AN ANALYSIS OF MAJOR FEDERAL LABORATORIES IN CALIFORNIA

VOLUME I: OVERVIEW

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 – this Overview and a Volume II that presents more details on policy options and the laboratories.

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The California Council on Science and Technology is a nonprofit organization established in 1988 at the request of the California State Government and sponsored by the major post secondary institutions of California, in conjunction with leading private-sector firms. CCST's mission is to improve science and technology policy and application in California by proposing programs, conducting analyses, and helping government implement policies and initiatives for a better economy and quality of life.

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1. Executive Summary

1.1 Current Laboratory Budgets and Programs

California has 48 federal R&D laboratories – more than any other state – and continues to have a significant percentage of total nationwide spending on federal laboratories – 17.8 percent in federal fiscal year (FY) 1995.

These laboratories have programs and research facilities in several areas of current and potential future importance to the California economy – including computing and electronics, lasers, communications, aerospace, robotics, biotechnology and medicine, energy, the environment, and agriculture and forestry.

1.2 Value to Date of Laboratory Interactions with Universities and Industry

University-operated federal laboratories in California conduct extensive joint research with professors and graduate students. One federal facility, the Jet Propulsion Laboratory (JPL), also makes significant external research grants to academic researchers.

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.

In the 1990s, federal laboratories in California have used these new policies to provide significant new benefits to companies. For example, these laboratories have issued hundreds of technology licenses, both to established companies and startups. Major laboratories have entered into dozens of cooperative R&D projects through which laboratory technology is shared with industry. And the laboratories have provided companies access to unique research facilities.

1.3 Trends in Laboratory Budgets and Missions and the Implications for California

Federal laboratory budgets in California and nationally have dropped in real terms over the past decade (see details later in this Overview). This drop results from both the end of the Cold War and tight federal budgets in the 1990s. However, today's strong national economy combined with the federal balanced-budget agreement of 1997 now makes further deep cuts unlikely.

In future years, federal laboratories in California generally can expect flat budgets, with few new projects likely at the scale of the Lawrence Livermore National Laboratory's (LLNL) National Ignition Facility (NIF) and the Accelerated Strategic Computing Initiative (ASCI).

Now and in the foreseeable future, federal laboratories will continue to focus on their traditional government missions, such as defense, energy, and space. The Department of Energy (DOE) did broaden its mission in the early and middle 1990s and funded special joint R&D projects at its laboratories to help U.S. industry improve technological competitiveness. Starting in 1995, Congress cut that funding.

1.4 Trends in Laboratory Interactions with Universities and Industry

In California, the most important new policy regarding laboratory interactions with universities is the decision of JPL to increase its extramural research grants to universities. Livermore and Lawrence Berkeley National Laboratory (LBNL) continue to maintain close relations with University of California campuses. Furthermore, Livermore is expanding its collaborations with Stanford University and the California Institute of Technology through the Academic Alliance Program, which is part of the ASCI.

In carrying out their traditional government missions, federal laboratories now work with industry in innovative ways to reduce procurement costs, reduce operational costs, and improve laboratory technical capabilities. These new policies create opportunities for California companies.

In addition, industrial and university participation is often an integrated part of major laboratory programs. The DOE's ASCI program, for example, involves all three sectors. In LLNL's NIF Program, over 70 percent of its total budget will go for work done in the private sector.

Although DOE no longer has dedicated funds to support new industry-laboratory projects, DOE laboratories continue to welcome industry funding for joint R&D, and industrial support at DOE facilities in California is growing. Such projects tend to be more closely focused toward specific products or product lines rather than exploratory research and thus, as reported by LLNL, are resulting in a higher incidence of subsequent licenses for commercialization. NASA and Department of Defense (DOD) laboratories also welcome industry-funded projects. Some barriers to joint projects remain, but at a time when many companies use R&D partnerships to reduce R&D costs and risks, federal laboratories are a resource for California firms.

1.5 Possible Ways to Expand Laboratory Contributions to the State's Economy

A number of steps could be taken by the federal government, state officials, the laboratories themselves, and universities and industries in California to expand the benefits that the state receives from these federal facilities (see Section 4 below).

These steps would not only strengthen current ties between the laboratories and California companies and universities but also could help address problems of particular importance to the state, such as environmental remediation and protection, transportation, and seismic studies and hazard reduction.

2. Federal Laboratory Contributions to the California Economy

2.1 Number, Total Budget, and Technical Capabilities of Federal Laboratories in California

California has 48 of the federal government's approximately 500 R&D laboratories – the highest number in any one state.[1] Volume II 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. Figures 1 and 2 present data for the two main types of federal laboratories in California: intramural civil-service-run facilities and federally-funded research and development centers (FFRDCs) operated for the government by universities and colleges.[2] The budget cuts have been particularly deep in intramural laboratories.

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

DOE, NASA, and DOD operate the largest federal laboratories in California. The Department of Agriculture (USDA) and the Department of Veterans Affairs (VA) also maintain extensive laboratory systems in the state.

These 48 laboratories have expertise in areas important to California's economy, including computing and electronics, lasers, communications, aerospace, robotics, biotechnology and medicine, energy, the environment, and agriculture and forestry.

2.2 Livermore, Berkeley Lab, and JPL

This report focuses particularly on three large laboratories in California with broad scientific and technical capabilities:

The Lawrence Livermore National Laboratory (the Livermore Laboratory or LLNL) is owned by DOE and operated by the University of California (UC). It is a multiprogram laboratory, focused on national security with special responsibility for nuclear weapons stewardship. The capabilities of the Laboratory are also applied in R&D activities that support other DOE mission areas – including energy, environmental science, and bioscience.

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

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.

Figure 4 shows the budgets for these three laboratories during the years FY 1993 through 1997. The figures are in current, non-inflation-adjusted dollars.

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[1] Overall, the federal government owns approximately 700 laboratories across the country and overseas, of which approximately 500 conduct R&D and the remainder primarily conduct analytical testing. 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.

[2] 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.

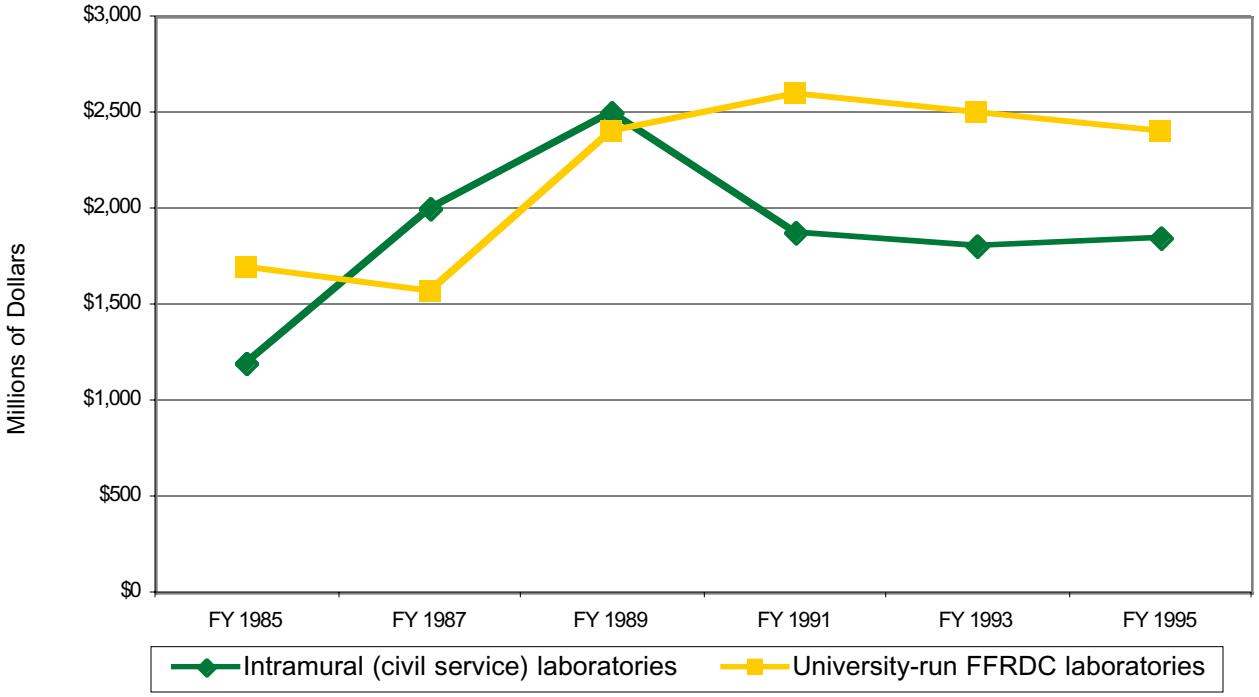

Figure 1. Selected Federal Laboratory Expenditures in California (Millions of Dollars)
Source: Linda Cohen of UC Irvine, using NSF data

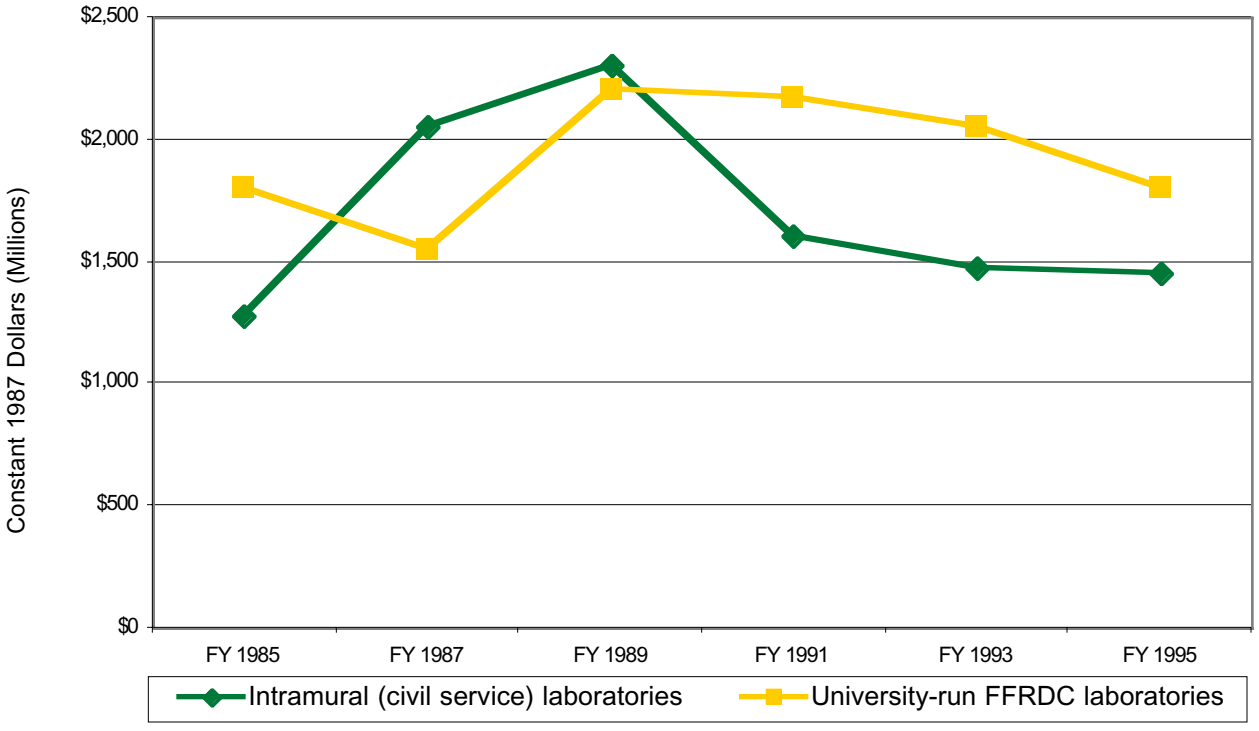

Figure 2. Selected Federal Laboratory Expenditures in California (Millions of Constant 1987 Dollars)
Source: Linda Cohen of UC Irvine, using NSF data

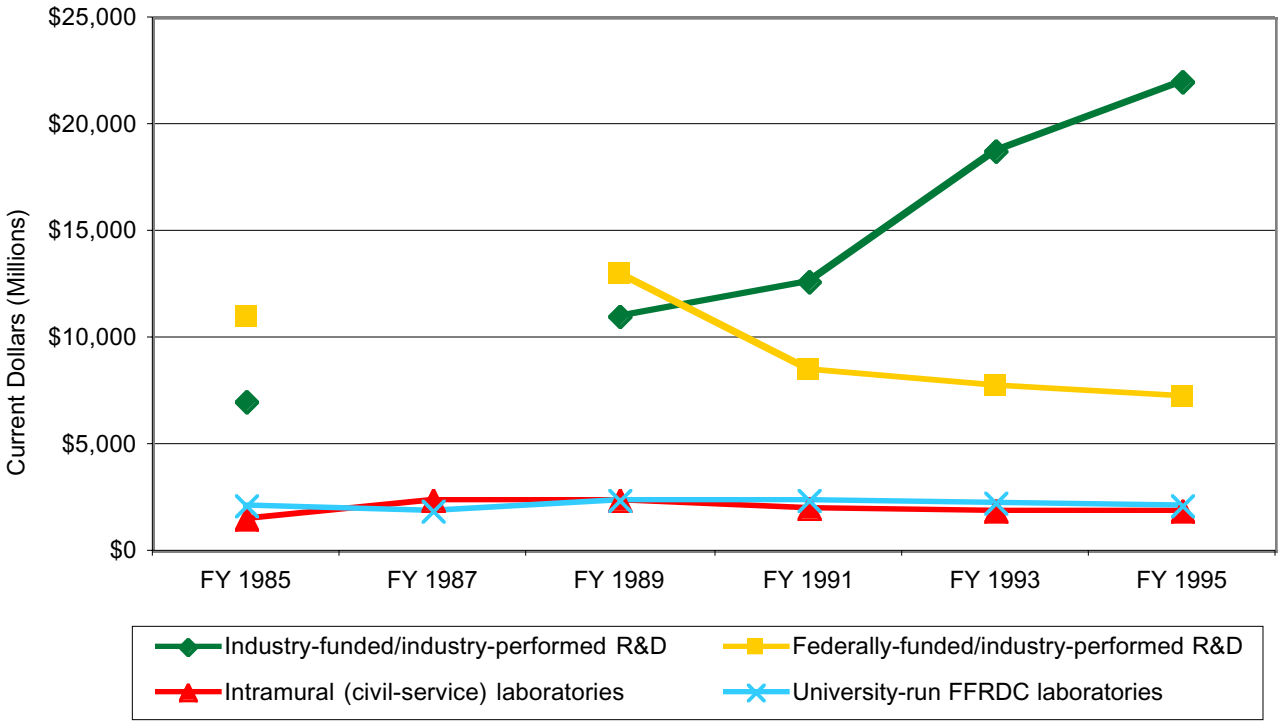

Figure 3. Selected R&D Expenditures in California -- FY 1985-1995 (in Millions of Current Dollars)
Source: Linda Cohen of UC Irvine, using NSF data

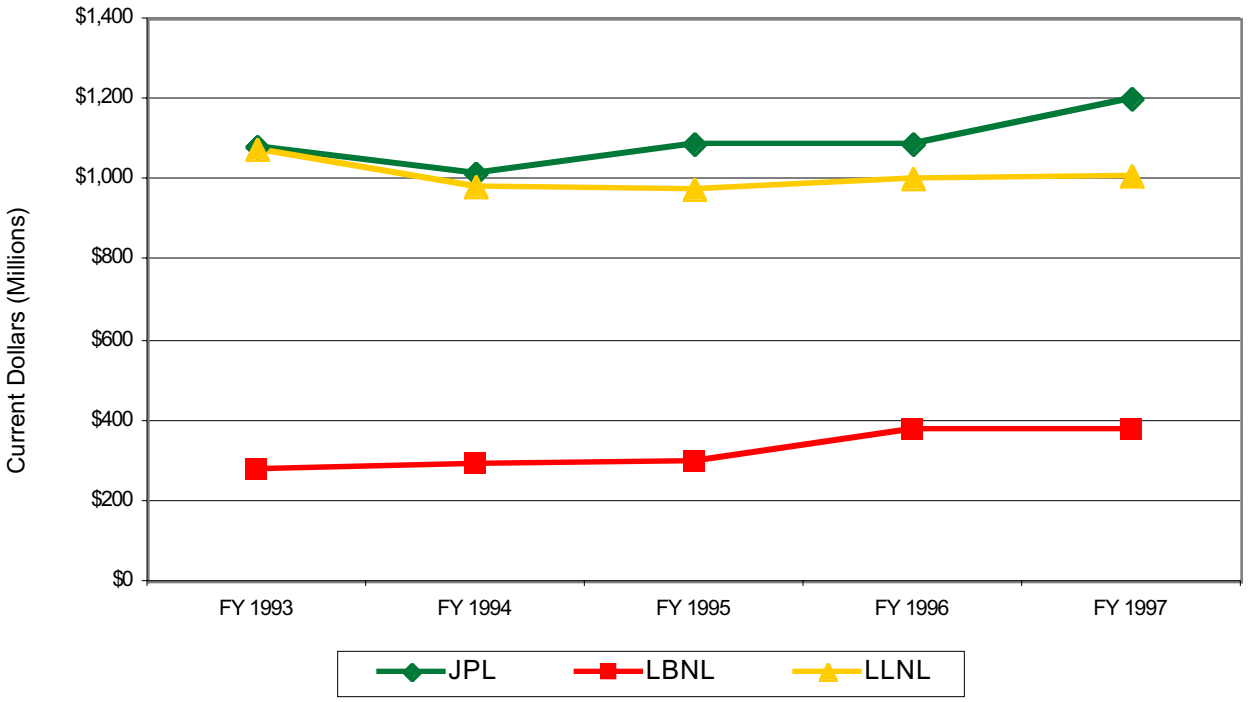

Figure 4. Budgets for LLNL, LBNL, and JPL -- FY 1993-1997 (in Millions of Current Dollars)
Sources: LLNL, LBNL, and JPL

2.3 Federal Policies Regarding Federal Laboratory Interactions with Universities

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.

2.4 Federal policies Encouraging Laboratory Interactions with Industry

Procurement. Procurements by federal laboratories run from routine items, such as office supplies, to highly technical equipment and services. In some cases technology developed in a laboratory is transferred to an industry partner, such as when large-scale experimental facilities require advances in state-of-the-art for instrumentation, equipment, or components. That partner, in turn, develops a commercial product line that then is available to supply both federal and other needs.

Similarly, technology advances made by a vendor in response to laboratory requirements sometimes serve dual federal/commercial uses.

Licensing of federal inventions. The Bayh-Dole Act of 1980 allowed federal laboratories run by civil service employees to license federal inventions. Amendments in 1984 allowed universities operating FFRDC laboratories to own and license inventions made at those laboratories. As a result, licensing has become an important method for transferring laboratory technology to industry.

Cooperative R&D agreements and the JPL equivalent. Under the Stevenson-Wydler Technology Innovation Act of 1980, as amended in 1986 and 1989, federal agencies may allow their laboratories to enter into what are called "cooperative research and development agreements" (CRADAs, pronounced "CRAY-DAs") – agreements to conduct joint research with companies or with other partners, including state and local governments. The CRADA mechanism has led to a significant expansion in laboratory-industry R&D projects. NASA chose to use separate but similar authority under the National Aeronautics and Space Act of 1958 and, furthermore, allows JPL to use a CRADA-like mechanism known as "technology cooperation agreements" (TCAs).

Work for others. In addition to CRADAs (in which laboratories usually contribute technology), federal law also allows the laboratories' federal sponsors to accept contracts from industry for the laboratories to perform new research or technical services. This second type of project is known as "work for others." It may involve contract research, technical consulting, or access to unique laboratory facilities. The principal groundrule is that the work draws upon laboratory resources that are unique and do not compete with private R&D providers.

Small Business Innovation Research. The Small Business Innovation Research of 1982 directs federal agencies with extramural R&D funds to set aside a percentage of those funds for small businesses. (That number is now 2.5 percent.) In most agencies, those awards are made at the headquarters level, not by laboratories. However, JPL is one example of a laboratory that does make SBIR awards. LLNL is an example of a laboratory that does not make SBIR awards itself but does work with interested small firms that have won DOE SBIR funds.

Implementation of these policies. Laboratories throughout the federal government now offer opportunities for licenses, CRADAs, and work-for-others projects. DOD and DOE laboratories in California and elsewhere must protect classified information, but these laboratories have many unclassified R&D activities and technologies that are open to companies.

DOE variations. DOE laboratories use CRADAs in three different ways:

In a "funds-in" CRADA, the focus is on joint research building on existing laboratory research, with funding for the laboratory's portion of the work usually coming from industry and sometimes from agency mission-program funds.

In a "funded CRADA" a DOE laboratory uses special DOE appropriations to pay for the laboratory's involvement in a new project of special interest to industry. Congress provided these special funds in the early and middle 1990s, but cut this funding severely starting in 1995.

In a "programmatic CRADA," the joint research with industry is done not for the primary purpose of helping the company but in circumstances when the laboratory and industry will equally benefit by concurrently serving laboratory programmatic needs and industry commercialization objectives. In this type of CRADA, the laboratory uses its own funds to pay for its personnel to participate in the project.

NASA and JPL. Under NASA's recent policy to reduce personnel at NASA centers, JPL increasingly has "outsourced" many of its scientific activities and its routine space-probe operations. At the same time, it is seeking to expand cooperative activities with industry to develop innovative new technologies.

2.5 The Contributions of Laboratories in General to California

As mentioned earlier, in FY 1995 $4.720 billion was spent on federal R&D laboratories in California. The budgets for LLNL, LBNL, and JPL that year totaled $2.302 billion – or 48 percent of the overall amount. The remainder went to other federal laboratories in the state.

How much of the overall budget for California laboratories is actually spent each year within California is unknown, since exact data are not available. But most of the salaries go to Californians, and many of the procurements are with firms in California (see Table 1 for details on procurement).

California's 45 other federal R&D laboratories are generally either more specialized than LLNL, LBNL, and JPL, or smaller than these three facilities, or both. But these other laboratories have considerable expertise in their specialized areas, and all of them have programs to work with industry. For instance, CRADAs are common in the unclassified portions of DOD laboratories – a fact that is particularly important to California's aerospace and electronics industries. One example is the Flight Test Center at Edwards Air Force Base, which by early 1998 had signed 19 CRADAs with companies.

2.6 Contributions of LLNL, LBNL, and JPL to California Universities

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

The number of university researchers working with Livermore has been increasing, although the number from California schools is roughly constant — in FY 1995, 499 from California out of a nationwide total of 1225 and in FY 1998 450 from California out of 1656. The Academic Alliances Program (part of the Accelerated Strategic Computing Initiative) is now establishing centers of excellence at Stanford University and Caltech, which will increase Livermore interactions with those schools. In addition, the Livermore Laboratory is exploring the possibility of establishing a close working relationship with the future UC Merced campus.

JPL works with academics mainly through research grants and contracts. While California universities do well in these competitions -- winning an average of 48 percent over FY 1993-1998 -- there is great variation from year to year. California's portion ranges from a high of 96 percent of these awards in FY 1994 to only 19 percent in FY 1997.

2.7 Contributions of LLNL, LBNL, and JPL to California 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 with California companies and occasionally state and local governments. Table 1 provides a summary of laboratory budgets, staffing, and the major procurement and technology benefits these laboratories generate for the state. Volume II's Appendix 5 presents further details.

Livermore Laboratory. Impacts occur through procurements, through joint R&D CRADAs, through licenses, and through less formal means transferring technology to the public and private sectors.

– In dollar terms, procurements are the largest interaction LLNL has with industry.

– In addition, though, the Laboratory is active in collaborative research. For example, data in Volume II's 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.

– Licensing of technology, particularly to startup companies, results in an even more directly observable impact on the California economy. From FY 1994-1998, 14 startup companies formed in California based on LLNL licenses.

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

Berkeley Lab. 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.

JPL. After procurements, JPL's main interactions 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).

Table 1 . 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 (est.)	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 1993-1997	236	92	544
(Number of these issued to CA entities)	(33)	(46)	(unknown)
Agency-funded CRADAs initiated FY 1993-1997	84	62	
(Number of these initiated with CA entities)	(29)	(33)	
Lab-funded CRADAs initiated FY 1993-1997	46	Not used	
(Number of these initiated with CA entities)	(14)		
Industry-funded CRADAs initiated FY 1993-1997	52	55	
(Number of these initiated with CA entities)	(19)	(25)	
TCA projects initiated FY 1993-1997			40
(Number of these initiated with CA entities)			(15)
Work-for-others projects initiated FY 1993-1997	123	122	79
(Number of these initiated with CA entities)	(48)	(63)	(39)
Number of new SBIR awards lab made FY 1993-1997	***	***	316
(Number of these awarded to CA small businesses)			(119)

Sources: LLNL, LBNL, and JPL. These data are excerpted from Volume II's Appendix 5.

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

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.

2.8 Contributions of the Laboratories to Important California Needs

In a number of cases the laboratories have worked closely with state agencies to address problems of particular importance to California. For example, in 1994 the California State Water Resources Control Board (SWRCB) contracted with LLNL to form a UC team to examine leaking underground fuel tanks ("LUFTs") and recommend ways to manage the risks. The team showed that almost all petroleum fuel releases can degrade naturally, a point SWRCB incorporated into its regulatory strategy. SWRCB has now contracted with Livermore to study cleanup options for MBTE (methyl tertiary butyl ether), a gasoline additive that does not naturally degrade if leaked into groundwater

Officials at several federal laboratories in California have sometimes encountered institutional barriers when they try to provide technical assistance to state and local government agencies. Several difficulties can arise: lack of a single point of contact, an absence of technical experts in the agencies 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.

3. Future Trends for the Three Major Laboratories

3.1 Overall Federal Budget Trends

In mid-1995, with Washington concerned about the budget deficit and a new Republican Congress favoring deep spending cuts, it appeared that federal civilian R&D budgets could be cut as much as a third over seven years. There was talk of cutting certain defense-related R&D. Some Republicans also wanted to eliminate DOE and many of its programs. However, cuts this severe did not occur. A strong national economy increased tax revenues, and in 1997 President Clinton and Congress reached a balanced budget agreement that allows modest, but not large, overall growth in federal spending.

Within this new budget environment, two federal R&D agencies are particularly popular and may continue to receive substantial annual increases – the National Institutes of Health (NIH) and the National Science Foundation (NSF). Other agencies face tighter budgets.

DOE's R&D budget is likely to remain essentially flat, with the exception of a few new projects, most but not all of them defense-related.

NASA faces a declining budget. The actual FY 1999 appropriation for NASA is $13.665 billion, and the President proposes for FY 2004 a budget of $13.750 billion. So the agency may not even receive full inflation increases. Cost overruns in NASA's top initiative, the International Space Station, makes the agency's budget situation even worse. NASA has tried to cope with this situation by cutting its staff rather than its program activities.

3.2 Policy Trends Regarding Laboratory Interactions with Universities and Industry

Fulfilling government missions. Within these generally flat budgets, federal agencies and laboratories are looking for more cost-effective ways to achieve their government missions and to maintain technical competence. New policies include:

– In procurements, either (1) buying commercial products whenever possible, as opposed to expensive products designed to meet government specifications, or (2) using commercial companies rather than in-house personnel to make specialized equipment.

– Contracting out functions once performed by laboratory personnel. This policy is particularly strong at NASA, where personnel are being cut, routine operations are being "outsourced" to industry, and scientific analysis is largely being "outsourced" to universities. NASA is trying to refocus its field centers, including JPL, on carefully defined areas of advanced technology and new science.

– Using new forms of technology partnerships with industry to meet agency mission needs. This is different than using partnerships to help general industry. Like many companies, federal laboratories realizing that as technology becomes more complex and fast-changing it is expensive and time-consuming for them to "go it alone" in developing new technologies to meet agency needs. Two notable innovations are (1) NASA's new policy to cost-share the development of new launch vehicles and (2) LLNL's use of Laboratory-funded "programmatic" CRADAs to draw upon the technical expertise of the private sector.

R&D partnerships. There are three important points about recent federal policy regarding industry-laboratory collaborations:

– Starting in 1995, Congress cut many federal technology programs to help general industry – including, as mentioned, appropriations for DOE funded CRADAs. The argument has been that such programs are "industrial policy" or "corporate welfare." Thus, from now on DOE laboratories will not have dedicated funds to help support joint R&D

areas of interest to commercial industry. NASA never did have such a program, although it supports information centers and, more recently, incubators to help entrepreneurs turn NASA technologies into products.

– However, Congress generally does not object to either licensing laboratory inventions or to standard CRADAs, in which companies and occasionally agency program offices pay the costs of joint research that builds on existing laboratory expertise. In fact, in 1998 the House passed legislation (H.R. 2544) that would amend current rules for licensing federal laboratory inventions to make it easier for companies to obtain licenses. This year's version is H.R. 209.

– DOE encourages CRADAs. Political problems can occur in the CRADA process – especially with large projects in which some companies seem to get special benefits – but the laboratories are willing and able to work with interested companies.

3.3 Likely Future Budgets, Missions, and Activities of the Livermore and Berkeley Laboratories

In this new budget and policy environment, budgets at LLNL and Berkeley Lab will be essentially flat. However, two major defense-related initiatives at Livermore – the National Ignition Facility and the Accelerated Strategic Computing Initiative – entail significant partnerships with industries and universities.

LLNL will continue to use laboratory-funded programmatic CRADAs. As LLNL seeks to tap expertise and technology in the private sector, these agreements are a useful mechanism. In procurement, LLNL is working with industry to meet the demands of its high-technology programs, such as precision optics for lasers and high-performance computing.

LLNL and LBNL will not have dedicated DOE funding to start new CRADAs in areas of interest to industry. However, both laboratories will continue to welcome industry-funded CRADAs and work for others that are consistent with their missions.

Both LLNL and LBNL see their future strengths as lying in areas of great potential value to the California economy, including advanced computing, lasers and inertial fusion, environmental management, 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.

Significant laboratory-industry cooperation – such as the Intel-led consortium's investment at LLNL, LBNL, and Sandia to develop extreme ultraviolet lithography for computer chip manufacturing – has promise to add vitality to the laboratories and enhance the competitiveness of industry. But many institutional hurdles arise.

3.4 JPL's Future

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.

4. Implications of These Trends for the California Economy

4.1 LLNL's and LBNL's Impacts on the California Economy

Neither the Livermore Laboratory nor Berkeley Lab is likely to go through major downsizings in the next few years. Payrolls and existing links to universities and companies should continue. At both laboratories, technical capabilities in key areas of importance to California are likely to continue – particularly in high-performance computing, lasers and opto-electronics, energy technologies, and biotechnology. Berkeley Lab also will continue to have major user facilities, particularly the Advanced Light Source.

Even with essentially flat budgets, there are procurement opportunities at these laboratories for California companies. The NIF is an obvious example, but opportunities also exist for companies interested in mutually-beneficial programmatic CRADAs at LLNL.

While Congress is unlikely to restore major appropriations for funded CRADAs, the laboratories' interest in partnering with companies through industry-funded CRADAs and work-for-others projects offers opportunities for California firms.

Technology transfer will continue to occur in less formal ways. As relationships with industry and universities increase, the use of non-patentable technology advances passed through professional relationships and papers also increase. Additionally, recent years have seen growth in flow of personnel across the laboratory/industry boundary.

LLNL is currently working with members of the Tri-Valley Business Council to establish an incubator-like Technology Enterprise Center. When open, this center is expected to contribute to the success rate of start-up companies based on LLNL technology as well as providing an incentive to locate in the area.

In general, LLNL and Berkeley Lab would like to be helpful to state officials. But, as mentioned, problems at the state level have hindered some efforts to date and, left unchanged, are likely to hinder any future efforts.

Even though barriers have limited federal laboratory cooperation with state agencies, an opportunity exists to combine laboratory, university, and industry efforts in an integrated manner to help solve problems of particular importance to California – such as environmental remediation and protection, transportation, and seismic studies and hazard reduction. An example might be state-led efforts to encourage and facilitate the use of advanced remediation technologies for brownfield recoveries.

4.2 JPL's Impact on the California Economy

Of the three major California laboratories discussed in this report, NASA's tight budget makes JPL the one still most at risk of long-term budget cuts -- although if NASA's overall budget is not cut further and if space station overruns do not cut deeply into the space science budget, JPL is now expected to avoid deep cuts and may even continue to see growth.

JPL will continue to expand its contracts with universities for the scientific analysis of data gathered by its spacecraft. As mentioned, over the period FY 1993-1998 California universities have won 48 percent of this money, but the year-to-year variations have been considerable. This fluctuation suggests that California universities are by no means certain to win large percentages of this money in the future.

With this budget situation, NASA's 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.

While budget stability means that JPL and other federal laboratories in California probably will maintain their core staffs and competencies, recent federal policy 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.

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.

5. Ways to Expand Laboratory Contributions to the State's Economy

What can be done to ensure that California receives as many benefits as possible from the federal laboratories in the state? Specifically, who should do what and when? This section of the Overview presents policy options and organizational options for strengthening the contributions that these federal laboratories make to the California economy.[3] These options are also presented in Volume II.

5.1 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

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

to the state's commercial satellite industry, and the Laboratory's expanding program of research grants to universities is already important to academic researchers 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.

5.2 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 a joint 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.

5.3 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.

5.4 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. One step 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 Volume II'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 in coming years, what they will be looking for in university research, and what areas California researchers might focus on. (Note: If JPL holds 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 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 toinform faculty, post-doctoral fellows, and graduate students of research opportunities at federal laboratories in California.

5.5 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.