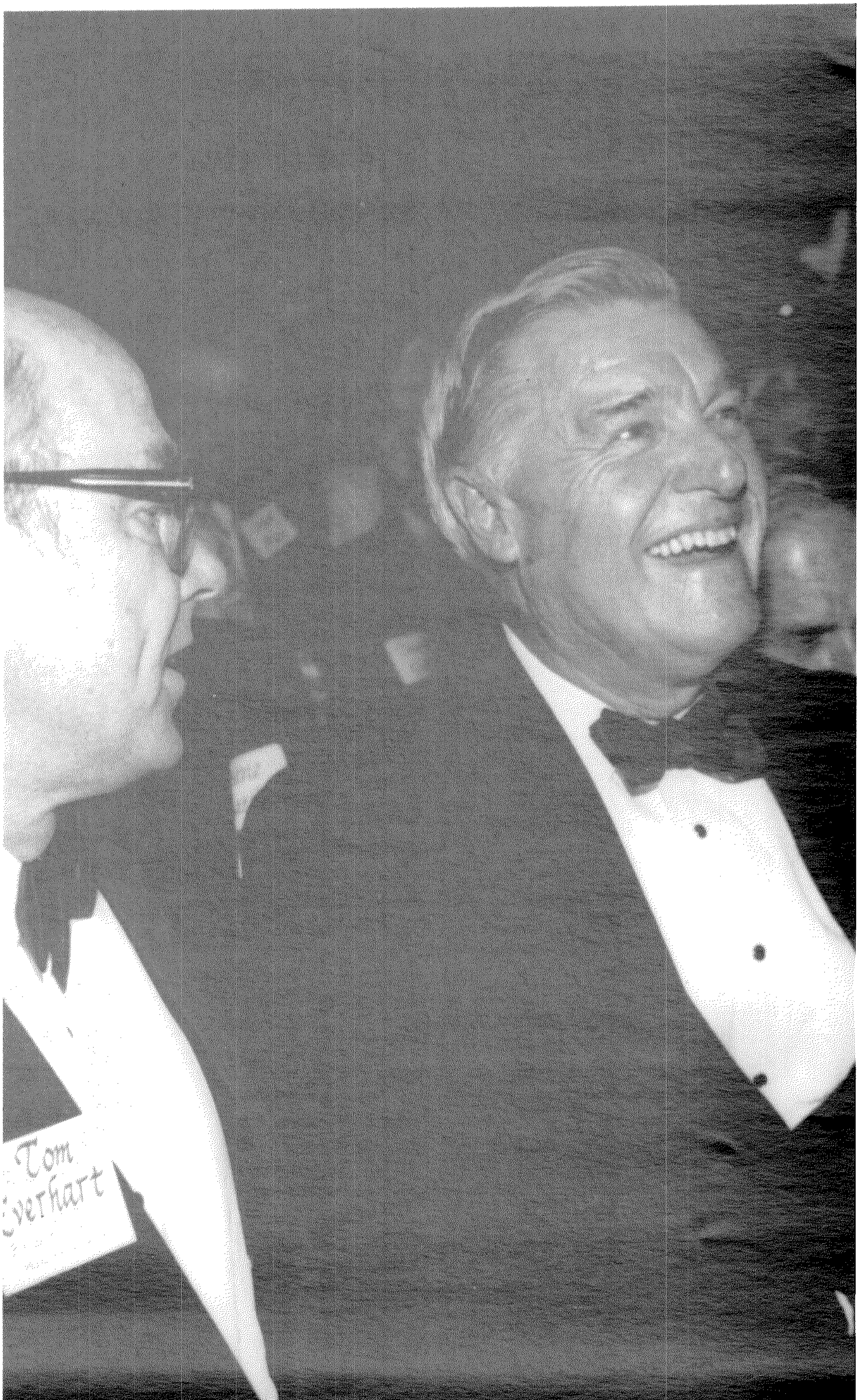
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Commercialization of Technology: Key to Competitiveness

by James D. Watkins

Why are we losing the race?

Secretary of Energy James Watkins and Caltech President Thomas Everhart enjoy the festivities at The Associates' annual dinner, where Watkins delivered this address.

The knowledge that comes from aggressive, fundamental research in science and technology is the indispensable base for the competitive posture of our nation. In energy, for example, geoscience research leads to advanced methods of oil and gas recovery, as well as to new techniques for environmental restoration. Research in materials science and engineering leads to stronger, lightweight materials that improve energy efficiency by reducing weight or by allowing machines to operate at higher temperatures. Advancing supercomputer technology and developing better algorithms enables more efficient and more effective design techniques to be used in a hundred fields. And the list goes on. At the Department of Energy, our challenge is to support the search for fundamental knowledge, and then to help translate that knowledge into practical applications for the U.S. economy and defense.

But are we losing the competitiveness race? By many measures the answer is, alas, a resounding "yes." Just look at the shelves of your local consumer electronics store. Many technologies pioneered by the United States have been "adopted" by foreign firms, improved upon, and sold back to us. Other nations are highly leveraging our initial research investments and reaping the benefits. In 1970, for example, U.S. firms had 90 percent of the color television market in the United States. By 1987, that market share had dropped to 10 percent. Similarly, while audio- and videotape recorders are U.S. inventions, U.S. companies have only a small share of the lucrative domestic consumer market today.

Even more disturbing to me, however, are the significant losses in the basic industrial strength that supports our national and economic security. For example, the United States once dominated the machine-tool industry. Today, the Department of Energy depends on suppliers in Japan, Germany, Switzerland, Korea, and other countries to provide the machine tools, precision measuring devices, and specialty metals needed to run our defense production lines. Our country has seen similar declines in industrial strength in steel, textiles, microelectronics, appliances, and automobiles. As a result, in the last 15 years alone, the overall U.S. merchandise trade deficit has gone from near zero to over $100 billion in the red.

Why are we losing the race? The root of the problem is certainly not in the nation's current research capability; the United States continues to be the world leader in basic scientific research, defense, and space technology.

- The National Science Foundation estimates total U.S. expenditures for research and development in 1989 at approximately $132 billion, with $62 billion provided by the federal government. This level of expenditure exceeds the combined research and development expenditures of Japan, Germany, France, and Great Britain.
- U.S. scientists are awarded more Nobel prizes than any other nation.
- In spite of recent setbacks, we still lead in space exploration.
- And, students from all over the world prefer to study in this country.

Mary Lidstrom, associate professor of applied microbiology, studies the genetics of methylotrophs, methane-eating bacteria that also devour chlorinated hydrocarbons, a principal component of soil and groundwater pollution. A DOE program that funds basic research in microbiology is helping her develop an energy-efficient process of environmental cleanup.

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So, the problem is not research and development. Rather, the problem lies in our inability to commercialize scientific and technological discoveries at a pace and scope equal to many of our international industrial competitors. The Department of Commerce recently published a survey of 12 "Emerging Technologies" that feature a combined global market potential of $1 trillion in annual product sales by the year 2000. According to that report, we are already behind Japan in five of these technologies: advanced materials, advanced semiconductor devices, digital imaging technology, high-density data storage, and optoelectronics. If current trends continue, in 10 years, we can also expect to be behind Japan in biotechnology, superconductors, high-performance computing, medical devices and diagnostics, and sensor technology—or a total of 10 technologies out of the 12. Unless we can learn to move the fruits of both public and private research into the marketplace faster and with more certainty, these R&D investments are at best "sunk costs," and at worst lost opportunities to regain badly needed economic strength for future growth.

It doesn't have to continue this way. In fact, we know that the United States can still compete effectively, not only at home, but in foreign markets as well. According to a recent *Washington Post* article, U.S. products are making significant inroads into selected Japanese markets. Our success stories include IBM computers, Kodak film, Microsoft computer software, and even Domino's Pizza.

The success of our economy has traditionally depended on the entrepreneurship of private firms. This is as it should be. But the federal government, including the Department of Energy, does have an important role to play in enhancing U.S. competitiveness. This role can range from taking steps to lower the cost of capital to developing more favorable trade policies. I believe that one of the most powerful ways for the government to help is to make it easier for U.S. industry to obtain the results of federally sponsored R&D, both through licensing and through collaborative research. And we need to facilitate that access in a way that allows industry to transfer new knowledge expeditiously into useful made-in-the-U.S.A. products and services.

In addition to its widespread support of university research, the federal government operates one of the largest and most extensive "machines" for research and development in the world. The complex of more than 700 federal laboratories accounts for one-sixth of the nation's total R&D spending. DOE is responsible for the largest of these facilities, the nine multi-program laboratories, three of which are in California: Lawrence Berkeley and Lawrence Livermore National Laboratories, which are operated for us by the University of California; and Sandia-Livermore National Laboratory, operated by AT&T. These labs represent a significant intellectual resource. All told, the DOE laboratories and production facilities employ more than 25,000 mathematicians, scientists, and engineers in nearly every scientific discipline.

These scientists and engineers have an impressive track record for excellence in innovation.

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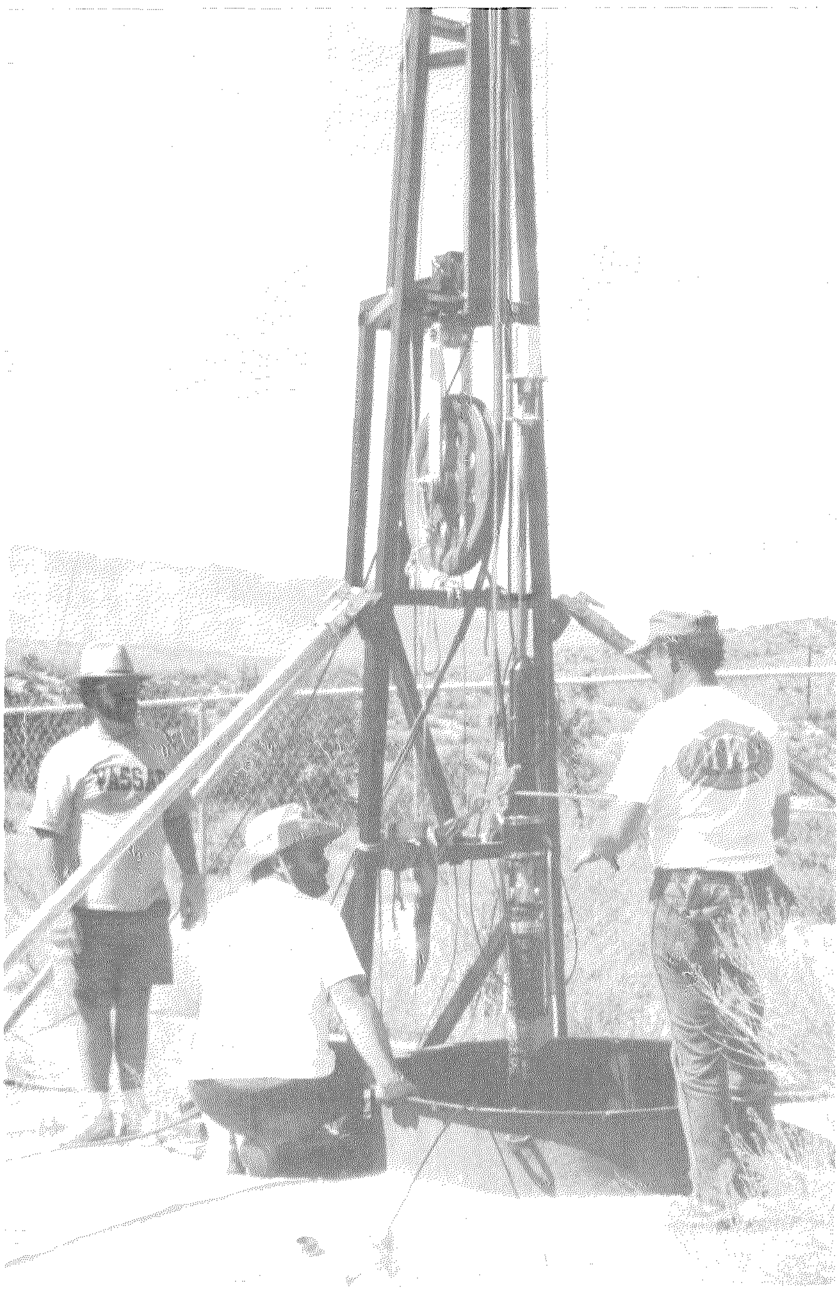

Professor of Geophysics Tom Ahrens (right), grad student Scott King (left), and technician Bob Taylor conduct field tests of their holographic stressmeter near Palmdale. Measuring stress in deep fluid-filled boreholes by interference holography provides information important for enhanced oil recovery. Other potential applications include geothermal resource exploitation and the monitoring of underground waste-disposal sites. A DOE grant is funding Ahrens's work.

The DOE laboratories are star performers in the R&D 100 Awards—an international competition that *Research and Development* magazine conducts each year to identify the 100 new products, processes, and materials deemed most significant from a technical perspective. Over the past 27 years, employees of DOE's laboratories and facilities have won more than 275 of these awards. While I don't have quite the same level of statistical detail to quote about the contributions that come from our support of research and development in universities, I know they are equally impressive.

Since 1963, 45 percent of DOE's award-winning technologies from its national laboratories have been commercialized, motivating the formation of 29 companies; laboratory employees were directly involved in establishing 76 percent of them. These are only a part of the larger universe of all spin-off companies that have started with DOE-developed technologies—more than 140 just since 1985. In the 1988 fiscal year alone some 25 new companies were reported in fields ranging from in-situ vitrification of waste to process-design technologies for the biochemical industry.

In spite of these successes we have barely tapped this wealth of talent. Numerous studies by recognized experts on U.S. R&D policy, including the President's Commission on Industrial Competitiveness, have suggested that the contribution of DOE and other government-funded laboratories to industrial competitiveness can be increased substantially. For example, although licensing of technologies from DOE

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laboratories has increased significantly in the last four years, income from such licenses in the 1989 fiscal year totaled much less than one percent of the total funding provided to the laboratories. There is no question that these and other measures of technology transfer can be improved as laboratories, universities, and private industry work together more closely toward the achievement of mutually beneficial goals.

For over a year now, the Department of Energy has been immersed in the development of a national energy strategy. Over the course of this process, we have become convinced that transferring the results of federal research and development from the labs and universities to the private sector is one of the keys to achieving the nation's energy, environmental, and economic goals. We have heard oral testimony from hundreds of industry, university, and government representatives and have received and reviewed more than 20,000 pages of well-thought-out written testimony. From this we have learned a great deal about what we on the federal side can do to help bridge the gap—the gap between the point at which federal research and development typically stops and industrial commercialization typically starts. These lessons include several important factors.

Market Pull

Last March, I hosted a Technology Transfer Round Table in Washington with the Secretary of Commerce. According to the 24 participants from government and industry, market pull is essential to the success of technology transfer. DOE and its laboratories must develop a better understanding of what U.S. industry, driven by consumer demand, wants to commercialize. And industry must better understand what federal researchers are capable of providing. To do this, we need to bring industry into the federal R&D planning process much earlier.

Cost-Shared Research

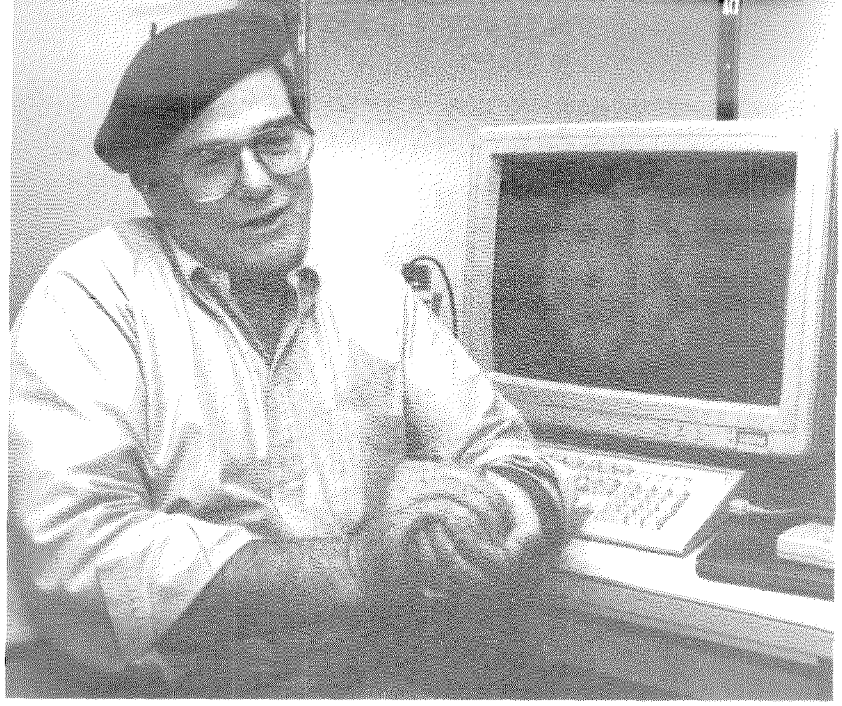
Many of DOE's more successful technology transfer programs involve the use of cost-sharing between DOE and industry. From our point of view, cost-sharing by industry serves as a measure of industry's interest in the technology as well as a way to leverage federal funds in times of budget constraints. From industry's point of view, cost-sharing by DOE serves as a means of reducing the risk of developing technologies that are potentially "market sweeping" in the long term.

One of the programs that successfully combines market pull and cost-shared research is the Energy-Related Inventions Program, which DOE runs in conjunction with the Department of Commerce. From 1974 to 1988, 88 technologies that were supported by this program generated a cumulative sales revenue of more than $400 million. This is a return of $7 for every $1 provided by the federal government. More than 700 jobs were created by the program, and in 1988 alone $3.2 million was returned to the Treasury through tax revenues.

Intellectual Property Protection

The U.S. has had a history of broad and rapid dissemination of results of its basic scientific research programs. Even results of nonclassified basic research associated with defense missions have been made widely available. This is appropriate, and we must continue to support world cooperation in understanding and advancing basic scientific principles. We know, however, that U.S. industry places a premium on protecting information with potential commercial value (in the form of patents, licenses, and copyrights), which can lead to a competitive advantage in the marketplace. We're also aware that the protection of intellectual property is a tough issue in the university community as well.

In the last few years we have "piloted" limited restrictions on the broad dissemination of information through specific applied-energy programs, such as the High Temperature Superconductivity Pilot Centers and the Clean Coal Tech-



DOE funds have contributed substantially to the new Materials and Molecular Simulation Center of the Beckman Institute. Here, William Goddard III, the Ferkel Professor of Chemistry and Applied Physics, explains a new molecule called "buckminsterfullerene"—60 atoms of carbon packed together in the shape of a soccer ball. Simulations in Goddard's lab have predicted the "bucky ball's" crystal structure and its vibrational and other properties, predictions helpful in characterizing such molecules, which may have useful applications in nanoscale devices, low-temperature tribology, and low-friction, high-temperature coatings.

nologies Program. According to several industry participants in the Pilot Center program, they would not be working with DOE today without this important protection. As a result of this success and others, Congress has extended the ability of all agencies to restrict the release for a designated period of information of potential commercial value under certain types of agreements. We feel this will be an important signal to industry that the federal government is serious about enhancing U.S. competitiveness in partnership with the private sector.

Collaborative Research

A phrase frequently used, and so true, is worth repeating: "Technology transfer is a contact sport." Much of the "technology" that can be transferred from the federal laboratories is not hardware on the shelf. Instead, it is in the form of knowledge contained in the minds of our scientists and engineers. In order to transfer that knowledge effectively, people must interact.

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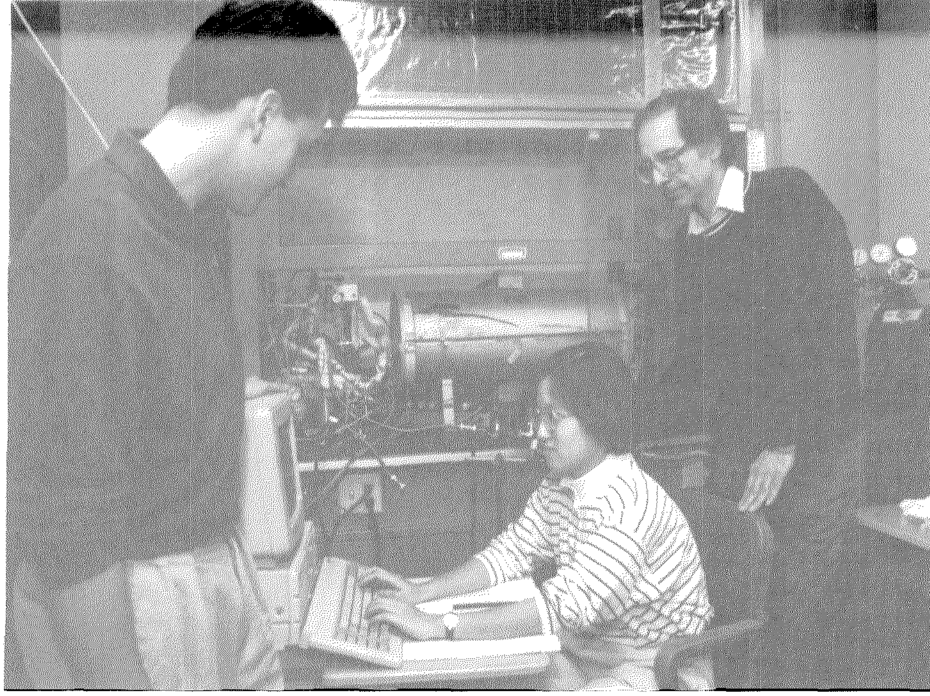
In July, we took some steps to further improve the access of industry to state-of-the-art technology developed in our national laboratories, particularly those believed by most to be serving defense programs exclusively. We signed two agreements, one with a consortium of specialty metals industries and the other with a consortium of manufacturing industries. Under both agreements, member companies will be able to work directly with our laboratories' best engineers and scientists. They will also be able to use some of the world's most sophisticated equipment to advance the state of the art in their respective manufacturing technologies. From DOE's perspective, the national laboratories, through this interaction, will gain insights into the technologies and techniques used by industry.

Speed And Certainty

We have learned that the federal government, including DOE, does not make a very good business partner. According to industry, our administrative processes are slow and cumbersome; policies are implemented differently by different agencies and even within different parts of the same agency; and the paperwork alone raises the cost of doing business. In order to encourage industry to work with the federal government through collaborative programs, we have to reduce or eliminate the administrative and legal barriers that now slow the process down and increase the economic risks of new technologies.

The president has established a Council on Competitiveness, of which I am a member, to address this problem. Through the biotechnology working group, the council has established principles that will help us reduce the administrative burdens on biotechnology companies and thus promote the rapid commercialization of new technologies. The council has also taken responsibility for important deregulatory initiatives started under the previous administration. Finally, the council recently formed a new working group on the commercialization of government research.



Under DOE funding Professor of Chemical Engineering George Gavalas (right) and grad students Michael Tsapatsis and Soojin Kim are investigating the use of an inorganic thin film membrane to separate hydrogen from coal gas. Such separation techniques would have applications in many facets of coal utilization and in petrochemical production.

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Technology Transfer "Agents"

It is not enough to make it easier for industry to work with the federal government. We have to make matches between what industry wants and needs and what the federal researchers can contribute. Further, even when a technology match is made, industry may need additional technical and business assistance. This is where state governments, universities, trade and professional associations, and other organizations have important roles to play.

For example, a program was recently initiated by DOE's Office of Energy Research to transfer advanced materials technologies developed at DOE laboratories to small, high-technology businesses in Michigan. Faculty from two-year (community and technical) colleges play a key role as brokers for transferring information and technology to participating small businesses.

DOE's Lawrence Berkeley Laboratory is participating in a coordinated effort with the California Energy Commission to transfer expertise and technologies to California electric utilities for analyzing energy consumption in buildings of all kinds.

The same California Energy Commission also runs one of the nation's most successful programs to promote energy-technology exports. California companies developing technologies in conservation, geothermal energy, cogeneration, solar electricity, and wind power are assisted through a program that is carefully designed to be complementary to other state and federal initiatives for export promotion. From its inception in 1986 to the present, the commission has stimulated more than $14 million in export sales, and another $45 million in expected sales are projected within the next six months. This translates into $12 in export sales for every dollar invested in this modest program—an outstanding achievement on a limited budget. It also is suggestive of how much more can be done.

But, to succeed, we each have to do our part. Scientists and engineers supported by DOE, in its national laboratories and in universities, are truly a national treasure in terms of their unparalleled capabilities and achievements. I am committed to seeing that these incredible resources are used more effectively to enhance the competitiveness of U.S. industry and the quality of life for U.S. citizens. In fact, the first task of my newly established and very prestigious Secretary of Energy Advisory Board, which is under the able chairmanship of Caltech's president, Tom Everhart, is to develop plans to help me better utilize the intellectual capital in the DOE national laboratories.

These national laboratories are already moving aggressively to improve technology transfer, thanks to the National Competitiveness Technology Transfer Act of 1989. This act made technology transfer a mission of all DOE laboratories and provided an additional mechanism for laboratory-industry-university cooperation, called the cooperative research and development agreements. The act also amended the Atomic Energy Act to make technology transfer an explicit mission of DOE's defense programs. We have mobilized more than a hundred people in the department and its laboratories to develop a program that will provide a fast, flexible, and predictable environment for technology transfer from our national laboratories.

There are, however, some obstacles in the way. One of the most serious problems facing the nation over the next 10 years is the declining number of young Americans who are interested in pursuing careers in science and engineering. Those who may be interested often receive neither inspirational counseling nor adequate preparation for such careers early in their schooling. This is particularly true in the case of women, minorities, and the disabled, who will make up 85 percent of net new work-force entrants by the year 2000. This situation represents a crisis in science and math education that has serious implications for our nation's continued economic and technological competitiveness.

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Just one year ago, I hosted a Math/Science Education Action Conference at the Lawrence Hall of Science in Berkeley, California. My cochairman for the conference was Nobel laureate Glenn Seaborg. This two-day meeting brought together more than 250 scientists, educators, policy makers, and industry representatives, as well as representatives from the administration and Congress. The conference report, which was released in May, lays out a specific plan of action for the Department of Energy and its laboratories, working in partnership with other federal agencies, such as NASA, and with the states, schools, and private-sector organizations. All of us need to be a part of the solution to this complicated problem, particularly at the pre-college level, where so many potential scientists and engineers are being lost today.

The challenge doesn't stop with basic science and math education, though. We must also teach technology management in our engineering schools and our business schools. According to the March 1990 issue of the *Engineering Management Journal*, 90 percent of high-tech managers feel they are inadequately prepared to lead innovation toward successful commercialization. This is where industry can play a critical part in working with universities to shape the curriculum in this area.

Finally, industry must take the lead in changing the management culture that keeps companies focused on short-term product improvements at the expense of longer-term technological innovation and expeditious commercialization.

I firmly believe that, if our nation can unite around the goal of renewing our competitive edge, we can enjoy unparalleled strength through a decade of advances in research and education in the 1990s. At a minimum, we can turn these advances into a source of competitive advantage for the United States in the fields of energy, environment, and trade—particularly important at a time when so many nations are struggling to enter the world of free markets for the first time.

It doesn't have to cost a lot of new money, either. Much of what needs to be accomplished can be done by better leveraging private and public resources that already exist. We can create an impressive payback on our research investment through expeditious commercialization, if we but have the will to grasp the moment. And achieving success will demand a serious change in thinking about how we organize and focus our national resources and institutional processes to meet these global challenges.

There is a saying in Scripture, "Where there is no vision, the people perish." If our nation is to have a competitive future in the world, we need a vision that takes us beyond exigencies of the moment—whether it is today's budget crises in the government or the next quarterly report from the oil industry. We need to see the broader and bigger picture of where we as a nation must go. We need to reach out to each other in new partnerships and alliances, with government, universities, and industry all supporting the three pillars on which our common future rests: research, education, and economic strength through the commercialization of technology. And we need to get serious on an action program to make those partnerships a working reality.

No one of us can do it alone. But together, we stand a fighting chance of ensuring that our country remains number one in the world as we enter the 21st century. □

James D. Watkins, Admiral, U.S. Navy (Retired), Secretary of Energy, delivered the above remarks at the annual black-tie dinner of The Caltech Associates on October 5, 1990. A graduate of the U.S. Naval Academy, Watkins holds a master's in mechanical engineering. He served on the Atomic Energy Commission for three years and from 1982 until his retirement from the Navy in 1986 was Chief of Naval Operations. From 1987 to 1988 he served as chairman of the Presidential Commission on the Human Immunodeficiency Virus (AIDS) and has been Secretary of Energy since March 1989. Watkins is a native Californian and considers Pasadena his home.