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DEFENSE INDUSTRY CONVERSION, BASE CLOSURE, AND THE CALIFORNIA ECONOMY: THE ROLE OF TECHNOLOGY TRANSFER AND EMERGING TECHNOLOGIES

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Defense Industry Conversion, Base Closure, and the California Economy

A Series of Working Papers by Ted K. Bradshaw (Project Co-Director), Cynthia Kroll (Project Co-Director), Rokaya Al-Ayat, Mary Corley, Lyn Harlan, Josh Kirschenbaum, and Jason Moody. Judith Innes, Principal Investigator.

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From December 1993 through June 1994, the Institute of Urban and Regional Development (IURD) and the Center for Real Estate and Urban Economics (CREUE) conducted research to provide background for the state's defense recovery strategic planning effort. The research resulted in a final report to the California Trade and Commerce Agency and a set of working papers on prospects for the California economy's recovery from defense cuts. The working papers are jointly published by IURD and CREUE and can be obtained from either institute. The full set of papers includes:

Defense Industry Conversion, Base Closure, and the California Economy: A Review of the Literature and Annotated Bibliography.

> This work summarizes existing published research through spring 1994 on the defense industry, military base closure, and recovery efforts, with the primary focus on California. An annotated bibliography is appended to the paper.

Defense Industry Conversion, Base Closure, and the California Economy: A Review of Research and Planning Activities for Recovery

> This paper reviews recent recovery efforts in California among counties experiencing defense industry job losses and communities experiencing base closures. The report also identifies ongoing research efforts on defense recovery topics.

Defense Industry Conversion, Base Closure, and the California Economy: The Role of Technology Transfer and Emerging Technologies *

> This paper describes technology transfer programs and efforts as they relate to the recovery and restructuring of the California economy.

Defense Industry Conversion, Base Closure, and the California Economy: Critical Issues for a Statewide Strategy

> Drawing from the three background working papers, this piece identifies critical needs for recovery and suggests some directions for recovery efforts.

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Defense Industry Conversion, Base Closure, and the California Economy: The Role of Technology Transfer and Emerging Technologies

Abstract

This paper examines the role of technology transfer and other targeted research and development (R&D) programs in the transition away from defense spending. Historically, the bulk of federal support for R&D has been for defense-related technologies. With the ending of the cold war and the changing competitive position of the U.S. economy, the direction of spending is shifting. Although many R&D programs are remaining with defense-oriented agencies, such as the Department of Defense and the Department of Energy, new programs emphasize cooperative research and development agreements (CRADAs) between national laboratories and businesses and advanced technologies programs. California's economy has shown strength in several important areas of new technology development, including electronics, computers and information technologies, environmental and biological sciences and technology, advanced materials and processing, and advanced transportation technologies. Each of these sectors may help to reinvigorate the California economy. Some of the new initiatives that have developed in California to contribute to recovery from defense cuts are oriented to building on the state's existing technological advantages. However, the state could take a broader role in coordinating and promoting federal, state and local programs aimed at technology development.

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EXECUTIVE SUMMARY

This report was prepared as part of a study supported by the California Trade and Commerce Agency (TCA), Defense Conversion/Base Closure Planning Program. It is one of several reports supporting the TCA's efforts to develop a State Plan to address the economic impact of defense downsizing and base closures in California. The report focuses on:

- Examining existing federal technology transfer efforts — the organizations involved, the funding mechanisms that are available, the processes by which technology transfer takes place — and how they can help the state deal with the economic impact of base closures and defense downsizing.
- Evaluating the role of technology transfer in helping California develop a strong, technology-based economy capable of competing in an increasingly competitive world marketplace.
- Identifying "critical technologies," and determining which of these technologies are likely to have the most impact on the economic future of the state and the nation.
- Reviewing current and proposed California technology transfer programs/initiatives and examining the role the state should play in supporting these efforts.

THE TECHNOLOGY TRANSFER DEBATE

Technology transfer is not a new phenomenon; however, the formal processes now promoting it are. Increasing international competition, slow economic growth, and, most importantly, the end of the Cold War have led to a reassessment of the role government-funded research can play in enhancing U.S. economic competitiveness. Out of this concern has come a number of legislative and institutional reforms aimed at encouraging collaborations between government and private industry. Passage of the National Competitiveness Act, for example, enables government laboratories to enter into cooperative research and development agreements with private industry. And various federal programs — such as the Department of Commerce's Advanced Technology Program and the Department of Defense's Technology Reinvestment Project — have been established specifically to develop technologies with both military and civilian applications.

The federal government's changing role has not come about without debate. Critics of current technology transfer efforts basically fall into three schools of thought. First, there are the free-market adherents, who question the wisdom of government involvement at all. A highly developed technology transfer apparatus, they warn, will put the government in the position of establishing strategic industrial policy and of picking winners and losers — a process bound to become politicized and fraught with waste. Second, there are those who stress the importance of government support to basic research and national security. Diverting the national laboratories to applied research for technology transfer, they say, not only dilutes the labs' national defense mission, it runs the risk of underfunding basic research, the wellspring of tomorrow's technological advances.

Finally, a third camp supports government involvement in setting strategic industrial policy, but argues against having the bulk of federal R&D dollars controlled by the Departments of Energy and Defense. The weapons complex, they say, is already too big for the post-Cold War era. Federal R&D funds should be distributed on a more competitive basis, with higher priority given to non-defense organizations, such as academic institutions, private research laboratories, and non-defense government facilities.

Defenders of expanding the national laboratories' role to include technology transfer counter that, for historical reasons, the defense labs are the largest R&D performers and are uniquely suited to take on the kind of long-term tasks needed to promote technological innovation. The new emphasis on technology transfer and cooperation with industry should permeate the agenda of all federal agencies; however, its greatest impact invariably will be felt by the DOE and the DOD — the two agencies which oversee the lion's share (more than 60 percent) of all federal R&D funding in this country. While technology transfer historically has not been a key element in either agency's national security mission, that has and must change. In today's world, national security rests as much on economic strength as military might. Furthermore, say the supporters of tech transfer, there are some areas in which technological progress is important to human welfare but not likely to attract private investment, especially if the costs are high and the monetary pay-offs are uncertain or long-term.

Key to the debate over the government's support of technology transfer is the question of whether or not the process can work as intended. Just what is the potential of technology transfer to generate economic growth and contribute to technological innovations in the U.S. economy, in general, and the California economy, in particular?

One can point to many instances where a defense-based technology has had considerable impact on the commercial sector. But, until recently, there have been few efforts to quantify such benefits in terms of job creation or cost-savings to existing industries. The DOE and others are now exploring ways to measure the "success" of technology transfer activities. However, this is proving to be a difficult task. Technology transfer is seldom, if ever, a simple, linear process, easily monitored with quantifiable and widely accepted measuring sticks. Economic measures, such as number of jobs created, are difficult to estimate because it is often difficult to distinguish whether the benefit is the result of the technological innovation or of some other aspect of the commercialization chain. And simple measures, such as number of patents, income from licenses or number/value of CRADAs, while useful, can leave out important benefits, such as potential for creating new industries, enhancing an industry's competitive edge, or maintaining U.S. dominance in a field.

Nonetheless, case studies suggest that, given the right environment and support mechanisms, successful technology transfer can occur and can create economic opportunities and growth. The "success" of technology transfer, however, depends largely on one's perspective. If the appraisal hinges on precise estimates of job creation, royalties, or other quantifiable measures of return, the net benefits often can be ambiguous. On the other hand, if one considers the benefits of knowledge exchange, the response of private participants or the number of projects which, because of their long-time horizons or diffuse social benefits, might not otherwise have been pursued, the measure of technology transfer can be quite positive. For example, it is hard to imagine what the biotechnology or aerospace industries would look like today had it not been for substantial publicly financed R&D investments. In the future, a more careful and complete monitoring of technology transfer efforts and results will help develop better measures and models for ensuring success.

THE ROLE OF HIGH TECHNOLOGY IN CALIFORNIA'S ECONOMY

The success of technology transfer in supporting economic recovery depends to a large extent on the types of technologies pursued and their potential for fostering economic growth and creating jobs. With this in mind, a number of federal agencies and industry groups have developed lists of so-called "critical technologies" that are likely to play an important role in the economic future of the nation and California, in particular.

These lists — by DOE, DOD, DOC, the Council on Economic Competitiveness, and the National Critical Technology Panel — do not address how to solve technological bottlenecks. Nor do they address the many legal and business issues involved. They do, however, provide a useful tool for focusing R&D efforts and setting R&D priorities. It is noteworthy, too, that, while these lists vary widely in terms of approach and focus, their results are surprisingly similar. They are also quite similar to lists generated by other nations, such as Japan and Germany.

Similar efforts have been undertaken by government and industry groups to identify technologies critical to California's economic future. A synthesis of these California "critical technology" lists can be divided into following broad categories:

- Electronics, computers, and information technologies
- Environmental and biological sciences and technologies
- Advanced materials processing and manufacturing
- Advanced transportation technologies

THE STATE'S ROLE IN TECHNOLOGY DEVELOPMENT AND TRANSFER

There is currently a wide array of initiatives and programs aimed at supporting economic growth, technical training, environmental cleanup, and technological development in California. This report briefly summarizes a sampling of these activities, representing various regions and technologies as well as a variety of partnerships and collaborations among the government, the private sector, national laboratories, and academia.

A key question that emerges from this effort is what role should the state play to take full advantage of these programs and initiatives? Currently California, unlike other states, arguably lacks a predominant, overarching agency or program to encourage the creation and diffusion of new technology. And while California may lead the country, indeed the world, in a number of high-tech areas, systematic planning and coordination on a statewide basis has been relatively infrequent. In the past, the state has relied on the free market; on a variety of federal, state, and local programs; and, most importantly, on its generous endowment of human and fiscal resources to promote economic growth and development. However, in today's world of fiscal austerity and increasing global competition, that approach will no longer work.

To address the question of California's appropriate role, the report examines some of the more successful technology development and transfer programs in other states — specifically, programs in Pennsylvania, Ohio, North Carolina, and New York. Two states in particular — Pennsylvania and Ohio — receive high marks for their efforts to promote technological innovation.

Of course, simply adopting the technology policy tools and techniques of these states is no guarantee for a successful strategy in California. Political factors, funding sources, and the business environment, also play a vital role. Still, there are valuable lessons to be learned from their efforts and experiences.

OBSERVATIONS AND RECOMMENDATIONS

With the end of the cold war, we have entered a new age of challenges and opportunities — an era in which national security rests as much on global economic competitiveness as on military might. In response to these developments, the federal government is placing increasing emphasis on technology transfer and cooperation with industry.

California is well positioned to benefit from this new focus. For example, the state has a large number of federal laboratories, including three DOE laboratories in Alameda County alone, as well as several in southern California. These laboratories perform leading-edge R&D, possess a broad spectrum of technological know-how, maintain state-of-the-art facilities, and have direct access to federal technology transfer resources. With proper coordination and political support, these laboratories in collaboration with universities and private industry have the potential to greatly impact the state's economy.

The challenge facing state planners is how best to take advantage of the new federal programs and encourage participation by the private sector. This is important because competition for these programs is intense. Success will take careful planning, a clear focus, and a demonstrated benefit to the state and the nation. It will also take strong state involvement — in making sure California companies know about the programs that are available; in helping companies understand and meet the requirements involved; and in using California's congressional delegation to actively influence federal policy so that national science and technology goals correspond to the state's needs.

Further, a forum is needed to foster a better understanding of what the national laboratories' capabilities are and how they can best be used in concert with California's long-term science and technology strategy. Also, the ongoing involvement and support of the private sector is critical. One of the distinguishing features of almost every successful technology development program in other states is strong industry involvement — both financially and organizationally.

It should be remembered, however, that the mechanisms promoting technology transfer today are still relatively new, and many questions remain. Additional data gathering and analysis is necessary. For example, a more careful and complete monitoring of technology transfer efforts and results is needed to develop better models for evaluating the commercialization process and its benefits. Additional data is also needed to assess the size of the high-technology sector and its potential for job creation and strengthening California's economic competitiveness.

In summary, the federal government has many programs in place to promote technology development and diffusion to the private sector. Moreover, economic competitiveness has been added to the national laboratories' basic defense mission. However, to take advantage of these new federal programs and policies, state planners must take a strong role in providing technical, administrative, financial, as well as political support to all possible participants — large firms and small, regional alliances, local communities, federal laboratories, and academic institutions.

1. INTRODUCTION

1.1 PURPOSE

Recent defense downsizing and military base closures are having a major impact on California's economy. To address some of these problems, the California Trade and Commerce Agency, under the auspices of the Defense Conversion Council, is developing a State Plan to support California's economic recovery and to deal with the impacts of base closures on displaced workers and local businesses. This report focuses on a very specific set of questions regarding federal technology transfer efforts and high technologies, and the role they could play in creating an economy capable of competing in the global marketplace. More specifically, the report addresses these questions:

- What are the existing federal technology transfer efforts — the organizations involved, the types of funding available, and the processes by which technology transfer actually occurs? And, more importantly, what key technologies and industries in California are involved?
- To what extent could these technology transfer efforts help the state deal with the problems created by base closures and defense downsizing — and at the same time help build a strong technological economy capable of competing in an increasingly competitive world market.
- What are the key "critical technology" areas, and which are likely to play an important role in the economic future of the nation and the state?
- What current initiatives are designed to support technology development and transfer in the state? And, what role should the state play in supporting these initiatives and in encouraging the coordination of federal, state, and private sector R&D activities to meet the need for job creation and economic growth in California?

This report addresses these questions, reviews the relevant literature, and presents a compendium of information in support of the state's effort. It is important to note, however, that many of the federal technology transfer efforts described here are new, and, in some cases, are the subject of considerable debate. In cases when definitive answers are not available, the report discusses the main issues involved and highlights the pros and cons of the debate.

1.2 REPORT ORGANIZATION

This report consists of seven sections and three appendices. Section 2 reviews the mechanisms by which knowledge and technology developed by federally sponsored research is transferred to the private sector. Historically, a very large percent of government-sponsored R&D has been directed toward national security. Therefore, the technology transfer efforts of the national laboratories administered by the Department of Defense and Department of Energy are of primary interest. However, the section also addresses the technology transfer activities of the National Aeronautics and Space Administration and the Department of Commerce, especially since the DOC plays such an important role in civilian technology development. In addition, given the potential role of small business in California's job creation, the section discusses federal efforts focusing on this sector, as well.

Federal technology transfer efforts are relatively new, and there is still considerable debate as to (1) what role government should play in this arena, and (2) how much potential technology transfer really has to contribute to national economic security. Section 3 highlights the pros and cons of this debate and discusses the need for a framework to evaluate the potential return of technology-partnering arrangements between the government and its federal laboratories and various industry sectors.

Naturally, the success of technology transfer efforts in supporting economic recovery depends to a large extent on the types of technologies pursued and their potential for encouraging economic growth and job creation in the state. To place the discussion in perspective, Section 4 reviews various high technologies likely to have significant impact on future growth in different industry sectors. The section also introduces "Critical Technology Lists" that have been generated by various government agencies in the U.S. and abroad. Finally, because of all the interest in the "information superhighway," this section ends with a case study on the telecommunications industry and its potential impact on California's economy.

A large number of initiatives aimed at economic, educational, and technological development currently are being pursued in California, and it would be difficult to discuss all of them. Section 5, therefore, presents a brief overview of selected programs and initiatives, representing different regions and technologies. These initiatives include a variety of partnerships and collaborations involving private firms, national laboratories, and California colleges and universities.

Section 6 presents a brief review of technology development and transfer activities in other states — and the lessons to be learned from other states' experiences. Finally, Section 7 presents a summary and conclusions.

2. FEDERAL TECHNOLOGY TRANSFER

2.1 BACKGROUND

In recent years, a variety of factors have given impetus to reexamining the role of federally supported research and development efforts. First, the rise in global competition has accelerated the rate of innovation worldwide, presenting a serious challenge to the United State's traditional preeminence in technological and economic development. The most serious challenge has come from countries with coherent industrial strategies in which government and industry demonstrate a high degree of coordination, cooperation, or collusion. The success of these policies has led many to question the adequacies of relying on the free market to dictate national technology development.

Second, the economic downturn of the early 1990s, followed by a lackluster recovery resulting in high debt holding by U.S. corporations, has made it difficult for U.S. companies to finance investments in R&D. Traditionally a source of strength in the U.S. economy, industry-funded R&D has remained essentially flat since 1989, in constant dollars, and has dropped as a percentage of Gross Domestic Product (OTA, 1993). Finally, and perhaps most importantly, the collapse of the Soviet Union and the end of the Cold War has led many of those institutions that have traditionally been the largest recipients of federal R&D expenditures to reevaluate their missions, set new priorities, and explore ways to support the nation's civilian economy in addition to their ongoing defense mission.

These factors, among others, were the primary impetus behind a series of legislative and institutional reforms during both the Bush and the Clinton Administrations in the area of technology transfer. Following are highlights of those reforms:

- The National Competitiveness Technology Transfer Act (NCTTA) of 1986 and 1989 allowed both Government Owned Government Operated (GOGOs) as well as Government Owned Contractor Operated (GOCOs) federal laboratories to enter into what are now known as Cooperative Research and Development Agreements (CRADAs) with private industry.
- The Defense Authorization Act of 1991 required that $20 million of the Department of Energy (DOE) Defense Programs' R&D funds be explicitly set aside for cooperative projects with industry. The sum was raised to $50 million in 1992, to $141 million in 1993, and is expected to grow to over $200 million in 1994. This funding is in addition to the goal expressed in the NCTTA and subsequent legislation to devote 10 percent of Defense Program funds to CRADAs.
- In 1990, Congress launched the Advanced Technology Program (ATP), administered by the Department of Commerce (DOC) National Institute of Standards and Technology (NIST), to provide funding to businesses investing in high-risk technologies. The ATP supports applicants on a cost-sharing basis for developing technologies with substantial potential to enhance U.S. economic growth. Funding for the program is at about $200 million per year, and is expected to

increase to $750 million dollars per year by 1997 (Executive Office of the President, November 1993).

- The Department of Defense (DOD) Advanced Research Projects Agency (ARPA) has been given expanded responsibilities and dramatic funding increases during the 1990s. For example, in 1994 ARPA funding jumped by about 41 percent over the previous year's funding level to more than $500 million. (McGraw-Hill, October 1993.)
- In March 1993, President Clinton announced the Technology Reinvestment Project (TRP), a $472 million program to provide grants for developing advanced technologies capable of use in both the civilian and military sectors.
- In November 1993, President Clinton announced the formation of the National Science and Technology Council to provide (with industry input) policy guidance and priority and multi-agency coordination of federal R&D programs.

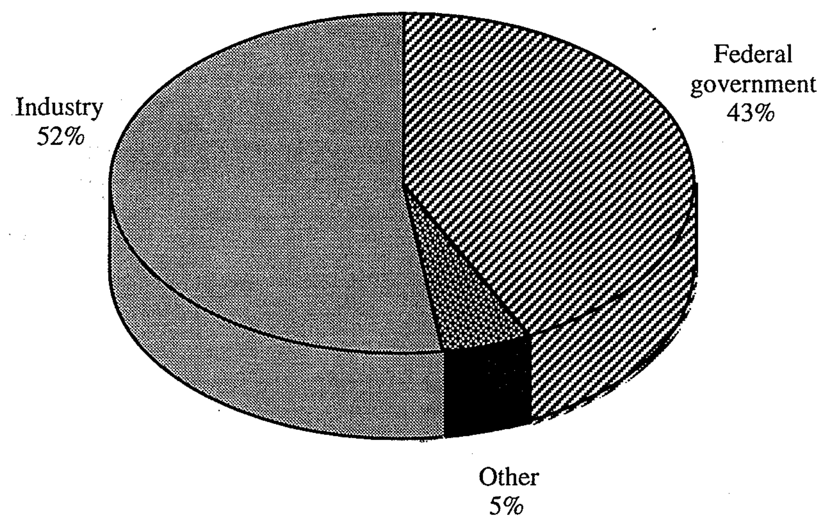
Although the new federal emphasis on technology transfer and cooperation with industry is intended to permeate the agenda of almost all federal agencies, their greatest impact has been felt by the DOD and DOE. These two agencies, being the principal managers of the nation's defense complex, oversee and implement the largest share of all federal R&D efforts.

In 1992, the federal R&D budget was about $70 billion, more than 40 percent of all R&D spending in this country (see Figure 1a). And of that, nearly 60 percent ($41.5 billion) was for military R&D. Figure 1b shows the distribution of federal R&D funds for 1992. In light of these numbers, the role of the DOE and DOD in promoting technological development takes on added significance. Indeed, R&D activities associated with the military establishment have had a pronounced effect on the American economy — in some cases, spurring the development of new-generation technologies in civilian industries such as computers, semiconductors, communications, and advanced materials.

Historically, however, technology transfer has not been a central part of the DOE or DOD missions. But, given the relative importance of DOE and DOD in the federal R&D picture and current political and economic forces, policymakers have begun to take a close look at the agencies' potential for fostering technological development and economic growth.

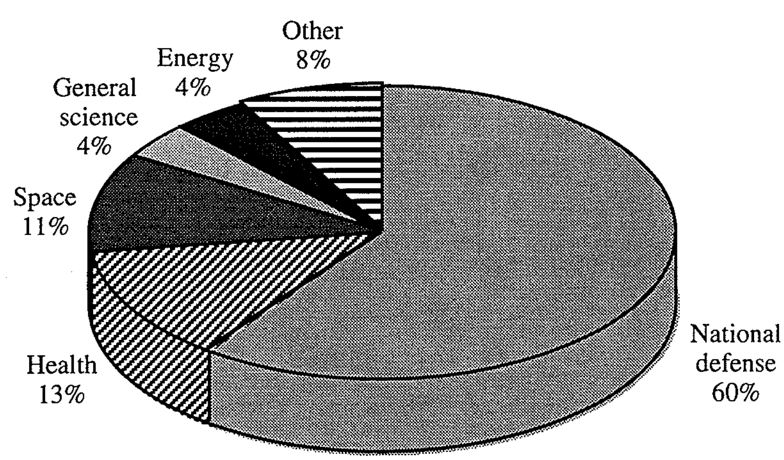
In addition to the size of the their R&D budgets, the DOE and DOD control a significant number of research laboratories that can serve as conduits for technology transfer. For example, the DOE has some 36 laboratories and research facilities performing about $6.6 billion worth of research annually on a wide spectrum of basic science and technology development activities ranging from fusion energy to biotechnology (*Technology Transfer*, DOE 1993). Other federal agencies with significant technology development programs, such as the DOC or ARPA, contract out many of their research projects to private entities. Even the DOD, which spent $9.9 billion on R&D in its laboratories in 1992, performs less than half of its work in-house (OTA, May 1993).

Figure 1a. National R&D spending, by source (1992).*



Total $157.4 billion

Figure 1b. Federal R&D funds, by budget function (1992).**



*SOURCE: National Science Board, *Science and Engineering Indicators–1991* (Washington, DC: U.S. Government Printing Office, 1991), table 4-1.

**SOURCE: National Science Board, *Science and Engineering Indicators–1991* (Washington, DC: U.S. Government Printing Office, 1991), table 4-17.

Although not discussed in this report, other federal entities also are involved in supporting the civilian economy through technology transfer. These include the National Institutes of Health and the Department of Agriculture, which have a long history of supporting the private sector.

Following is a more detailed discussion of technology transfer efforts at DOE, DOD, DOC, and NASA. Efforts and initiatives aimed at supporting small businesses receive special attention because of their importance to the California economy and their potential for job creation.

2.2 TECHNOLOGY TRANSFER IN THE DEPARTMENT OF ENERGY

Technology transfer involves the transmission of knowledge, information, processes, and/or machines and expertise. As such, it can take many forms, from conferences and publications, education and training activities, consulting arrangements, patenting and licensing of intellectual properties and cooperative R&D activities, to the creation of spin-off companies for commercializing specific products and technological innovations. Though technology transfer has occurred in some form or another throughout DOE's history, the legal/institutional infrastructure supporting technology transfer is relatively new. Furthermore, due both to the newness and diversity of technology transfer, any attempt at providing a formal description of the process invariably will leave out important interactions and relationships likely to spring from large-scale public R&D efforts. Nevertheless, there have been several attempts to document and classify technology transfer, especially by the DOE. Although the following discussion focuses primarily on the DOE effort, many of the technology transfer vehicles are also relevant to other agencies, namely DOD, NASA, and DOC.

Mechanisms for Technology Transfer at DOE

The DOE technology transfer program provides a variety of institutional instruments for collaborating with the private sector (DOE *Technology Transfer*, 1992). Perhaps the most highly publicized of these is the Cooperative Research and Development Agreement (CRADA). Other forms include licensing and patent agreements, small-business support, personnel exchanges, and consultation, as well as allowing industrial partners access to DOE high-technology facilities. Following is a brief discussion of these technology transfer mechanisms.

Cooperative Research and Development Agreements. A CRADA is a contractual arrangement in which a DOE research laboratory and one or more industrial partners collaborate, share costs, and pool the results from a particular research project. Typically, the DOE provides scientists, facilities, equipment, and up to 50 percent of the cost, all of which helps private partners leverage their R&D expenses and obtain access to resources otherwise unavailable. Of course, both parties benefit from the "shoulder-to-shoulder" learning experience that results when scientists from different backgrounds work together on a common project. Ownership of CRADA-developed intellectual property may be held by the private partner, the laboratory, or both, and is protected for up to five years from use by competitors.

Currently, the most signed CRADAs are in the DOE's Defense Programs area, which is primarily under the jurisdiction of four laboratories: Lawrence Livermore, Los Alamos, and Sandia National Laboratories, and Martin Marietta Energy Systems (Y-12). The only other laboratory to generate comparable interest in CRADAs is Oak Ridge National Laboratory. Together, Livermore, Los Alamos, Sandia, and Oak Ridge accounted for about 60 percent of all the CRADA activity at the end of 1992. The DOE's Conservation and Renewable Energy programs also have generated a fair amount of CRADA activity, though a far second to Defense Programs (OTA 93).

Despite early disappointments in the CRADA process caused mostly by administrative delays, industry participation is currently at an all-time high, with far more proposals being submitted than can be funded. Having gained the authority to sign CRADAs in 1989, the DOE labs had negotiated only 15 CRADAs by 1991. However, by July of 1993, the number had jumped to 465 (DOE, July 1993; see Figure 2).

An estimate of the number of executed CRADAs at three national laboratories, the dollar value of those CRADAs and the number and value of those being performed with California-based industrial partners is shown in Table 1. Table 2 contains a partial list of California companies participating in the CRADA process. And Table 3 lists examples of project areas and technologies involved in these CRADAs.

Increased utilization notwithstanding, the CRADA process is not without its critics. From an industry perspective, perhaps the biggest problem is the time and legal/administrative hurdles involved in reaching an agreement. Historically, negotiating a CRADA was a time-consuming process taking upwards of eight months to negotiate after a proposal had been submitted — a process that itself can take months to iron out. For businesses with highly competitive product lines and short lag times, this can be a significant deterrent.

Critics also believe that the labs' strongest attributes — technical talent, in-depth multidisciplinary teams, expensive state-of-the-art equipment, long time horizons — seem more suited to large projects, large companies or entire industries (Zimmerman, December 1993).

However, this is not generally true. According to one study of the DOE's 601 CRADAs negotiated by the summer of 1993, about 30 percent were with small businesses (Executive Office of the President, 1993). Nonetheless, many of the recent CRADAs have been with large U.S. consortia of companies including: the Advanced Battery, U.S. Car/New Generation Vehicles, SEMATECH, American Textile, and Financial Services Consortia.

Another complaint, especially among firms with substantial overseas ties, is the DOE's preference for product lines that are produced in the U.S. In a world economy of transnational business, highly mobile capital, and complex international agreements, some firms regard this as creating favoritism and placing unrealistic and burdensome restrictions on potential partnering arrangements.

Figure 2. DOE Cooperative Research and Development Agreements as of July 1993.

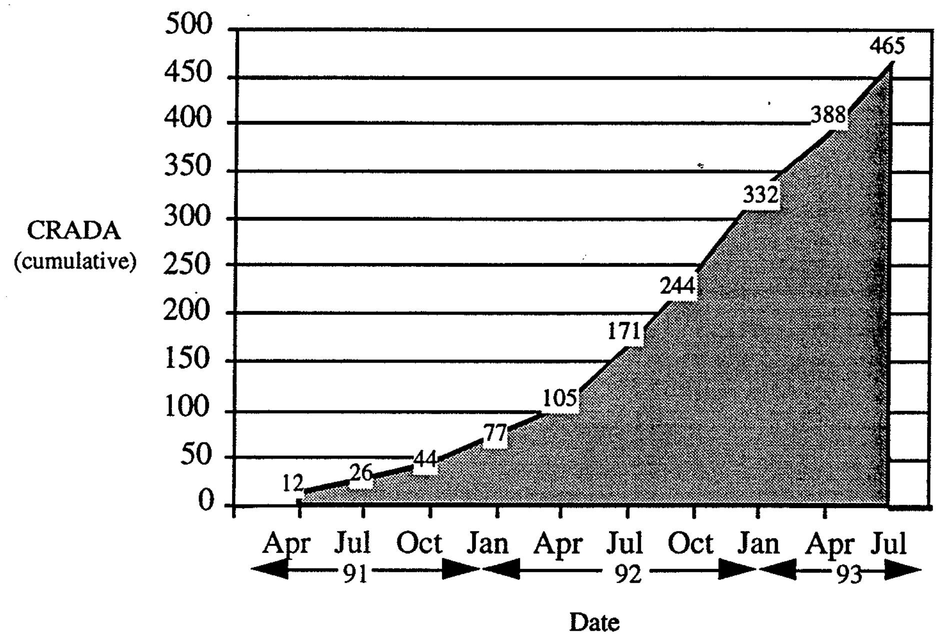


Table 1. Summary Statistics for Executed CRADAs at Three National Laboratories.

	No. of Executed CRADAs	Total Value of CRADAs ($Million)	No. Of Executed CRADAs in California	Total Value of California CRADAs ($Million)
LLNL	103	328	44	168
SNL	128	474	18*	95
LBL	13*	27	NA	NA

* Reflects number of CRADAs in California initiated and managed by personnel from Sandia National Laboratory, Livermore.

Table 2. Examples of California Companies Participating in CRADAs.

Major Corporation	Small Business Company
Kaiser Aluminum & Chemical Pleasanton	Aetemum Corporation Menlo Park
Industrial Tools Oaji	JAMAR Technology Company San Diego
Rhor Industries, Inc. Chula Vista	Ultratech Stepper Santa Clara
Intel Corporation Santa Clara	Tinsley laboratories Richmond
Ampex Corporation Redwood City	Phoenix laser Systems, Inc. San Francisco
Varian Associates Palo Alto	Sputtered Films, Inc. Santa Barbara
Schlumberger Technologies San Jose	BIOSYM Technologies, Inc. San Diego
Chevron Petroleum Technology La Habra	Conductus Sunnyvale
Hewlett-Packard Palo Alto	Xsirius Marina Del Rey
MacNeal-Schwendler Los Angeles	Purus San Jose
Watkins-Johnson Scotts Valley	MDC Vacuum Products

Table 3. Examples of CRADA Project Areas.

Project
Design of High-Precision Slicing Machines
Manufacture of Lithographic Optics
Electromagnetic Simulations for Aerospace Applications
Advanced Instrumentation for DNA Analysis
Enhanced Accuracy of High-Productivity Machine Tools
Electroplating Process Control
Physical Security Technology
Light-Weight Materials for Automotive Applications
Fiber Optic Hydrogen Sensing
High-Performance Storage System Testbed
Lasers for Medicine
Advanced High-Power Microwave Devices
Oil Shale Technology
Molecular Design of Polymer Alloys
Field Emission of Flat-Panel Display
Advanced Manufacturing Techniques for Optoelectronics
No-Cleaning Soldering Process
CVD of Copper for Integrated Circuits
Micro Thin Lens
Battery Technology

Licensing and Patents. Another form of technology transfer is the licensing of patented inventions to commercial enterprises. Subject to broad guidelines, federal laboratories are generally free to negotiate a variety of terms and conditions for their technology licenses and to collect royalty payments. The laboratories advertise licensing opportunities widely through press releases, by attending trade shows and technical conferences, and through informational mailings. Moreover, in recent years, the laboratories have increased their efforts to expand this technology transfer mechanism. Between 1987 and mid-1992, federal invention disclosures increased from 2,700 to 3,500; federal patent applications rose from 840 to 1,600; and patent licenses increased from 140 to 260 (OTA, 1993). Still, royalties from these licensing activities, though increasing, remain relatively small, and more attention is being given to exploring ways to improve management of the labs' intellectual property used for commercial products.

Small Business Initiatives. There are several federal programs designed to increase the participation of small businesses in technology transfer activities. These include the Small Business Innovation Research Program (SBIR), the Small Business Technology Transfer Program (STTR), and the DOE Defense Programs Small Business Technology Transfer Initiative. The latter program was recently approved to provide short-term consultation as well as funding projects (up to $50K) in support of small businesses. (See Section 2.6 for more information on small-business technology transfer initiatives.)

Other DOE technology transfer mechanisms (DOE *Technology Transfer*, 1993) include:

- **Scientific User Facilities**. University and industrial scientists are allowed access to a DOE laboratory or facility after submitting research proposals, which are peer-reviewed. Users who publish the results of their work incur no charges unless proprietary information is obtained as a result of their visits.
- **Technical Personnel Exchanges**. Exchanges of personnel with U.S. industries and academicinstitutions are conducted through specific research and development programs or arranged on an informal basis. In addition, there is a separate technical personnel exchange program which focuses on technology transfer and supports the travel, living, and other costs of the participants.
- **Reimbursable Work For Others.** The facilities and scientists are available to perform work for industry or other federal agencies as long as the work pertains to the mission of the respective lab, does not affect the achievement of a DOE program, and does not compete directly with capabilities available in the private sector.
- **Consulting Arrangements.** Scientist and engineers are available to consult in their areas of expertise. Each laboratory has its own consulting practices, but the staff is generally free to consult for a fee.

Although not stressed by DOE, spin-off or start-up companies, where scientists leave a DOE laboratory and start their own company, can be an effective technology transfer vehicle. Through spin-offs, the labs can contribute to a high-tech entrepreneurial environment that breeds technological innovation and job creation. Such a vehicle has not been encouraged in the past. Nonetheless, several spin-off companies have been formed. In California, for example, more than 30 companies with combined annual sales of about $1 billion have resulted from LLNL-developed technologies. These companies include such well-known names as Valid Logic Systems, Phoenix Lasers, and Physics International. Today, the laboratories are exploring ways not only to encourage such entrepreneurial ventures, but to share in their equity as a means of generating revenue for DOE. For this to become a reality, however, a number of legal and political issues must be resolved, including conflict of interest and fairness of opportunity.

Another avenue of technology transfer is simply the exchange of individuals between the public and private sector as a result of employment turnover, attrition, and re-hiring. When DOE lab scientists are hired by the private sector, for example, they take with them the experience and knowledge gained at the laboratory. This knowledge is often used to develop new products or processes that may contribute to the firm's profitability.

2.3 TECHNOLOGY TRANSFER IN THE DEPARTMENT OF DEFENSE

DOD technology transfer efforts were mandated by the Federal Technology Transfer Act (FTTA) in 1986. The Act allowed GOGO labs to enter into CRADAs with any outside organization. Moreover, Executive Order 12591 (issued in April 1987) required that the directors of GOGO labs be delegated the authority to negotiate and approve CRADAs. This has contributed to a short and streamlined approval cycle for CRADAs with DOD laboratories.

Ib general, the technology transfer mechanisms used by DOD are similar to those used by DOE. And, as with DOE, the number of CRADAs executed at DOD laboratories has been steadily increasing. In 1992, 253 CRADAs were in place at the Army, Navy, Air Force, and DOD Research, Development, and Engineering Centers, with an estimated total value of about $123 million. Many of the defense labs' CRADAs, however, are not with firms operating in commercial markets but rather with traditional defense contractors who may be only looking for ways to secure future defense contracts. As a result, this may not be a reliable mechanism for creating technology that ultimately will benefit the civilian economy and support defense conversion efforts. This bias may be reinforced by the federal government which, unlike the case for DOE, does not provide DOD with funding earmarked specifically for new CRADAs.

In addition to its in-house R&D activities, the DOD has oversight responsibility for several agencies involved in the development of so called "dual-use" technologies with both civilian and military applications. One such agency is the Advanced Research Projects Agency (ARPA), which has won high marks for its promotion of technological innovation . Although under DOD jurisdiction, ARPA is a semi-independent office charged with conducting high-risk, long-range R&D for advanced technologies with potential for dual-use in the civilian and military sectors. Established in 1958 independent of the armed services, ARPA does not have its own research facilities or research staff. Instead, the agency channels funding to researchers in industry, universities, and non-profit research centers and laboratories using its small staff to provide management oversight and technical direction.

In 1988, ARPA was given the responsibility to fund SEMATECH, the Semiconductor Manufacturing Technology Consortium. More recently, with the passage of the High Performance Computing Act of 1991, ARPA was given the lead in the High Performance Computing and Communication Initiative (HPCCI). In 1993, total funding for HPCCI, a multi-agency project aimed at accelerating the development and deployment of high-performance computers, stood at $805 million — of which ARPA allocated $275 million. Other agencies involved in HPCCI include DOE, NASA, NIST, and the National Science Foundation.

ARPA also coordinates the Technology Reinvestment Project, which is currently funded at $472 million per year (ARPA, 1993). TRP was approved by President Clinton to support defense conversion efforts and facilitate the transition of defense-dependent companies and communities into a post-Cold War economy. The program, through a competitive process, funds dual-use technology development efforts on a cost-shared basis. Funding is provided for three types of effort: (1) development of technologies with the potential for commercialization within five years; (2) state- and community-based manufacturing extension programs and other innovative techniques to deploy existing technology; and (3) college and university programs to educate and train manufacturing engineers and technicians. The initial TRP solicitation generated major interest; some 2,850 proposals were submitted, requesting $8.5 billion in funding. The last round of winning proposals was announced February 23, 1994. Tables A-1, A-2, and A-3 in Appendix A, list the winning proposals where a California company is the lead proposer in development, manufacturing, and deployment categories, respectively.

2.4 TECHNOLOGY TRANSFER IN THE DEPARTMENT OF COMMERCE

The DOC is also involved in the nation's technology transfer efforts. Although funding levels for DOC's principal technology agency, the National Institute of Standards and Technology, has increased dramatically under the Clinton Administration, its R&D budget is still relatively small compared to DOE or DOD budgets. For example, NIST received about $450 million in 1992, compared to more than $6 billion for DOE. Although NIST had approved 131 CRADAs as of January 1992, they generally were much smaller than those executed by DOE. As the federal agency responsible for advancing commercial goals and competitiveness, NIST has often been cited as a candidate for expanded authority as the nation's primary civilian technology agency.

Advanced Technology Program

One NIST's key technology transfer activities is the Advanced Technology Program (ATP), which funds civilian technologies in the nation's competitive interest. The program is funded at about $200 million for FY 1994, and is expected to increase to $750 million per year by 1997 (Executive Office of the President, 1993). ATP offers cost-sharing grants on a competitive basis to businesses and joint ventures for the development of new or radically improved products. Although critics charge that the program is little more than "a flat out give-away to the private sector," supporters counter that the agency has the potential to impact the U.S. economy because, unlike other federal technology programs, ATP makes investments explicitly for technology transfer rather than for some other national goal. Awards to individual companies are limited to $2 million over three years, and can be used only for direct R&D costs, not product development. Awards to joint ventures can be for up to five years, though the joint venture must provide more than 50 percent of the resources needed for the project (U.S. Department of Commerce, 1993).

Proposals for ATP funding are evaluated based on technical feasibility, business strategies for making the idea commercial, and the ability to match public funding: proposals are subjected to two levels of review — first by DOC technical experts and then, if there is sufficient technical merit, by a panel of businesspeople, who evaluate the proposal's commercial merit.

Manufacturing Extension Partnership

NIST also manages the Manufacturing Extension Partnership – a national network of manufacturing extension centers that serve as an industry outreach program to help smaller firms modernize their operations and improve their competitive performance. As part of this network, the California Manufacturing Technology Center, for example, assists manufacturing firms in such areas as enhancing product quality; incorporating advanced materials technology in products; reducing product cycle time; and assessing new market opportunities (McGraw Hill, October 1993).

2.5 TECHNOLOGY TRANSFER IN THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

A long-standing practitioner of technology transfer, NASA operates the largest non-defense laboratories in the U.S., including the Jet Propulsion Laboratory in Pasadena, California. The agency's mission statement stipulates that it provide for "the widest practicable and appropriate dissemination of information" resulting from its activities (GAO, March 1993). Although the agency spent about $3.5 billion in its labs in 1992, much of that funding went to its space program, which affects the civilian economy only indirectly. In 1992, according to the GAO report, NASA had 265 research contracts and cooperative agreements worth a total of $105 million.

NASA's role in the development of the satellite communication industry is often regarded as one of the best examples of the government's ability to generate advanced technologies for commercial purposes (Alic et al., 1993). The institutional innovations resulting from this effort include COMSAT, the quasi-public corporation established to promote satellite communication, and INTELSAT, the international consortium responsible for worldwide satellite telecommunications. NASA also financed the construction of a huge space launch and ground support infrastructure which it made available, at marginal cost, to the nascent satellite communication industry.

In addition to a host of other technology transfer activities, NASA participates in the CRADA process and, like NIST, has significantly shortened the approval time by delegating negotiation authority to its individual laboratory heads. NASA also operates Regional Technology Transfer Centers (RTTC), including their Far West RTTC at the University of Southern California.

2.6 TECHNOLOGY TRANSFER TO SMALL BUSINESSES

A number of federal programs also have been developed specifically to help small businesses participate in joint activities with federal R&D efforts. The two most prominent of these are the Small Business Innovation Research Program (SBIR) and the Small Business Technology Transfer Program (STTR), both of which offer financial incentives to small businesses for joint R&D efforts with federal agencies. The main difference between the two programs is that SBIR exploits commercially promising ideas that originate in the small business community, whereas STTR uses small companies to exploit commercially promising ideas that originate in universities, federal laboratories, and non-profit research institutions. The programs also differ in the share of private contributions required for their respective projects. However, both programs operate on a competitive, peer-review basis and offer annual solicitations for proposals. Also, in both cases, the small-business participants retain the rights to the data generated from the research for at least four years from the end of the project. Eleven specified federal agencies are required to set aside a percentage of their budgets for SBIR projects; five must do the same for STTR projects. Created in 1982, the SBIR program has funded more than 20,000 small businesses totaling nearly $3 billion.

ARPA's Technology Reinvestment Project also funds a pilot project designed to help small businesses participate in technology transfer activities. For small businesses in California, New Mexico, or the greater Washington, D.C., area, TRP will provide up to 50 percent of the costs of linking into an integrated system of Video Teleconferencing, Internet, and other networking facilities (e.g., e-mail, on-line news, bulletin boards, and special interest groups). The aim of this funding, according to the TRP enacting legislation, is to "provide assistance to small businesses that are economically dependent on defense expenditures to obtain access to a national network of scientists and engineers, and to information resources ... (to) facilitate the development and commercialization of new products." Currently, according to proponents of the project, collaborations via various telecommunication networks are generally not feasible for small businesses. This is because they do not have access to on-line video teleconferencing networks unless they happen to be located near one of the few existing commercial facilities. And even then, user fees and scheduling difficulties make repeated usage problematic. While many small businesses have dial-up access to Internet, these services are often slow and unreliable. The TRP pilot project is based on the belief that better access to information networks could result in new markets, new products, and improved interactions for small businesses.

In another effort to help small firms, DOC's NIST has recently joined with the Small Business Administration (SBA) to establish Small Business Development Centers. These Centers are to be based at NIST's seven Manufacturing Technology Centers, one of which is located in Los Angeles. NIST will provide about $250,000 annually to each of its Manufacturing Technology Centers to finance these Small Business Development Centers. These Centers can help regional manufacturers analyze requirements for improving quality and efficiency, assist in selecting appropriate modern technologies, and help with workforce training in developing business plans and operations. This new program broadens an earlier agreement between NIST and SBA designed to create ties between the NIST's Manufacturing Technology Centers and SBA's loan-guarantee program for small businesses.

More recently, a three-year pilot technology transfer program was initiated to fund joint research by small businesses and laboratories or universities on topics dealing with biotechnology and the development of environmentally benign industrial solvents. Research grants of up to $100,000 over a nine-month period are available — with the potential for follow-on awards of up to $500,000 over two years for second-phase research. Five federal agencies, including DOE, are participating in this program.

3. TECHNOLOGY TRANSFER ISSUES AND CONCERNS

Federal technology transfer efforts are relatively new, and there is considerable debate as to the role the government should play in this arena. There is also debate regarding just how much potential technology transfer has in contributing to national economic security. This section highlights some of the pro and con arguments in this debate. It also discusses various attempts at assessing the potential "return on investment" of technology partnering arrangements between the federal government and its national laboratories and various industry sectors.

3.1 THE TECHNOLOGY TRANSFER DEBATE

Critics of current technology transfer efforts generally fall into three camps. In the first, free-market adherents question the wisdom of involving the federal government in an area that is best left up to market forces. Proponents of this school of thought caution that a highly developed technology transfer apparatus will necessarily put the government in the position of establishing strategic industrial policy and of picking winners and losers, a process that will quickly become politicized, leading to pork-barrel projects and waste.

In the second camp, advocates of the importance of government in basic research argue that giving the DOE technology transfer responsibilities diverts it from its more important function of national security and basic scientific research. According to one observer, "keeping basic science underfunded while steering the most productive investigators toward applied work might yield new products in the short-term, but will certainly lead to a lack of intellectual ideas on which to build the innovations needed for success in the next century" (Zimmerman, December 1993). Similar sentiments were expressed in a recent article entitled "Save Our National Laboratories." The article raised concerns about the impact of diverting the national laboratories' efforts towards industrial applications, and its potential for "the death of science and ... the destruction of our society" (*21st Century*, Winter 1993-1994).

The third camp in the technology transfer debate, while supporting the notion of government involvement in a strategic industrial policy, argues that having the DOE and DOD control the bulk of federal R&D money makes them the *de facto* administrators of the country's industrial policy, a task they neither have the competence nor the authority to perform. These analysts add that the weapons complex is already too large for the post-Cold War era and that federal R&D funds should be distributed on a more competitive basis, with higher priority given to non-defense R&D performers such as academic institutions, private research laboratories, and other government facilities.

Defenders of the current expanded mission for the national laboratories counter that, for historical reasons that cannot be reversed, the largest R&D performers, namely the DOE labs, are uniquely suited to take on the kind of long-term tasks needed to promote technological innovation. The staff at these laboratories have unique capabilities for taking on projects where science and engineering, team-work, and a multidisciplinary approach are essential. In addition, the defenders argue, market signals alone are insufficient to assure that American companies maintain a prominent place in the world economy. There are some areas in which technological progress is important to human welfare, but are not likely to attract private investment, especially if the costs are high and the monetary pay-offs are uncertain and far off in the future.

3.2 EVALUATING THE BENEFITS OF TECHNOLOGY TRANSFER

The potential of technology transfer to generate economic growth and contribute to technological innovations in support of the commercial sector is also a topic of considerable debate. Transfer of technology from the defense to the civilian sector is not a new phenomena; however, the formal processes now promoting it are. As such, although one can point to many instances where a defense-based technology has had considerable impact on the commercial sector, there have been very few efforts to quantify these benefits in terms of job creation or cost-savings to existing industries. Recently, DOE and others have been exploring ways to measure the "success" of technology transfer activities, both to formally quantify the benefit of technology transfer to the economy and to help establish funding priorities.

One problem with measuring the success of technology transfer is that currently there is no uniform agreement on what it is or how it occurs. The concept of a "linear model of technology transfer," where researchers develop state-of-the-art techniques or instruments in their laboratories and then pass the results on to industry for commercialization, is clearly not valid. In fact, transferring research results that industry can use for commercial gain is a much more complex process. In a recent report, Gibson and Smilor described successful technology transfer as follows:

> Successful technology transfer is a continuous, interactive process where individuals exchange ideas simultaneously, and continuously. Feedback is so pervasive that the participants in the transfer process can be viewed as — transceivers — thereby blurring the distinction between the source and destination of information... The technology to be transferred is often not a fully formed idea. Technology often has no definitive meaning or value. Researchers, developers, and users are likely to have different perceptions about the technology. As a result, technology transfer is often a chaotic, disorderly process involving groups and individuals who may hold different views about the value and potential use of the technology (Gibson and Smilor, 1991).

Given the dynamic nature of technology transfer, it is not surprising that establishing a definitive method for evaluating its potential benefits to the national economy has been difficult. Economic measures, such as number of jobs created or value-added technological innovations, are hard to estimate, given that it is often difficult to determine which portion of the "return" is due to innovation and which is attributable to other "complementary assets" in the commercialization chain. Simple measures, such as number of patents, income from licenses, or number and value of CRADAs, might be useful, but they leave out important benefits, such as potential for creating new industries, enhancing an industry's competitive edge, or maintaining U.S. worldwide dominance.

A recent study attempted to determine the "value" of one of Lawrence Livermore National Laboratory's spin-off technologies — a computer code (DYNA3D) for modeling complex interactions and responses to explosions. The code, initially developed for the weapons program, has been transferred to the automobile industry for use in crash simulations, to Boeing for use in designing structures to contain failed turbine blades, to Adolph Coors for use in more efficiently manufacturing aluminum cans and, more recently, to the biomedical area for modeling the effects of impact tr,auma on humans. The study, performed by researchers from the University of California at Davis, focused on assessing the commercial benefits of DYNA (Walter et al., 1993). For the study, the researchers interviewed individuals who were using the code, as well as technical experts and financial analysts. The value of the code was determined by addressing three indicators: use of DYNA and "DYNA-like" codes; savings generated by using the code; and the market size of all "DYNA-like" codes.

The study concluded that DYNA, in addition to helping create an industry, helped reduce users' costs in two ways. First, using DYNA decreases the need for product testing, a saving estimated at about $250 million annually. Second, its use reduces product-development time, a saving estimated at $100 million annually. The study also highlighted some important lessons for future technology transfer efforts.

Another successful technology transfer area is biotechnology. A recent article, "University Technology Transfers: Impacts on Local and U.S. Economies" (Parker, April 1993), points out that virtually all biotechnology companies in the Bay Area today have their roots in U.C. San Francisco. Not only did U.C.-sponsored research provide enabling technology for the industry as a whole, most of the biotechnology firms owe their existence to trained scientists or former professors from U.C. Berkeley, U.C. San Francisco, or Stanford University.

Moreover, many of the benefits flow both ways. Biotechnology is by far the largest single generator of patent, licensing, and royalty revenues to both the UC system and Stanford University. The potential for collaboration with local companies helps the universities recruit new faculty, and the accessible brain power keeps biotechnology companies close by. Formal and informal consulting arrangements with university faculty are very common in biotechnology. Combining all university/industry ties, the Office of Technology Assessment (OTA, 1988) estimates that 46 percent of all biotechnology firms support research at universities. The relationship fits well the characterization of technology transfer as an interactive, nonlinear, and formal as well as informal process. Another example in the biotechnology field is the Massachusetts Institute of Technology. MIT estimates that it has spun off approximately 40 biotechnology firms in the past five years and raised over $70 million in venture capital funds to help create these start-up companies.

Another study that has attempted to evaluate the need for and benefits of technology transfer was reported in a case study involving Teltech of Minneapolis — a technology information clearinghouse providing on-line assistance to interested firms. The study, which was published in the Winter 1992 issue of *Economic Development Review,* revealed wide participation and measurable economic benefits to the system users (Baron, 1992). Teltech consists of a network of several thousand technical experts drawn from universities, federal laboratories, and technical consulting groups. These experts answer technical questions from client companies, receiving a fee for each interaction. Teltech also offers "interactive literature search" capabilities, enabling a client company to keep abreast of all relevant technical and business literature in the field. Teltech has sold its service privately since 1985, mostly to mid- and large-size technology-driven companies.

In addition, in late 1990 the state of Minnesota, through a program called Minnesota Project Outreach (MPO), began subsidizing provisions of Teltech's services to small companies in the state. In 1992, the U.S. House of Representatives Small Business Committee did a random survey of 30 of the companies participating in MPO. According to the survey, the companies attributed a large increase in profit to MPO services — the median increase being about $55,000, the mean increase about $770,000. Teletech also surveyed 23 of their non-subsidized clients. Table 4 shows the results, indicating a large return on the investment in the service.

Keeping in mind the small size of the population surveyed, these results indicate that a technology transfer program of this sort can yield enormous benefits. Minnesota spent a total of $1.6 million in the first 18 months for MPO, and they estimate that the benefit to "the 100 original charter subscribers alone during the first 12 months pays for that many times over."

Table 4. Results of Teltech Survey of 23 Non-Subsidized Clients.

	Median ($K)	Mean ($K)
Cost of Service	12.5	16.8
Increase in Annual Profit	100	304

3.3 SUMMARY

A distinguishing feature of the technology transfer successes described here is strong industry involvement both financially and organizationally. In the case of biotechnology, private companies often participate in or jointly sponsor university R&D, facilitating the transfer of ideas and personnel. Similarly, for inter-industry transfer and in the utilization of private data-bases, the economic costs and incentives are generally well-understood by the key participants. Thus, technology transfer appears to work best when there is a clear incentive structure and both parties in the process are familiar with the relevant activities of the other.

The success cases discussed here provide evidence that, given the right environment, technology transfer does occur and can create economic opportunities and growth. But they also demonstrate that the process depends as much on the institutional setting as it does on technology. Thus, the extent to which the models for success can be transferred to the federal laboratories will depend on a host of economic, institutional, political, and technical factors. Historically, many of the federal laboratories, especially the DOE and DOD labs, have had limited relationships with the private sector. Moreover, as was pointed out in a recent GAO report, the researchers were given little financial incentive or institutional support to make their work commercially relevant (GAO, 1993). However, in recent years, due in part to the political and economic environment, there has been a clear effort to change. Lessons learned from technology transfer activities in other settings may help guide these efforts.

The new emphasis on CRADA and small-business support are a clear example of the federal government's efforts to improve technology transfer by encouraging joint partnership and shared financial responsibility. However, it may still be too early to judge the economic or institutional effectiveness of these initiatives. As mentioned earlier, well established channels of communication are essential to technology transfer — and a key component of this is time. With CRADAs, it may take time to develop awareness and confidence within industry, and to re-orient the scientist and administrators who make up the federal laboratories. The fact that private-sector participants, who have their own internal measures of success, continue to contribute substantial amounts of capital and resources to participate in the process is one indication that the labs may be on the right track.

In sum, the success of technology transfer from the public to the private sector depends to a large extent on one's perspective. If the appraisal hinges on precise estimates of job creation, royalties, or other quantifiable measures of return, then the net benefits are often ambiguous. On the other hand, if one also looks at the benefits of knowledge exchange, the response of private participants or the number of projects which, because of their long time horizons or diffuse social benefits, might not otherwise have been pursued, many technology transfer efforts might receive a very positive evaluation. For example, it is hard to imagine what the biotechnology or aerospace industries would look like today had it not been for substantial publicly financed R&D investments. In the future, a more careful and complete monitoring of technology transfer efforts and results will help develop models and processes that ensure successful commercialization.

4. HIGH TECHNOLOGIES AND THEIR ROLE IN CALIFORNIA'S ECONOMIC RECOVERY

As discussed in the previous section, the success of technology transfer efforts depends to a large extent on the institutional mechanisms that support them. However, equally important to these efforts is the technology itself and whether it is relevant to the needs of the private sector, and to society as a whole. Thus, a key challenge facing R&D decision-makers is how to set priorities so as to increase the impact on pressing R&D needs and technical bottlenecks of the public and private sector. Clearly, these allocation decisions depend on information about economic trends, social needs, trade policies, and global competition, which is often very difficult to assess or predict. In reviewing the literature, however, there seems to be a consensus on the broad areas of science and technology likely to be critical to California's economic competitiveness and growth.

After a brief discussion of the importance of technological innovation to California's economy, this section identifies key technology areas deemed critical by a wide variety of public and private sources. This is followed by a more detailed discussion of selected areas that are of particular interest to California. It is important to note here that technological innovation is only one of many factors that will play a role in promoting growth and competitiveness in California. And, as was stressed in the previous sections, even the best technological innovation does not necessarily sell itself without effective institutional transfer mechanisms. However, given the wealth of California's human capital and its technological infrastructure, much of which is now available for new uses as a result of defense cutbacks, establishing a science and technology policy for the state is likely to be vital to the success of defense conversion efforts.

4.1 HIGH TECHNOLOGY

There has been much disagreement among economists, regional planners, and social scientists about the importance of high technology to the economy and the role it plays in generating jobs. Advocates of high technology argue that, despite the sector's relatively small size, it is vital to economic competitiveness — not only in creating new industries, but in improving the performance of existing industries. In general, high-technology developments spur innovations that increase in our nation's standard of living and create high-wage, high-skill jobs often at a faster rate than in the economy as a whole. On the other hand, critics of high-technology-investment policies question high technology's potential to create new jobs in the future, especially since growth in the sector historically has been heavily dependent on military spending, which may not be forthcoming in the years to come.

While neither argument is totally without merit, there are reasons to believe that high technology will continue to have significant impact on California's economy. First, California is the nation's leading high-technology performer. For example, according to a recent study, California employs 14.8 percent of the nation's high-tech industry workers, more than twice the proportion of any other state (Hadlock et al., July 1991). Second, the sector has a far larger share of California's economic base when compared with the nation — roughly twice as large. In terms of manufacturing shipments, high tech accounts for 18.9 percent in California as compared to 8.7 percent in the nation. When measured by value-added, high tech is 23.1 percent in the state, 11.1 percent in the nation (Center for the Continuing Study of the California Economy, 1993).

In addition, California's high-tech firms continue to dominate the ranks of the state's fastest growing firms. For example, some 20 percent of the annual Inc. 100 fastest growing firms by sales growth are from California, and all but one of these are high-technology firms. Also, because high technology has established such a strong foothold in California, important services and support networks have developed to nurture new efforts. For instance, firms in California attract about four times more venture capital than those in Massachusetts and seven times more than those in Texas — the second and third highest states, respectively (Office of Science and Technology Policy, 1993).

The existing base of companies also means there is a ready source of engineers and potential entrepreneurs to spin off new ventures. This is supported by the fact that California employs about 15 percent of the nation's engineers and about 12 percent of its scientists, and is responsible for nearly 10 percent of the nation's patents (*California Almanac*, 1991). Moreover, a large percentage of workers displaced by base closure and defense conversion are likely to be technically trained, skilled workers. Finally, the synergy that exists between the private sector and the state's premier academic institutions and the high number of DOE, DOD, and other research facilities located here contribute to this environment.

Despite the significance of high technology in California, it is important not to overstate future employment growth generated by emerging technologies. Due to high productivity gains, many economic analysts predict only minimal job growth in emerging or high-technology fields. Although total output is expected to grow as fast or faster than the economy as a whole, large increases in productivity may keep total employment from growing significantly (Center for the Continuing Study of the California Economy, 1993; Office of Science and Technology Policy, 1993). This fact, however, does not negate a strategy of promoting the growth of high technologies. The 1989 Economic Report of the President credits innovation and diffusion with about half of the historical increase in the U.S. standard of living. More to the point, the productivity gains produced by new technologies often lead to high wages and profits in other sectors as well. In addition, innovation can lead to the creation and retention of new jobs and growth opportunities in other industries. If a company introduces a new or better product or begins using a more efficient process, technology benefits will likely accrue to consumers, in the form of lower prices or better products, and to other producers, who may imitate the new product or process. Empirical studies commissioned by the National Science Foundation have found that benefits to the whole economy from fairly routine industrial innovations are, on average, two to three times the size of benefits to the innovator (Baron, 1992).

4.2 CRITICAL TECHNOLOGY LISTS

The flurry of attention to high technology in recent years and the debate about this sector's role in the economy has led a number of agencies and researchers to assemble lists of so-called "critical technologies." The stated goal of most of these lists is to focus on generic, pre-competitive technologies that are vital to the U.S. economic future, and to provide a framework for establishing effective science and technology strategies. These lists include:

- **1990 Department of Defense Critical Technology Plan.** This document identified 20 critical defense technologies (U.S. DOD, March 1990) derived from requirements statements of needed military capability 15 to 20 years in the future. It represents a judgment as to the most important technologies for supporting long-term military goals.
- **Department of Commerce List.** The list, also published in 1990, divided the technology areas of interest to DOC into four categories: materials, electronics and information systems, manufacturing systems, and life science application (U.S. DOC, 1990).
- **Council on Economic Competitiveness.** This is a privately formed advisory panel made up of leaders from business, labor, and academia. The list, published in 1991, includes additional areas that were viewed as critical to "America's future." In addition to "critical technologies" mentioned above, the council's list includes information and communication, energy and the environment, aeronautics, and surface transportation.
- **National Technology Panel.** This list, published in March 1991, is very similar to the list generated by the Council on Economic Competitiveness.
- **Department of Energy Defense Critical Technologies List.** The DOE list focuses on technologies considered "essential for maintaining confidence in the U.S. nuclear deterrent" (1992 DOE Defense Critical Technology Plan, March 1992).

These lists are shown in Appendix B (Tables B-1 to B-5). For comparison, Appendix B includes similar lists for Germany and Japan (Tables B-6 and B-7). While the methodologies used by the organizations may differ, the lists are very similar. The lists have been justified as an organizing and priority-setting strategy. However, they have also been criticized for being both over- and under-inclusive. They are over-inclusive, some argue, because a close examination of many of these lists reveals that virtually every area of modern technology has been identified. Critics claim that this does little to help the government set priorities or allocate scarce funds.

The lists can also be under-inclusive, critics charge, because their emphasis on the developers of high technology often excludes the equally important users and implementers of advanced technology. Many firms producing products with no high-technology components use a wide variety of sophisticated high-technology products and processes in the production process. For example, a microchip firm would be classified as high-technology, whereas a potato chip company would not, despite the fact that that firm may use the most advanced research methods biotechnology has to offer.

Similar efforts have been undertaken to develop high-technology categories viewed as important to California's economy. These include efforts by the Council on California Competitiveness and the Assembly Democratic Economic Prosperity Team (ADEPT), as well as a report prepared by Joint Venture: Silicon Valley entitled "Blueprint for a 21st Century Community." The next section provides a synthesis of these lists and describes key high-technology sectors important to the state's economy.

4.3 .... HIGH TECHNOLOGIES IMPORTANT TO CALIFORNIA

For ease of discussion, these high technologies are divided into four categories:

- Electronics, Computers, and Information Technologies
- Environmental and Biological Sciences and Technology
- Advanced Materials and Processing
- Advanced Transportation Technologies

In each of these categories, several research and development areas are identified that could lead to further growth in the sector. It is important to note that the technology classifications used were chosen primarily for intuitive simplicity and are not meant to convey any scientific insight into the productive process. It is also worth noting that, as one would expect, there is significant overlap among the industries listed under each heading and that in the real world it is hard to identify which industries will benefit from which technological breakthroughs. For example, advances in computer science will also generate significant benefits to the biotechnology sector as the enormous amount of data involved in classifying the human genome is made easier to access and evaluate. Finally, due to time and research constraints, there are undoubtedly important omissions in the following classifications.

Electronics, Computers, and Information Technologies

Although this category encompasses a wide range of industries, the supporting technology is often functionally interdependent in both the production process and in the end product. This dependence is especially obvious in such end-use, high-growth areas as office equipment products, home entertainment systems, and telecommunication devices (see Council on Competitiveness critical technology categories: Information Technologies and Electronic Components). The dynamic nature of the field can be illustrated by the high level of venture capital that flows to it, the amount of R&D involved, and the number of new entrants and high-growth firms in the market. For example, more than 40 percent of all venture capital goes to the computer, electronic, and communications industry, and they combine for over half of Inc. 100's fastest growing firms (Pope, March 93). They also make up about 30 percent of Business Week's so-called "Little Giants" — firms with sales under $100 million, but market values in the league with the nation's top publicly traded companies. This is a good indicator that investors, and thus the market, predict they will continue to exhibit substantial growth in the future.

The telecommunications field is an especially good example of the dynamic and interdependent nature of electronics, computer, and information technologies. The Clinton Administration's plan to promote the development of a communication "superhighway," for example, involves linking advanced super-computers and software over a high-speed fiber-optic network, making a broad array of new information and services available to schools, libraries, and homes via modem. The easing of legal restrictions on phone and cable companies is also likely to spur rapid technological innovation and investment in this area. Some analysts predict that in the not too distant future a vast telecommunications system linking phone networks, cable-TV systems, satellite broadcasts, and multimedia libraries will make getting connected to anything or anyone in the most remote parts of the world a simple matter. Envisioned interactive "hyper-media" systems could allow people to carry on the business of daily life — from shopping and banking to entertainment and date-setting — from their home computers (see case study in Section 4.4),

Although the U.S. position in electronic, computer, and information technology is generally strong, it has lost considerable ground in a number of sectors because of an inability to convert its lead in basic technology into competitively produced commodities. For example, the almost total U.S. dominance of the domestic consumer electronic market during the 1960s and early 1970s fell to about 52 percent in 1985 and to 34 percent by 1990 (McKeeney, 1993). The U.S. semiconductor industry, which is central to the entire computer industry, also fell behind Japan during the 1980s, but has rebounded in the last several years in part because of efforts by the SEMATECH consortium.

In the U.S., California is by far the most competitive state in the field, accounting for some 23 percent of the country's computer, electronics, and information firms and 22 percent of the jobs. In the semiconductor field, for example, the state is home to seven of the top 12 firms, as ranked by total sales, assets, and stock market value (*Business Week*, 1993). Although predictions are difficult, according to a study by the UCLA Business Forecasting Project, employment in a broad set of industries encompassing communications, electronics, and office computers and equipment is expected to reach 309,800 by 1994 — the highest level in the 1990s, but still below the peaks of the mid-1980s.

The high concentration and diversity of computer-related firms in California, the state's excellent post-secondary education system, and its highly skilled workforce make it poised to take advantage of new breakthroughs in electronic, computer, or information technologies. Although difficult to predict where these breakthroughs will occur, following are some important areas of research and development that could bolster the California economy:

- **Storage, Retrieval, and Computation**. Efforts to improve the speed, memory, and computational capacity of computer systems are vital to the advancement and competitive position of the industry as a whole.
- **High-Speed Networking and Communications**. Advances in the ability to move large amounts of data over great distances and to enhance communication links within computer

systems — such as integrating smaller networks with larger ones or crossing computer languages — could provide a boon to the telecommunications and personal computer markets.

- **Graphics and Visualization**. Improvements in the processing and display of vast amounts of information and further developments in virtual reality, holographic images, and interactive collaborative environments could provide a boost to the telecommunications and home entertainment industry.
- **Miniaturization, Portability, and Durability.** While consumers are not likely to spend a lot of money for systems only slightly superior to what they already have, they generally will pay more for increased flexibility and durability. The cordless phone and the laptop computer are two examples in which further technological innovation in this area may add significant value to the market.
- **Modeling and Simulation of Complex Systems**. Predictive modeling and simulation have broad commercial applications in such areas as reducing the need for expensive and time-consuming device and design tests, studying social science phenomena, performing computationally intensive studies such as global change modeling, weather changes forecasting, earthquake prediction and seismic analyses, and streamlining of manufacturing processes. New breakthroughs in this area can provide significant market opportunities.

Two examples of the kind of pre-competitive path-breaking research that might benefit electronic, computer, and information technologies are in the area of microlithography and high-density magnetic information storage. By determining the size and functional capabilities of microchips, microlithography is the most critical technology in the semiconductor manufacturing process. Although the U.S. currently lags behind Japan in most facets of this technology, it holds a strong lead in the cutting edge areas of the science which, with critical R&D investments, could set the stage for future competitive advantage and new markets. Magnetic information storage is also critical to the computer industry in that 97 percent of all information storage products today is magnetic. Projections show that the $60 billion worldwide market for magnetic information storage devices could grow to $500 billion in the next decade and that the field is potentially ripe for innovation (OTA, September 1993).

Environmental and Biological Sciences and Technology

This category encompasses a wide variety of industries. It includes, for example, many facets of the health care industry, including medical equipment and pharmaceuticals, as well as the biotechnology field and the emerging environmental protection and clean-up industry. Like the electronics, computer, and information technology categories, this field is highly innovative and dynamic, as demonstrated by the high level of venture capital flowing to it, the number of new start-up firms and patents, and the high ratio of R&D expenditures. For instance, the health care industry alone accounts for almost 35 percent of venture capital disbursements nationwide (Pope, 1993). In addition, biotech firms, which are closely associated with the health care industry, constitute almost 40 percent of Business Week's so-called "Little Giants."

Although the industries included under this heading are not as big and have not generated as much employment as those in the other categories, a number of other factors make their potential to contribute to the California economy highly favorable. For example, unlike many of the other industries mentioned so far, environmental and biological technologies are not highly dependent on U.S. military expenditures. Although both health care and environmental protection are undoubtedly affected by the activities of the federal government, public policy trends in these areas appear to present new opportunities rather than setbacks. In addition, unlike the two other high-tech industries that have found a prominent place in the California economy, computers and aerospace, biotech, health care, and environmental protection industries showed continued growth during the last several years despite the poor performance of the overall economy. Finally, the U.S. is the undisputed world leader in these industries and continues to hold a distinct competitive advantage in these fields, something that cannot be said for many of the other high-technology areas.

California's leadership position in health care, biotechnology, and environmental sciences may also work to make these industries important to the state's economic future. As the birthplace of biotechnology, northern California firms alone account for about 40 percent of all biotech revenues, more than any other region. Currently, the industry employs more than 40,000 scientists, technicians, and support staff in California, and is projected to create about 50,000 new jobs in the region in the next ten years (Schafroth, May 1992). California is also home to the nation's largest concentration of companies in biomedical instrumentation, according to several sources. In Orange County, this industry is expected to replace defense-related companies as the leading employer. Finally, five of the 10 largest environmental engineering contractors in the country are located in California. Also, the state's burgeoning ranks of "eco-entrepreneurs," according to a study by the San Diego-based Environmental Business Council, are expected to generate another 64,000 new jobs statewide by 1996 (Environmental Business Council, 1993).

Despite their impressive potential, most of the industries described above have yet to find the defining product or market that will make them the kind of large-scale employment generators needed to fill the gap created by massive defense cutbacks. As relatively young industries, both biotechnology and environmental protection companies, for example, are still highly dependent on technological innovation for future growth. Some research and development areas that are likely to benefit these industries include:

- **The Human Genome Project.** The National Institute of Health- (NIH) and Department of Energy-sponsored Human Genome Project, a 15-year, $3-billion effort to draw a genetic map of human beings and other organisms, could continue to result in breakthroughs that will allow biotech firms to expand into new areas of genetically-based therapeutic and diagnostic procedures. It is highly probable that biotechnology research will eventually provide the impetus for the cure of such life-threatening diseases as cystic fibrosis and AIDS.

- **Agricultural Biotechnology**. New research into the genetic make-up of plants and animals could pave the way for transgenic mutations aimed at increasing the shelf-life, flavor, and yields of agricultural products. This research is also relevant to environmental technologies since genetic engineering can result in pest-resistant plants and organisms that decompose toxic waste.
- **Waste and Environmental Contamination Minimization**. This involves developing new or improved processes that generate less waste or pollution than currently used techniques. Specific examples are laser, electron beam, and plasma processing, and "smart" process controls as well as robotics. Substitutes for processes now based on volatile organic compounds and toxic substances may also be developed.
- **Environmental Clean-Up and Remediation**. The development of new techniques for treating waste or pollution before it is released into the environment is key to the environmental protection industry. Advancements in inter-industry re-cycling methods is one potential area of growth, as is the development of new end-pipe screening and filter mechanisms. Bioremediation and dynamic stripping are two relatively inexpensive techniques now being developed to clean up contaminated sites. New fiber-optic sensors that can characterize underground contaminants, measure chemical processes at remote points, and monitor wastes with underground imaging techniques also could contribute to this field.

Advanced Materials and Processing

This category includes industries involved in the synthesis, fabrication, and processing of advanced materials such as plastics, ceramics, composites, adhesives, and inorganic chemicals. Although not all of the industries in this field can be classified as high-tech, many of them do require new and innovative applications using the tools of chemistry, physics, and engineering (see Council on Competitiveness critical technology categories: Materials and Associated Processing and Engineering and Production Technologies). Fabrication processes, including laser technology, advanced welding techniques, and precision machining, also require a high degree of specialization and training. Innovations in new materials technology can drive advances in products and processes vital to the manufacturing sector, which constitutes roughly 25 percent of the U.S. economy (DOE, Oct. 1993). These materials can make products stronger, lighter, and more effective, as well as spur the development of totally new products.

The leading countries in the production of new materials and processing technologies are likely to be Japan and the U.S., followed by Germany. For example, most estimates show Japanese production accounting for about half of the rapidly growing world market for advanced ceramics between 1980 and 2010. The U.S., meanwhile, is the world leader in the production of plastics. Statistics for California are more difficult to come by, although the advanced materials and processing fields do not appear to play as significant a role in the state's economy as other high-tech fields (Office of Science and Technology Policy, 1993). According to one estimate, about 9 percent of all advanced materials firms are located in the state. It is important to note, however, that electronic and photonic materials — such as silicon, superconductors, display, and magnetic materials — play a vital role in the computer industry. In addition, light-weight plastics and ceramics are important to the aerospace industry.

Advanced Transportation Technologies

Technologies in this category include engines for products used in the transportation, manufacturing, and farming sectors as well as in aeronautics and robotics. Although the industry has been around for more than 100 years, in one form or another, because of its size and competitive nature, technological innovation is still of critical importance and R&D is very high, especially in absolute terms. Therefore, its inclusion as a critical high-technology category is justified, given the central role the industries involved play in producing high-value-added commodities.

While there has been much discussion about the U.S.'s declining position in the motor industry, especially in the auto sector, many sectors in this category remain highly competitive and continue to grow. California's contribution has increased in recent years, but the competitive advantage still remains in the Midwest and South. However, future innovations in this field — in both the production process and final product — will depend heavily upon advances in computer technology as well as materials and processing, both of which, as discussed earlier, are relevant to the California economy.

In addition, the state is still the world leader in aerospace technology, despite massive defense cutbacks in this area. And the aerospace industry's contribution to California's employment picture, although diminished, cannot be ignored. As late as 1987, aerospace employed almost 400,000 people. Today, the figure is about 250,000 (Quinn, Feb. 1993). Since the trend in defense spending is not likely to change, the future success of this industry will depend on its ability to carve out new markets through technological innovation aimed at a new class of customers — the commercial aircraft, rocket launch, and satellite industries, to name a few.

Other research and development areas in machine, powertrain, and propulsion technologies were discussed in a recent DOE document (DOE, 1993) and are relevant to the California economy. These include:

- *Improved Engine Efficiency and Cleanliness.* Engine research based on advanced diagnostic techniques to improve fuel efficiency and meet environmental standards could have an important impact of both California consumers and producers. This includes engine sensor and diagnostic technology, advanced combustion technology, and innovative control techniques for nitrogen oxides.
- *Alternative Fuels and Fuel Additives.* Alternative fuels to replace imported petroleum, improved biofuels such as ethanol, advanced storage of gaseous fuels, accelerated development of fuel deliv-

ery systems, and research on renewable hydrogen for use in fuel cells could be exploited to the benefit of California producers and consumers.

- *Electric Transportation.* Research on electric transportation to reduce petroleum use and vehicle emissions is already being conducted in California. This could include electric and hybrid vehicles, magnetic levitation technologies, fuel cell technologies, thermal energy storage systems, and even mass transit research.
- *Robotics.* Among other things, robotics involves the development of production processes that improve product quality, lower production costs, decrease product cycle time, and reduce the potential for error and waste. Although the short-term impact on employment is usually negative, in the long run new jobs may be created through increased competitiveness and the opening of new markets. Moreover, advances in the robotics area will play an important role in medical technologies, hazardous material handling, and environmental clean-up activities.

4.4 CASE STUDY: NATIONAL INFORMATION INFRASTRUCTURE

Probably no other industry exemplifies the dynamic and complex nature of high technology more than telecommunications. To even call telecommunications an industry is misleading since it cuts across several rapidly blurring distinctions that once existed between the telephone, the radio, the computer, and the television. By offering products and services that will potentially revolutionize the way the modern world communicates, works, and plays, it will impact other industries as well and in ways that are impossible to predict. Already its affects have been felt in all services, health care, entertainment, and education, and experts believe that its potential has just barely been tapped. The cross-cutting nature of telecommunications can also be seen in the large number of mergers and joint ventures between cable-TV, telephone, computer, and cellular companies that have occurred within the last year alone. Undoubtedly the most important year for telecommunications since the break up of AT&T, 1993 witnessed behemoths in several fields — AT&T, Paramount, Warner Bros., the Baby Bells, Apple, IBM — jockeying for position in a market that some estimate will reach $3 trillion by the end of this decade (Standard & Poors, July 1993).

The question of what role the state or federal government should play to ensure that the telecommunication revolution generates domestic employment opportunities and economic growth is difficult to answer. Clearly, the public sector has a role in providing adequate education and training, ensuring equal access, setting uniform standards, and designing a regulatory environment that promotes competition and innovation. Arguments over the government's future role range from those who advocate major public investment — similar to that which occurred in the early years of the telephone industry — to those who call for a government-industry consortium to collaborate on investment and regulatory strategy, to still others who support a complete deregulatory, hands-off approach. Whatever the case, a better understanding of the scope, structure, and growth potential of the telecommunications industry will help put these arguments in perspective.

Market Growth and Employment

As with many high-tech fields, it is difficult to predict the telecommunications industry's future growth areas. Nonetheless, the sector's importance to the economic health and competitiveness of the U.S. and California is evident. It is often argued that the nations that control the flow and content of information ultimately pave the way for economic and cultural development. In terms of raw numbers, the domestic telecommunications market is estimated at about $172.5 billion, in addition to a $14-billion-a-year cable TV market, a $13-billion home video market, and a $25-billion software market (Schrage, Jan. 1996). To put these numbers in context, the U.S. domestic multimedia market is more than twice as large as total trade with Mexico. Worldwide, it is estimated that the U.S. controls slightly more than 30 percent of the market for telecommunication equipment, a figure which does not account for the U.S.'s strong position in the computer, entertainment, and cable industry (Aoyama, Castell, March 1993).

Although statistics on California are more difficult to come by, the state's dominance in computer technology and the entertainment industry are one indication of its potential role. According to data collected by the Center for the Continuing Study of the California Economy, the state accounts for nearly 15 percent of all communications equipment produced in the U.S. This figure does not include California's clear competitive advantage in most aspects of the entertainment industry. Indeed, many of the state's top players in the field — Paramount Communications, Viacom Cable, Disney Productions — are investing heavily in new telecommunications ventures. In the computer industry — where California accounts for more than 30 percent of U.S. production — companies such as Apple, Intel, Silicon Graphics, and Autodesk are also on the cutting edge of the telecommunications field. Still, statistics on the size of the industry in California vary, depending on how one defines "telecommunications." Its powerful potential impact on the state's economy, however, is unquestionable.

With regards to employment trends, as is the case with many high-tech sectors, it is difficult to make projections based merely on regional or corporate dominance. First, it is not clear what the next employment-generating product will be or where it will be produced. Second, many argue that telecommunications technology is likely to displace as many jobs as it creates, especially in the short run. Worker re-training efforts may be necessary to fill the new "information-rich" occupations created from telecommunication technologies — a potential area for government action — but since the future is still uncertain, precisely what kind of training will be necessary is not entirely clear. However, displaced military personnel may be ideally suited to fill many of the new jobs, given their training with technologically advanced systems. According to estimates by Project California, the telecommunications industry will produce about 34,000 new jobs by the year 2000.

Future Products and Markets

Growth in the telecommunications industry certainly will be driven by new technologies, like digitization and optical fiber, capable of replacing the television with an interactive, 500-channel network for home-shopping, databases, teleconferencing, movies-on-demand, and computer games. Others foresee developments in virtual reality and high-definition television complimenting this "communicopia," as it has been dubbed. Delivering this system into the home will require hardware that combines the functions of a standard cable box with those of a personal computer. Transmitting these services to the public will also require a significant infrastructure investment, especially in fiber-optic cables (thin glass strands that exponentially increase capacity and quality over the traditional coaxial cables). Both telephone and cable companies are investing heavily in these new networks, but it is still unclear who will emerge as the winners and/or whether government entities should intervene to help them. The long-term employment benefits of this activity is also unclear, but expected to be positive.

Some telecommunications analysts predict that future markets also will be driven by an explosion of new office equipment and so-called "personal digital assistance" mechanisms (Lewis, 1992). Aided by developments in cellular or wireless technology, these systems will combine the best features of personal computers, facsimile machines, pagers, personal secretaries, and appointment or address books. However, these types of products make predicting economic consequences of the telecommunication revolution even more difficult since, if successful, they may dramatically change the work environment, making traditional occupations expendable while creating new ones. In addition, regional impacts are made ambiguous by the fact that, by their very nature, many telecommunication systems are designed to defy geography. New technology, for example, may allow a company to have its corporate headquarters in New York, its employees in Louisiana, and its main market in California. Although the state or federal entities may want to tap into such enormous potential — at the very minimum for their own record-keeping purposes — the desirability of subsidizing an industry that by its very nature is transnational is debatable.

Perhaps the biggest question mark regarding new telecommunications products is if and when they will be made available in a competitively priced, user-friendly form that is attractive to more than just high-technology aficionados. Most of the revenue from the multimedia networks described above will be generated by products, such as interactive televisions and programming for hundreds of channels, that do not yet exist. In addition, systems now available to provide extensive, on-line, up-to-the-second information for browsing, downloading, and profit (e.g., Prodigy, American On-line, Compuserve) have yet to generate widespread appeal. Adding to these technological constraints, there is concern about whether the entertainment industry and cable programmers will be able to deliver. Cable and telephone companies will need lots of new programs to fill the 500 or more channels made possible by extensive investments in fiber optics. In short, average consumers are not likely to trade their television set for an expensive new system with lots of special features and programs that they neither understand nor desire.

Technology Transfer

The telecommunications industry is both a recipient and a conduit of technology transfer efforts. On the one hand, the industry continues to benefit from research done at the DOE, DOD, and NASA labs. The military's expertise in wireless communications, for example, is considered far superior to what is now being used commercially, and the transfer opportunities are high. On the other hand, telecommunications stands to greatly facilitate the technology transfer process by allowing businesses to quickly access information and assistance that would otherwise be unavailable to them due to cost or geographical constraints. Up-to-date information on the latest breakthroughs in a given field or on-line assistance from highly trained specialists offer the potential to greatly accelerate the innovative process, especially for small businesses. Examples of these developments were cited earlier in the context of evaluating technology transfer efforts (see Minnesota Project Outreach, Section 3.2) and in discussing small business initiatives (Section 2.6).

Regulatory/Policy Environment

Making the telecommunications revolution available to all, including remote hospitals, inner-city school districts, and under-funded libraries, is the stated goal of the Clinton Administration's National Information Infrastructure, or "information superhighway" initiative. In fact, one of the chief policy concerns expressed by the Administration and other lawmakers is that there will be no costly tollbooths along the information highway making it accessible only to the wealthy. To truly make the information superhighway available to all, however, will require extensive financial investments by the federal government and/or regulations forcing companies to serve low-income, rural areas potentially at a loss. The first of these is probably beyond the means of a financially strapped federal government; the second undoubtedly will be resisted by the powerful cable and telephone lobbies. The Clinton Administration generally has been given credit for raising public awareness of telecommunications and making it a campaign issue. Most experts, however, interpret the Administration's initiatives to mean that the Federal Communications Commission will soon be given a fresh deregulatory agenda (*Economist*, Feb. 1993).

The current regulatory environment stems from the break-up of AT&T ten years ago, which split telephone service into a two-tiered system: several competing long-distance carriers (Sprint, AT&T, MCI) at the national level, and regionally-based "Baby Bells, " who were given a protected monopoly on local calls. T he law also prevents a company from owning both a telephone and a cable system in a single operating area. Lifting this ban, according to industry analysts, could spark the type of private infrastructure investment needed to make the information superhighway a reality. Although several pieces of legislation being considered by Congress would all but repeal this law, the FCC has indeed become increasingly tolerant of cable and telephone company efforts to play in each others' fields, and has allowed dozens of telecommunication giants to merge or form joint ventures (Standards & Poors, July 1993).

Today, Baby Bell companies are purchasing cable networks outside their jurisdictions — giving them a foothold in the markets of other local phone carriers. Long-distance carriers are joining with cellular communication systems — allowing them access to the local phone markets. And all of the above are forging alliances with various entertainment conglomerates. Competition is also coming from other sources. Satellite makers, like Hughes Aerospace, and electric utilities, like PG&E, have announced their intention to get into the telecommunications industry. A number of defense firms also are seen as potential competitors, since sophisticated communications capability has long been a important military technology. In all of these areas, California companies continue to be powerful players.

Extensive competition and market restructuring within the last year has been evident on Wall Street. Investors are pouring money into telecommunications companies, giving tiny newcomers multi-billion-dollar valuations, often for work that is still in the R&D stage. As a result, many argue that government-financed R&D would not only be redundant but a potential waste of taxpayers' money. Ultimately, however, the direction and content of private investment may have to be guided by government policy, to ensure the widespread access necessary to transform the telecommunications industry into the kind of employment and growth generator that many envision. Ensuring the success of this endeavor may require input from and collaboration of a broad spectrum of industry and government participants. Moreover, the state needs to address a variety of issues, including:

- Regulations and incentives aimed at ensuring widespread access and deployment in a wide range of industries (e.g., hospitals, schools, libraries, government agencies).
- Formation of an industrial consortium to explore the potential uses, technological bottlenecks, cooperative agreements, and regulatory environments — with special emphasis on the role state and federal government should play.
- Educational efforts aimed at displaced military personnel, preferably with technical and financial input from industry.

5. SELECTED CALIFORNIA TECHNOLOGY TRANSFER INITIATIVES

Among the wide array of programs and agencies promoting technology transfer and development in the private sector, several have been focusing primarily on supporting California's defense conversion efforts. In addition to the many CRADAs with small and large businesses in California, a number of activities are being pursued which are aimed at fostering environmental technologies, enhancing computer capability, bolstering entrepreneurship and technology diffusion, and creating jobs and providing training of skilled workers. Although linked in most cases to the extensive network of academic institutions and research laboratories in the state, many of these projects are oriented toward improving the competitiveness of the private sector and preparing it for future markets.

This section briefly describes some selected initiatives and programs either being developed or already underway to facilitate technology transfer in California and support the state's defense conversion efforts. The programs presented here are by no means all-inclusive. Rather, they are representative of a wide array of initiatives. It is also worth noting that most of these efforts focus on technology development and training in areas consistent with the discussion in the previous section regarding technologies critical to California's economic recovery and defense conversion needs.

5.1 TECHNOLOGY DEVELOPMENT AND COMMERCIALIZATION

Regional Technology Alliances

In December 1993, the State of California approved the designation of three Regional Technology Alliances. Based in San Francisco, Los Angeles, and San Diego, these RTAs are designed to raise and leverage funds in support of technology development, commercialization, and application. The RTAs directly serve those companies interested in developing dual-use technologies. The Bay Area Technology Alliance (BARTA) is being developed with help from the Joint Venture Silicon Valley, the Alameda County Economic Development Advisory Board, and the DOE.

Joint Venture: Silicon Valley (JVSV)

Formed in early 1992, JVSV is a nonprofit corporation representing leaders from business, government, and the community focusing on improving the competitiveness of the Silicon Valley region. It sponsors a variety of initiatives to develop and reduce the cost of doing business as well as to attract, retain, and create new enterprises and jobs. Smart Valley, Inc., is an example of one of JVSV's initiatives. Funded in part through a TRP grant, this project is developing an advanced information infrastructure to improve the existing Internet network so it can be used for daily business transactions. The state, local universities, and numerous high-tech companies are contributing to this project.

Cal State Hayward's Center for New Venture Alliance (CNVA)

This center is dedicated to the hands-on study of every stage of the product development process — from technological development to pricing and commercialization. The CNVA has constructed a "pipeline model" for technology commercialization whereby it manages business planning, incubation, market introduction, and growth. It also sponsors a program with business school students who are working with LLNL and SNL/CA to find markets for their technologies.

Centers for Applied Competitive Technology

This program operates through centers at eight community colleges in California. It conducts workshops and seminars, arranges equipment loans, and offers problem-solving advice to small businesses. It is affiliated with the NIST-funded California Manufacturing Technology Center in Los Angeles, and also receives technical support from the DOE laboratories.

East Bay Professional Network for Entrepreneurs & Technologies (East Bay NET)

East Bay NET is a group of professionals dedicated to helping early-stage-technology companies succeed. These professionals, who provide their services without fees, are highly skilled business advisors who can help find innovative and practical solutions to challenges facing entrepreneurs. Specific areas of assistance include: assessing technology, analyzing business formation alternatives, locating financing, preparing business plans, analyzing markets, legally protecting assets, and evaluating real estate or space requirements. East Bay NET includes individuals with expertise in: strategic planning; technology assessment and market research; venture capital and banking; legal; accounting; real estate; and entrepreneurs. East Bay NET is dedicated to the concept of encouraging and promoting the growth of technology companies in the East Bay.

Technology Market Assessment & Profiling (TMAP)

This program is a cooperative effort between the Center for New Venture Alliance (CNVA) at the California State University at Hayward (CSUH) and Sandia National Laboratory/California. The intent is to use joint resources and capabilities to:

- Investigate methods and procedures for effective engagement and training of CSUH students in federal laboratory technology transfer processes.
- Extend outreach activities to the students to promote transfer of Sandia technologies to the private industry.
- Create appropriate curricula for instructing CSUH students in technology transfer mechanisms, technology innovation, and new product development.
- Provide direct experience for CSUH students to supplement instruction in technology innovation and new-business development.

CSUH business school students are a cost-effective and efficient way to identify and investigate new-business prospects for federal laboratory technology in commercial industry.

5.2 ENVIRONMENTAL TECHNOLOGY INITIATIVES

Environmental restoration is a worldwide problem. The closure of California bases provides a major opportunity for exploring and establishing the state as a leader in state-of-the-art environmental technologies. Most of the initiatives discussed below focus on clean-up activities, testing and demonstration of new technologies, and education and training. In addition to the clean-up activities, these endeavors could create new industries and skilled workers for the state and throughout the world.

Alameda Center for Environmental Technology (ACET)

This proposal for the East Bay Conversion and Reinvestment Commission was prepared by the Alameda County of Economic Development Advisory Board and the ACET Ad Hoc Committee, which is made up of representatives from the environmental and biotechnology industries, three national laboratories, several major academic institutions, and a variety of civic leaders, advocacy groups, and regulatory bodies. The project is designed to promote the demonstration and commercialization of environmental technology for clean-up, ecological restoration and waste management, environmental policy and land-use planning, analysis and environmental training and retraining to facilitate assimilation of advances in environmental technologies. As currently proposed, ACET would be located on the Alameda Naval Air Station and would include various demonstration facilities, scientific laboratories, and specialty institutes. If approved, the center would be a private, not-for-profit corporation guided by a board of directors from industry, regulatory agencies, universities, and national laboratories.

Bioremediation at the Naval Air Station, Alameda

NAS is funding a collaboration with the University of California and the Lawrence Berkeley Laboratory to use steam injection for cleaning and removing underground hydrocarbons. The project also will employ microbes to remove the small toxic residue that remains after steam-cleaning.

California Environmental Enterprise

Developed primarily by UC's Lawrence Livermore and Lawrence Berkeley National Laboratories with cooperation and support from Sandia National Laboratory, the non-profit Institute for Environmental Solutions, and direct encouragement from DOE. The purpose of this organization is to apply federal and commercially developed "smart-technology" to the clean-up and restoration of military bases, government facilities, industrial and agricultural sites, and private real estate. Projects in Oakland and Antioch have already begun, and are in their initial stages.

Partnership for Environmental Technology Education (PETE)

This program links the technical resources of the DOE, DOD, EPA, and NASA laboratories; federal and state agencies; private industry; and professional societies with participating community colleges to assist in the development and presentation of curricula for training hazardous materials technicians and for encouraging more transfer students to pursue studies in environmental science, engineering, and management at four-year institutions. Originated by LLNL in the western states, this program is now affiliated with similar programs across the country and around the world.

Fastrack

Spearheaded by LLNL with cooperation and support from UC Berkeley, LBL, and SNL/CA, this program proposes the large-scale demonstration of three specific new technologies for the clean up of contaminated soil and groundwater at the Alameda Naval Air Station, to be funded by the Navy. The objectives of this project include both clean-up of the Navy property and commercialization and job creation in the clean-up technology areas.

Presidio Consortium on Global Change

The Presidio Consortium would bring together U.S. and foreign researchers to study global climate models and experimental databases on the impacts of civilization and natural processes on the global climate. Institutions which have expressed interest in joining this effort include UC Santa Cruz, San Francisco, and San Diego; Stanford; CSU at San Francisco; and LLNL. The Consortium would utilize existing Presidio facilities as well as proposed new facilities, and would be funded by both state and federal sources.

Strategic Education Planning Group at Mare Island

Mare Island Naval Shipyard, UC, CSU, and the California Community College system are developing a program to retrain workers for Mare Island site restoration. Lawrence Berkeley Laboratory involvement has been suggested in demonstrating DOE-developed environmental methodologies and technologies in the characterization and remediation efforts; providing internships at LBL to give hazardous waste and environmental trainees opportunities for experience in the field; and having LBL scientists or staff augment the community college staff by acting as instructors in hazardous materials courses.

Military Base Closure Working Group/Western Governors' Association

The Western Governors' Association Committee to Develop On-Site Innovative Technologies (DOIT) in partnership with DOE, DOD, the Department of Interior, and the Environmental Protection Agency will sponsor an environmental remediation technology demonstration project at military bases. LBL is the primary DOE contact for selecting sites and technologies for demonstration.

Research and Technology Center at Fort Ord

Recently approved by the UC Regents, this center will provide both basic research and commercialization opportunities in the area of marine ecology and the environment.

5.3 TRANSPORTATION, ENERGY, HIGH-PERFORMANCE COMPUTER DATA STORAGE, AND MATERIALS

CALSTART

This is a consortium of private companies, non-profit organizations, and California state agencies with $4 million in cost-sharing funds from DOE aimed at creating a new industry of transportation technologies and systems. CALSTART members include aerospace companies, utilities, universities, small high-tech companies, transit agencies, and representatives from environmental and labor groups. A main impetus behind the group is the California Air Resource Board's Zero Emission Vehicle Mandates requiring that, by 2003, ten percent of the cars sold in the state produce no emissions. This has spurred major R&D efforts in electric vehicles and batteries technologies — and is also one of the pushes behind the Advanced Battery Consortium, a collaborative effort among the "Big Three" American automakers with $260 million from the DOE. CALSTART recently has been working to establish a northern California facility, possibly at the Alameda Naval facility.

CALSTART and LLNL are pursuing the creation of an Advanced Transportation Technology Assistance Center, at which the modeling and analytical capabilities of LLNL will be made available to public and private sector partners. Prototype analysis and proof-of-concept testing will be performed at this center for advanced transportation technologies, particularly clean-fuel vehicles. This technology-assistance center will be closely linked to a business incubator at CALSTART, known as "Project Hatchery." State-of-the-art machine shop facilities, as well as the testing and data analysis facilities mentioned above, will be available at the incubator to enable qualifying start-up firms to develop prototypes of advanced transportation technologies and prepare them for commercialization.

National Center for Energy Efficiency

The primary mission of this proposed center, to be located at the Alameda Naval Air Station, would be to improve energy efficiency in the nation's economy. The center would take advantage of expertise residence in the Bay Area, including: the Energy and Environment Division at LBL, the Center for Environmental Design Research at UC Berkeley, and the California Institute for Energy Efficiency.

The National Storage Laboratory

A collaboration of six U.S. companies (four in California) and the Lawrence Livermore National Laboratory, this project is aimed at researching and commercializing technologies for high-performance computer storage systems. It aims to reduce the barriers to transferring and storing large amounts of information and diverse types of data — a bottleneck that often requires computer users to wait hours or even days to retrieve their supercomputer data.

Energetic Materials Center (EMC)

A joint effort of Lawrence Livermore and Sandia National Laboratories, EMC's mission is to promote technical partnerships with U.S. industry, government laboratories and agencies, and academic institutions for long-term, high-payoff R&D of energetic materials. The EMC includes a technically diverse staff of more than 200 scientists and engineers with proven expertise in high explosives, propellants, and pyrotechnics. It includes some $400 million worth of modern research and testing facilities specifically designed for energetic materials work.

5.4 SCIENCE AND TECHNOLOGY EDUCATION

Bay Area Science and Technology Education Collaboration (BASTEC)

Formed under the auspices of the DOE to efficiently bring the scientific and technical resources of the national laboratories to educational agencies in the greater San Francisco Bay Area, BASTEC is comprised of LBL, LLNL, SNL/CA, Stanford Linear Accelerator Center, UC Lawrence Hall of Science, and UC Mathematics and Engineering Student Association. Other organizations represented include: CSU, Hayward; Holy Names, Mills, and Samuel Merritt Colleges; Alameda County Soviet Exchange Program; Chabot Science Center; East Bay Conservation Corps; Interface Institute; and the National Organization of Black Chemists and Chemical Engineers. Initial efforts have focused on helping the Oakland Unified School District develop a comprehensive science/technology education program. The program has been reviewed by Oakland's superintendent, teachers, and principals, and is expected to expand to other schools in the Bay Area.

Science Education Academy of the Bay Area (SEABA)

Members collaborate as a network in the science and technology education of teachers in grades K through 12. Members include four national laboratories, several offices of education, state universities, the DOE, U.S. Geological Survey, Marine World Africa USA, Monterey Bay Aquarium, Exploratorium, KQED, California Academy of Sciences, NASA Ames Research Center, and the San Francisco Zoological Society. SEABA transforms the array of teacher education efforts of its members into a science-and-technology teacher academy. Staff development opportunities are designed to contribute to the implementation of the *Science Framework for California Public Schools.*

Technical Assistance to California Industries at the California Community Colleges

An agreement has been established between California Community Colleges (CCCs) and SNL/CA to provide technical assistance to California industries to improve their economic competitiveness.

This agreement is also intended to facilitate the improvement of science and engineering education through teaming, information exchange, and joint program/curriculum development. California Community Colleges have been in the forefront of providing education and training in science and engineering to students entering the higher education system. The challenge of this agreement is to provide an education experience that links the latest technical and business approaches with real-world problems and opportunities. By integrating CCC's education and training programs with Sandia's research and technical resources, the proposed alliance can meet the needs of industry, improve the science and engineering education of CCC students, and help in the direction and delivery of Sandia's technologies.

Alameda Science City: International Institute for Technology Development

Led by LLNL, but envisioned as pulling together resources from all of the laboratories, universities, and private industry in the Bay Area, this center for science and technology development would derive support from DOD and other federal, state and private sources to pursue a broad range of technologies, including production processes with lasers or optics, health care, environment, production/manufacturing, and computation, as well as science and technology education and socio-economic policy studies. The center would take advantage of international connections with the scientific community and resources of emerging East European countries and Russia. The center would be located at the Alameda Naval Air Station and in the surrounding city of Alameda.

6. STATE ROLE IN TECHNOLOGY DEVELOPMENT AND TECHNOLOGY TRANSFER

6.1 INTRODUCTION

As reviewed in Section 5, there is a wide variety of programs in California promoting technology transfer and development. Nevertheless, unlike other states, California arguably lacks a predominant, overarching agency or program to encourage the creation and diffusion of new technology. Although California leads the country, indeed the world, in the development and commercialization of a number of key technology areas, systematic planning and coordination on a statewide basis has been relatively infrequent. In general, the state has relied on the free market; on a variety of federal, state, and local programs; and, most importantly, on a generous endowment of both human and natural capital to promote economic growth and development. This policy has proven sufficient, perhaps even optimal, during times of relative prosperity and expanding state and federal spending. However, such a policy may fall short in a period of fiscal austerity and increasing global competition.

This section summarizes some of the more successful technology transfer and development programs that have been implemented in other states. After discussing these programs in general, two states which have received high marks for their efforts to promote technological innovation — Pennsylvania and Ohio — will be examined. Clearly, the organization and structure of these programs reflect the unique economic and social environment of their host states. However, some general conclusions can be drawn that may be helpful to policymakers in California contemplating new initiatives aimed at easing the economic effects of massive defense cuts. The final section will discuss some of the key lessons derived from an analysis of other state programs, and their relevance to the California experience.

6.2 STATE TECHNOLOGY PROGRAMS

Although several state science and technology programs have been around for many years, most of them got their start in the early 1980s during a period of massive economic restructuring, dislocation, and downturn. They first gained prominence in the so-called "rust belt" states, where the erosion of America's technological leadership was especially pronounced and where in many cases the survival of whole communities depended upon a more coherent government strategy than had traditionally applied. Indeed, the economic health of areas with strong bases of high-tech firms, such as Silicon Valley and Route 128 in Massachusetts, led other states to seek to create the conditions which had supported the development and growth of technology-based businesses in these regions.

As an example of their increasing popularity, before 1980 only nine states had programs designed to stimulate technological innovation. Today, all 50 states have at least one program or activity designed to promote technological growth, and they account for a total of some $2 billion in spending annually (National Governor's Association, 1993). Moreover, these state programs have flourished despite a clear lack of federal support. Both the Reagan and Bush Administrations preferred to focus on basic research or defense-related R&D and generally steered away from funding programs with a specific commercial agenda. As a result, by the late 1980s, the states had arguably taken the lead in terms of promoting commercial technology development (Fellar, 1992).

Although President Clinton has been more forthcoming in his support of technology development than his Republican predecessors, few states have found that his initiatives have made their own programs redundant. In fact, in many cases states with strong technology programs have found themselves better positioned to take advantage of the new federal efforts. An advantage of state-administered programs is that they generally offer a hands-on approach, detailed knowledge of local conditions, familiarity with potential industrial participants, and, above all, a degree of flexibility that federally administered programs cannot readily duplicate.

Indeed, the Clinton Administration has envisioned a cooperative relationship between state and federal programs. The Administration's Technology Plan notes that "the states have pioneered many valuable programs to accelerate technology development and commercialization. Our (federal) efforts should build on these programs" (NGA, 1993). Clinton's Technology Reinvestment Project, for example, targets for funding small- and mid-size manufacturers hurt by defense cuts and the regional programs that help them. A number of state programs are already among the beneficiaries of this initiative (Pittsburgh *Business Times & Journal*).

Despite clear regional differences in these state programs, scholars have documented a number of similarities in terms of the activities they support and institutional arrangements that guide them. The National Governor's Association (1993), for example, characterized these state technology programs as including one or more of the following:

- **Technology Offices:** Usually governed by boards consisting of members from technology-based industries, these offices include executive or independent state agencies, state boards, commissions, or foundations. Some actively manage state programs, others are only advisory.
- **Cooperative Research Centers:** These usually operate with a mix of public and private funds, but are under the supervision of the state government. They are often housed in universities, and offer collaborative R&D between academic researchers and industrial researchers from several firms in a given technical area.
- **R&D Grants:** Usually provided by states to a team of researchers in an industrially relevant technical field, often with matching support by industry.
- **Nurturing Start-Up Firms:** Here a variety of mechanisms are used, such as seed or venture capital, managerial assistance or consulting, and equity or royalty investments, as well as provision of space in incubators and research parks to encourage new capital formation.

- **Networking:** This involves bringing together executives and entrepreneurs from technology-based business on issues of common concern. Some states have formal technology-oriented chambers of commerce.
- **Technology Extension:** State-sponsored scientists provide consultation and technical assistance to firms on-site through networks of field agents or regional centers. Often these efforts target small- and medium-size firms.
- **Technical Training:** These are programs to upgrade workforce skills so as to enable greater participation in businesses using advanced technology.

Though most of the state programs provide one or more of the services described above, the age, size, scope, and orientation of these services varies significantly. The host of technology-related programs in California, for example, contain elements of all these services, but they are controlled by different organizations and are relatively small given the size of the state economy. In 1992, California ranked 39th nationwide in total spending on technology programs, with outlays of about $3 million. This compares to $25 million spent by North Carolina, which, despite the small size of its economy, has the oldest, one of the most active and fourth-largest technology programs in the country (Carnegie Commission, Sept. 1992).

Clearly, a wholesale adoption of all the technology policy tools described above will not ensure a successful state strategy since political factors, funding sources and the business environment also play a vital role. Various states have emphasized different components according to their regional needs and policy objectives. Appendix C presents two case studies: Pennsylvania's Ben Franklin's Partnership Program and Ohio's Thomas Edison Project.

6.3 LESSONS LEARNED FROM STATE TECHNOLOGY TRANSFER PROGRAMS

There have been several attempts by independent groups and scholars to evaluate state technology programs and draw conclusions about their effectiveness. But, because of their relative newness and because of methodological and empirical difficulties associated with evaluating so many diverse programs, quantifiable measurements of success remain difficult to define. One of the more useful independent evaluations was done by the National Research Council on the Thomas Edison Centers in 1990. The report concluded that, given the difficulty in obtaining hard data, "the realistic evaluations are qualitative" and the Centers should be judged "according to evidence of networking, a broad base of industrial and academic support, the willingness of large companies to invest money and of small companies to invest time, and clearly defined missions and programs aimed at regional economic development."

Despite the lack of quantitative data on state science and technology programs, some policy recommendations designed to aid policymakers contemplating new initiatives can and have been made. In an article entitled "Ten Lessons for Successful State Technology Policy Making," Robert Atkinson, one of the more noted scholars on the subject, described the political and institutional arrangements that underlie the more successful programs. A brief description of several of his recommendations follow:

- **Obtain the active support of business, organized labor, and universities.** This recommendation, also echoed by a number of other researchers in the area, reflects the fact that the higher the stake the various affected parties have in the process, the harder they are likely to work to make it succeed. With regard to business, this usually takes the form of cost-sharing arrangements, often in exchange for low-interest loans or access to public research facilities.
- **Involve interest as ongoing partners in the policymaking process.** According to Atkinson "the form as well as degree to which interests participate ... is important." By far the most effective mode of involvement is through long-term, participatory institutional arrangements.
- **The governor needs to make economic development a top priority.** Historically, the most successful state programs are those that were initiated by the executive rather than legislative branch and were the result of leadership and commitment by the governor.
- **The less recruitment the better.** All too often a state's technology policy involves large incentives and giveaways designed to influence business-location decisions. Unfortunately, recruitment and technology policy usually compete for scarce tax dollars since decision-makers often view the two as substitutes. In many states, large sums of money have gone to recruit one or two large plants which could have been used to develop broader technological infrastructure.
- **Policy development should be based on a strong planning foundation.** An in-depth analysis and understanding of the state's economy is needed before policy is implemented. In addition, results of such an analysis must be relied upon, as opposed to allowing lobbying or special interests drive the process.

Some of these recommendations were also echoed in a 1992 report by the Carnegie Commission on Science, Technology, and Government. The report, entitled "Science, Technology, and the States in America's Third Century," also suggested that each governor appoint a designated science and technology advisor and that each state form an independent advisory body on the issue. Although decision-makers are increasingly called upon to make decisions that have important scientific and technological dimensions, they generally lack staff sources for sound science advice and assessment. The Carnegie report also recommended that states play a more active role in influencing federal policy to ensure that national goals build on foundations the states have already laid.

7. SUMMARY AND CONCLUSIONS

In this document a large number of programs and studies has been reviewed to assess the potential role of technology transfer and emerging technologies in supporting California's economic recovery. These included many articles, reports, and studies performed by a variety of government agencies, industry leaders, and academic entities. Technology transfer activities are relatively new, and researchers differ on their potential role in job creation and economic recovery. Yet, one can point to many areas where, given the right environment, high-technology transfer has been instrumental in creating new industries and/or maintaining the competitiveness of others. Examples include biotechnology, semiconductor, and aerospace industries.

Passage of the National Competitiveness Technology Transfer Act (NCTTA) has created many opportunities for collaborations between the government and the private sector. A wide variety of mechanisms and institutional instruments have been established through which the technological developments within the network of federal laboratories can be transferred to the private sector. These include Cooperative Research and Development Agreements (CRADAs), licensing and patent agreements, small-business support programs, and personnel exchanges, as well as providing access to the specialized facilities of the various federal laboratories. Other programs, such as the DOC Advanced Technology Program and the DOD Technology Reinvestment Projects, have been established to assist states and industries impacted by military cutbacks.

California is well positioned to benefit from these new programs and initiatives. For example, the state has a large number of federal laboratories, including three DOE laboratories in Alameda County alone and several in southern California . These laboratories perform leading-edge R&D, possess a broad spectrum of technological know-how, and own state-of-the-art facilities. Moreover, they have access to the federal government's R&D and technology transfer resources. With proper coordination and political and legislative support, these laboratories in collaboration with universities and the private sector have the potential to greatly impact the state's economy.

In this new environment, an important question facing state planners is how best to take advantage of these new federal policies and to foster participation by the private sector. This is especially important because, based on recent experiences, competition for these programs is very intense. For example, in the FY 1994 TRP call for proposals, more than 2,000 proposals were received, with less than 200 scheduled for funding. Likewise, private-sector demand for CRADAs far exceeds federal funding for the program. Success in this environment requires careful planning, a clear focus, and a demonstrated benefit to the state and the nation. As such, a concerted effort by state policymakers is needed to support these efforts and to ensure that the challenges entailed by submitting winning proposals are met.

Based on the experiences of other states, a strong state involvement is necessary to help coordinate and promote the variety of federal, state, and local programs aimed at technological development.

If California companies are to benefit from programs such as TRP, ATP, CRADAs, or efforts by private groups such as Joint Venture Silicon Valley, they must first be made aware of the existence of these opportunities and their potential. Many companies also need assistance in understanding the bureaucratic requirements, meeting official deadlines, negotiating contracts, and accessing the variety of resources available. The state could play an important role in supporting these activities, and could also provide an overarching strategy or coherence to the state's technology goals. More importantly, California's congressional leadership can play a more active role in influencing federal policy and ensuring that national science and technology goals are in concert with the state's current and future needs.

To ensure that the variety of initiatives and programs maintain a strong focus, a forum is needed to foster mutual understanding of what the national laboratories' capabilities are and how they can best be used in concert with the state's long-term science and technology strategy. The experience of other states also demonstrates that the chances of success will be improved with the ongoing involvement and support of the private sector. A distinguishing feature in almost every successful technology development program, from technology transfer activities to the provision of seed capital, is strong industry involvement, both financially and organizationally.

The potential from collaborations among the national laboratories, academia, and the private sector is evident by the large number of initiatives that have already been proposed and/or implemented in California. These include joint efforts in the areas of environmental clean-up, biotechnology, energy, telecommunications, and computers. More importantly, these institutions can be instrumental in creating new industries and in providing high-technology training opportunities for the many highly skilled workers displaced by defense conversion and base closure.

In discussing technology transfer and its potential for supporting economic recovery, it is important to remember that existing technology transfer efforts are relatively new. Many questions remain unanswered, and can benefit from additional data gathering and analysis. For example, a more careful and complete monitoring of technology transfer efforts and results will help develop better models, thereby fostering commercialization and other benefits. Additional data is also needed to understand the size of the high-technology sector and its potential for job creation and for enhancing California's competitive position.

In summary, the federal government has many programs in place to promote technological innovations and diffusion to the private sector. Moreover, it is expanding the role of its national laboratories to add economic competitiveness to their basic defense mission. To take advantage of these new federal policies, state planners must play a strong role in providing technical, administrative, and financial as well as political support to all possible participants. These include small and large firms, regional alliances, local communities, federal laboratories, and universities.

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APPENDIX A

ARPA'S TECHNOLOGY REINVESTMENT PROJECT LEAD PROPOSERS FROM CALIFORNIA

Table A-1 Technology Reinvestment Project - Lead Proposers from California (continued)

DEVELOPMENT

Participants	City	State/Zip	Title	Total Cost *
American Rocket Company	Ventura	CA 93003	Hybrid Technology Option Project (HyTOP)	$22,200,000
Air Force/30th Space Wing	Vandenberg AFB	CA 93437		
Air Force/6595 Test & Evaluation Group	Vandenberg AFB	CA 93437		
Air Force/Phillips Laboratory	Edwards AFB	CA 93524		
Martin Marietta Manned Space Systems	New Orleans	LA 70129		
United Technologies Corporation	San Jose	CA 95138	FOCUS: Vehicle Technology	
Apple Computer, Inc.	Cupertino	CA 95014	East/West Consortium: Next Generation Authoring Tools & Instructional Applications	$6,000,000
Carnegie Mellon University	Pittsburgh	PA 15213		
Houghton Mifflin Publishing Company	Boston	MA 02116		
PWS Publishing Company	Boston	MA 02116		
Stanford University Medical School	Stanford	CA 94305		
University of Colorado	Boulder	CO 80309	FOCUS: Training/Instruction Technology	
University of Massachusetts	Amherst	MA 01003		
ArrayComm, Inc.	Santa Clara	CA 95054	Spatial Division Multiple Access Wireless Communication Systems	$11,400,000
Spectrian, Inc.	Mt. View	CA 94043		
Watkins-Johnson Company	Gaithersburg	MD 20878		
			FOCUS: Information Infrastructure	
BART/HMK Alliance	Oakland	CA 94604	Advanced Automatic Train Control (AATC) System	$39,000,000
Hughes Aircraft Company (HMK)	Fullerton	CA 92634		
Morrison Knudsen Corporation (HMK)	Boise	ID 83729		
San Francisco Bay Area Rapid Transit (BART)	Oakland	CA 94604		
			FOCUS: Information Infrastructure	
Bell Atlantic Healthcare Systems, Inc.	Greenbrae	CA 94904	National Academic Medical Center Information Collaborative	$15,800,000
Columbia Presbyterian Medical Center	New York	NY 10032		
Duke University Medical Center	Durham	NC 27710		
Georgetown University Medical Center	Washington	DC 20007		
Medical University of South Carolina	Charleston	SC 29425		
Navy/National Medical Naval Center	Bethesda	MD 20889	FOCUS: Health Care Technology	
Stanford University Medical Center	Stanford	CA 94305		
Sun Microsystems, Inc.	Mt. View	CA 94043		
University of Chicago Hospitals	Chicago	IL 60637		
University of Massachusetts Medical Center	Worcester	MA 01655		
CALSTART	Burbank	CA 91505	Turboalternator for Electric Hybrid Vehicles (93-66351-1)	$7,100,000
AlliedSignal Aerospace	Torrance	CA 90504		
Hughes Power Control Systems Division	Torrance	CA 90509		
			FOCUS: Vehicle Technology	

* Federal Share to be Negotiated

Table A-1 Technology Reinvestment Project - Lead Proposers from California (continued)

DEVELOPMENT

Participants	City	State/Zip	Title	Total Cost *
Electric Power Research Institute	Palo Alto	CA 94303	Power Electronic Building Blocks for Affordable	
Harris Semiconductor	Melbourne	FL 32902	High Performance of Electric Power	$7,600,000
			FOCUS: Electronics Design & Manufacturing	
GM Hughes Electronics				
DOE/Sandia National Laboratories	Newport Beach	CA 92658	The MCM Consortium - The Path to a Globally	$40,000,000
IBM	Albuquerque	NM87185	Competitive MCM Industry in the U.S.	
Micromodule Systems	Hopewell Junction	NY 12533		
Motorola	Cupertino	CA 95014		
Polycon	Chandler	AZ 85248		
Texas Instruments	Tempe	AZ 85282	FOCUS: Electronics Design & Manufacturing	
nChip	Dallas	TX 72565		
	San Jose	CA 95132		
Ginzton Research Center	Palo Alto	CA 94304	An Amorphous Silicon Medical Imager	
Xerox Palo Alto Research Center	Palo Alto	CA 94304		$7,500,000
			FOCUS: Health Care Technology	
Hi-Shear Technology Corporation	Torrance	CA 90505	Pyrotechnic Actuated Vehicle Rescue Equipment	
City of Torrance Fire Department	Torrance	CA 90501		$1,600,000
			FOCUS: Health Care Technology	
Hughes Aircraft Company				
Delco Electronics	Los Angeles	CA 90009	Automotive Collision Avoidance System	$12,200,000
Delco Systems Operations	Kokomo	IN 48904		
Environmental Research Institute of Michigan	Goleta	CA 93117		
General Motors Corporation	Ann Arbor	MI 48113		
Hughes Research Laboratories	Warren	MI 48090		
Systems Technology, Inc.	Malibu	CA 90265	FOCUS: Vehicle Technology	
University of California	Hawthorne	CA 90250		
	Davis	CA 95616		
Hughes Research Laboratories	Malibu	CA 90265	In-situ Process Control for Growth of InP-Based	
Bandgap Technology Corporation	Broomfield	CO 80021	Heterostructure Materials For Gigahertz Circuits	$4,900,000
EMCORE Corporation	Somerset	NJ 08873		
J. A. Woollam Company	Lincoln	NE 68508		
			FOCUS: Electronics Design & Manufacturing	
Hughes Research Laboratories	Malibu	CA 90265	Analog Optoelectronic Module Development	$17,500,000

* Federal Share to be Negotiated

Table A-1 Technology Reinvestment Project - Lead Proposers from California (continued)

DEVELOPMENT

Participants	City	State/Zip	Title	Total Cost *
Amoco Laser Company	Naperville	IL 60563		
Boeing Company	Seattle	WA98124		
GM Hughes Electronics Research Laboratories	Malibu	CA 90265		
GTE Laboratories Inc.	Waltham	MA 02254		
MIT Lincoln Laboratory	Lexington	MA 02173	FOCUS: Electronics Design & Manufacturing	
Navy/Naval Command, Control and Ocean Surveillance Center	San Diego	CA 92152		
Ortel Corporation	Alhambra	CA 91803		
United Technologies Photonics, Inc.	Bloomfield	CT 06002		
Lear Astronics Corporation	Santa Monica	CA 90406	Autonomous Landing Guidance	$42,000,000
Air Force/Wright Laboratory	Wright Patterson AFB	OH 45433		
AlliedSignal	Fort Lauderdale	FL 33309		
FLIR Systems, Inc.	Portland	OR 97224		
Interstate Electronics Corporation	Anaheim	CA 92803		
Malibu Research Associates	Calabasas	CA 91302	FOCUS: Aeronautical Technologies	
Northwest Airlines	St. Paul	MN55111		
Norton Performance Plastics Corporation	Ravenna	OH 44266		
United Airlines	Chicago	IL 60666		
Lockheed Missiles & Space Company, Inc.	Sunnyvale	CA 94088	High Capacity Solid Polymer Battery Development	$3,000,000
General Motors Corporation	Anderson	IN 46018		
Valence Technology, Inc.	San Jose	CA 95119		
			FOCUS: Advanced Battery Technology	
Loral Western Development Labs	San Jose	CA 95161	Advanced PACS	$2,800,000
Georgetown University Medical Center	Washington	DC 20007		
University of California, Irvine	Irvine	CA 92717		
			FOCUS: Health Care Technology	
Magnavox Electronic Systems Company	Torrance	CA 90503	Computer-Aided Earth Moving With DP-GPS	$17,700,000
Army Corps of Engineers	Vicksburg	MS39180		
Caterpillar, Inc.	Peoria	IL 61629		
Spectra-Physics Laserplane, Inc.	Dayton	OH 45424		
			FOCUS: Vehicle Technology	
Power-One Inc.	Camarillo	CA 93012	Advanced Power Conversion Based On the Aerocapacitor	$1,900,000
Aerojet	Rancho Cordova	CA 95741		
California Trade & Commerce Agency	Pasadena	CA 91105		
DOE/Lawrence Livermore National Labs	Livermore	CA 94551		
Polystor Corporation	San Jose	CA 95129		
Rockwell International	Thousand Oaks	CA 91358	FOCUS: Advanced Battery Technology	

* Federal Share to be Negotiated

Table A-1 Technology Reinvestment Project - Lead Proposers from California (continued)

DEVELOPMENT

Participants	City	State/Zip	Title	Total Cost *
Raytheon Co.	Goleta	CA 93117	Millennium: 21st Century Broadband Digital Telecommunication Technology	$18,400,000
Air Force/Wright Laboratories	Wright Patterson AFB	OH 45433		
Honeywell Inc.	Bloomington	MN 55420		
NASA/Lewis Research Center	Cleveland	OH 44135		
TRW, Inc.	Redondo Beach	CA 90278		
			FOCUS: Information Infrastructure	
Rockwell International	Los Angeles	CA 90009	Electric Actuation and Control System	$6,700,000
Air Force/Wright Laboratory	Wright Patterson AFB	OH 45433		
Caterpillar, Inc.	Peoria	IL 61656		
Moog, Inc.	East Aurora	NY 14052		
			FOCUS: Aeronautical Technologies	
Rockwell International	Canoga Park	CA 91309	EcoScan - A Tunable IR Laser Remote Sensing System	$5,200,000
ARCO	Los Angeles	CA 90071		
Air Force/Wright Laboratories	Wright Patterson AFB	OH 45433		
Army/Edgewood Research, Development and Engineering Center	Aberdeen Proving Ground	MD 21010		
Army/Night Vision & Electronics Sensors Directorate	Fort Belvoir	VA 22050		
California Environmental Protection Agency	El Monte	CA 91731	FOCUS: Environment Technology	
DOE/Oak Ridge National Laboratory	Oak Ridge	TN 37831		
INRAD, Inc.	Northvale	NJ 07647		
LaSen, Inc.	Las Cruces	NM 88001		
Michigan State University	East Lansing	MI 48824		
NASA/John C. Stennis Space Center	Stennis Space Center	MS 39529		
Rockwell Defense Systems	El Paso	TX 79914		
Rockwell Science Center	Thousand Oaks	CA 91358		
San Diego Gas & Electric	San Diego	CA 92101		
South Coast Air Quality Management District	Diamond Bar	CA 91765		
WAHLCO, Inc.	Santa Ana	CA 92704		
Rockwell International Corporation	Newbury Park	CA 91320	Wire-Com Engine for Communication Products	$7,200,000
BEL-Tronics, Ltd.	Covington	GA 30209		
Georgia Institute of Technology	Atlanta	GA 30332		
			FOCUS: Information Infrastructure	
Space Systems/Loral	Palo Alto	CA 94303	Beam-Agile Active Transmit Phased Array System	$2,000,000
Air Force/Rome Laboratory	Griffiss AFB	NY 13441		
Syracuse Research Corporation	Syracuse	NY 13210		
			FOCUS: Space/Aerospace	
TRW Space & Electronics Group	Redondo Beach	CA 90278	Precision Laser Machining	$33,800,000
Belforte Associates	Sturbridge	MA 01566		

* Federal Share to be Negotiated

Table A-1 Technology Reinvestment Project - Lead Proposers from California
DEVELOPMENT

Participants	City	State/Zip	Title	Total Cost *
Boeing Company	Kent	WA 98032		
Caterpillar, Inc.	Mossville	IL 61552		
Chrysler Corporation	Madison Heights	MI 48071		
Cummins Engine Company, Inc.	Columbus	IN 47202	FOCUS: Mechanical Design & Manuf.	
Edison Welding Institute	Columbus	OH 43212		
Fibertek, Inc.	Herndon	VA 22070		
Ford Motor Company	Livonia	MI 48150		
Frank DiPietro	West Bloomfield	MI 48323		
General Electric Aircraft Engines	Cincinnati	OH 45215		
General Electric CRD	Schenectady	NY 12301		
General Motors Technical Center	Warren	MI 48090		
Hughes	Malibu	CA 90265		
Newport News Shipbuilding	Newport News	VA 23607		
Northrop Corporation	Hawthorne	CA 90251		
Pennsylvania State University	State College	PA 16804		
Process Equipment Company	Tipp City	OH 45371		
SDL	San Jose	CA 95134		
Science Research Laboratory, Inc.	Somerville	MA 02143		
Stanford University	Stanford	CA 94305		
TRW VSSI	Mesa	AZ 85205		
United Technologies Corporation	East Hartford	CT 06108		
University of Illinois	Urbana	IL 61801		
Utilase Systems, Inc.	Detroit	MI 48205		
TRW Space and Electronics Group	Redondo Beach	CA 90278	Passive Millimeter Wave Camera	$8,400,000
Air Force/Wright Laboratory	Wright Patterson AFB	OH 45433		
Army Research Laboratory	Fort Monmouth	NJ 07703		
EPI/ETA Technologies	Colorado Springs	CO 80907		
McDonnell Douglas Aerospace	Long Beach	CA 90846		
NASA/Langley Research Center	Hampton	VA 23665	FOCUS: Information Infrastructure	
University of California, Los Angeles	Los Angeles	CA 90024		
University of California, San Diego	La Jolla	CA 92093	Advanced Composites for Bridge Infrastructure	$21,000,000
Amoco Performance Products, Inc.	Alpharetta	GA 30202	Renewal	
Hercules, Inc.	Magna	UT 84044		
J. Muller International, Inc.	San Diego	CA 92123		
Trans-Science Corporation	La Jolla	CA 92037		
University of Delaware	Newark	DE 19716	FOCUS: Materials/Structures Manuf.	

* Federal Share to be Negotiated

Table A-2 Technology Reinvestment Project - Lead Proposers from California (continued)

MANUF. EDUCATION & TRAINING

Participants	City	State/Zip	Title	Total Cost *
University of California, San Diego	La Jolla	CA 92093	UCSD MS Program in World Class Manufacturing Engineering	$5,200,000
ALCOA Electronic Packaging, Inc.	San Diego	CA 92127		
Hewlett-Packard Company	San Diego	CA 92127		
Hughes Aircraft Company	Carlsbad	CA 92009		
TITAN Linkabit	San Diego	CA 92121		
Economic Development Corporation (EDC)	Los Angeles	CA 90028	Center for Advanced Technology - Los Angeles	$2,000,000
L. A. Unified School District	Los Angeles	CA 90012		
Rebuild L.A.	Los Angeles	CA 90017		
Workforce L.A.	Los Angeles	CA 90031		
California State University	Long Beach	CA 90840	Southern California Coalition for Education in Manufacturing Engineering	$8,000,000
California State University	Fullerton	CA 92634		
California State University	Los Angeles	CA 90032		
University of California	Los Angeles	CA 90024		
University of Southern California	Los Angeles	CA 90089		
California State University	Fullerton	CA 92634	CSUF Integrated Environmental Training Program for Defense Industry Engineers	$1,100,000
Sierra College	Rocklin	CA 95677	Manufacturing Engineering Curriculum Development	$900,000
Aerojet Headquarters	Rancho Cordova	CA 95670		
Auburn Electronics Group	Auburn	CA 95604		
Pasco Scientific	Roseville	CA 95678		
Utah State University	Logan	UT 84322		
University of California	Los Angeles	CA 90024	Integrated Manufacturing Engineering Program for Advanced Transportation Systems	$9,700,000
CALSTART	Burbank	CA 91505		
Ciba Composites	Anaheim	CA 92807		
Hughes Aircraft Company	Los Angeles	CA 90009		
Northrop Corporation	Hawthorne	CA 90250		
Rockwell International Corporation	Los Angeles	CA 90009		
State of California	Los Angeles	CA 90014		
Structural Dynamics Research Corporation	Milford	OH 45150		
The Aerospace Corporation	Los Angeles	CA 90009		
W. Brandt Goldsworthy & Associates	Rolling Hills Estates	CA 90274		
University of California	Irvine	CA 92717	Microfabrication Manufacturing Training and	$6,200,000

* Federal Share to be Negotiated

Table A-2 Technology Reinvestment Project - Lead Proposers from California
MANUF. EDUCATION & TRAINING

Participants	City	State/Zip	Title	Total Cost *
ACCELERATE	Irvine	CA 92717	Education	
California Manufacturing Technology Center	Hawthorne	CA 90250		
County of Orange	Santa Ana	CA 92705		
DQ University	Davis	CA 95617		
Irvine Valley Community College	Irvine	CA 92720		
Orange County Small Business Development Center	Santa Ana	CA 92701		
State of California	Sacramento	CA 94280		

* Federal Share to be Negotiated

Table A-3 Technology Reinvestment Project - Lead Proposers from California
DEPLOYMENT

Participants	City	State/Zip	Title	Total Cost *
Aerojet General Corporation	Rancho Cordova	CA 95741	Aerojet Commercialization Pilot Project	$2,300,000
Admiral Company	Galesburg	IL 61402		
Benteler Industries, Inc.	Grand Rapids	MI 49548		
Boeing Commercial Airplane Group	Seattle	WA98124		
California Manufacturing Technology Center	Hawthorne	CA 90250		
DOE/Lawrence Livermore National Laboratory	Livermore	CA 94550		
Federal Aviation Administration	Atlantic City Int'l Airport	NJ 08405		
General Motors- Cadillac Motor Car Division	Detroit	MI 48232		
Glacier Bay, Inc.	Emeryville	CA 94608		
Lawrence Berkeley Laboratory	Berkeley	CA 94720		
Michigan Energy Research & Resource Agency	Ann Arbor	MI 48113		
California Manufacturing Technology Center	Hawthorne	CA 90250	California Manufacturing Technology Center to Help 300 Defense Suppliers Diversify To Dual Use	$1,500,000
California Community College	Sacramento	CA 95814		
California Trade & Commerce Agency	Sacramento	CA 95814		
El Camino Community College District	Torrance	CA 90506		
Clean Air Now	Venice	CA 90291	The Xerox Can Plan for a Solar Powered Hydrogen Generating Facility and Hydrogen Powered Vehicle Fleet	$2,500,000
Advanced Machining Dynamics	Highland	CA 92346		
Hamilton Standard/United Technologies Corporation	Windsor Locks	CT 06108		
Praxair, Linde Corporation	Danbury	CT 10591		
Sea Corporation	Sunnyvale	CA 94086		
United Technologies Corporation Technologies Center	East Hartford	CT 06108		
United Technologies/Hamilton Standard	Los Angeles	CA 90045		
Xerox Corporation	El Segundo	CA 90245		
Yen & Associates	Sherman Oaks	CA 91403		
Enterprise Integration Technologies Corporation (EIT)	Palo Alto	CA 94301	Smart Valley CommerceNet	$8,000,000
BARRNet/WestREN Corporation	Stanford	CA 94305		
Center for Information Technology	Stanford	CA 94305		
Institute for Research & Technical Assistance	Santa Monica	CA 90404	The Pollution Prevention Center: An Unusual Partnership	$500,000
California Environmental Protection Agency	Sacramento	CA 95812		
Los Angeles City Sanitation District	Los Angeles	CA 90039		
Los Angeles County Sanitation District	Whittier	CA 90601		
Orange County Sanitation District	Fountain Valley	CA 92708		
South Coast Air Quality Management District	Diamond Bar	CA 91765		
Southern California Edison Company	Irwindale	CA 91702		

* Federal Share to be Negotiated

Source: *The Clinton Defense Reinvestment and Conversion Initiative* (February 1994)

APPENDIX B
CRITICAL TECHNOLOGY LISTS

Table B-1
U.S. Department of Defense Critical Technologies Plan

Semiconductor Materials an Microelectronic Circuits	Weapon System Environment Data Fusion
Software Producibility	Computational Fluid
Parallel Computer Architectures	Dynamics
Machine Intelligence and Robotics	Air-Breathing Propulsion Pulsed Power
Simulation and Modeling	Hypervelocity Projectiles
Photonics	High Energy Density Materials
Sensitive Radar's	Composite Materials
Passive Sensors	Superconductivity
ignal Processing and Signature Control	Biotechnology Materials and Processes

Source: U.S. Department of Defense, *Critical Technologies Plan* (for the Committee on Armed Services, United States Congress) March 15, 1990

Table B-2
U.S. Department of Commerce's Emerging Technologies

Materials	**Manufacturing Systems**
Advanced Materials	Artificial Intelligence
Superconductors	Flexible Computer
Electronic and Information Systems	Integrated Manufacturing
Advanced Semiconductor Devices	Sensor Technology
Digital Imaging Technology	**Life Science Applications**
High-Density Data Storage	Biotechnology
High-Performance Computing	Medical Devices and Diagnostics
Optoelectronics	

Source: U.S. Department of Commerce, Technology Administration, *Emerging Technologies: A Society of Technical and Economic Opportunities*, Spring 1990.

Table B-3
Council on Economic Competitiveness Critical Technologies

Materials	Database systems
Advanced structural materials	Displays
Materials Processing	Hardcopy technology
Electronic & photonic materials	Information storage
Manufacturing	Human interface & visualization technologies
Design & engineering tools	Networks & communications
Commercialization & production systems	Portable telecommunications equipment & systems
Process equipment	**Biotechnology and Life Sciences**
Information & Communication	Biotechnologies
Software	**Aeronautics&Surface Transportation**
Microelectronics	Propulsion
Electronic controls	Powertrain
Optoelectronic components	**Energy & Environment**
Electronic packaging & interconnections	Environmental technologies
Computers	

Sources: Council on Competitiveness, *Gaining New Ground: Technology Priorities for America's Future* (Washington, D.C., 1991)

Table B-4
National Critical Technologies Panel

Materials
Materials synthesis and processing
Electronic and photonic materials
Ceramics
Composites
High-performance metals and alloys
Manufacturing
Flexible computer integrated manufacturing
Intelligent processing equipment
Micro- and nanofabrication
Systems management technologies
Information and Communications
Software
Microelectronics and Optoelectronics
High-performance computing and networking
High-definition imaging and displays
Sensors and signal processing
Data storage and peripherals
Computer simulation and modeling
Biotechnology and Life Sciences
Applied molecular biology
Medical technology
Aeronautics and Surface Transportation
Aeronautics
Surface transportation technologies
Energy and Environment
Energy technologies
Pollution minimization, remediation, and waste management

Sources: U.S. National Critical Technologies Panel, *Report of the National Critical Technologies Panel* (Washington, D.C.: U.S. Government Printing Office, March 1991)

Table B-5

DOE Defense Critical Technologies

Computational Science
Science of Complex Systems
Modeling and Simulation of Complex Systems
High-Performance Computing
Nuclear Weapons Predictive Capability
High-Energy-Density Systems
Dynamic Testing in Severe Environments
High-Energy/Density Materials
Laser Technology
Pulsed Power and Accelerators
Safety and Control
Safety Assessments and Engineering
Use Control and Security
Nonproliferation and Verification
Electronics and Materials Design and Processing
Microelectronics and Photonics
Nuclear Materials
Engineered Materials
Quality Manufacturing and Dismantlement
Flexible Manufacturing
Intelligent Machines and Robotics
Environmentally Conscious Manufacturing
Waste Management

Sources: U.S. National Critical Technologies Panel, *Report of the National Critical Technologies Panel* (Washington, D.C.: U.S. Government Printing Office, March 1992)

Table B-6

Japanese Ministry of International Trade and Industry, Basic Technologies for Industry

New Materials	Process Technologies
High-Temperature Superconducting Materials	Precision Molecular Alignment Technology
Nonlinear Optoelectronic Materials	Evaluation, Analysis, and Measuring Technology
Ferromagnetic Materials	Design and Simulation Technology
Molecular Functioning Materials	Photoreactive Process Technology
Advanced Composite Materials	Processing Technology for Extreme Environments
Alloys/Metallic Compound	**Bioelectronics**
Fine Ceramics	Protein Alignment Technology
Carbon Materials	Biomembrane Technology
Amorphous Materials	Analysis of Bio-Related Materials
Highly Pure Polymer Materials	**Biomaterials**
Silicon Chemical Materials	Bio-Mimicking Materials
Microelectronic Materials	Biocompatible Materials
Electronics	Biochemical Technology
Superconducting Devices	Bioprocessing
Quantized Elements	**Computer Software and Systems Engineering**
Power Electronic Elements	Self-Organized Data Processing Systems
Biotechnology	Self-Organized Neural Networks
Animal and Plant Cell Engineering	Ultraparallel Processing Architecture
High Performance Enzymes and Biomaterials	Integrated Mechanical Control Software
Genetic Engineering	Software Development Technology
Biodatabanks	Disaster Prevention Technology
Screening and Isolation of Genes from all sources	Environmental Control Technology
Bioreactor Technology	Human-Related Technology
New Material/Electronics- Related Technologies	Resource and Energy Technology
Atomic Level Precision Manipulation Technologies	Robotics Technology
Metallic and Inorganic Materials	

Source: Japanese Ministry of International Trade and Industry, *Trends and Future Tasks in Industrial Technology* (Sangyo Gijutsu no Doko to Kadai). Tokyo, October 20, 1988

Table B-7
European Community Critical Technologies

Information Technology and	**Aeronautics**
Telecommunications	Aerodynamics and Flight Mechanics
Electronic Components	Materials
Software and Information Processing	Acoustics
Peripherals	Computation
Fundamental Research	Airborne Systems and Equipment
Prenormative Research (standards,	Propulsion Integration
systems-integration-related)	Design and Manufacturing Technologies
Broadband Infrastructure	**Life Sciences**
Broadband Equipment	Basic Plant Biology
Broadband Services	Molecular Investigation of Genomes of
Industrial Materials and Technologies	Complex Organisms
Quality and Reliability Technologies	Neuroscience
Techniques for Shaping, Joining and	Biotechnology Based Agro-Industrial
Assembly, and for Surface Treatment	Research and Technology Development
Catalysts and Membranes	**Energy**
Powder Technology	Controlled Nuclear Fusion
Other High-Value Materials	Non-Nuclear Energy
(composites, etc.)	Renewables
Superconducting Materials	Energy Efficient Technologies
	Energy from Fossil Fuels
	Energy Modeling and Environment

Source: Commission of the European Communities, *First Report on the State of Science and Technology in Europe,* Fall 1988

APPENDIX C
CASE STUDIES:
STATE TECHNOLOGY TRANSFER PROGRAMS

C.1 PENNSYLVANIA'S BEN FRANKLIN'S PARTNERSHIP PROGRAM

Initiated in 1983, the Ben Franklin Partnership Program (BFP) relies on ties to Pennsylvania's university system to promote entrepreneurial growth in specific technological areas corresponding to regional specializations and strengths. BFP accomplishes its mission primarily through four unique, geographically dispersed Advanced Technology Centers (ATCs) which offer programs tailored to the particular economic development needs of the locales they serve. Each ATC is affiliated with a university or consortium of universities, and oversees discrete projects conducted by a network of academic researchers, non-profits and private sources. Funding comes from all the participants, as well as from state and federal sources. The ATCs also provide training programs in technical and other skill areas, assistance programs to help entrepreneurs in the preparation of business plans, feasibility studies for start-ups, and technology transfer activities. These efforts were expanded in 1988 to include eight private nonprofit Industrial Resource Centers (IRCs) to help small manufacturers improve quality and productivity.

The BFP's emphasis is on the rapid commercial application of R&D results, with an orientation toward small firms as the principal source of technological innovation and new-job creation. In its relationship with the university system, BFP stresses applied research and a preference for projects with clear commercial potential rather than generic scientific exploration. In allocating funds to its centers, BFP gives considerable weight to matching contributions by private interests, on the grounds that this tends to weed out commercially less viable projects. BFP also emphasizes seed research grants, small-business incubator loans, and low-interest venture capital to firms investing in technology-based projects. Its Challenge Grant program, for example, provides about $25 million to new enterprises annually, matched by private-sector resources valued at more than $75 million.

The BFP program has been widely praised by its beneficiaries and independent observers for promoting job creation, economic growth, and technological innovation. Despite intense nationwide competition, the agency already has been awarded funds through the Clinton Administration's TRP for four separate economic development projects.

C.2 OHIO'S THOMAS EDISON PROJECT

Like the Ben Franklin Program, Ohio's Thomas Edison Project consists of autonomous, geographically distributed centers affiliated with an Ohio university which link public research institutions with private companies in an effort to commercialize technological advances. And, like the Ben Franklin Program, it also encourages technological innovation by providing matching funds to research partnerships that involve Ohio companies. In addition, the program has established five "Edison Incubators," which provide low-cost space, shared services, and managerial and technical assistance.

The Edison program is slightly different from BFP, however, in that it is controlled by a board of directors whose majority is from the private sector and it supports both generic and proprietary research. Its nine centers are organized around specific research areas such as biotechnology, advanced manufacturing, and polymer innovations. The centers differ substantially in everything from fee structure to office and laboratory facilities. However, their general emphasis on generic research has tended to attract the participation of Fortune 500, R&D-intensive firms, as well as regionally based companies.

As a privately-run organization dependent on state funds for about half of its budget, the Edison program has been careful to document the benefits and progress of its work. Data on the overall scope of its activities are collected regularly. Following are some highlights from the period July 1990 to December 1991:

- The technology centers have about 675 members, with an average annual rate of increase in membership of 44 percent.
- The centers are credited with about $195 million economic impact on Ohio's economy, creating 2,2128 new jobs and helping retain about 4,285 jobs.
- Industry invested about $32.4 million in these centers.
- The centers allocated $24.8 million among 557 research grants and contracts.
- The centers support about 488 faculty, graduate students, and staff and directly employed 266 research and management personnel.
- The centers offered 260 Edison Center classes and seminars, which were attended by more than 12,000 professionals.
- During this period, 15 licenses were awarded, 15 patents granted and 40 patent applications were filed.
- The centers supported 398 technical papers, Ph.D. dissertations and Masters' theses.