundwater. Based on this study, MTBE is estimated to occur at over 10,000 of those sites. MTBE is a very recalcitrant chemical, which undergoes natural biodegradation in groundwater at an insignificant rate, and may present a cumulative contamination hazard due to MTBE's persistence and mobility in groundwater. Further LLNL studies on the search for biological agents, which are capable of biodegrading MTBE, are continuing.

In some cases, state agencies and federal laboratories such as Livermore work well together. However, in other cases several difficulties can arise: lack of a single point of contact, an absence of agency technical experts to work with, concern on the agencies' part about disclosing the existence of an R&D budget that might then be cut by legislators, or difficulty in affording even discounted laboratory services.

5.5 Ernest Orlando Lawrence Berkeley National Laboratory

The University of California also manages the Lawrence Berkeley National Laboratory (LBNL, or Berkeley Lab), and the laboratory sits in the Berkeley hills, just above the campus of UC Berkeley. The director is Dr. Charles Shank.

5.5.1 History

The laboratory was established by UC in 1931 to advance physics and biomedical research through the development and application of the cyclotron, invented by Professor Ernest O. Lawrence. During the early days of World War II, the federal government turned to Professor Lawrence for advice on physics and possible nuclear weapons. During the war and after, the Berkeley laboratory remained a major research center, while Dr. Lawrence helped his protégé, Dr. Robert Oppenheimer, establish the nuclear weapons laboratory at Los Alamos, New Mexico. The Berkeley Lab primarily reports to

DOE's Office of Energy Research, the department's division supporting general research in energy sciences.

5.5.2 Missions

LBNL's goals are: to perform leading multidisciplinary research in the energy sciences, general sciences, and biosciences; to develop and operate unique national experimental facilities; and to transfer knowledge, technological innovations, and science education through partnerships with the private sector.

5.5.3 Areas of Competency

LBNL's core competencies are:

- Advanced computing sciences
- Bioscience and biotechnology
- Particle and photon beams
- Characterization and synthesis of materials
- Advanced technologies for energy supply and energy efficiency
- Chemical dynamics, catalysis, and surface science
- Advanced detector systems
- Environmental assessment and remediation

5.5.4 Scientific and Technical Achievements

Berkeley Lab achievements include the following:

The world's most advanced accelerators, including: the first cyclotron, synchrotron, proton linac, and more recently an advanced third generation synchrotron, the Advanced Light Source; the design basis for Fermilab, the Asymmetric B-Factory, the Relativistic Heavy Ion Collider (RHIC); and the physics basis for fusion heavy ion accelerator drivers.

The world's most advanced detector systems, including the liquid hydrogen bubble chamber, the time projection chamber; leading the development of the Solenoidal Tracker at RHIC.

Discovery of the anisotropy of cosmic background microwaves and design of the world's largest telescope – the Keck telescope.

The world's highest resolution positron emission tomograph for disease diagnosis, the molecular basis of cancer expression, the genetic basis of blood systems diseases, the world's most efficient genome sequencing technology, and the development of particle beam treatment since used on thousands of patients.

Developed the most efficient window technology currently available, built energy analysis models now widely used, and transferred advanced lighting technology to industry.

Developed the highest resolution systems for measurement and control of subsurface environmental processes, including subsurface imaging, accurate prediction of subsurface transport, and cost effective solutions to containment of inorganic soil contamination.

Developed models for materials based on first quantum physics principles and their synthesis including the world's hardest materials, unique molecular clusters, advanced catalytic materials, the first low-noise solid state detectors and high temperature superconducting magnetometers.

Further defined the mechanisms of hydrocarbon reactions essential to combustion, the development of new forms of antibody-based catalysis, and determination of the pathways of photosynthesis.

The discovery of 15 chemical elements.

Major user facilities. These include the following:

Advanced Light Source

- National Energy Research Supercomputing Center
- 88 Inch Cyclotron
- National Center for Electron Microscopy
- National Tritium Labeling Facility

5.5.5 Budget, Staffing, and Principal Program Activities

Appendix 2 provides detailed information on Berkeley Lab's budget, personnel, and interactions with universities and industry. By way of summary, in FY 1997, Berkeley Lab's overall budget was $347 million – an increase over the FY 1993 budget of $276 million. By FY 1999, LBNL estimates that its budget will drop to $337 million. Staffing has fluctuated, from 2,715 FTEs in FY 1993 to 2,490 in FY 1996 to an estimated 2,897 in FY 1998. The number of on-site contractors has grown from 206 FTEs in FY 1993 to 365 FTEs in FY 1997.

- Principal program activities, as a percentage of the laboratory's overall FY 1996 budget, were as follows:
- Energy Research (since renamed Science), 64 percent
- Energy Efficiency and Renewable Energy, 8 percent
- Environmental Management, 6 percent
- Civilian Radioactive Waste Management, 1 percent
- Other DOE, 5 percent
- Work for Others, 16 percent

Additional information about Berkeley Lab's programs, resources, and achievements can be found at its Web site: *http://www.lbl.gov*.

5.6 Berkeley Lab Interactions to Date with Universities, Industry, and State Government

5.6.1 Universities

The Berkeley Lab, as mentioned, is physically adjacent to the UC Berkeley campus. Faculty and students from the Berkeley campus have long worked with LBNL researchers and had access to the laboratory's facilities. Areas of cooperation include physics, chemistry, computer science, biophysics and biotechnology, and of course energy and environmental sciences. Over 250 Berkeley Lab scientists are faculty members at UC Berkeley, UC San Francisco, and other campuses. They and other Berkeley Lab researchers guide the work of over 600 graduate students pursuing their advanced degrees through research at the Lab. Berkeley Lab estimates that over 90 percent of its interactions with university researchers (faculty, post-docs, and graduate students) is with individuals from UC Berkeley.

5.6.2 Industry

Berkeley Lab has an active Technology Transfer Department[17] that uses the following partnership mechanisms:

Information exchange. The informal and free exchange of information through publications, presentations, briefings, workshops, and visits.

Technical assistance. Short-duration (5 working days) efforts focused on timely assistance to small businesses.

Personnel exchange. Exchanges of personnel between industry and Berkeley Lab for less than one year.

User facility agreement. Allows industry and university partners to conduct proprietary and non-proprietary research at the Laboratory's facilities.

CRADAs. As in other laboratories, cooperative projects that are supported by both DOE and industry and have a specific technical development focus with planned outcomes.

Work for others (sponsored research). R&D projects and technical assistance efforts that are fully funded by industry. Work must use a unique capability of the Laboratory and not place the Laboratory in direct competition with the private sector.

Licensing. Transfer of rights to patented inventions or copyrighted software. May be exclusive or non-exclusive, for a broad or limited field-of-use, to be negotiated on a case-by-case basis.

In general, Berkeley Lab uses the same partnership mechanisms as LLNL, with one exception: LBNL does not use laboratory-funded programmatic CRADAs, while LLNL does. Of the other two types of CRADAs -- industry-funded and agency-funded (TTI for LLNL, Laboratory Technology Transfer Program for LBNL) -- Berkeley Lab has had significant numbers, despite having a budget only approximately one-third of LLNL's. In FY 1993-97, Berkeley Lab initiated 62 agency-funded CRADAs while the Livermore Laboratory initiated 84, and during those same years Berkeley Lab initiated 55 industry-funded CRADAs while LLNL initiated 52. It may be that one reason why Berkeley Lab has a higher number of these CRADAs on a budget-adjusted basis is that many activities at the larger Livermore Laboratory are classified, but this issue needs further exploration.

With respect to CRADAs and work for others, Figure 5 summarizes the distribution of funds -- from both DOE and outside sources -- that have funded these projects at Berkeley Lab in recent years. More detailed quantitative data on R&D partnerships and licensing at LBNL are available in Appendix 5 of this volume.

Many of Berkeley Lab's R&D partnerships have been with California companies and research organizations. Examples include:

Biotechnology and health care. Somatix Therapy: neurochemical imaging for gene therapy.

Advanced materials and chemistry. Conductus: SQUID-based magnetometers.

Energy and the environment. Mobil, Calresources, Unocal, Crutcher-Tufts, and Santa Fe Energy: optimized secondary oil recovery. Ceramatec and Electric Power Research Institute: thin-film electrolytes for solid oxide fuel cells.

X-ray and accelerator technologies. Advanced Lithography Group, Inc.: ion source and beam control technologies for lithography. General Atomics: medical accelerator technology. *Computing sciences.* Intel Corporation: characterization of wafer contaminants. Kaiser Foundation Hospital: network-based data management system for distributed health care imaging.

5.6.3 State Government

Berkeley Lab has long provided technical assistance to the California Energy Commission.

5.7 How Federal Budget and Technology Partnership Policies for the Two Laboratories are Evolving and Implications for the California Economy

What are the likely the future missions and budgets for these two DOE major laboratories, what will be their policies regarding technology transfer and R&D partnerships, and what are the implications of those missions, budgets, and technology partnership policies for the California economy? This section attempts to answer these questions.

[17] The Technology Transfer Department maintains a Web site at *http://www.lbl.gov/Tech-Transfer/*. For a summary of LBNL's overall contributions to the California and Bay Area economies, see Ernest Orlando Lawrence Berkeley National Laboratory, *Economic Impact Analysis,* Pub-782, October 1996.

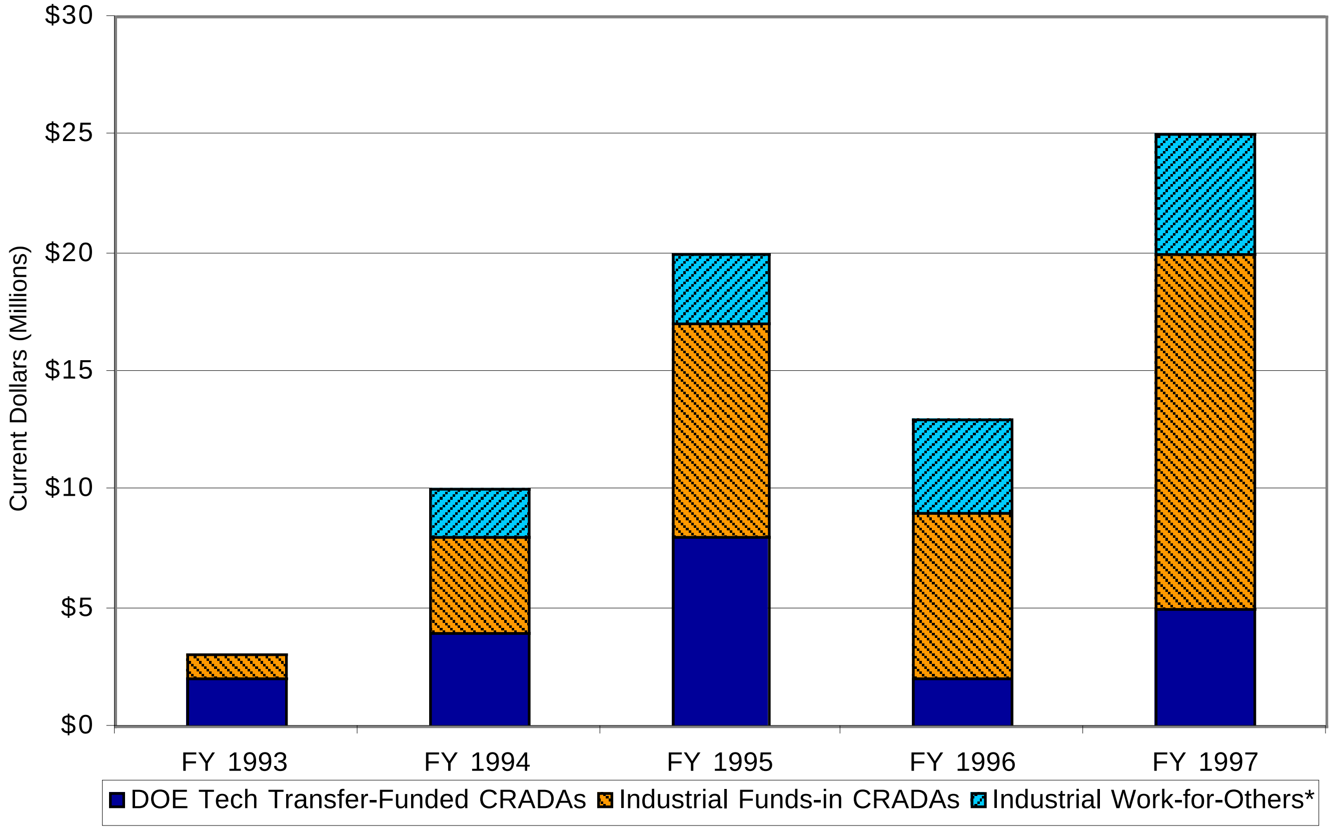

Figure 5. LBNL partnering activities by funding source
Source: data supplied by LBNL

* No data available for Work-for-Others prior to FY 1995; amounts were small

Note: LBNL does not support lab-funded (programmatically-funded) CRADAs

5.7.1 Overall DOE Missions and Budget

In 1997, with federal revenues high due to the strong national economy, Congress and the President reached a balanced-budget agreement that will prevent major cuts in overall federal R&D. This was a significant change from just two years before, when both the Republican Congress and President Clinton contemplated cutting non-defense R&D by up to a third over seven years.

With that budget agreement in place, R&D programs at DOE grew in FY 1998 to $6.477 billion, an increase over the FY 1997 level of $6.234 billion. For FY 1999, President Clinton proposed a total of $7.174 billion, and Congress provided $7.002 billion – an increase of $714 million or 11.4 percent in non-inflation-adjusted terms. (Later budget adjustments eventually changed that FY 1999 total to $6.974 billion.) Much of the FY 1999 R&D increase went into a few select facilities and projects.

The budget for the new National Spallation Neutron Source (to be built at Oak Ridge in Tennessee), rose from $23 million in FY 1998 to $130 million in FY 1999.

Two programs important to Lawrence Livermore also received increases. The NIF's budget rose from $198 million in FY 1998 to $284 million in FY 1999. The ASCI, which supports advanced supercomputing work at LLNL and other laboratories, rose from $224 million to $306 million.

For FY 2000, the President is requesting $7.467 billion for DOE R&D, an increase of $493 million or 7.1 percent. This is a significant increase. DOE Atomic Energy Defense R&D would rise for an adjusted FY 1999 level of $3.234 billion to $3.417 billion. Non-defense R&D would grow from an adjusted FY 1999 amount of $3.740 billion to $4.049 billion – an increase of 6.4 percent. The FY 2000 non-defense request includes $70 million for the Scientific Simulation Initiative (SSI), DOE's contribution to the Administration's Information Technology for the 21st Century (IT^2) initiative. The budget also includes $214 million for the Spallation Neutron Source. There also would be increases of 20 percent for Solar and Renewables R&D and Energy Conservation R&D.[18]

5.7.2 Livermore Laboratory's Mission and Budget

The President's FY 2000 budget proposes no major changes in the Livermore Laboratory's mission but would increase DOE funding for the Laboratory from $1.090 billion in FY 1999 to $1.114 billion. (In addition to DOE funding, Livermore of course receives some additional funds from other agencies and from industry, so the DOE allocation is not the Laboratory's total budget.) The major increase in DOE funds is in the stockpile stewardship element of the nuclear weapons program.

Out-year budgets – that is, DOE budgets beyond FY 1999 – will depend in part of course on the final FY 1999 appropriations. At the moment, however, the Department expects to continue the stockpile stewardship program at about the 1999 level in the out-years. Continued out-year support for construction of the National Ignition Facility (until 2003) and for the Accelerated Strategic Computing Initiative seems likely. No other major planned increases or decreases have been announced.

5.7.3 Berkeley Lab's Missions and Budgets

The FY 2000 DOE budget request for LBNL is virtually unchanged from FY 1999: $275 million versus $277 million in FY 1999. Most of the individual elements in the budget are largely unchanged as well, and the budget proposes no major changes in LBNL's missions or programs.

Out-year budgets for Berkeley Lab are also likely to be fairly stable. The DOE Science program, which provides about three quarters of the DOE funding at Berkeley Lab, expects to have a moderately increasing budget over the next five years. There will be many demands on any increases, however, such as the construction National Spallation Neutron Source at Oak Ridge. Relatively little, if any, facilities increases may wind up at Berkeley Lab. With the completion of the Advanced Light Source five years ago and the recent move of the National Energy Research Supercomputing Center (NERSC) to LBNL in 1996, there are no major new facilities planned for the next few years.

5.7.4 Future Trends in DOE Technology Transfer Policy

In the FY 2000 budget request, DOE funds for new technology partnerships effectively fall to zero. The Administration proposes to cut the Technology Partnerships account from $43.1 million in FY 1999 to $22.2 million in the coming year, and the FY 2000 money will go to existing projects. Many ongoing funded CRADAs will begin to close out in FY 1999.[19]

Despite the end of dedicated DOE technology transfer funds, work with industry now seems to be firmly established at LLNL and Berkeley Lab, and these two laboratories will continue their efforts to make unclassified mission-developed technology available to industry.[20] In addition, individual investigators at all three laboratories now seem much more interested than in past years in working with industry – especially if industry is willing through CRADAs or other mechanisms to help fund some of their research. Both laboratories continue to try to make their technology transfer processes simpler and more user-friendly.

There are still barriers to collaboration. Some are operational. For example, in some cases California companies believe that the partnership process at DOE laboratories is unnecessarily long and complex because of the requirement to get approval from three sets of officials – those at the laboratories, those at the University of California, and those at DOE itself. However, as the laboratories have gained experience in writing CRADAs, the negotiation process appears to be going more smoothly.

But beyond such operational problems and the political upheavals DOE experienced in the mid-1990s, there are also some important political tensions and limitations inherent in the CRADA model -- factors mentioned in Chapter 3's discussion of technology transfer policy. As mentioned there, Cohen and Noll point out that inherent in the CRADA approach are the risks that (1) DOE and other agencies will be accused of "picking winners and losers" by choosing to work with some companies and (2) the agencies will be accused of using taxpayer-supported technology to help some companies make visibly large profits.[21]

A recent example of the first type of political problem -- controversy generated by helping individual companies -- is the debate over the extreme ultraviolet lithography (EUV) CRADA. This $250 million multi-year CRADA is between Intel and other semiconductor manufacturers and LLNL, Berkeley Lab, and Sandia. Livermore will provide the critical optics and coatings for

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[18] American Association for the Advancement of Science, *Modest Increases Proposed for Federal R&D in FY 2000: AAAS Preliminary Analysis of R&D in the FY 2000 Budget, February 4, 1999.* Source: AAAS Web page.

[19] Department of Energy, *The FY 2000 Budget Request for the U.S. Department of Energy*, page 66.

[20] At the time this report is being written, Congress is considering organizational changes at DOE aimed at strengthening security. It is currently unclear whether these changes, if adopted, will have any impact on technology transfer policies and activities at DOE facilities such as LLNL.

[21] As mentioned in an earlier chapter, laboratory-funded programmatic CRADAs are less likely to encounter criticisms of "corporate welfare" or "picking winners and losers," since they serve laboratory mission needs as well as help corporate partners.

the lenses, and "mask blanks" for making patterns on chips. Here controversy arose primarily because of initial concern that Intel would license technology developed under the CRADA to Japanese or European semiconductor equipment manufacturers, potentially putting U.S. equipment firms at an unfair competitive disadvantage.

The controversy in this case arose not over the proposed deal itself – which is to transfer and further refine important chip-making technology developed at LLNL and other laboratories. The controversy arose because of Intel's desire to make that technology available to foreign manufacturers of lithography equipment. Intel wanted to ensure that its major suppliers would have this improved technology. But that proposal led one American lithography company and some Members of Congress to ask why taxpayer-developed technology was to be given to foreign competitors. Moreover, some officials at the Departments of Commerce and Defense raised questions about whether the transfer should get an export-control review. The EUV CRADA is now the subject of intense discussion in Washington, and it is quite possible that it will be restructured in ways that address the concerns of American lithography companies. But even if resolved, this debate may have a chilling effect on other proposed partnerships, and may also lead to a reexamination of rules and procedures regarding foreign licensing of technologies developed in CRADAs.

The EUV case raises three specific, interconnected issues for both Washington policy-makers and the laboratory officials who carry out federal technology transfer policy:

First, what constitutes a "good" deal for the United States when it comes to CRADAs, especially as companies and suppliers become more global? It used to be that the biggest political objection to CRADAs was that they benefit one U.S. company over another. That is still an issue, of course, but the involvement of foreign companies now also looms large.

Second, until this first issue is settled many laboratory officials feel they are in a "lose-lose" situation: if they do not enter into CRADAs, they will be criticized by Congress for not transferring technology, but if they approve projects in this global, competitive marketplace then often someone will criticize them over the details. The lack of clear political guidance on how to write CRADAs that will meet with broad approval is source of great frustration to laboratory leaders.

Third, are new formal rules needed or appropriate? The EUV case has led to a new proposal in Congress to add another layer of government review to the approval of "major CRADAs." In 1998, Congresswoman Ellen Tauscher (D-CA), who represents the district that includes the Livermore Laboratory, offered an amendment that would require the Director of the White House Office of Science and Technology Policy to establish procedures for the interagency review of proposed major CRADAs.[22] The intent is to vet these proposals before they are approved and to avoid the kind of interagency fight that occurred after DOE approved the EUV project. But another layer of review might also add further delay and uncertainty into an already long process of negotiating and approval CRADAs. The risk is that new rules may not only complicate and delay CRADA negotiations but also deter companies from trying to work with DOE.

While many smaller industry-funded CRADAs that do not encounter this type of political controversy, other problems can arise – including lawsuits over intellectual property.[23] Despite the successes of many CRADAs, frequent political and legal problems will continue to pose challenges for federal laboratories, including those in California. The results are likely to be, first, a limited number of often small CRADAs and, second, a renewed interest on the part of the laboratories in "programmatic CRADAs" that serve politically-defensible laboratory missions as well industry needs. These points do not mean that LLNL and Berkeley Lab will not continue to use the CRADA mechanism to make contributions to the California economy. It simply means that there are likely to be political limits to the process that go deeper than simply annual technology transfer budgets.

5.7.5 Policies Regarding Assistance to State and Local Governments

DOE encourages its laboratories to try to be good neighbors and provide assistance, when asked, to their communities. Employees at both LLNL and Berkeley Lab volunteer in local schools and make other contributions. They also have sometimes offered technical assistance to state and local agencies. Two examples mentioned earlier include Livermore's assistance

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[22] Congresswoman Tauscher's amendment was added to a bill approved by the House of Representatives on July 14, 1998 (H.R. 2544). As mentioned earlier in this volume, the proposed Technology Transfer Commercialization Act of 1997 did not become law. But Congresswoman Connie Morella (R-MD), the bill's sponsor, reintroduced it into the 106th Congress as H.R. 209, and it passed the House again on May 11, 1999. The type of supervision called for in the Tauscher amendment was foreseen by Cohen and Noll. They write:

> The historical record of responses in government procurement suggests that the likely response [when CRADAs generate political problems] will be for the government to institute much more elaborate cost accounting and oversight, the traditional baggage of procurement policies that CRADA legislation sought to avoid. Expanded oversight will create conflicts with the confidentiality provisions of CRADAs and the flexibility of laboratories in contracting with firms (a hard-won right), and bodes poorly for private interest in cooperative research.

[23] For examples, third parties sometimes sue a laboratory, saying that they, not the laboratory, first invented a particular technology that the laboratory has licensed or developed through a CRADA.

to the California State Water Resources Control Board and Berkeley Lab's help to California energy agencies.

However, other efforts have encountered some problems that are not the fault of either DOE policy or the laboratories. In some cases, state agencies have small R&D and technical service budgets, making it difficult for them to afford even discounted services from the laboratories.

5.7.6 Impact of these DOE Trends on the Two Laboratories

The overall effect of these trends in DOE's missions, budgets, and technology partnering policies is one of maintaining the status quo.

The missions and budgets for most LLNL and Berkeley Lab programs are likely to be relatively stable over the next several years; no major cuts are contemplated, and the Livermore Laboratory will see some growth. With stable budgets, budget considerations are unlikely to cause major changes in the two laboratories partnerships with industry.

The Livermore Laboratory will remain strong in a wide range of key sciences and technologies. Moreover, it will remain strong, and probably become even stronger, in several mission areas particularly relevant to the California economy, most notably lasers and optics (through the National Ignition Facility), advanced computing, and biotechnology and genomics (through its continuing role in the human genome project). Key parts of both NIF and the computer initiative will be classified, but other parts will be open.

Berkeley Lab sees it future as lying primarily in five core areas, all important to California: computational science, especially computation of large scale; genomics; materials characterization; fusion energy; and energy R&D. In computation, for example, Berkeley Lab is focusing on the development of usable, adaptable software codes for very fast supercomputers, codes that can be used for modeling complex phenomena such as protein development and global change and doing so over the Internet. In fusion energy, Berkeley Lab has a much smaller program than Livermore, but believes that its inertial confinement fusion technology, which uses charged particles instead of lasers, is well-suited for possible commercial fusion energy projects. This work could help boost California's position as a world leader in fusion energy. In general energy R&D, the Lab will continue to work closely with the California Energy Commission on energy-efficient lighting, windows, and appliances.

As part of research opportunities in these various areas, Berkeley Lab's user facilities will remain available to industry. These include the Advanced Light Source, the National Energy Research Supercomputing Center, and the National Center for Electron Microscopy. In 1997 a DOE panel raised questions about the Advanced Light Source, but the combination of an

Table 6. FY 1999 DOE R&D Budget (Budget Authority in Millions of Dollars)

	FY 1998	FY 1999 Request	FY 1999	Change from FY98	Percent increase
Energy Supply R&D	550	709	642	92	16.7%
Fossil Energy R&D	276	295	301	25	9.2%
Energy Conservation	356	455	386	30	8.4%
Science	2,228	2,445	2,422	194	8.7%
Atomic Energy Defense	2,979	3,279	3,291	313	10.5%
Clean Coal (rescissions)	-101	-40	-40	61	-60.4%
Total DOE R&D	6,288	7,142	7,002	714	11.4%

Source: American Association for the Advancement of Science (November 13, 1998) improved budget picture, organizational changes, and a new list of scientific opportunities has persuaded DOE managers to keep the facility open and even to consider a funding boost.[24] It will thus remain available to university and corporate researchers.

Dedicated DOE appropriations to support new funded CRADAs of interest to industry will be phased out during FY 1999 and FY 2000.

Even without dedicated DOE technology transfer funds to support new laboratory research in support of CRADA projects, both the Livermore Laboratory and Berkeley Lab show a strong dedication to CRADAs and other forms of R&D partnerships with industry. The possibility of political controversy over CRADAs remains a concern, but the two laboratories will continue to seek ways to work with companies in California and elsewhere.

5.7.7 Implications of these Trends for the California Economy

The trends in federal budgets and policies mentioned above have several important implications for the California economy, including private companies and universities.

Livermore and Berkeley Lab generally will maintain their budgets, employment levels, and levels of procurement – although procurement at LLNL will decline once the NIF is completed in FY 2003.

LLNL and LBNL will maintain their current technical capabilities and facilities, and while DOE is unlikely to change its mission and place a great emphasis on helping U.S. economic competitiveness, the laboratories remain open to working with California companies. Companies will have to pay their own way, however, since dedicated DOE money for funded CRADAs will remain small

In general, LLNL and Berkeley Lab would like to be helpful to State officials. Most successes to date have been in the environmental and energy areas.

6. Appendix 3. The Jet Propulsion Laboratory

6.1 Summary

This appendix examines JPL – its programs and budgets; its contributions to date to the California economy; major federal budget and policy trends that will affect the Laboratory in the future; and the implications of those trends for California. These are the main points:

The Jet Propulsion Laboratory (JPL) is owned by NASA and operated by the California Institute of Technology (Caltech). It is NASA's lead field center for the robotic exploration of outer space, and has particular technical expertise in microelectronics and robotics, communications, and imaging.

In terms of interactions to date with California universities, JPL works with academics mainly through research grants and contracts. While California's average percentage of these awards over FY 1993-1998 is 48 percent, there is great variation from year to year – ranging from a high of 96 percent of these awards in FY 1994 to only 19 percent in FY 1997.

After procurements, JPL's main interactions to date with industry have come from its Technology Affiliates Program, a technical assistance program that helps primarily smaller firms and is counted in Table 1 under the category of "work for others." JPL does have a CRADA-like mechanism for joint industry-laboratory R&D, called technology cooperation agreements (TCAs). The number and dollar value of such projects are less than at the comparably-sized Livermore Laboratory – in part because NASA has never provided DOE-type dedicated funds for joints projects.

In the future, NASA faces a declining budget. The FY 1999 appropriation for NASA is $13.665 billion, and the President proposes an FY 2003 budget of $13.750 billion – a level that does not provide inflation increases. The budget situation is in fact even tighter than that, given anticipated cost overruns in its top initiative, the International Space Station. NASA has tried to cope with this situation by cutting its staff rather than its program activities.

Given the budget and policy trends mentioned above, JPL is currently undergoing a major reduction in staff – from 7,463 people on site in FY 1993 (5,856 employees and 1,607 on-site contractors) to 4,800 people by the beginning of FY 2000 (4,300 employees and 500 on-site contractors). This is a 35.7 percent cut over seven years. Many routine activities are being outsourced, and the laboratory is now focusing on the final assembly of space probes and the development of innovative technologies for future space missions.

The increased emphasis on technology development includes microelectronics, digital imaging, and advanced communications – all areas of potential interest to California industry. JPL and Caltech are continuing to develop new policies for the license of JPL inventions and for undertaking joint technology projects with industry.

The increase in JPL science awards to university researchers has been dramatic over the past two years – from $84.9 million in FY 1996 to $372.3 million in FY 1998. This emphasis on extramural research awards is expected to continue.

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[24] Andrew Lawler, "Future Brightens for Berkeley Facility," *Science*, Vol. 280, 3 April 1998, page 28.

6.2 NASA

Today NASA is divided into four main activities or, as the agency calls them, "strategic enterprises:" aeronautics; human exploration and development of space; earth systems science (a set of satellites and research projects to study the global environment and global change); and space science. In FY 1999, NASA received an overall appropriation of $13.665 billion. Of this amount, $2.119 billion went to space science.

NASA operations are conducted through a series of 14 field facilities around the country, including both R&D centers and other facilities. All of them except JPL are government-operated facilities – that is, they are staffed by federal civil servants. As mentioned earlier, the California Institute of Technology (Caltech) operates JPL for NASA, using non-government personnel. In addition to JPL, three other NASA facilities are located in California:

- Ames Research Center, Mountain View
- Moffett Federal Airfield, Mountain View
- Dryden Flight Research Center, Edwards, CA

NASA has gone through dramatic organizational and programmatic changes in recent years. Among the key changes:

Budget. As mentioned, NASA's budget is no longer growing. In fact, it has been flat in recent years, meaning that it is not getting inflation increases. This has put severe budget pressure on many programs.

Outsourcing. Partly because of the budget pressures, and partly as a result of the overall federal effort to "reinvent" agencies, NASA has cut its civil service and JPL personnel and "outsourced" many operations to private contractors. Examples include contracting with a private consortium to run space shuttle operations in Florida and the use of a private company to handle operations for some of JPL's deep space probes.

New technology. NASA Administrator Dan Goldin has emphasized new technology in two ways. First, in unmanned space missions he has moved away from large, expensive satellites and space probes to the use of technologies that result in missions that are "smaller, faster, cheaper." Second, in all areas of NASA he has placed a heightened priority on the development of new innovative technologies. Examples include innovative new launch vehicles and new technologies for unmanned missions.

6.3 Overview of JPL

6.3.1 History and Mission

JPL is an FFRDC, operated, as mentioned, by Caltech. The laboratory is located in Pasadena, California, not far from the Caltech campus. Dr. Ed Stone serves as JPL's director.

The laboratory's history dates back to before World War II, when the United States Army Air Corps contracted with Caltech to help develop rocket technologies, including strap-on rockets (called JATO, for "jet-assisted take-off" rockets) to help overloaded Army airplanes to take off from short runways. Then from 1945 until 1959, Army Ordnance was the laboratory's institutional sponsor, supporting work in rocket technology and missile system development. (Even after the Army Air Corps/Army Air Forces became the U.S. Air Force in 1947, the Army retained responsibility for air defense missiles and other rocket programs.) By 1959, NASA had become the prime institutional sponsor of the laboratory – although DOD and even DOE supported some JPL programs in the 1970s, 1980s, and 1990s.[25]

Since 1959, JPL has been NASA's lead laboratory for robotic, unmanned missions to explore the solar system. JPL spacecraft have visited the Moon and all the known planets except Pluto, and a Pluto mission is currently under study. JPL has developed and managed a long string of robotic craft, including the Pioneer, Mariner, Ranger, Surveyor, Viking, and Voyager missions. Most recently, the laboratory successfully operated the Mars Pathfinder and Mars Global Surveyor missions. Today JPL's Cassini spacecraft is on its way to Saturn. The laboratory also conducts extensive scientific research in earth sciences, planetary science, and astrophysics, and develops space instrumentation for other NASA spacecraft, including the shuttle. In addition, JPL manages the worldwide Deep Space Network, which communicates with spacecraft and conducts scientific investigations from complexes in California, Spain, and Australia.

JPL is recognized as having world-class technical capabilities in several areas, particularly in communications, imaging systems and digital image processing, microelectronics, advanced instruments and sensors, and intelligent automated systems.[26]

While JPL's main mission – robotic exploration of space – continues, new NASA policies are changing how the Laboratory carries out that mission. Three changes are particularly noteworthy:

First, JPL is transferring much of its scientific analysis of the planets from its in-house scientific staff to outside university scientists. JPL has always worked

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[25] For more on JPL's history, see the fact sheet at: *http://www.jpl.nasa.gov/information/fsheet.*

[26] One interesting question is whether new technologies in these areas are of interest to California venture capitalists and associated entrepreneurs. No information is available at the present time to answer this question, but one policy option presented in Chapter 1 of this volume is that CCST or the California Trade and Commerce Agency consider facilitating meetings between JPL research leaders – and research managers from other laboratories, as well – with venture capital firms. (See Chapter 1 for details.)

closely with academic scientists, but will do even more so in the future.

Second, the Laboratory is now outsources more of its spacecraft development and flight operations. JPL no longer manufactures most of the components that go into spacecraft and instead focuses on design, final assembly, and testing. And many routine operational aspects of JPL's space missions are being contracted out to private firms; private engineers will now play a large role in monitoring spacecraft as they proceed on their missions.

Third, from now on JPL engineers and scientists will focus on two primary responsibilities: the design, assembly, and testing of spacecraft and the development of innovative new technologies for future missions. In particular, JPL is focusing on miniaturized, low-cost components and autonomous robotic systems that can direct themselves when a spacecraft is billions of miles from earth. The focus on new technologies and smaller, lower-cost components reflects NASA's new emphasis on smaller, less-expensive spacecraft and technical innovation. The Cassini mission, now on its way to Saturn, will be the last of the large, expensive space probes. Examples of new space probes using the new technology include the Mars Pathfinder mission (with its small Mars rover, Sojourner) and the Mars Global Surveyor mission.

Dr. Stone describes JPL as now being in its third era of space exploration. The first era was “getting there” (the Mariner missions); the second era was “finding out what’s there” (Voyager, Viking, Magellan, Cassini, and Galileo); and the third era is “getting out there often and getting back.” This third era includes the new smaller, cheaper Mars missions, including a planned mission to bring a sample of Martian soil back to earth. JPL’s approach towards technology has changed as the eras change. In the second era, the large missions developed their own technologies. “Third era programs do not have the funds or time to follow this approach, and the linked technology programs address this element,” he says. So JPL is now focusing on developing innovative new technologies that can be used in a number of missions. Instrument technology is a key focus.[27]

6.3.2 Programs, budget, and personnel.

Detailed data on JPL's budget, personnel, and interactions with universities and industry are included in Appendix 5. By way of summary, in FY 1996, the total budget for JPL was $1.063 billion, 93 percent of which came from NASA, five percent from DOD, and two percent from other sponsors (government and private). This staff was, in turn, divided into support offices, a program office, and several program directorates. The program office and program directorates are:

- Cassini Program Office
- Mars Exploration Directorate
- Space and Earth Science Programs Directorate
- Technology and Applications Program Directorate
- Telecommunications and Mission Operations Directorate
- Engineering and Science Directorate
- Engineering and Mission Assurance

Additional information on JPL's programs can be found at the Laboratory's Web site: *http://www.jpl.nasa.gov*.

In line with directives from NASA headquarters, JPL is undergoing major changes. The most dramatic change is the reduction in staff. In FY 1993, JPL had 7,463 people on site (5,856 employees and 1,607 on-site contractors); as part of overall NASA staff reductions, Laboratory officials expect to have 4,800 people by the beginning of FY 2000 (4,300 employees and 500 on-site contractors). This is a 35.7 percent reduction in seven years.

6.4 JPL Interactions to Date with Universities and Industry

6.4.1 Universities

JPL enjoys close contacts with Caltech, particularly in space exploration, robotics, electronics, and other fields where the laboratory has established core competencies.

But as noted above, today JPL's primary way of working with universities is not by having a large in-house scientific research enterprise that university scientists visit but rather by supporting academic scientists who study data obtained by JPL space probes. As a result, the main indicator of laboratory-university interactions for JPL is not the number of academics who join JPL research projects – since JPL now has fewer on-site scientific analysis projects – but rather the size of the research contracts the Laboratory has with university scientists. And in the last year, as JPL "out-sources" more of its scientific work, this figure has grown dramatically – a point that illustrates how important JPL is to university science in California and the nation, particularly in astronomy and earth and planetary sciences.

The data presented below in Table 7 cover (1) the total contracts JPL has had with all universities throughout the country, by fiscal year; (2) the amounts of those totals going to California universities; and (3) the percentages of these JPL amounts going to California universities each year. A key point is that these percentages vary a great deal over the years, suggesting that California universities cannot take it for granted that they will automatically do well in these JPL competitions. California universities

[27] Remarks of Dr. Ed Stone, “Meeting Report, NASA Advisory Council, December 3-4, 1998,” at http://www.hq.nasa.gov/office/codez/nac/mins.htm.

Table 7. JPL Research Contracts with Universities (in Millions of Dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	Totals 1993-1998
Total contracts with all universities	74.8	35.5	115.7	84.9	61.4	372.3	744.5
Contracts with universities in California	34.0	34.0	64.6	34.1	11.5	178.2	356.4
Percentage that year to CA universities	45%	96%	56%	40%	19%	48%	48%

Source: Jet Propulsion Laboratory

may wish to talk with NASA and JPL about what steps would make these universities even more effective in competing for these funds.

6.4.2 Industry

JPL has benefited industry, including California industry, in three main ways: procurements, technology transfer and commercialization programs, and grants to small businesses through the Laboratory's Small Business Innovation Research (SBIR) Program.

Procurements. JPL's benefits to industry come first through its procurement activities, many of which involve high-technology components and a close working relationship between the Laboratory and companies. During FY 1993 through FY 1997, JPL spent a total of $2.727 billion on procurements from industry, and $1.465 billion of that was spent in California.

Technology transfer. In addition, JPL maintains an active Technology Transfer and Commercialization Program.[28] That program has six main activities:

Technology Affiliates Program. Through this program, companies get technical assistance from the Laboratory to solve a range of industry problems. This is JPL's largest technology transfer program, in terms of the number of companies participating and the number of projects undertaken. To date, more than 120 companies have generated more than 200 specific technical assistance projects to meet their needs.

One successful example is Displaymor, a mid-sized Los Angeles refrigeration company; JPL helped make its refrigerated display cases colder and less resistant to cracking. In another example, JPL's spacecraft communications experts helped McCaw Cellular develop improved cell phone communications technology. A third example is how JPL experts in earth imaging helped the National Geographic Society develop a digital photographic map of the Earth that is the most accurate yet.

Targeted Commercialization Office. This group is relatively new. It arranges projects which aim to transfer and commercialize JPL mission-derived technologies that have considerable commercial potential. The office looks to the private sector as the predominant source of million-dollar-level funding for commercial technology applications, and is developing programs in remotely-sensed imagery, telecommunications, and health care. A first project was initiated in FY 1997.

Technology Cooperation Agreements Program. Projects in this program are similar to CRADAs in other laboratories. (As mentioned in an earlier section, Caltech and JPL does not use the CRADA authority under the Federal Technology Transfer Act and instead, with NASA's approval, uses a type of university partnership model.) These projects involve joint development efforts between JPL and industry in technologies with both NASA and commercial applications. Research topics are chosen that are mutually beneficial to both JPL/NASA and the partner company. JPL operates these as "no exchange of funds" agreements aimed at developing technologies that are commercially viable within three years of initiation. The partner company must have a plan to commercialize the results of the collaboration. From FY 1994 through FY 1997, JPL entered into 40 of these agreements, with JPL contributing a total of $11.1 million to these projects and industry partners contributing a total of $17.3 million.

Intellectual property management. This is the technology licensing operation. As at other university-operated federal laboratories, the parent university holds the patent rights. The JPL-developed technology portfolio currently consists of more than 170 patents and 60 applications for patent protection. From FY 1993 through FY 1997, Caltech licensed a total of 29 royalty-bearing JPL licenses and 525 non-royalty-bearing licenses. Total royalty income from these licenses during this five-year period totaled $2.480 million. This is lower than some other laboratories the size of JPL, but in part reflects a Caltech/JPL policy of licensing a patent to its Caltech or JPL inventor rather than seeking to maximize royalties by licensing it to a large corporation. Some of these licenses have led to spin-off companies. One notable example is Photobit, of La Crescenta, CA.

[28] For further information, see: *http://techtransfer.jpl.nasa.gov*. The types of projects available and their benefits are illustrated by the "success stories" presented at on the JPL Web site at: *http://techtransfer.jpl.nasa.gov/success/success.html*.

The company licensed JPL technology for a new, very small digital camera originally developed for future spacecraft. The company has in turn sub-licensed this promising technology to Kodak and others.

Technology Reporting and Communications. This group provides detailed technical information regarding the more than 300 new technology disclosures made by JPL employees every year. This program also manages a large volume of new computer-software disclosures and licenses, and maintains a World Wide Web site that provides current information on JPL's technology transfer activities, a listing of technical support package titles, and more than 850 available technologies.

Small Business Innovation Research. The SBIR program at JPL seeks innovative concepts from small businesses that address NASA/JPL needs. Companies submit proposals, which are designed to stimulate technological innovation in the private sector, and contracts are awarded to those proposals judged most promising. In some cases, the winners will provide JPL with equipment or components it needs, meaning that the SBIR efforts complements overall procurement activities. The SBIR process is highly competitive, with about 50 contracts a year being awarded out of about 500 submissions. About half of those awarded SBIR Phase I contracts in the first year later received Phase II contracts, where the dollar amount is much larger. One example of a project is a robotic arm of laparoscopic surgery developed through an SBIR award by Computer Motion, Inc., of Goleta, CA. In addition, JPL is the process of establishing a new business incubator to help startups and other small firms with business support services for the primary purpose of commercially applying NASA technology. JPL and NASA's Dryden Flight Research Center will jointly run the new incubator.

6.5 How NASA Policies are Evolving and Implications for the California Economy

What are likely to be the future missions and budgets for JPL, and what are the implications for the California economy? Related, how are federal policies regarding laboratory interactions with industry and universities evolving in so far as JPL is concerned, and what are the implications of these trends for the California economy?

6.5.1 Mission and Budgets

Today, NASA's overall budget picture is tight, although JPL is nonetheless expected to come out relatively well. Three key factors are at work:

Overall budget. NASA's overall budget is slowly declining – although, as with DOE, it will not suffer the deep cuts proposed before Congress and the President completed the 1997 balanced-budget agreement. While top political leaders in Washington like the space program, it is not the highest priority and is not scheduled, in either the President's budget plans or Congressional budget resolutions, for any significant growth in coming years. The agency may not even get increases equal to inflation. Table 8 shows the out-year numbers for NASA that the President proposes.

Table 8. Out-year NASA Budget Numbers Proposed by the President

FY 1999 (actual appropriation)	$13.665 billion
FY 2000 (proposed)	13.578 billion
FY 2001 (proposed)	13.752 billion
FY 2002 (proposed)	13.757 billion
FY 2003 (proposed)	13.750 billion
FY 2004 (proposed)	13.750 billion

Source: President's FY 2000 budget request

Space station. The budget squeeze is compounded by the fact that NASA's highest priority, the International Space Station, continues to run into political problems and cost overruns. The political problems stem from the fact that Russia, a key partner in the project, refuses to provide adequate funds to construct and launch its parts of the project. The cost overruns involve, first, increased costs for American components and, second, the fact that the Russians have not delivered promised components, forcing the United States to spend additional funds of its own. There is constant concern among some observers that serious cuts will have to be made in other NASA programs, including space science, to pay for the station overruns. One reason for their concern is that NASA has consistently promised to pay for the station within its regular budget, and at the moment neither Congress nor the White House seem predisposed to provide extra money to the agency to pay for the additional station costs.

Space science and JPL. That being said, the NASA space science budget has many supporters in Congress and the Administration, and any proposal to make deep cuts in the space science budget will not go unchallenged. The President's budget proposes steady increases in the space science account – from $1.984 billion in FY 1998 (later adjusted under transfer authority to $2.043 billion) to $2.119 billion in FY 1999 to a proposed $2.851 billion in FY 2004. The President's FY 2000 request for space science at NASA is $2.197 billion. The President's FY 2000 budget actually requests an increase in JPL's ASA funds – from $1.158 billion in FY 1999 to $1.381 billion this coming year.[29]

[29] Another sign of White House support for the Space Science account is the fact that it is one of four NASA programs included in the proposed Research Fund for America – the President's list of his highest-priority civilian R&D programs. (The other three NASA programs in the RFFA are Earth Science (formerly Mission to

The "bottom line" is that JPL's budget should be steady and might even achieve modest growth in the coming years – unless space station costs balloon and NASA is forced to take the required station funds out of other agency accounts.

6.5.2 Policies Regarding Interactions with Universities

As mentioned earlier, JPL, with NASA's encouragement, is continuing its process shifting scientific analyses previously done in-house to universities. JPL estimates than in a few years research scientists studying spacecraft data will make up only about five percent of the JPL staff. Thus, one can expect JPL's contracts with university scientists not only to continue but expand. JPL is, and will remain, an important and valued source of funding for many astronomers and earth and planetary scientists in California and elsewhere.

6.5.3 Policies Regarding Industry Interactions

In the last two years, NASA's policies regarding industry have moved from simply outsourcing many routine agency functions to include as well a new interest in working with industry more closely in the development of new space technologies. This does not mean that NASA has shifted from its traditional mission focus and now will provide a higher percentage of its budget to helping general U.S. industry with its technology needs. On the contrary, under NASA's policies JPL is unlikely ever to devote more than one percent of its budget to technical assistance for, and technology transfer to, general American industry. As in the case of DOE, NASA will remain focused on its traditional missions of space and aeronautics. But with its space mission, NASA is now more interested in working jointly with industry to develop new space technologies of mutual interest.

This is a change. While NASA's aeronautics program has long worked closely with industry on topics of mutual interest, a process that has been responsible for many cutting-edge advances in aircraft technology, the situation was traditionally different in the space field. Here there was little tradition of NASA and industry working together to develop new technologies that would benefit both the government and private sector. NASA would either license its existing mission technologies to industry or, more often, would contract with companies to build NASA-designed hardware. In part, this situation reflected the lack of a strong commercial space industry that wanted to build its own commercial rockets, satellites, and payloads. And in part NASA thought it knew best how to design its projects.

Planet Earth), Advanced Space Transportation Technology, and Aeronautics Research and Technology.)

As a result of the tight budgets and policy changes mentioned earlier, NASA is now working more closely with commercial industry in three main ways.

First, in projects of purely government interest with little potential commercial applications – projects such as the space shuttle or planetary missions – the agency and its centers increasingly rely on commercial companies to develop hardware and provide operational support. The space shuttle, for example, once operated by NASA employees, is now operated by a private consortium working under contract to the agency. At JPL, as mentioned earlier, project leaders managing the development of new space probes increasingly contract out much of design as well as manufacturing work to private firms, much more so than in the past, and increasingly aim for simpler, smaller spacecraft which use more commercial components. The implication here is not only more contracts for commercial firms but also growing technology ties between NASA and the private sector.

Second, in some key fields with both government and commercial applications, NASA has begun to undertake joint development projects with private industry. One important example outside of JPL is the X-33, a prototype reusable rocket. NASA is providing some funding and ran a competition to see which proposed vehicle design was best. However, several features of this project make it different from traditional procurements: the contractors, not NASA, are providing the detailed technical specifications; the winning company (Lockheed-Martin in this case) is co-funding development of the prototype; and NASA is saying that the follow-on, operational reusable launch vehicle will be totally privately funded and operated (although NASA eventually may provide indirect financial support through contracts to carry government payloads). This policy trend, if continued, would have major implications for commercial space firms looking for government money to co-fund projects of mutual interest.

Third, NASA appears to be encouraging JPL and its other centers to increase efforts not only to spin-off its technologies to the private sector but also to undertake joint work to refine specific technologies. JPL's Technology Cooperative Agreements are a step in that direction.

Exactly how these trends will impact JPL in the long term remains to be determined. But at a minimum, they open up new opportunities for companies in California and elsewhere to work with JPL and other NASA centers on technology matters of mutual interest.

6.5.4 Policies Regarding Assistance to State and Local Governments

JPL tries to be a good neighbor and provide assistance, when asked, to its community. The Laboratory has tried two types of involvement, the first with considerable results and the second with less success.

Assistance to K-12 education and community colleges. At the invitation of the Los Angeles County school system, JPL has developed a Technology for Learning program that helps provide computers and computer training for teachers. The Laboratory is also now helping to develop innovative curricula in science and mathematics. The Los Angeles County school system is huge – 1.6 million students in 81 local school districts. If JPL's efforts continue to succeed, they have a broad and benefit impact. JPL is also working with the California Community College Foundation and the California Community College Association to offer professional development opportunities to community college science, engineering, and mathematics faculty. In general, JPL would like to amend its prime contract with NASA to allow and encourage all Laboratory employees to help with educational outreach activities.

Technical assistance to local and State entities. JPL also has tried to offer technical assistance to local governments in the Los Angeles region, but here it has had less success. Even when JPL can help with an important local problem, local officials sometimes seem unable or unwilling to work in a sustained way with the Laboratory.

6.5.5 Implications of these Trends for the California Economy

The trends in federal policy and budgets mentioned above have several important implications for the California economy:

Laboratory budgets. As in the cases of LLNL and Berkeley Lab, JPL's budget will not fall sharply the way many expected just two years ago. The booming national economy and associated tax revenues have help lead to a balanced federal budget, and if these conditions continue they will enable the government to avoid cuts in the overall federal R&D budget for at least several years. Of the three major California laboratories discussed in this report, JPL is the one still most at risk of long-term budget cuts. The reason is simply that NASA's overall budget will continue to be tight. It may not be cut significantly further, but it will not receive increases, either; the NIH and NSF will be higher R&D priorities. Also, because of internal pressures within NASA's essentially fixed pie – pressures primarily due to space station costs – the space science projects JPL relies may see little real growth. But even so JPL is now expected to avoid deep cuts and may even see modest growth.

Interactions with California universities. As discussed above, JPL will continue to contract with universities for the scientific analysis of data gathered by its spacecraft. California universities have done well so far in winning these contracts, but that competition may increase in the future.

Procurements. With this budget situation, NASA's growing interest in procuring products and services from industry and in co-funding R&D projects, when appropriate, offers new opportunities for California companies to work with JPL.

Laboratory missions. While budget stability means that JPL and other federal laboratories in California probably will maintain their core staffs and competencies, the federal policy that has emerged in recent years means that these facilities also will continue to focus on their traditional government missions. We will not see a major shift that transfers funds and staff to R&D related to general industrial competitiveness and assistance to general industry. JPL will not see its main mission shift from space exploration to helping commercial companies. What is new and important, however, is the steady shift of more of JPL's budget and focus to developing new technologies relevant to space exploration and a greater interest in working with industry on projects of mutual interest. In the years to come, JPL is likely to become even more a source of innovative new technologies than in the past. These new technologies, while developed for NASA mission purposes, will nonetheless be a valuable resource for California companies that seek them out.

Technology transfer policies. JPL as well as other federal laboratories will continue existing efforts to make unclassified mission-developed technology available to industry. In addition, individual investigators now seem much more interested than in past years in working with industry – especially if industry is willing to help fund some of their research.

Work with State and local agencies. JPL appears willing to continue to try to provide technical assistance, when asked, to local and State agencies in California. However, unless some of the problems that have affected earlier efforts are dealt with, Laboratory officials are limited in what they can do.

7. Appendix 4. Other Major Federal Laboratories in California

7.1 Summary

Of the federal government's 500 R&D laboratories, 48 are in California. Table 2 lists these laboratories.

In FY 1995, the last year for which detailed data on federal laboratory expenditures are available, the budgets for LLNL, LBNL, and JPL totaled $2.302 billion – or 48 percent of the overall $4.720 billion spent that year by federal laboratories in California. That means just over half of federal laboratory activities in the state were at other facilities, a sizable amount.

In general, California's 45 other federal R&D laboratories are either more specialized than LLNL, Berkeley Lab, and JPL; or smaller than these three facilities; or both. But in their specialized areas, these other laboratories have considerable expertise, and all of them have programs to work with industry.

7.2 Other Major Federal Laboratories

7.2.1 Laboratories Discussed in this Appendix

This appendix provides brief reviews several other laboratories in California. These laboratories are:

- Sandia/California
- Stanford Linear Accelerator Center
- Ames Research Center and the Dryden Flight Research Center
- Department of Defense (DOD) laboratories in California
- U.S. Department of Agriculture (USDA) laboratories
- Department of Veterans Affairs (VA) Rehabilitation R&D Center

In each case, the discussions will focus on two topics: (1) a brief general introduction to the laboratory, and (2) information on technology transfer and commercialization programs at that laboratory. Also, Web addresses will be identified.

7.2.2 Sources of Information

In addition to checking the Web sites of the individual laboratories, interested individuals and organizations also may want to check the following two valuable sources of information about federal laboratories.

Federal Laboratory Consortium for Technology Transfer (FLC). Established by federal statute, the FLC is an association of technology transfer officers from major federal laboratories. The FLC Web page *(http://www.fedlabs.org*) and its databases provide information on key technical capabilities available at major laboratories as well as the names, phone numbers, and e-mail addresses of technology transfer officials. Not all federal R&D laboratories in California are active in the FLC, but most are. A list of 33 agency and laboratory contacts in California can be found on the Web (see *http://www.fedlabs.org/cgi-win/flclist.exe*). A few of the laboratories on the list do not conduct R&D (and thus are not included in this volume's Table 4), but nonetheless can sometimes provide valuable technical assistance or information. Examples include the Army Defense Language Institute and the Naval Postgraduate School, both in Monterey.

RaDiUS database. The Critical Technologies Institute, an analytic FFRDC managed by the RAND Corporation and serving the White House Office of Science and Technology Policy (OSTP), maintains an extensive database on federally-funded R&D. It is called the "RaDiUS" database (Research and Development in the United States). Introductory information on the database is at *http://www.rand.org/centers/cti/radius.html*.

7.3 Sandia/California

7.3.1 Overview

Sandia National Laboratories is one of DOE's three nuclear weapons laboratories, along with Los Alamos and Livermore. Sandia's main campus is in Albuquerque, NM. The Sandia/California facility is in Livermore, CA, adjacent to LLNL.

Sandia specializes in the non-nuclear components of nuclear weapons, particularly electronics and machined components. For many years AT&T managed the facility for the government; today Lockheed-Martin operates the laboratory. Sandia/California's budget in FY 1995 was $158.5 million, and although smaller than LLNL or Berkeley Lab it is multiprogram laboratory with broad scientific and technological capabilities. Many of its programs open to U.S. industry. Detailed information can be found at the Laboratory's Web address: *http://www.ca.sandia.gov*.

The following are the major programs at Sandia/California:

- Combustion (the laboratory has a highly-regarded Combustion Research Facility)
- Environment
- Information systems
- Integrated manufacturing
- Materials and proliferation
- Program development
- Technology foundations
- Weapons stewardship

7.3.2 Economic Benefits: Employment and Procurements

As of April 1996, the direct payroll at Sandia/California was close to $50 million per year for 970 full-time employees and 67 part-time and limited-term employees. The professional staff at that point included more than 400 people with advanced degrees. In FY 1995, the overall Sandia organization spent $690 million on procurement, and $106 million of that in California. Sandia/California's portion of that overall Sandia procurement was $60 million, of which $42 million was spent in California.

7.3.3 Economic Benefits: Technology Partnerships

Sandia/California has an active Technology Partnerships and Commercialization Program (for details see *http://www.ca.sandia.gov/Tt.html*). That program undertakes the following activities:

CRADAs. According to information supplied by the Laboratory, Sandia as a whole (both New Mexico and California) has undertaken a total of 277 CRADAs; more have been with companies based in California (58 current CRADAs) than with any other states, and Sandia/California now heads up 29 active CRADAs.

CRADA partnerships are distributed more or less evenly over five broad technical areas: advanced manufacturing technologies, computer architecture and applications, energy and environment, advanced materials and processes, and microelectronics.

Licensing program. Sandia/California does license technologies and currently have 45 available for licensing.

Small business partnerships. The methods used to work with small business include: technical assistance, user facility agreements, CRADAs, and personnel exchanges.

User facility agreements. Sandia/California has three major facilities available for both nonproprietary and proprietary research: the Combustion Research Facility, the Integrated Manufacturing Technologies Laboratory, and the San Jose Microelectronics Office.

Regional economic development. The Laboratory is available to respond rapidly to the needs of local business and government agencies.

Technology showcase. This part of the Technology Partnerships Program licenses copyrighted software packages.

7.4 Stanford Linear Accelerator Center

7.4.1 Overview

The Stanford Linear Accelerator Center (SLAC) is a national basic research laboratory, probing the structure of matter at an atomic scale with x-rays and at much smaller scales with electron and positron beams. The laboratory is operated by Stanford University under an FFRDC contract from DOE. SLAC's Web address is: *(http://www.slac.stanford.edu).*

The Stanford Linear Accelerator Center has a FY 1999 budget of $172 million, with $177 million requested for FY 2000. Its primary mission, now and in the future, is to explore high energy physics. Over 80 percent of its funding devoted to high energy physics. This figure includes funding for a major new facility, the B-factory, that will be completed in 1999.

A second mission, which accounts for about $20 million of its annual funding and provides greater opportunities for interaction with California industry, is to support the Stanford Synchrotron Radiation Laboratory. This is a national user facility that provides synchrotron radiation – extremely bright x-rays – used for basic and applied studies on the structure of matter. Over 1,300 researchers from 170 institutions (including industry, universities, and other government labs) use the facility each year. The facility is used by researchers in many areas, including biology, chemistry, geology, materials science, electrical engineering, chemical engineering, physics, astronomy, and medicine.

7.4.2 Economic and other Benefits

SLAC's staff is currently around 1,300, 150 of whom are Ph.D. physicists. Typically, 800 physicists from universities and laboratories around the world participate in the high energy physics program and, as mentioned, hundreds of scientists from universities and industrial laboratories are active in the synchrotron radiation program. That program is also the major way in which SLAC has contributed to California industry and medicine.

7.5 Ames Research Center and the Dryden Flight Research Center

7.5.1 Ames Research Center

NASA's Ames Research Center is a civil-service-operated laboratory located at Moffett Field, south of San Francisco. Ames was founded on December 20, 1939, as an aircraft research laboratory by the National Advisory Committee on Aeronautics (NACA) and in 1958 became part of NASA. The center's Web address is: *http://www.arc.nasa.gov.*

The center's NASA budget for FY 1999 is $614 million, and the President has requested $625 million for FY 2000. Ames has three principal activities:

It serves as NASA's Center of Excellence for Information Technology, with responsibilities for supercomputing and networking, high-assurance software development, verification and validation of computational models, and related matters. Among its other areas of expertise, Ames is now a leader in digital compression technology.

In aeronautics, it serves as NASA's lead center for Aviation Operations Systems, that is, for research efforts in air traffic control and human factors. Ames also leads NASA's research efforts in rotorcraft technology and has major responsibility for wind tunnel testing and the computer simulation of aircraft performance.

It also serves as NASA's lead center for astrobiology, a new field that studies how life might arise across the universe – a subject that has become urgent with the discovery of new forms of life on Earth and suggestions that ancient bacteria might have existed on Mars. In 1998 Ames unveiled its new Astrobiology Institute.[30]

Along with local economic benefits from employment and procurements and the general benefits that Ames research produces for aircraft and the air traffic control system, the center also maintains an active Commercial Technology Office. Ames offers three main types of partnerships with industry:

[30] For more information on the new Astrobiology Institute, see Andrew Lawler, "Ames Tackles the Riddle of Life," *Science*, vol. 279, 20 March 1998, pages 1840-1841.

Joint sponsored partnerships. These projects are funded jointly by NASA and industry to commercialize NASA technologies. Overall, NASA has entered into six of these partnerships worth a total of $214 million. Two of these projects are managed out of Ames. One involves a major aircraft company and a university, with a focus on new technology to predict aircraft performance and reduce design cycle costs. The other Ames-managed partnership involves six aircraft companies, seven universities, the Navy, and the State of Virginia. It has developed a successful aircraft design tool.

Dual-use partnerships. Dual-use partnerships are used when a project will benefit both NASA mission objectives and industry commercial objectives.

Regional alliances. Ames can establish alliances with local, state, and regional organizations to leverage resources and support regional economic clusters.

Ames also operates a small business incubator, the Ames Technology Commercialization Center, in San Jose. The Center provides assistance for start-up companies utilizing NASA technologies. Among the graduates are four companies: Communication Network Systems, Interval Logic Corporation, ITV Corporation, and Real-Time Innovations, Inc.

7.5.2 Dryden Flight Research Center

Dryden, located at Edwards, CA, is NASA's primary installation for flight research. Projects at Dryden over the past 50 years have lead to major advancements in the design and capabilities of many civilian and military aircraft. NASA funds at Dryden totaled $186 million for FY 1998, and the FY 1999 request is for $178 million. Dryden maintains an Office of Technology Commercialization and Utilization. The center's Web address is: *http://www.dfrc.nasa.gov.*

7.6 DOD Laboratories

7.6.1 Overview

California is home to a large number of DOD R&D laboratories. Table 4 of this volume lists 12 such laboratories, including the Aerospace Corporation.[31]

Since the end of the Cold War, DOD laboratories have gone through a period of downsizing and consolidation. However, that process seems largely completed at this point. Budgets for major DOD laboratories are generally expected to stay stable for the next few years, although some may not get inflation increases due to the tight defense budget. Besides producing economic benefits for California through their employment and procurements, many of these laboratories have technical expertise in areas important to the State's industries, including electronics, aircraft, and rockets and satellites. And while these facilities naturally undertake a great deal of classified work, they all have technology transfer offices and all are willing to consider entering into CRADAs and technology licenses on unclassified projects.

What follows are brief summaries of the largest of these laboratories and their technology transfer and commercialization activities, starting with Air Force facilities and then listing Navy laboratories. Web addresses are included for those who would like additional information.

7.6.2 Aerospace Corporation, Los Angeles

The Aerospace Corporation *(http://www.aero.org)* is a private, nonprofit corporation established in 1960. It operates as an FFRDC for DOD, and its primary customer is the Space and Missile Systems Center of the Air Force Material Command. Other government customers include NASA and the National Oceanic and Atmospheric Administration (which is responsible for weather satellites). Most of the company's work is hands-on engineering associated with the design, test, evaluation, and initial operation of launch vehicles and satellites. The aim is to reduce the technical risks of space missions, at a reasonable cost, in order to avoid ruinous, expensive system failures. The corporation has a high success rate with launch vehicles such as the Titan, Atlas, and Delta. The company is also providing technical reviews for the next generation of unmanned rockets, the Evolved Expendable Launch Vehicle (EELV). Aerospace employs more than 2,800 people. Approximately 66 percent are members of the technical staff.

Aerospace's contract with DOD allows it to do some work with private companies. Recently, for example, Aerospace helped Orbital Sciences correct problems with its Pegasus XL rocket. Aerospace also has helped commercial satellite companies.

Since the aerospace industry remains an important part of California's economy, even after the downsizings of the past decade, the Aerospace Corporation is a valuable technical resource for the state.

7.6.3 Air Force Research Laboratory -- Propulsion Directorate, Edwards AFB, CA

Recently, Air Force R&D laboratories across the country were combined into a single Air Force Research Laboratory with headquarters at Wright-Patterson Air Force Base in Ohio. One key component is the Propulsion Directorate *(http://www.ple.af.mil),* which develops and tests rocket engines and is located at Edwards Air Force Base. The Propulsion Directorate has over a billion dollars worth of research, development, and test facilities and a team of nearly 300 scientists, engineers, technicians, and support staff. Technology

[31] The Aerospace Corporation is sometimes classified as a laboratory and sometimes as a systems engineering and integration center. This report follows the standard practice of defining the Aerospace Corporation as a federal laboratory.

developed at the laboratory has been used in nearly every modern rocket propulsion system, including the Minuteman, Peacekeeper, Titan IV, and the space shuttle's solid rocket boosters and main engines.

The directorate will make its test facilities and expertise available to U.S. industry. Today, for example, it is helping Boeing test new engines for the Delta IV evolved expendable launch vehicle -- a rocket that may be used for both military and commercial launches. The overall Air Force Research Laboratory maintains a Technology Transfer Branch (*http://tto.wpafb.af.mil*), which helps the Propulsion Directorate and other units of the Laboratory to enter into CRADAs and license patented inventions.

7.6.4 Flight Test Center, Edwards Air Force Base

A separate Air Force facility also located at Edwards Air Force Base is the Flight Test Center *(http://www.elan.af.mil)*, the home of "X planes" and the test site for Air Force aircraft. The Center has technology capabilities in aircraft avionics and instruments and will help flight test commercial airframes. As of earlier this year, the Center had 19 signed CRADAs; some of the subjects included helping Boeing test antennas for receiving Direct TV satellite broadcasts; helping Lear test an autonomous landing guidance system; helping the California Department of Forestry test an infrared pod on a fire-fighting aircraft; and helping the Clark County (Nevada) Health District improve models for predicting air pollution. Five new CRADAs were under negotiation. In addition, in FY 1997 the Center awarded Small Business Innovation Research awards to 12 companies, with a total value of $5.1 million.

7.6.5 Naval Air Warfare Center Weapons Division (China Lake)

China Lake is one of the two major sites for the Naval Air Warfare Center Weapons Division; the other is Point Mugu, discussed below. The overall mission of the Center is to be the Navy's research, development, test, evaluation, and in-service engineering center for weapon systems associated with air warfare. China Lake's technology transfer operation *(http://www.nawcwpns.navy.mil/techtransfer)* is one of the most active in DOD and has won several awards. Technical areas of expertise include air vehicle design, composite structures, control systems, sensors, electronic devices, embedded computer technology, microwave devices, optical devices and materials, and polymers, composites, and adhesives. Apple Computer is one of the California companies that has worked extensively with China Lake.

7.6.6 Naval Air Warfare Center Weapons Division (Point Mugu)

Point Mugu *(http://rdskb.mugu.navy.mil)* employs a work force of 3,800 people and serves as the hub for a 32,000 square-mile sea test range. The facility has technical expertise in areas such as sensors, embedded computing, target recognition, and test instrumentation systems. It also has an active technology transfer operation which uses CRADAs, patent licenses, and agreements with potential Navy contractors. The patent portfolio is considerable: approximately 60-80 new patents are added each year. Point Mugu operates a incubator facility on-base for developing technologies in an area called ring vortex flow phenomena. In addition, off-base the laboratory helps support the Ventura County Business Incubator.

7.6.7 Navy SPAWAR Systems Center, San Diego

"SPAWAR" stands for the Space and Naval Warfare Systems Command. It is the technology center for Navy command, control, communications, computing, and intelligence activities, responsible for satellite communications and information processing. Much of this work is highly classified. However, SPAWAR does maintain a technology transfer office *(http://manta.spawar.navy.mil)* that offers CRADAs, patent licenses, and potential-contractor agreements in areas such as command and control, communications, imaging, and surveillance systems -- technologies useful in such applications as traffic management, law enforcement, and environmental remediation.

7.6.8 Naval Health Research Center, San Diego

This medical research laboratory *(http://www.nhrc.navy.mil)* has collaborative relationships with 12 universities across the United States, including UC San Diego, San Diego State, UC San Francisco, and the Claremont Graduate University.

7.7 USDA Laboratories

In addition to supporting research at universities in California, the U.S. Department of Agriculture (USDA) also has 12 of its own laboratories in the state. Two divisions of USDA maintain these research facilities. The Agricultural Research Service has eight laboratories, focusing on general agricultural issues as well as specific issues such as salinity, cotton, aquatic weed control, and irrigated desert crops. The U.S. Forest Service (USFS) maintains six laboratories in the state. The principal facility is the Pacific Southwest Research Station (PSRS) in Albany, and four of the remaining sites are PSRS field laboratories. The final USFS facility in California develops, tests, and applies technologies for fighting forest fires.

Agriculture and timber are important parts of the California economy, and these USDA laboratories provide valuable research and technology for these two industries.

7.8 VA Rehabilitation R&D Center

The Department of Veterans Affairs' Rehabilitation Research and Development Center (*http://guide.stanford.edu/RRD.html*) is located at the Veterans Affairs Palo Alto Health Care complex and is one of the largest VA research laboratories in California. It is part of the VA's Rehabilitation Engineering Research and Development Service, and focuses on improving mobility in veterans and others with strokes, other neurologic impairments, and orthopedic impairments such as arthritis and osteoporosis. The principal goal is to develop new clinical treatments and devices for neuromuscular and musculoskeletal rehabilitation. The researchers work closely with clinical colleagues at the VA Palo Alto facility, the Stanford Medical Center, Stanford engineering departments, the Robotics Laboratory of the Stanford Computer Science Department, NASA Ames, and a wide range of other hospitals and engineering schools.

The center is active in technology transfer, and a wide range of products have been marketed as a result of these R&D collaborations. These products include innovative wheelchairs, communication devices, software for musculoskeletal modeling, and a new type of seat cushion for wheelchair users. Several of these products have been marketed by California companies.

8. Appendix 5. Data on Budgets, Personnel, and University and Industry Interactions at LLNL, LBNL, and JPL

The following data have been supplied to the authors by the three laboratories. The authors are grateful to the labs for their assistance.

8.1 Lawrence Livermore National Laboratory

I. Laboratory Budget -- FY 1993 Through FY 1999 (In Millions of Current Dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999
DOE funding	$873.6	$800.4	$781.3	$820.9	$823.2	$878.1	$1090.3
Other federal agency funding	174.7	161.6	159.7	185.3	161.5		
Funds from private industry	0.5	2.5	3.4	2.7	27.8		
CA State funding (if any)	0.2	0.7	0.5	1.2	0.3		
Total Laboratory budget	**$1049**	**$965.2**	**$944.9**	**$1010.1**	**$1012.8**		

II. Laboratory Employees (FTEs)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
Scientists (PhD/MS)	1840	1816	1644	1641	1566	1585
Engineers (PhD/MS/BS)	1163	1132	987	971	919	934
Technicians	3037	2880	2572	2505	2331	2467
Administrative/support staff	2290	2287	2086	2063	1912	1579
Total Laboratory employees (FTEs)	**8330**	**8115**	**7289**	**7180**	**6728**	**6565**
On-site contractors (FTEs)	**1867**	**1516**	**1235**	**926**	**654**	**827**

III. Laboratory Collaborations With University Researchers And Students

	FY 1995	FY 1996	FY 1997	FY 1998
UC faculty	183	174	38	58
UC research staff (including postdocs)	79	61	92	142
UC students	237	173	46	60
Total collaborations with UC personnel	**499**	**408**	**176**	**260**
Other CA faculty			22	22
Other CA research staff			23	27
Other CA students			140	141
Total collaborations with other CA personnel			**185**	**190**
Non-CA faculty	90	54	117	116
Non-CA R&D staff	369	85	115	156
Non-CA students	267	890	982	934
Total collaborations with non-CA personnel	**726**	**1029**	**1214**	**1206**

* Number of university and college faculty, research staff, and students involved in collaborations with the Laboratory, either at the Laboratory, their home institutions, or both

IV. Laboratory Interaction with Industry (Budget Figures in Millions of Current Dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-1997
Total spending that year on procurements from industry	**$434**	**$333**	**$353**	**$305**	**$473**	**$1,899**
Amount of that total spent in California	N/A	N/A	204	184	303	
Amount of total spent for tech-based procurements	N/A	N/A	11	19	41	
Amount spent for tech-based procurements in CA	N/A	N/A	8	10	29	
Total number of licenses issued by Lab that year	**16**	**36**	**59**	**60**	**65**	**236**
Number of those licenses to CA entities	2	5	8	8	10	33
Dollar total of royalties (from both old & new licenses)	0.36	0.56	1.1	1.1	2.4	5.6

Summary of R&D partnering activities by funding source

	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1991-1997
TTI-Funded CRADAs	$4.8	$10.5	$38.4	$51.2	$55.5	$52.3	$19.4	$232.1
Lab-Funded CRADAs	3.6	4.1	6.1	5.1	6.3	6.4	4.1	35.7
Industrial Funds-in CRADAs				2.7	3.1	3.3	16.9	26.0
Industrial Work-for-Others *				1.3	2.7	4.6	11.2	19.8
Totals	$8.4	$14.6	$44.5	$60.3	$67.6	$66.6	$51.6	$313.6

* No data available for Industrial Work-for-Others prior to FY 1994; amounts were small.

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-1997
Total number of TTI-funded CRADAs active that year (both new and continuing TTI CRADAs)	**55**	**84**	**114**	**85**	**55**	
Number of new DOE TTI-funded CRADAs initiated that year	42	20	21	1	0	84
Number of those new CRADAs with CA entities	16	7	6	0	0	29
DOE funds that year for both new & continuing TTI CRADAs	$33.4	$51.1	$55.5	$52.3	$19.5	$211.8

IV. (continued) Laboratory Interaction with Industry (Budget Figures in Millions of Current Dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-1997
Total number of Lab-funded CRADAs active that year (both new and continuing Lab-funded CRADAs)	**8**	**10**	**20**	**26**	**24**	
Number of new Lab-funded CRADAs initiated that year	8	7	15	5	11	46
Number of those new CRADAs with CA entities	3	3	4	4	0	14
DOE funds for both new & continuing Lab-funded CRADAs	$0.6	$3.2	$2.9	$3.4	$4.4	$14.5
Total number of funds-in (industry-funded) CRADAs active that year (both new & continuing CRADAs)	**2**	**10**	**12**	**22**	**34**	
Number of new funds-in CRADAs initiated that year	1	8	10	15	18	52
Number of those new CRADAs with CA entities	1	3	2	4	9	19
Industry funds-in dollars that year for new & continuing CRADAs	$0.2	$4.3	$6.8	$4.9	$17.8	$34
Total number of work-for-others projects with industry that year (both new & continuing projects)			**41**	**56**	**85**	
Number of new WFO projects initiated that year			30	48	45	123
Number of those new WFO projects with CA entities			14	18	16	48
Industry WFO funds that years for new & continuing projects			$2.7	$3.6	$3.4	$9.7
Other partnerships (e.g., AVLIS) active that year		1	1	1	1	1
Total industry funds that year		**40**	**60**	**100**	**120**	**320**
Number of new SBIR projects at the Lab that year (funds into LLNL)			**16**	**5**	**3**	**24**
Number of those awards to CA entities			3	0	0	3
Number of new spin-off companies that year *		**2**	**3**	**2**	**4**	**11**
Number of those spin-off companies in CA		2	3	2	2	9

* Includes new companies started by either Lab employees who leave or outsiders who use Lab technology

8.2 Lawrence Berkeley National Laboratory

I. Laboratory Budget -- FY 1993 Through FY 1999 (in millions of current dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998	FY 1999
DOE funding	$230.9	$233	$250.5	$302.2	$291.6	$274.4	$277
Other federal agency funding	174.7	161.6	159.7	185.3	161.5		
Private/state/local/other *	16.1	16.5	16.3	11	21.2		
Total Laboratory budget	**$271.5**	**$276.8**	**$291.6**	**$346.6**	**$346.2**	**$336.5**	

* FY 1996 breakdown: universities, 46%; state/local/non-profit, 15%; domestic for-profits, 23%; other, 16%

II. Laboratory Employees (FTEs)

	FY 1993	**FY 1994**	**FY 1995**	**FY 1996**	**FY 1997**	**FY 1998**
Scientists & engineers (headcount)	1211	1159	1271	1380	1710	N/A
Technicians (headcount)	1041	932	937	893	1221	N/A
Administrative/support staff (headcount)	653	670	615	496	548	N/A
Total Laboratory employees (headcount)	**3535**	**3489**	**3434**	**3385**	**4153**	**N/A**
Total Laboratory employees (FTEs)	**2715**	**2630**	**2576**	**2490**	**2566**	**2897**
On-site contractors (headcount)	**206**	**206**	**199**	**266**	**365**	**N/A**

III. Laboratory Collaborations With University Researchers And Students *

	FY 1993	**FY 1994**	**FY 1995**	**FY 1996**	**FY 1997**
Faculty	234	231	238	254	306
Research staff (including postdocs)	121	157	156	150	233
Students	630	613	567	580	614
Total collaborations with university personnel **	**985**	**1001**	**961**	**984**	**1153**

* Number of university and college faculty, research staff, and students involved in collaborations with the Laboratory, either at the Laboratory, their home institutions, or both

** Over 90 percent of these individuals are estimated to be from the University of California

IV. Laboratory Interactions With Industry (budget figures in millions of current dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-1997
Procurement spending from industry (includes subcontracts) *	$69	$79.8	$87.9	$125.6	$141	$503
Procurement/subcontract spending with universities *	$8	$15.6	$15	$11.8	1$0.1	$60.5
* Data not available on how much of these procurement funds spent in California						
Total number of licenses issued by Lab that year	**16**	**14**	**24**	**15**	**23**	**92**
Number of those licenses to CA entities	8	4	10	9	15	46
Dollar total of royalties (from both old & new licenses)	$0.154	$0.051	$0.12	$0.127	$0.354	$0.806
Total number of DOE tech transfer-funded CRADAs that year (both new and continuing CRADAs)	**10**	**25**	**59**	**51**	**32**	
Number of new DOE-funded CRADAs initiated that year	9	13	35	2	3	62
Number of those new CRADAs with CA entities	5	9	15	2	2	33
DOE funds that year for both new & continuing DOE CRADAs	$1.7	$4.3	$9.6	$2.4	$3.8	$21.8
Industry funds (mostly in-kind) for new & continuing CRADAs	$1.6	$5.1	$16.6	$9.9	$9.2	$42.4
Number of new funds-in CRADAs initiated that year	**4**	**5**	**12**	**18**	**16**	**55**
Number of those new CRADAs with CA entities	1	1	5	8	10	25
Industry funds-in dollars that year for new & continuing CRADAs	$1.5	$1.9	$3.7	$2.8	$12.2	$22.1
Number of new WFO projects initiated that year	15	18	20	30	39	122
Number of those new WFO projects with CA entities	7	9	10	16	21	63
Industry WFO funds that year for new & continuing projects	$5.1	$8.6	$2.2	$6.3	$10.3	$32.5
Number of new industry technical assistance projects initiated that year			**9**	**6**	**5**	**20**
Number of those projects in CA			3	4	2	9
Number of new spin-off companies that year *	**1**	**0**	**1**	**1**	**3**	**6**
Number of those spin-off companies in CA	1	0	1	1	3	6

* Includes new companies started by either Lab employees who leave or outsiders who use Lab technology

8.3 Jet Propulsion Laboratory

I. Laboratory Budget -- FY 1993 Through FY 1999 (in millions of current dollars)

	FY 1993	**FY 1994**	**FY 1995**	**FY 1996**	**FY 1997**	**FY 1998**	**FY 1999**
NASA funding	$979.0	$945.9	$1001.8	$1009.0	$1134.0	$1101.8	$1158.2
Other federal agency funding	88.4	67.5	58.5	48.2	50.6		
Funds from private industry	3.8	6.0	4.7	5.7	5.2		
CA State funding (if any)	0 .143	0	0	0	5.4		
Foreign . .	0.0490	0.632	0	0.136	0.004		
Total Laboratory budget	**$1072**	**$1020**	**$1065**	**$1063**	**$1196**		

II. Laboratory Employees (FTEs)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
Scientists/engineers/MBAs	3689	3590	3545	3574	*	N/A
Technicians	644	617	600	59	*	N/A
Administrative/support staff	1523	1403	1310	1245	*	N/A
Total Laboratory employees (FTEs)	**5856**	**5610**	**5454**	**5415**	**5251**	**4925**

* Beginning in FY 1997, JPL introduced a new employee classification system which now tracks employees by education level (i.e., bachelors, masters and professional, and PhD) rather than by the earlier classifications

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
On-site contractors (FTEs)	**1607**	**1367**	**1228**	**1054**	**849**	**685**

III. LABORATORY CONTRACTS WITH UNIVERSITIES *

	FY 1993	**FY 1994**	**FY 1995**	**FY 1996**	**FY 1997**	**FY 1998**	**Totals**
Total contracts by year with all universities	**$74.8**	**$35.5**	**$115.7**	**$84.9**	**$61.4**	**$372.3**	**744.6**
Total contracts with CA universities	$34.0	$34.0	$64.6	$34.1	$11.5	$178.2	356.4
Percentage that year to CA universities	45%	96%	56%	40%	19%	48%	48%

* JPL does not have data available on the number of individual researchers with whom it works; it does have data on the amount of money spent on research contracts with universities.

IV. Laboratory Interactions With Industry (budget figures in millions of current dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-97
Spending on procurements from industry	**$467.2**	**$437.1**	**$563.0**	**$580.0**	**$679.4**	**$2,727**
Amount of that spent in CA	$285.6	$289.4	$299.0	$268.7	$322.0	$1464.7
Number of licenses issued that year (royalty|non-royalty)	**2|21**	**3|78**	**2|62**	**12|186**	**12|178**	**29|525**
Number of those licenses to CA entities						10|––
Dollar total of royalties (from both old & new licenses)	$0.32	$0.21	$0.57	$0.8	$0.58	$2.48
Total number of Technology Affiliates Program projects that year (both new and continuing projects)	**37**	**42**	**40**	**26**	**78**	
Number of new TAP projects initiated that year	9	11	16	18	25	79
Number of those new projects with CA entities	4	6	8	9	12	39
Total industry payments that year for TAP projects	$0.909	$3.917	$1.063	$3.705	$2.769	$12.363
Total number of Targeted Commercialization Office projects that year (both new & continuing)					**1**	**1**
Number of new TCO projects initiated that year					1	1
Number of those new CRADAs with CA entities						
Total NASA/JPL dollars that year for these projects					$0.1	$0.1
Total industry matching dollars that year					$0.1	$0.1
Number of new Technology Cooperation Agreements Program projects that year	**0**	**20**	**8**	**8**	**4**	**40**
Number of those new TCAP projects with CA entities	0	7	5	1	2	15
NASA/JPL funds that year (for both new & continuing projects)	$0	$3.1	$3.8	$3.0	$1.2	$11.1
Industry funds that years (for both new & continuing projects)	$0	$4.0	$5.4	$5.5	$2.4	$17.3

IV. (continued) Laboratory Interactions With Industry (budget figures in millions of current dollars)

	FY 1993	FY 1994	FY 1995	FY 1996	FY 1997	Total FY 1993-97
Number of new SBIR awards that year	**54**	**69**	**59**	**66**	**68**	**316**
Number of those new awards to CA entities	21	21	27	26	24	119
Total JPL funds that year for SBIRs (both new & continuing)	$10.26	$11.87	$16.03	$15.22	$16.83	$70.21
Number of new spin-off companies that year *				**2**		**2**
Number of those spin-off companies in CA				2		2

* Includes new companies started by either Lab employees who leave or outsiders who use Lab technology