Economic Competitiveness

The Laboratory works with private industry toward goals neither might reach alone. LLNL's important national goals involve defense, energy, and the environment, while industry's goals in working with us involve furthering their technologies. We both require cost-effective results. Together we contribute to the country's economic strength by providing technologies required for successful competition in a global economy.

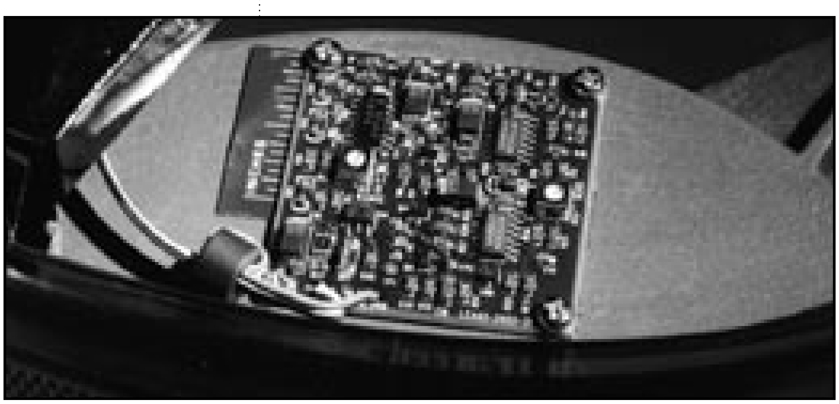
Cooperation with industry is an integral part of much of our work at Livermore. The aim is to realize our core programmatic goals—such as those in defense, energy, and the environment—in the most cost-effective way, while often simultaneously contributing to the nation's economic success.[1] The projects vary according to the nature and complexity of the technology, its degree of development, its perceived applications, and its proprietary status. Some are set up as licensing and consulting agreements,[2,3] while others are carried out as cooperative research and development agreements (CRADAs).[4] Those agreements involve partnerships in which, generally, government funds are used to support the Laboratory's work, and industry funds are used to support its work. Each organization may have separate applications in mind, but by each doing a specialized portion of the project, all benefit from the synergistic results and savings.

Last year, about 6% of the Laboratory's budget supported efforts at forming industrial partnerships. Results have been impressive.

- From March 1992 to November 1994, we amassed 137 CRADAs worth $480 million in government and industry funds. These partnerships support a variety of technologies related to our core competencies: 30% of these agreements in materials and manufacturing; 18% in computing and communications; 14% in semiconductors, microelectronics, and photonics; 11% in electronics manufacturing; 8% in biotechnology and health care; 7% in modeling of industrial processes; 7% in environmental remediation; and 5% in energy-related technologies or processes.
- Over the last few years, the number of licensing agreements has steadily increased. We now have 100.

A selection of these projects follows.

A new radar-based sensor is shown here in an automobile taillight, where it could be installed to serve as a collision or pedestrian warning system. The small, sophisticated invention has been licensed to California-based Amerigon, Inc., for several automobile safety applications.



Catalysts for Reducing Nitrogen Oxide Emissions

We have been working with General Motors (GM), Ford, Chrysler, and Sandia and Los Alamos national laboratories to develop aerogel catalysts and a catalytic converter system that meet current and future mandated Clean Air Act standards for motor vehicle emissions. The project's goal is to reduce nitrogen oxide (NOx) emissions from both diesel and lean-burn gasoline engines.

So far the prototype catalysts—metal oxide aerogels developed at Livermore and hydrous metal oxides developed at Sandia—have been characterized and modeled at Los Alamos and are now being tested at GM, Ford, and Chrysler, on dynamometers and in vehicles, for adherence to emission control standards.

Participation in this project has allowed us to refine our capabilities in aerogel synthesis, processing, and molecular modeling. This, in turn, has improved our understanding of how catalysts behave in amorphous and crystalline inorganic oxides. It has also given us the opportunity to sharpen our modeling capabilities in the kinetics of combined heterogeneous and homogeneous reactions.

Flywheel Batteries for Hybrid Cars

In July 1994, we entered into a three-year, $2.5 -million CRADA with GM to evaluate the flywheel battery (a battery in which kinetic energy is stored in a flywheel and transferred and processed electronically between the flywheel and the load) as part of a hybrid system to power future passenger vehicles. The agreement, co-sponsored by GM and DOE's Hybrid Vehicle Program, is part of GM's contribution to the broad-based Partnership for a New Generation of Vehicles—a concerted, "precompetitive" effort by Ford, GM, and Chrysler (the Big Three) to investigate ways to produce safer, more energy-efficient passenger cars. The ultimate goals are to reduce petroleum consumption in order to minimize dependence on foreign oil and to decrease carbon dioxide emissions contributing to global warming.

As part of the hybrid fuel system, the flywheel battery would capture and store the energy dissipated during braking, thus harnessing what was once wasted braking power. It would also power the car for quick accelerations uphill or after a stop.

Flywheel Battery for Regulating Power Supply

In 1994 we began a cooperative research project with Trinity Flywheel Batteries and Westinghouse Electric Corporation to develop a flywheel battery for quality power applications. In such applications, the objective is to mitigate the perturbations and interruptions in electrical power (i.e., common power surges) that can damage computers and process-control equipment. Westinghouse uses an active power line conditioner (APLC) that continuously monitors and controls the power supplied to a critical load—such as a programmable logic controller or a machine tool—to maintain good power quality. Westinghouse requires high-performance energy storage to provide the APLC with the ability to ride through total power outages of up to tens of seconds. The electromechanical battery developed by LLNL and manufactured by Trinity meets this need. It provides almost 10 times as much power in a small package as the best chemical battery does and offers the potential for a long, maintenance-free life.

Superconducting Materials for Digital Electronics

We are collaborating with Varian Associates to develop a superconducting building block for a variety of electronic devices—from high-speed digital signal processors and central processing units to microwave circuits and detectors. Key to the development of such materials is the fabrication of high-quality wafers and devices with specific characteristics. We have determined that a multilayer structure composed of high-temperature superconducting materials, metallic and insulating barrier materials, and associated substrate and electrode materials can provide devices with characteristics that make them suitable for use as sensors or electronic circuits. We also catalogued the microscopic defects that occur in such structures, investigated their origins, and identified the most critical process variables for tunnel barrier quality.

Highlights for 1994

- Worked with General Motors, Ford, Chrysler, Sandia National Laboratories (SNL), and Los Alamos National Laboratory (LANL) to develop advanced catalysts and catalytic converter systems to reduce nitrogen oxide emissions.
- Worked with Trinity Flywheel Batteries and Westinghouse Electric Corporation to develop an electromechanical, flywheel battery for power-quality applications.
- Began working with Webster Research Center of Xerox Corporation on atomic-level materials theory and modeling software to extend capabilities in etching, passivation, growth of thin films, and other microelectronic processes.
- Worked with Cincinnati Milacron to improve the accuracy of its machine tool products.
- Signed the three-year, $52-million Industrial Computing Initiative with Cray Research, Inc., Los Alamos National Laboratory, and eight other industrial partners to conduct research in massively parallel computing.
- Worked with BioNumerik Pharmaceuticals, Inc., to develop new anticancer drugs by computer simulation.
- Worked with Varian Associates to investigate methods to provide high-temperature, superconducting multilayer films required for high-speed, low-power signal processors and detectors.
- Made radar detection and cell sorting technologies available to industry for commercialization through two licensing agreements.

Simulating Molecular Dynamics of Surface Processes

In a cooperative venture with Webster Research Center of Xerox Corporation, we are using our atomic-level materials theory and modeling software to study the surface processes—such as etching, passivation, and thin-film growth—that figure in the development of a microelectronic device. This collaboration enables Xerox to extend its capabilities in microelectronics research and development so that it can improve the quality of its industrial and consumer products.

By extrapolating what we know about the surface interaction of a few atoms to large numbers of atoms, layers of atoms, and eventually to the quantities of material needed to build microchips, we expect to learn how to optimize the processes used to fabricate new materials and devices. With such knowledge, Xerox will be able to improve process control, lower process temperature, and achieve more abrupt multilayer material interfaces for improved electrical performance.

Improving the Accuracy of Machine Tools

We are working with machine tool manufacturer Cincinnati Milacron to improve the accuracy of competitively priced, general-purpose machine tools. The company anticipates that by combining our expertise in precision engineering and machine tool development with its high-volume production capabilities, it will be able to produce the quality machine tools that the U.S. machine tool industry needs to regain its share of the market from long-time foreign competitors.

The focus of this effort is Cincinnati Milacron's latest horizontal machining center, the Maxim 500 CNC, which was installed at the Laboratory's facility for collaborative research and development earlier this year. Through analysis and testing of the Maxim, engineers from the Laboratory and Cincinnati are developing a capability that can achieve a tenfold increase in machine tool accuracy without degrading productivity or significantly increasing capital equipment costs. The capability derives from the Laboratory's deterministic approach to machine tool development—that every effect has an identifiable cause that one can find if one looks hard enough, and that, therefore, random errors do not exist[5]—and from an array of analytical tools used by Livermore researchers to improve the accuracy, speed, throughput, and reliability of computer-controlled machine tools.[6] The net result will be a system that encourages engineers to assess a machine tool's capabilities during design rather than after prototyping. This will ultimately lower production costs and cut down on the time it takes to bring the machine tool to market.

Cincinnati Milacron's latest horizontal machining center, the Maxim 500 CNC. Through analysis and testing of this machine tool, engineers from LLNL and Cincinnati Milacron are developing a capability that can achieve a tenfold increase in machine tool accuracy.

Medical Laser Systems

We are working with Beckman Laser Institute and Medical Clinic (Irvine, California) to design, build, and test three medical laser systems. We expect these systems to be more compact and less expensive than current medical laser systems and offer greater efficiency, reliability, and flexibility. Beckman is identifying the system specifications, designing the delivery systems, and evaluating the lasers' performance in clinical trials. Our task is to design and build the prototypes.

The new systems are made possible by two of our recent laser technologies: a modular diode package that uses water and silicon-etched microchannels to cool the laser diode for operation at high power levels—much higher than is possible with other cooling techniques—and a 350-µm-diameter optical lens that precisely channels light for delivery to laser crystals.

The first system developed under the three-year, $1.3-million CRADA will be used for photodynamic therapy, a type of cancer treatment in which the photosensitized cells of a malignant tumor are shot through with laser light. The light raises the cells to a higher-than-normal energy level, causing them to interact with and convert oxygen into a lethal form. The second system, which will be used to remove birthmarks, will be a small, notebook-sized flashlamp-pumped laser with a pulse length of 1 to 8 milliseconds. The third system, a thulium:yttrium-aluminum-garnet device that delivers infrared light, will be used to drill tiny holes in the surfaces of human and animal eggs to increase their probability of being fertilized by sperm.

Industrial Computing Initiative

In 1994, we signed a $52-million, three-year agreement with Cray Research, Inc., Los Alamos National Laboratory, and eight other companies—IT Corporation, Boeing, Halliburton, Alcoa, Hughes Aircraft, Arete Engineering Technologies Corporation, AT&T, and Xerox Corporation—to do research in massively parallel computing. The machine being used for this cooperative venture is the Cray T3D, a 128-processor capable of operating at a speed of 18 billion floating point operations per second.

The Laboratory's goal in this project is to work with U.S. industry to develop software that will pave the way for the use of massively parallel computers in all areas of the economy. The specific goals have been defined by each industrial partner's use of the T3D:

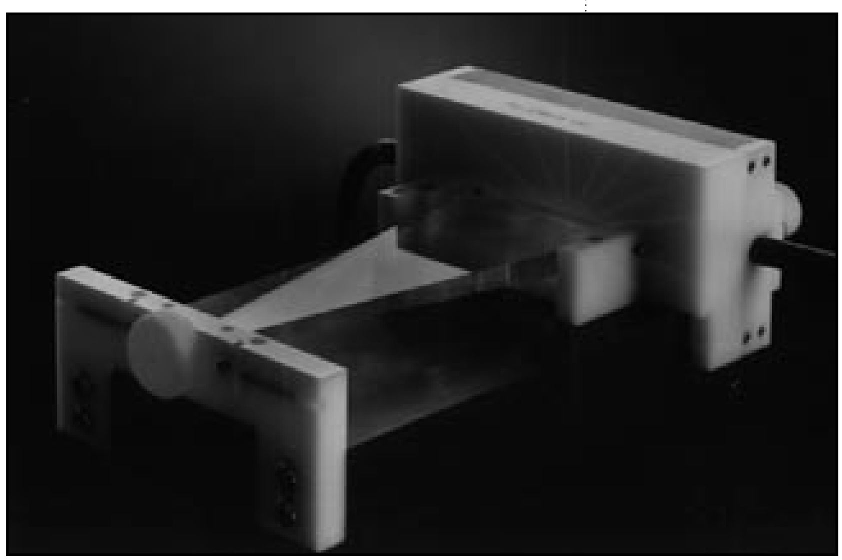
- IT Corporation—to develop underground terrain models.
- Boeing—to develop a global atmospheric transport model.
- Halliburton—to develop software for nuclear oil-well logging.
- Alcoa—to simulate the formation of ingots from molten aluminum alloys.
- Hughes Aircraft—to design better components for communications satellites.
- Arete Engineering Technologies Corporation—to model the interaction of underwater acoustic signals and underwater objects.
- AT&T—to develop models that will predict the behavior of materials for the next generation of microelectronics.
- Xerox—to develop atomic-level material simulation codes.

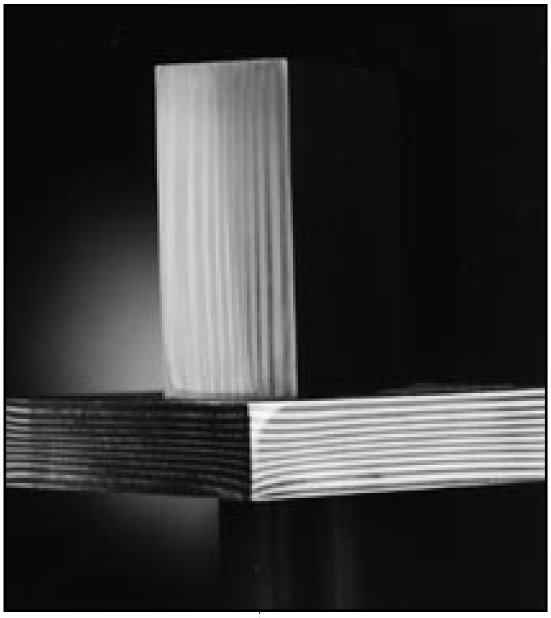
Small Business Initiative

The Small Business Initiative (SBI) is a national effort to help small companies (those with 500 or fewer employees) overcome technological barriers by giving them access to resources at the national laboratories. In essence, the laboratories provide the companies with the assistance, facilities, or equipment they need to test and develop the products that will enable them to compete successfully in domestic and foreign markets.

Recently, the LAST Factory of Livermore, California, a small manufacturer of liquid preservatives for magnetic media (e.g., compact discs, audiotapes), came to LLNL under the SBI for help in developing a line of products that would comply with the environmental regulation to eliminate freon from all industrial products and processes. With technical assistance from LLNL and its industrial partner Allied Signal (Kansas

The new medical laser systems we are developing with Beckman Institute and Medical Clinic incorporate two of our most recent laser technologies: a high-power, continuous-wave modular diode package that uses water and silicon-etched microchannels to cool the laser for operation at high power levels and a 350-µm-diameter optical lens that precisely channels light for delivery to laser crystals.





An example of the type of superconducting, multilayered, laminated metal composite material that the Laboratory and Varian are developing as building blocks for electronic devices. It is designed for toughness and fatigue behavior as well as high vibration suppression and high damping.

City, Missouri), LAST achieved a freon-free line of products and spent considerably less than expected on R&D.

California Manufacturing Technology Center

A memorandum of agreement with the California Manufacturing Technology Center (CMTC) and the California Community College Centers for Applied Competitive Technologies represents another opportunity for us to help small manufacturing firms gain a competitive edge. Under this agreement, CMTC members and other small- and medium-size manufacturing firms throughout the state have access to our expertise, equipment, and facilities (through training, lectures, and technical assistance). This kind of collaboration keeps us informed of the state's manufacturing needs and gives us the opportunity to meet members, introduces small firms to the latest in manufacturing technology, and helps individual firms resolve specific manufacturing problems.

Applications for New Radar Technology

Recently, we granted a limited exclusive license to two companies for a radar-based technology developed in one of our engineering programs. One company, Amerigon Incorporated (Burbank, California), anticipates using the technology to create an on-board warning device that will alert a driver who is backing up or parking a vehicle to an object in the "blind spot." The other company, Zircon Corporation (Campbell, California) will adapt the technology for use in electronic hand tools. The key to both applications is a patented receiver that can detect echoes of rapid, wide-band radar pulses (about 1 million per second) from objects that are very close or as much as 200 feet away.

High-Speed Cell Sorter

In 1992, we patented a high-speed cell sorter that can analyze cells and chromosomes at a rate of 20,000 per second and separate them at up to 2,000 per second, which is up to ten times faster than today's standard commercial machines. This year, we granted a limited exclusive license to Cytomation, Inc. (Fort Collins, Colorado), to manufacture and sell this technology. The license covers all research and clinical applications of the technology except for the sorting of human blood-forming cells; we granted a license for that application to SyStemix, Inc. (Palo Alto, California). This technology would also be useful in pharmaceutical research and development and in the study of infectious diseases.

Drugs by Computer Design

Since June of this year, we have been working with BioNumerik Pharmaceuticals (San Antonio, Texas) to develop "pharmaceutical discovery software" and computer simulation techniques that can help advance research on existing drugs and provide information for developing new drugs. BioNumerik estimates that such technology could save $200 million in development costs per drug and cut the time it takes to get a drug to market by as much as six years.

BioNumerik intends to use this technology to help characterize and identify the molecular interactions of proteins or DNA that are altered by disease so that it can develop "selective" anti-cancer drugs—those that kill cancer cells but spare normal ones. The drugs will target the most common and lethal cancers (solid tumors of the lung, breast, colon, prostate, and pancreas, which do not respond to chemotherapy), and should mean better treatment and fewer side effects for cancer patients. The company also intends to use the technology to study the development of new molecules that may reverse or prevent coronary artery disease.

The software is being written in Sisal, an LLNL-developed language particularly suited to parallel programming yet also inherently portable.

This means that the software will be able to run on a variety of different machines (e.g., the Cray supercomputer family, Convex II, IBM RISC/6000, Silicon Graphics and Sparc workstations, and Encore Multimax) in a variety of environments without sacrificing performance.

Summary

For several years, we have been working with key industries to help reach major Laboratory program goals most cost-effectively. That cooperation has often simultaneously sped the development of technology to produce better products, improve processing or production methods, and stimulate higher productivity and growth. Our relationships with these industries are thus strategic and vital because they enable us to fulfill LLNL's core missions, and, very significantly, they also provide some of the technical infrastructure necessary for successful competition in the rest of the economy.

Notes and References

1. According to various government agencies (Departments of Energy, Defense, and Commerce; the Council on Economic Competitiveness; and the National Critical Technologies Panel), the nation's future economic standing will be determined by industrial development in computing, electronics, machine tool manufacturing, transportation technology, materials development, information and communication technology, and biomedical and environmental technology.

2. A licensing agreement makes the Laboratory's patented or copyrighted products and processes available to industry for commercialization. A company interested in licensing a Laboratory-developed product or process will refine, manufacture, and market it, subject to fees and royalties defined in the negotiated agreement.

3. For a list of technologies available to transfer, see *Opportunities for Partnership*, Lawrence Livermore National Laboratory, Livermore, California, UCRL-TB-110794, 1993.

4. CRADAs, chartered by the National Competitiveness Technology Transfer Act of 1989, encourage the national laboratories to seek out U.S. industries for mutually beneficial research and development projects. Under such agreements, each party contributes personnel, facilities, equipment, and equal funding.

5. At the Laboratory, determinism has figured heavily in developing Laboratory machine tools such as the Large Optics Diamond Turning Machine—which maintains an overall accuracy of 0.02 μm (about 1/5000 the thickness of a human hair) across a 1.65-m contoured optical surface.

6. Included in this array of analytical tools are the Laboratory's finite-element modeling codes, which predict static, dynamic, structural and thermal behavior and break errors down into separate, identifiable components.

For further information contact Alan Bennett (510) 423-3330.

The Cray T3D is the massively parallel supercomputer that will be used by LLNL and the other eight participants in the Industrial Computing Initiative to carry out research and development projects that make extensive use of massively parallel computing.