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# CRS Report for Congress

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## Cooperative Research and Development Agreements and Semiconductor Technology: Issues Involving the “DOE-Intel CRADA”

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## **ABSTRACT**

In March 1997, a consortium of U.S. semiconductor companies (called the EUV LLC), led by Intel and including Motorola and Advanced Micro Devices, signed a cooperative research and development agreement (CRADA) with three Department of Energy laboratories to develop commercial applications for a semiconductor manufacturing technology called extreme ultraviolet lithography. There has been some opposition to this CRADA based on concerns over the participation of foreign equipment suppliers in applying the results of the collaborative work. This report provides information on the federal interest in cooperative R&D and the laws that shape such efforts. Also included is background on the specific type of technology under consideration, as well as a discussion of the U.S. and global semiconductor industries. Intended to assist congressional decisionmakers assess the process by which the Department of Energy and its laboratories develop cooperative research and development agreements, this report will be updated if events warrant such action.

# Cooperative Research and Development Agreements and Semiconductor Technology: Issues Involving the “DOE-Intel CRADA”

## Summary

In March 1997, a consortium of U.S. semiconductor companies (called the EUV LLC), led by Intel and including Motorola and Advanced Micro Devices, signed a cooperative research and development agreement (CRADA) with three Department of Energy laboratories to develop commercial applications for a semiconductor manufacturing technology called extreme ultraviolet (EUV) lithography. The promise of EUV technology is to allow semiconductor chip manufacturers to make chips with more computing speed and memory capacity.

Created by law, a CRADA offers the means to transfer federally funded technologies and manufacturing techniques to industry where they can be further developed and commercialized for the marketplace. The work performed must be consistent with the government laboratory's mission. In pursuing joint efforts, the federal research institution may accept funds, personnel, services, and property from the collaborating party and may provide personnel, services, and property to the participating organization. The government can cover overhead costs incurred but is explicitly prohibited from providing direct funding to the industrial partner. According to the legislation, preference for selecting CRADAs is to be given to small businesses, companies which will manufacture in the United States, or foreign firms from countries that permit American companies to enter into similar arrangements.

The successful implementation of the legislative mandate to transfer technology has led to expanded use of this mechanism and to questions regarding individual CRADA arrangements. Much of the opposition to the CRADA between DOE and the EUV LLC rests on concerns over the participation of foreign equipment suppliers in applying the results of the collaborative work. Critics state that the potential for providing foreign firms access to technology developments originating in federal laboratories will be detrimental to American companies and hurt national economic security interests. Proponents maintain that the law has been followed and the requirements for U.S. manufacture and existing export control regulations are sufficient to address concerns over foreign companies. In addition, they argue, since the consortium is funding the work in the federal laboratories, it has the right to seek out and use the best manufacturing technology sources.

Globalization of the international marketplace and the rapid diffusion of new technologies and manufacturing techniques throughout has provided many opportunities and generated many conflicts. Successful companies are those that provide innovation and quality in a timely manner. The legislation does not prohibit participation of foreign-owned firms due, in part, to the fact that these businesses often provide jobs for American workers and significantly contribute to the U.S. economy. Still, it is in the national interest to maintain and improve domestic technological advancement, manufacturing, and product development. The final consideration may be how to encourage American-owned and U.S.-based firms to be the most innovative technology suppliers and manufacturers in a global economy.

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# Cooperative Research and Development Agreements and Semiconductor Technology: Issues Involving the “DOE-Intel CRADA”

## Introduction

The laboratories of the Department of Energy (DOE) have been actively pursuing cooperative research and development (R&D) efforts in conjunction with the private sector. There are various mechanisms used to facilitate collaborative ventures between the laboratories, industry, and academia. Those include the use of special facilities and centers set up in particular technological areas; personnel exchanges and visits; licensing of patents; work for others; cooperative assistance to state and local programs; educational initiatives; information dissemination; and the spin-off of new firms. Generally, access to the laboratory's unique scientific facilities is determined through peer review of proposals. Cost reimbursement is required if the company's work is proprietary and patent rights in this case generally are assigned to the firm. If the work is to be published, no charges are incurred.

Additional partnerships have been established through the use of a cooperative research and development agreement (CRADA). That document defines the scope of the joint effort and circumscribes the legal relationship between the DOE research facility and the private sector parties. Created by law, a CRADA offers the means to transfer federally funded technologies and manufacturing techniques to industry where they can be further developed and commercialized for the marketplace. Department of Energy (DOE) laboratories have entered into approximately 3,000 CRADAs since obtaining a legislative mandate to use this approach in 1989.

In March 1997, a consortium of U.S. semiconductor companies signed a CRADA with three DOE facilities—Sandia National Laboratory, Lawrence Berkeley National Laboratory, and Lawrence Livermore National Laboratory. That consortium, called the EUV LLC (EUV Limited Liability Corporation), is intended to develop commercial applications for a semiconductor manufacturing technology known as extreme ultraviolet (EUV) lithography.<sup>1</sup> During the manufacturing process, EUV lithography can be used to etch circuit patterns on semiconductor chips. The great promise of EUV technology is to allow semiconductor chip manufacturers to make products that have finer circuit lines etched on each surface. In turn, that means more computing speed and memory capacity can be handled by an individual semiconductor chip. While any number of advances may lead to the

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<sup>1</sup> Although commonly known as the “DOE-Intel CRADA,” the legal agreement is between the Department of Energy and the EUV Limited Liability Corporation. Reference in this paper will be to the DOE-EUV LLL CRADA.

next generation of more powerful and faster chips, many believe that commercial EUV technologies will dominate production in the future.

The consortium is led by Intel Corporation, and includes Advanced Micro Devices (AMD) and Motorola. EUV LLC will provide \$250 million to the three Department of Energy laboratories for continued development of extreme ultraviolet lithography technology. For the consortium, the DOE facilities can play an important role because that is where EUV technology was created in the late 1980s as part of the government's Strategic Defense Initiative. Cutbacks in the program at DOE, as well as other agency budget reductions have caused apprehension on the part of the U.S. semiconductor industry that the technology may be lost if not further developed. The EUV LLC is willing to provide industrial funding to ensure that this does not happen.

While the arrangement may benefit the U.S. semiconductor manufacturers and the DOE laboratories, other concerns have been raised. The consortium is currently negotiating licensing arrangements with several equipment suppliers including the Nikon Corporation of Japan.<sup>2</sup> Nikon already is the dominant player in producing lithography equipment with 50% of the global market. Some contend that this arrangement may provide a foreign competitor with U.S. taxpayer-sponsored technology. Because American equipment suppliers make up less than 10% of the world market, there has been some worry that Nikon may be able to eliminate the U.S. lithography industry by successfully transferring the technology to Japan.

At the heart of the issue are questions regarding the origin, definition, and purpose of CRADAs. Since policymakers may need an understanding of that type of collaborative activity before they can accurately assess the merits or problems of the DOE-EUV LLC cooperative research and development agreement, this report provides information on the federal interest in technology transfer and the laws that shape such efforts. It then furnishes background on the specific type of technology, EUV lithography, under consideration, as well as information on the U.S. and global semiconductor industries. The paper is intended to assist congressional decisionmakers determine whether or not the process instituted by the Department of Energy meets the legislative mandate for cooperative R&D; whether or not the DOE-EUV LLC CRADA meets the requirements of the agency's policies and practices; and whether or not there are larger domestic and international technology policy issues which fall outside of the CRADA process but require legislative attention.

## **Government-Industry R&D Partnerships**

### **Technology Transfer Defined**

The federal departments and agencies spend approximately \$72 billion per year on research and development in pursuit of governmental mission requirements. Such

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<sup>2</sup> The nature of equipment suppliers—companies that provide the technology necessary to manufacture the semiconductor chip—is discussed in the section on the semiconductor industry below.

an effort has resulted in new and improved technologies and manufacturing techniques that may provide additional benefits beyond specific mission-related use. For example, while the major portion of total federal R&D spending has been in the defense arena, government-financed work has led or contributed to new commercial products and processes including, but not limited to, antibiotics, plastics, jet aircraft, computers, electronics, and genetically engineered drugs (e.g., insulin and human growth hormone). Technology transfer is one way, proponents argue, that federally funded R&D can be further developed and applied by the private sector to meet other national needs associated with economic growth. The increasing competitive pressures on U.S. firms in the international marketplace, coupled with the government's requirements for goods and services, can make the collaboration between federal laboratories and industry through technology transfer beneficial to both sectors. Although opponents may argue that these activities detract from budgeted research, the knowledge base created by agency-supported R&D may serve as a foundation for additional commercially relevant efforts in companies while the government research enterprise is advanced through interaction with innovative firms.

The movement of technologies, manufacturing techniques, and expertise from the federal laboratories to industry is achieved through technology transfer. This is a process by which a technology, a production process, a skill, or knowledge developed in one organization, in one area, or for one purpose is applied in another organization, in another area, or for another purpose. Technology transfer can have different meanings in different situations. In some instances, it refers to the transfer of legal rights, such as the assignment of patent title to a contractor or the licensing of the government-owned patent to a private company. It can mean a formal cooperative R&D effort or, in other cases, the informal movement of information, knowledge, and skills through person-to-person interaction. A successful transfer is in the actual use of the product or process. Without this, the benefits from more efficient and effective provision of goods and services are not achieved.

The federal interest in the transfer of technology is based on several factors. With the rapid pace of technological advancement in industry, the expertise, skills, products, and processes necessary for the agencies to meet their mission requirements often is only available in the private sector. Thus, cooperative activities with industrial scientists and engineers can be critical to the laboratory's successful completion of its research activities. The government also requires certain goods and services to operate. Much of the research it funds is directed at developing the knowledge and expertise necessary to formulate these products and processes. However, because the government has neither the mandate nor the capability to commercialize the results of the federal R&D effort, it must purchase technologies from the private sector to meet mission requirements. Technology transfer is a mechanism to move federally generated technology and technical know-how to the business community where it can be developed, commercialized, and made available for use and adaptation in the public sector.

Federal involvement in technology transfer also arises from an interest in promoting the economic growth that is vital to the Nation's welfare and security. It is through further improvement, refinement, and marketing that the results of research become diffused throughout the economy and can generate growth.

Economic benefits of a technology or technique accrue when a product or process is brought to the marketplace where it can be sold or used to increase quality and productivity. When technology transfer is successful, new and different goods and services become available to meet or induce market demand. Transfer from the federal laboratories thus can lead to substantial increases in employment and income generated at the company level. In addition, it may be a way to assist businesses that have been dependent on defense contracts and procurement to convert to manufacturing for the civilian marketplace.

## **The Legislative Foundation**

The primary legislation affording industry access to the federal laboratory system is P.L.96-480, the Stevenson-Wydler Technology Innovation Act of 1980, as amended by P.L. 99-502, the Federal Technology Transfer Act of 1986; P.L. 101-189, the FY 1990 Defense Authorization Act (the relevant title is known as the National Competitiveness Technology Transfer Act); P.L. 104-113, the Technology Transfer Improvements and Advancement Act; and others. Although technology transfer was on-going prior to its passage, the Stevenson-Wydler Technology Innovation Act provided the federal departments, agencies, and affiliated laboratories with a legislative mandate to pursue such activities. The Act specifically states that it is the responsibility of the federal government to ensure "... full use of the results of the Nation's Federal investment in research and development," and mandates that, where appropriate, technology be transferred to state and local governments and the private sector.

The original 1980 legislation established an organizational structure and specific mechanisms to carry out the new agency responsibilities.<sup>3</sup> Section 11 requires that each federal department with at least one laboratory make available not less than 0.5% of its R&D budget for transfer activities (later increased to 0.8%), although this requirement can and has been waived. To facilitate transfer from the laboratories, each is required to create an Office of Research and Technology Applications (ORTA); laboratories with annual budgets exceeding \$20 million must have at least one full-time staff person for this office (although the latter provision can also be waived). The function of the ORTA is to identify technologies and ideas that have potential for application in other settings.

Additional incentives to promote technology transfer from government-owned, contractor-operated (GOCO) laboratories—primarily those of the Department of Energy—were included in P.L.96-620, Amendments to the Patent and Trademark Laws (the Bayh-Dole Act). Under Title V, federal laboratories run by universities and non-profit institutions may retain title to inventions made in the laboratory within certain defined limitations while specific rights are reserved for the government. The law permits decisions to be made within GOCO laboratories as to the award of licenses for patents generated in-house. The contractor may receive royalties generated by the license for use in additional R&D, for awards to individual

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<sup>3</sup> For a detailed discussion see: Congressional Research Service, *Technology Transfer: Use of Federally Funded Research and Development*, by Wendy H. Schacht, CRS Issue Brief 85031, updated regularly.

inventors on staff, or for educational activities. A cap exists on the amount of royalties returning to the laboratory.

The initial response to new opportunities for use of federal laboratory resources was less than expected on behalf of both the private and public sectors. As a consequence, additional incentives were considered by the Congress, resulting in enactment of P.L. 99-502, the Federal Technology Transfer Act of 1986. This law established a new tool, the “cooperative research and development agreement (CRADA),” to be used for joint work between federal laboratories and the business community. First limited to government-owned, government-operated laboratories, the authority to enter into CRADAs was extended to government-owned, contractor-operated laboratories of the Department of Energy by P.L. 101-189, the FY 1990 Defense Authorization Act. The Technology Transfer Improvements and Advancement Act of 1996 (P.L. 104-113) provided additional guidelines to simplify the negotiation of CRADAs and to reduce private sector uncertainty in working with the government.

### **Cooperative R&D Agreements (CRADAs)**

A cooperative research and development agreement is a specific legal document (*not* a procurement contract) that defines the collaborative venture. It is intended to be developed at the laboratory level, with limited agency review. In agencies that operate their own laboratories, the laboratory director is permitted to make decisions to participate in CRADAs in an effort to decentralize and expedite the technology transfer process. At the Department of Energy, where contractors run the major laboratories, the agreement, while negotiated by the research institution, must also be approved by headquarters within a specified time period. The conference report to accompany the legislation permitting GOCOs to enter into cooperative R&D agreements states:

Technology transfer is most successful when agencies handle their own affairs and when government officials, technology transfer experts, and scientists at the local level have latitude in designing and carrying out CRADAs. Any regulations must recognize that a purpose of section 12 of Stevenson-Wydler is to allow prompt consideration and disposition of proposed CRADAs.<sup>4</sup>

The work performed under a CRADA must be consistent with the laboratory’s mission; technology transfer and cooperative efforts are expressly forbidden to interfere with the laboratories’ R&D mission-related responsibilities. In pursuing these joint efforts, the laboratory may accept funds, personnel, services, and property from the collaborating party and may provide personnel, services, and property to the participating organization. The government can cover overhead costs incurred in support of the CRADA, but is explicitly **prohibited** from providing **direct** funding to the industrial partner. In most agencies, support for the joint work comes from R&D program funding. The Department of Energy originally included a line item for financing the federal portion of the laboratories’ technology transfer initiatives

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<sup>4</sup> House, *Conference Report to accompany H.R. 2461*, 101<sup>st</sup> Cong., 1<sup>st</sup> sess., 7 November 1989, H.Rept. 101-331, 1149.

and relied on a competitive selection process run by headquarters to allocate funding. However, the FY 1994 appropriations eliminated the line item in the non-defense budget, instructing that such activities be part of on-going programs. At this time, the line item still exists in the budgets for the DOE defense laboratories, but at a significantly decreased level of funding.

The relevant legislation does not specify the dispensation of patents derived from the collaborative work, allowing the agencies to develop their own policies. However, under a CRADA, title to, or licenses for, inventions made by a laboratory employee may be granted in advance to the participating company by the director of the laboratory. The director may also negotiate licensing agreements for related government-owned inventions previously made at that laboratory if it facilitates cooperative ventures. In addition, he can waive, in advance, any right of ownership the government might have in inventions resulting from the joint effort. Further clarification of the assignment of intellectual property rights is made under P.L. 104-113. The House Science Committee report to accompany this law states that in considering intellectual property, “the important factor is that industry selects which option makes the most sense under the CRADA.”<sup>5</sup> *In all cases, the government retains a nonexclusive, nontransferable, irrevocable, paid-up license “to practice, or have practiced,” the invention for its own needs.*

Laboratory personnel and former employees are permitted to participate in commercialization activities if these are consistent with the agencies’ regulations and rules of conduct. Federal employees are subject to conflict of interest restraints. In the case of government-owned, contractor-operated laboratories, P.L. 101-189 required the development and implementation of conflict of interest regulations within 150 days of the enactment of the law. The law states that preference for selecting which CRADAs to enter into be given to small businesses, companies which will manufacture in the United States, or foreign firms from countries that permit American companies to enter into similar arrangements. According to the Senate report accompanying the legislation (S.Rept. 99-283), “the authorities conveyed by [the section dealing with CRADAs] are permissive” to promote the widest use to this arrangement.

## **Implementation at the Department of Energy**

### **Policy Development**

The Department of Energy operates nine multiprogram laboratories, commonly called the “National Laboratories,” as well as 24 single purpose institutions which perform research in specific disciplines. The research and development budget for these facilities is approximately \$6.5 billion a year. A majority of the laboratories are operated under contract by organizations outside of the government, including universities, non-for-profit institutions, and for-profit companies. In government-owned, contractor-operated laboratories the agency provides funding and policy direction, while management and technical expertise are furnished by the contractor.

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<sup>5</sup> House Committee on Science, *National Technology Transfer and Advancement Act of 1995*, 104<sup>th</sup> Cong., 2<sup>nd</sup> sess., 20 December 1995, H.Rept. 104-390, 16.

This arrangement emerged out of the Manhattan Project during World War II when time was a critical factor in the war effort. The government funded the construction of the research facilities but rather than assembling and developing its own expertise and operating processes, universities and firms with existing and established systems were utilized. In addition, scientific, technical, and engineering personnel can be paid at rates higher than generally available in federal service; a situation that can be important in attracting and retaining qualified, experienced personnel.

Prior to 1989, the Department of Energy (headquarters) appeared resistant to promoting government-industry cooperation, although management of several of the individual laboratories actively pursued joint ventures. This was documented in testimony on the implementation of the Stevenson-Wydler Technology Innovation Act; in hearings on the Federal Technology Transfer Act proposal; in a 1988 General Accounting Office report titled, *Technology Transfer, Constraints Perceived by Federal Laboratory and Agency Officials*; in House and Senate testimony on legislation to extend technology transfer obligations and practices required of government-owned, government-operated laboratories to those contractor-operated DOE facilities; and in a 1988 report issued by the Research and Technology Utilization Panel of the Energy Research Advisory Board. To summarize, complaints were made that central Department of Energy management was preventing the timely transfer of technology. Among the points addressed were: laboratory directors had not been given discretion to assign patents and licenses; DOE headquarters was taking up to two years to decide upon allowing the laboratories to enter into agreements concerning patents, licenses, or cooperative arrangements when time was of the essence; class waivers on titles were not being granted to DOE laboratories operated by for-profit companies; and national security was being invoked even when it was clear that the technology was to be transferred within a civilian context.

However, the situation has changed significantly due, in part, to legislative requirements as well as to the changing global defense situation and new demands on the Department. This is reflected in policy decisions and altered practices in both DOE and its laboratories. In January 1991, the Secretary of Energy formally instituted a new departmental technology transfer policy (SEN-30-91) with the goal of helping "... enhance U.S. competitiveness and national security, by expanding and accelerating the transfer of Federally-funded technologies and knowledge into commercial applications by U.S.-based industry." To accomplish this, the Department stated that it will increase participation by American industry in DOE R&D "... at all stages of program development and execution," augment the extent to which DOE and laboratory personnel are involved in technology transfer (consistent with other mission requirements), and facilitate the transfer process.

As part of the 1992 National Energy Strategy developed to lay "... the foundation for a more efficient, less vulnerable, and environmentally sustainable energy future," the Department of Energy articulated several objectives and identified initiatives which affected the laboratories. A "major part" of this Strategy was the expansion of the role science and technology "... play in achieving U.S. objectives

for energy security, economic growth, and enhanced environmental quality.”<sup>6</sup> In addition to reiterating the commitment to maintaining “... a balanced and diverse Federal portfolio of research investments in fundamental science and engineering research” which meet the goals of the Strategy, the Department stated the necessity of preserving the high quality, world class user facilities which are available to industry and academia.<sup>7</sup>

The National Energy Strategy also promoted technology transfer to accelerate joint industry-government R&D efforts toward the commercialization of new technology in the private sector “... in order to enhance U.S. competitiveness.”<sup>8</sup> To accomplish this, the Strategy proposed that industry be given additional incentives to increase its research, development, and commercialization activities and that adequate protection for intellectual property be developed. Also recommended were improvements in the speed, efficiency, and scope of federal efforts to transfer technology to industry. This included “. . . support for cost-shared programs that help demonstrate the technical feasibility of generic, enabling technologies and that provide technical assistance for the development of spinoff applications by industry.”<sup>9</sup>

Initial attempts to implement the mandate of P.L. 101-189 at the Department of Energy and its laboratories were hampered by several problems. The contractual nature of the laboratories’ relationship with the Department of Energy meant that the operating contracts had to be renegotiated to reflect several new legislative requirements. According to Gerald Yonas, then Vice President for Systems Applications, Sandia National Laboratories, the Department took over a year to establish rules and regulations for implementation and to alter contracts to allow for CRADAs. The approval process that was first established for cooperative agreements was considered too long and cumbersome. The standard contract provisions were seen by industry as favoring DOE to a great extent.<sup>10</sup> In addition to the legal aspects of the collaboration, there were also problems with cultural differences: laboratory personnel and industry representatives generally approached the effort with different expectations, different operating methods, and different needs.

In response to the changing priorities at DOE, the agency developed several mechanisms to support technology transfer from the laboratories. The Department has codified its implementation of the technology transfer mandate in 48 CFR Part 970 (effective January 22, 1996). While responsibility for collaborative ventures resides primarily in the DOE research facilities, the Department created a model CRADA for use by the laboratory directors in negotiating joint research and

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<sup>6</sup> Department of Energy, National Energy Strategy, *Powerful Ideas for America*, Washington, D.C.: GPO., February 1991, p. 20.

<sup>7</sup> *Ibid.*, p. 21.

<sup>8</sup> *Ibid.*, p. 21.

<sup>9</sup> *Ibid.*, p. 21.

<sup>10</sup> Gerold Yonas, *Technology Transfer in the National Laboratories*, [Sandia Report, SAND91-1840] August 1991, p. 4.

development activities. DOE headquarters review of the CRADA is required to insure that the collaboration fits within the mission of the Department and to avoid any indication of undue influence at the laboratory level. As the law now stands, the Department has 90 days to review the joint work statement between the parties (30 days in the case of small business, as amended by section 3135 of the Defense Authorization Act of 1993, P.L. 102-484) and 30 days to review the CRADA.

## **The Model CRADA**

The model CRADA was designed to streamline the process and encourage partnership efforts. Revised several times, this model provides standard language and terms—with several options—covering the scope of the collaborative venture. These reflect the legislative mandate and the regulations promulgated in 48 CFR Part 970. General guidance is offered as it pertains to each section of the document. Typically, a CRADA outlines rules and responsibilities regarding the following: definitions; the work statement; term, funding, and costs; personal property; disclaimers; product liability; obligations as to proprietary information; obligations as to protected CRADA information; rights in generated information; export control; reports and abstracts; pre-publication review; copyrights; reporting of subject inventions; title to subject inventions; filing of patent applications; trademarks; mask works; cost of intellectual property rights; reports of intellectual property use; DOE march-in rights; U.S. competitiveness; assignment of personnel; force majeure; administration of the CRADA; records and accounting for government property; notices; disputes; modifications; termination; and project management. (The model CRADA, as well as a model CRADA for joint ventures with small businesses, can be found on the Department of Energy home page located on the internet at <http://www.doe.gov/techtran/cradamd.html>.)

Of particular concern to industry is the dispensation of intellectual property resulting from the collaborative research and development. As noted above, the laboratory directors are provided broad discretion in determining assignments of title to inventions and licensing arrangements. Article XV of the model CRADA requires that the allocation of rights between the parties be set forth in the agreement. Option 2 under this Article allows the parties to determine which of the participants will own any invention arising from the research. The government always “. . . retains a non-exclusive, non-transferable, irrevocable, paid-up license to practice or to have practiced for or on behalf of the United States every Subject Invention under this CRADA throughout the world.” The CRADA also must stipulate that the Department of Energy has certain march-in rights to any subject invention which, under exceptional circumstances (such as to meet health or safety needs, meet mission requirements, or failure to comply with the agreement), would require that the collaborating party grant a license to others.

Under the Stevenson-Wydler Technology Innovation Act, as amended, the director of the laboratory, in deciding which cooperative agreements to enter into, is mandated to

give *preference* [emphasis added] to business units located in the United States which agree that products embodying inventions made under the cooperative research and development agreement or produced through the use of such

inventions will be manufactured substantially in the United States and, in the case of any industrial organization or other person subject to the control of a foreign company or government, as appropriate, take into consideration whether or not such foreign government permits United States agencies, organizations, or other persons to enter into cooperative research and development agreements and licensing agreements.<sup>11</sup>

The Department of Energy has taken this directive and incorporated it into agency policy regarding collaborative ventures under a CRADA. The policy, first articulated in a February 10, 1993 memorandum issued by the Department and codified in 48 CFR Part 970, states that in negotiating an agreement, the laboratory is to give preference to “business units located in the U.S. that agree to substantially manufacture resulting technology in the U.S.” In instances where this is not possible, individual exceptions may be made based on “contractual commitments to appropriate alternative benefits to the U.S. economy.” When there are multiple partners and limited resources, preference is to be given to those partnerships which meet the U.S. manufacturing requirement. These “U.S. competitiveness” issues are to be resolved before the completion of the joint work statement between the laboratory and the partner, prior to forwarding it to the relevant DOE program office.

Article XXII of the model cooperative research and development agreement states that a “... purpose of this CRADA is to provide substantial benefit to the U.S. economy.” The guidelines in the model established by DOE for use in determining issues of U.S. competitiveness regarding foreign participation affirms that the agency is

seeking to transfer technology to companies with significant manufacturing and research facilities in the United States in a way which will provide short and long term benefits to the U.S. economy and the industrial competitiveness of such companies. The preferred benefit to the U.S. economy is the creation and maintenance of manufacturing capabilities and jobs within the U.S.

However, if an increased number of jobs can not be substantiated as a result of the transfer, the participants are required to identify other substantial economic benefits that would accrue. Among the benefits which might be considered are:

- ! Direct or indirect investment in U.S.-based plant and equipment.
- ! Creation of new and/or higher quality U.S.-based jobs.
- ! Enhancement of the domestic skills base.
- ! Further domestic development of the technology.
- ! Significant reinvestment of profits in the domestic economy.
- ! Positive impact on the U.S. balance of payments in terms of product and service exports as well as foreign licensing royalties and receipts.
- ! Appropriate recognition of U.S. taxpayer support for the technology, e.g., a quid-pro-quo commensurate with the economic benefit that would be domestically derived by the U.S. taxpayer from U.S.-based manufacture.

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<sup>11</sup> U.S.C. 15 sec. 3710a (c)(4)(B).

! Cross-licensing, sublicensing, and reassignment provisions in licenses which seek to maximize the benefits to the U.S. taxpayer.<sup>12</sup>

In establishing a collaborative venture, the CRADA must contain language which notifies the participants that the resulting technologies and information are subject to existing export controls. The statement is to be “conspicuous” so that there is no misunderstanding. Should “... access to classified information, access to special nuclear materials, or unescorted access to security areas of Departmental facilities [be involved], the requirements of the Atomic Energy Act of 1954, as amended, also must be met.” The procedure for determining and addressing foreign ownership and control is delineated in Appendix A. All foreign participants must also abide by U.S. export control laws.

As part of 48 CFR Part 970, the Department states that the laboratory contractors shall “... take all reasonable measures to ensure widespread notice of availability of technologies suited for transfer and opportunities for exclusive licensing and joint research arrangements.” In providing for “fairness of opportunity,” the House conference report on P.L. 101-189 states that while the laboratories are directed to broadly disseminate information on technology transfer, “this would not require a laboratory to solicit bids or publicize each potential CRADA ...” The conferees also noted their intent “... that the laboratory managers be granted authority to facilitate technology transfer to the fullest extent authorized by law.”<sup>13</sup>

To further simplify private sector collaboration with the Department of Energy research institutions, three laboratories—Sandia, Lawrence Livermore, and Lawrence Berkeley—created the Virtual National Laboratory (VNL) in 1996. The purpose of the activity is to allow private sector partners to deal with only one “organization” in pursuing the resources of all three laboratories. A management tool, with no legal standing, the VNL provides for communication among the laboratories and promotes the coordination of relevant R&D across the facilities. Decisions as to technology access, contractual matters, and costs can be made through the VNL rather than separately with each laboratory. The initial thrust of the organization is to bring together resources in the areas of information technologies and related industries.<sup>14</sup> Under the DOE-EUV LLC CRADA, the companies will work through the Virtual National Laboratory.

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<sup>12</sup> Department of Energy, Model CRADA, available on the web at <http://www.doe.gov/techtran/cradamg.html>

<sup>13</sup> House Committee, *Conference Report to accompany H.R. 2461*, p. 1148.

<sup>14</sup> Mark Crawford, “DOE Designs Virtual Lab to Boost U.S. Companies,” *New Technology Week*, 24 February 1997, p. 1.

## **Semiconductor R&D, Federal Laboratories, and Industry**

The federal government, and particularly the federal laboratories, have had a long history of nurturing pre-competitive technology research and development of benefit to industry. Government laboratory programs and partnerships with industry have fostered innovations ranging from developing thermite ignition devices to improving the manufacture of photovoltaic systems.<sup>15</sup> At the very beginning of the U.S. computer industry, the laboratories played an important role both developing and using new information technologies.<sup>16</sup> Semiconductor chips, the heart of almost any computer system, also have received significant support from federal laboratories for nearly forty years. Advances in materials research, connection devices, and the design and fabrication of semiconductor chips either have been directly or indirectly aided by federal support.<sup>17</sup>

Among the many recent and ongoing federal laboratory CRADAs in semiconductor technology development are efforts with the SEMATECH consortium, made up of U.S. semiconductor chip manufacturers, to develop better environmental and safety engineering systems, with increased product reliability and performance for integrated chip manufacturing. SEMI-SEMATECH, a small business consortium of 160 semiconductor fabrication equipment and materials suppliers, is working with Sandia National Laboratory under a cooperative R&D agreement to improve manufacturing technologies. While Sandia provides capabilities in core competencies such as manufacturing subsystems, computing and modeling, material characterization, and reliability assessments, industry is providing the laboratory with commercial, state-of-the-art equipment which may be used in DOE's defense programs for radiation-hardened and other custom microelectronics. Several DOE laboratories are participating, or have participated in CRADAs with companies such as Cray, E.I. DuPont deNemours, Bristol-Meyers Squibb to develop massively parallel simulation of large molecular systems. The goal of this activity is to develop software tools to model and design new compounds. The competency developed at the federal laboratories subsequently can be used in defense program applications such as simulation of nuclear detonations.

### **Semiconductor Chips and the Information Age**

The semiconductor chip is a device which has a function of receiving, storing, reading, and retrieving information. Usually built upon silicon wafers, semiconductor chips provide the operations, mechanisms, and instructions in products ranging from hand-held calculators to personal computers, from personal

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<sup>15</sup> Presentation by Dan L. Hatrley, Vice President, Laboratory Development Division, Sandia National Laboratory, "Strategic Partnering—Critical to Success," 12 November 1997.

<sup>16</sup> Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology*, Washington: The Brookings Institution, 1988, p. 52.

<sup>17</sup> Office of Technology Assessment, *Microelectronics Research & Development: Background Paper*, March 1986, 33 pages.

computers to communications satellites. There are many varied types of semiconductor chips, ranging from basic “memory” devices which store and retrieve data to more sophisticated multiprocessor logic and “flash” semiconductor chips.<sup>18</sup> What all of these devices share is that they are critical for today’s information and telecommunications technologies and services. Some contend that semiconductor chips are to the Information Age what oil was to the Industrial Age.

How do semiconductor chips work? Created out of a silicon wafer, a semiconductor chip has an intricate circuit pattern etched onto its surface that can conduct electrical currents. The electrical currents are “read” by the semiconductor chip as a series of “0’s” and “1’s.” When “0’s” and “1’s” are strung together they form words, pictures, and other forms of data. It is the speed of this process and the capacity of semiconductor chips to receive, store, read, and retrieve information which is one of the key factors fueling the entire electronics industry. As a result, powerful personal computers have replaced many larger mainframe computer systems in everyday use.

This is a very simple explanation of sophisticated devices, made more complex by the rapid development of the speed and capacity of today’s semiconductor chips. Over the last two decades, semiconductor chips’ speed and capacity have grown very rapidly, and generational leaps in semiconductor technologies have been measured in months, not years. This growth was foretold by Gordon Moore, one of the founders of the Intel Corporation. Moore predicted in the 1970s that advances in semiconductor chip design and manufacturing would result in a doubling of chip speed and memory capacity continuously about every two years. “Moore’s Law” means a geometric rather than an arithmetic procession of advances in semiconductor chips.<sup>19</sup>

The doubling of semiconductor chip speed and capacity can occur because semiconductor chip manufacturers are able to produce semiconductor chips that are capable of performing more functions on smaller surfaces. But many experts in the semiconductor industry contend that to do more with smaller-sized semiconductor chips, new manufacturing technologies will have to be developed and commercialized.

## Semiconductor Manufacturing Technologies

One of the important steps in manufacturing a semiconductor chip is the process that provides clean and resolute circuit patterns on silicon surfaces. The circuit patterns are measured in **linewidths** per semiconductor chip. Over the last decade, semiconductor manufacturers have produced chips below the **micron**, or **sub-micron** level (a micron is 1/100,000th the width of a human hair). Current manufacturing technologies permit clear and resolute linewidths at .35 micron. Beyond that level, current manufacturing technologies cannot guarantee consistent high-volume, high-quality production runs.

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<sup>18</sup> See: Peter Van Zant, *Microchip Fabrication: A Practical Guide to Semiconductor Processing*, 2d ed. (New York: McGraw Hill Publ. Co., 1990), 527 pages.

<sup>19</sup> Otis Port, “Gordon Moore’s Crystal Ball,” *Business Week*, 23 June 1997, p. 120.

The semiconductor chip manufacturing process is iterative, often with hundreds of steps being repeated to ensure quality and performance as a silicon wafer is made into a semiconductor chip. A key component in this process is where chemicals are placed onto the surface of the silicon wafers in layers. A pattern representing a circuit path is then etched onto the chemical. The next process involves stripping away the chemicals. When this stripping process occurs, the resulting pattern results in an electrically conductive circuit on the face of the wafer. Each of these steps has a specific name. The chemicals layered on the silicon are **photo resist** substances. The **mask** holds the circuit pattern, and it is the shadow of light on the wafer surface which provides the actual circuitry on the semiconductor chip. After the light hits the photo resist, the area sensitized by the light is washed away—the stripping process. The technology used to beam light waves onto the silicon wafer is **lithography**.

The current state-of-the-art lithography technology is **photo optical**. This technology has permitted the .35 micron linewidths, but likely cannot provide clearer resolution below this level. Several alternatives to photo optical are **x-rays, deep ultraviolet (DUV), and extreme ultraviolet (EUV)**. All of these technologies have been in development for over a decade, although none are currently used in high-volume, high-quality semiconductor chip manufacturing. But all use shorter waves from the portion of the spectrum invisible to the naked eye. It is shorter lightwaves which will likely provide the kind of manufacturing resolution needed below .35 micron.

The **stepper** is the entire unit that conducts the exposure process described above. This includes the light source, the lenses that focus the light source, and the technologies that control the exposure process as the lithography unit emits waves upon different parts of the wafer. Quality of performance of the stepper, product life cycles of semiconductor chips, and cost of the stepper unit all are factors which determine technology advancement and commercialization. New lithography technologies like EUV could make the entire stepper unit more accurate and productive at sub-micron levels.

## **Semiconductor Industry and Markets**

The semiconductor industry, whether domestic or global, generally is comprised of two major components—the semiconductor chip manufacturers and the semiconductor equipment and materials suppliers.<sup>20</sup> In the former category are U.S. companies like the Intel Corporation, Motorola, and Texas Instruments. Leading firms from Japan include NEC, Hitachi, Toshiba, and Fujitsu. Other firms such as

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<sup>20</sup> This is a very broad distinction, which, for the purpose and length of this report, does not present several finer distinctions. These include some U.S. companies, like IBM, which produces its own semiconductor chips for IBM computers but not for external retail sale. Companies like this are called “captive” manufacturers. Several niche semiconductor chip manufacturers serve specific markets, such as only manufacturing devices for the Department of Defense. On the supply side, the equipment suppliers and materials suppliers are two distinct industries. Finally, in foreign markets like Japan and Korea, vertical integration can blur distinctions between manufacturers and equipment suppliers.

Korea's Samsung Electronics, Hyundai Electronics and LG Semicon, and France's SGS-Thomson also manufacture semiconductor chips.

Semiconductor chip technology was invented in the United States in 1958, and for most of the 1960s through mid-1970s, U.S. manufacturers held more than two-thirds of the global market. However, increased foreign competition and a drop-off in the quality and reliability of U.S. products eroded that lead. By 1987, U.S. semiconductor manufacturers held about 37% of the global market, while Japanese firms held about 47% of the global market for semiconductor chip sales.<sup>21</sup>

In response, U.S. industry and the federal government (individually and collectively) undertook several initiatives. These included the 1988 semiconductor agreement to open Japanese markets to U.S. products, an industry "roadmap" which provided a strategic outline for the U.S. semiconductor manufacturers and equipment suppliers, and actions by U.S. firms to dramatically innovate and improve the quality of their products. Importantly, many industry leaders also contended that better communication between U.S. semiconductor chip manufacturers and equipment suppliers was needed to strengthen the link between equipment suppliers and manufacturers. In 1987, an industry-government funded consortium called SEMATECH (for **S**emiconductor **M**anufacturing **T**echnology) was created to meet that goal. By 1997, U.S. semiconductor chip manufacturers had regained a global market share of 46%, while Japanese firms held 36%.<sup>22</sup>

For semiconductor equipment suppliers, 1987-1997 also resulted in a turnaround. After losing the global market lead to the Japanese in 1990, by 1997 U.S. equipment suppliers held 50% of the global market, the Japanese 41%.<sup>23</sup> One U.S. firm, Applied Materials, is the largest semiconductor equipment supplier in the world. Applied Materials provides important technologies and tools in the etching and removal of chemical vapor deposition during the semiconductor manufacturing process, as well other technologies. But it is important to note that Applied Materials does not produce steppers for semiconductor manufacturing.

However, for the stepper component of the semiconductor equipment market, the story is different for U.S. firms. Foreign companies have continued to dominate the global semiconductor equipment market for a decade. Two companies from Japan, Nikon and Canon, have 50% and 29% of the world stepper market, respectively. ASM Lithography of the Netherlands follows with 10% of the world stepper market. U.S. firms such as Ultratech Stepper, Silicon Valley Group Limited (SVGL), and Integrated Solutions Inc. (ISI) follow with a total global market share of under 10%.

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<sup>21</sup> For a history of this technology and the industry, see Kenneth Flamm, *Creating the Computer*, 282 pages, Global market percentages are rounded to whole numbers, SEMATECH, 1996 Annual Report, Austin, Texas: 1996, p. 24.

<sup>22</sup> SEMATECH, 1996 Annual Report, Austin, Texas: 1996, p. 24.

<sup>23</sup> Ibid.

While market share percentages show the substantial global positions of Nikon and Canon, they do not tell the entire story. For example, Nikon and Canon are the leaders in the development and commercialization of photo optical lithography, but are not considered leaders in either EUV or DUV technologies. ASM Lithography has made a substantial investment in EUV lithography although it is not yet ready to commercialize its technology. Ultratech has focused most of its efforts in producing lithography tools which have lower resolution but cost less, rather than develop more advanced tools. SVGL has had a long history of making the resists that coat the silicon wafer during production, but only recently has it become a major competitor in the stepper market. ISI provides custom lithography technologies and advanced stepper products.

## Observations

Changes in federal funding for R&D, as well as scientific and technological advances in the private sector, have affected the way government laboratories meet mission requirements. Legislative activity over the past 15 to 20 years has encouraged cooperative research and development between and among government, industry, and academia. The intent is to facilitate collaborative ventures and thereby reduce the risks and costs associated with R&D while permitting work to be undertaken that crosses traditional boundaries of expertise and experience.

The Department of Energy has taken the congressional mandate to transfer technology from government laboratories to the private sector and created the means to implement this responsibility. The individual laboratories have also established programs that reflect their operating styles, while meeting their obligations to undertake collaborative R&D with industry. As articulated in a May 1997 Sandia National Laboratory publication, strategic partnering supports the laboratories' traditional missions by

- ! leveraging government funding in critical areas,
- ! sustaining and strengthening [the laboratory's] scientific and technical excellence,
- ! accelerating technology development and deployment, and
- ! fostering closer relationships with industries that are critical to our primary missions.<sup>24</sup>

However, in recent weeks, questions have been raised as to the procedures followed by the Department, by the laboratories, and by the private sector participants in the EUV LLC.

There has not been an independent, cross-agency evaluation of CRADAs which might be helpful in answering questions regarding the DOE-EUV LLC agreement. That is in part a result of the absence of standardized departmental measures of success. The General Accounting Office (GAO) reviewed 10 CRADAs among a group selected by agencies as having achieved their goals. In the December 1994

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<sup>24</sup> Sandia National Laboratories, Technology Transfer & Commercialization Program, May 1997, p. 5.

study, GAO found that the benefits of collaboration include new commercial products, advances in R&D programs, and assistance in meeting agency mission requirements. Noting that the CRADAs studied were not necessarily representative of all such efforts, the report concluded that CRADAs can be a “valuable asset” and “... government-industry collaboration can have a positive impact on certain economic, health, and environmental needs of the United States.”<sup>25</sup>

In preparing a report on partnering, the Office of Technology Policy in the Department of Commerce collected information from government agencies, industry, and the university community which led to a finding that “technology partnerships enhance the effectiveness of government mission-related R&D.”<sup>26</sup> The report goes on to argue that state-of-the-art R&D performed by the private sector is necessary for the laboratories to achieve their mandates and can be acquired through collaborative work. In addition, even in cases where federal R&D is more progressive, generation of “government-unique” technologies often is too expensive to be developed solely by the public sector. The potential of commercial markets can interest industry in participating in such activities and, thus, reduce costs.<sup>27</sup>

The growing industrial interest in CRADAs, as well as an increase in the number of these cooperative arrangements used by the business community seems to indicate that both the public and private sectors see value in the approach. In addition, CRADAs may meet the interests of the current Congress for supporting basic research and facilitating technology development through indirect measures particularly since no federal funds are provided to the industrial partner. The successful implementation of the legislative mandate to transfer technology, however, has led to expanded use of this mechanism and as such, to questions regarding individual CRADA arrangements.

Much of the opposition to the DOE-EUV LLC cooperative R&D agreements rests on concerns over the participation of foreign equipment suppliers. As noted previously, the inclusion of companies such as Nikon Corporation of Japan in licensing arrangements to utilize the results of the CRADA has given rise to objections that U.S. taxpayer supported technology may benefit foreign-owned companies. Critics of the partnership have stated that the potential of providing foreign companies access to U.S. technology developments originating in federal laboratories will have a serious and destructive effect on American equipment and material suppliers and, thus, hurt national economic security interests. They point to the SEMATECH consortium, which linked U.S. semiconductor manufacturing and supplier firms, as an example of a constructive federal policy that addressed similar concerns. While acknowledging that the parallel to SEMATECH is not identical, proponents of this argument maintain that, in this case, it is clearly in the interest of U.S. policymakers to consider amending the current DOE-EUV LLC CRADA. They

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<sup>25</sup> General Accounting Office, *Technology Transfers: Benefits of Cooperative R&D Agreements*, RCED-95-52, December 1994, Washington, 1994.

<sup>26</sup> Office of Technology Policy, Department of Commerce, *Effective Partnering: A Report to Congress on Federal Technology Partnerships*, Washington, April 1996, p. 39.

<sup>27</sup> *Ibid.*, p. 40.

assert that U.S. semiconductor equipment and materials suppliers, if not served exclusively, should at the very least be primary beneficiaries of this venture.

Those supporting the DOE-EUV LLC CRADA point out that the government and the private sector participants have followed not only the legal guidelines for creating a cooperative R&D agreement, but also the intent of the law as dictated in congressional documents accompanying the relevant legislation. Congress instructed the agencies to promote technology transfer of benefit to both the government and industry. The work encompassed under the current cooperative R&D agreement is precisely the type of critical technology nurtured at a federal laboratory that should be developed by the private sector. Proponents argue that the consortium, which is funding the laboratory R&D, has the right to seek out and use the best manufacturing technology sources. The requirements for U.S. manufacture of the resulting products and processes and existing export control regulations are seen as sufficient to address concerns over the participation of foreign firms.

In congressional discussion over the DOE-EUV LLC cooperative research and development agreement, certain issues might need to be resolved. A starting point may be whether or not this specific CRADA followed the rules and regulations developed by the Department of Energy. Another question is whether both the model CRADA and the procedures established by 48 CFR Part 970 accurately reflect the mandate provided under the law? Does the current law represent the best method of fostering technology transfer for the benefit of the U.S. economy given the changes in the R&D environment since the legislation was enacted? Is opposition to this cooperative effort driven by political and economic concerns created by competitors in the marketplace or are there other reasons to reassess this arrangement?

Any resolution of differences might involve the issue of balance. Are there other national considerations which should further temper the current technology transfer mandate? Industries (and companies) typically are interdependent; thus, can a balance be achieved between the technology transfer interests of U.S. firms that have a technological lead and those that do not? What does economic security mean in a situation such as this? How does the government balance the interests of one industry or one company with another; e.g. the semiconductor producers with the needs of the equipment manufacturers? And how can the government's interests be balanced with those of industry? Does the current system allow both the laboratories—thus, the American public—and the private sector to achieve commensurate benefits?

The globalization of the international marketplace and the rapid diffusion of new technologies and manufacturing processes throughout has provided many opportunities and generated many conflicts. While there are often national security (including economic security) concerns, it is generally acknowledged that keeping technology within domestic borders is nearly impossible, although firms can keep certain technological developments within corporate boundaries for some time. Successful companies are those which provide innovation and quality in a timely manner. In recognition of this, the legislation does not prohibit participation of foreign-owned companies due, in part, to the fact that these firms often provide jobs for American workers and significantly contribute to the U.S. economy. The measure often used is that of “value added” to the national well-being. Therefore, efforts to

restrict what is considered an “American technology” from foreign sources, or attempts to direct which suppliers a manufacturer can use, may result in a fruitless or even deleterious national policy. Still, it is in the national interest to maintain and improve upon processes of technological advancement, manufacturing, and product development. The final consideration may be how to encourage American-owned and U.S.-based firms to be the most innovative technology suppliers and manufacturers in a global economy.