Los Alamos
beginning the second fifty years

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The following is based on an address presented at Los Alamos on April 16, 1993, at the close of a week-long seminar series held in celebration of the Laboratory's fiftieth anniversary.

Where do we go from here? This has been a fascinating week, very much in keeping with the motto of our fiftieth anniversary, "A proud past and an exciting future." We can and should be proud of our past. And many things presented this week should make us excited about our future. I'm going to talk about future directions. In doing so, I will try to act as if Washington gave me the keys to the car, remembering, of course, that they control the money for gas. And so we'll see how far we can get.

During the past fifty years we have been fortunate to receive generous government support to build and maintain one of the finest scientific institutions in the world. To fight the Cold War, we developed an incredibly broad science and technology base. We were allowed and encouraged to contribute to other important problems such as nuclear power, nuclear propulsion, alternative energy technologies, and biomedical applications. Our sponsors recognized the importance of basic research in maintaining our science and technology base. Consequently, we have become a world-class laboratory working on complex scientific and technological problems of national importance. Basic research and evolving missions helped to rejuvenate our institution for fifty years.

Today, several fundamental changes strain not only the foundations of our laboratory, but also the nation's entire science and technology enterprise. The collapse of the Soviet Union has made us the world's only military superpower. At the same time the rise of Japan, Germany, and other industrial countries to economic parity means we are no longer the world's only economic superpower. These profound changes in military and economic status require the United States to adopt a new approach to technology policy. In their recent book, *Beyond Spinoff,* Alic et al. make a strong case for changing the nation's policies, institutions, and habits of mind.

The new priorities are primarily domestic and economic. Defense spending, the mainstay of the Laboratory's existence for the past fifty years and formerly the primary engine driving the nation's R&D effort, will decrease. Such fundamental changes require us to re-examine how we do science and technology in this country and how laboratories like ours should contribute to the new national order.

The central question today is not: Can we still do good science? We *must* do good science. And our seminar series highlighted plenty of examples. Doing good science, however, is necessary but not sufficient. Since we're a billion-dollar R&D institution, the real question is: How can we help the nation solve the pressing problems of tomorrow?

In retrospect, defense was easy. Government control of defense makes sense because the government is the customer. Our principal role—that of designing nuclear weapons—has been well matched to our capabilities, since from the beginning that has been our reason for being. We had the entire responsibility for the full life cycle of nuclear weapons, from generating the ideas for new designs all the way through production, deployment, and, finally, to retirement. And we did not let the nation down in that

Post-Cold-War Strategic Vision of the Laboratory

The end of the Cold War allows the Laboratory to address numerous other needs of the nation in addition to its continuing military responsibilities. Among the nonmilitary needs are those of our society and of our industry. Tapping the exceptional technical expertise and capabilities of the Laboratory will not only help tackle the new priorities but also keep the requisite defense expertise strong.

Military needs
- Stewardship of nuclear weapons
- Maintenance of nuclear know-how and judgment
- Limiting and countering nuclear proliferation
- Responding to nuclear accidents or acts of terrorism
- Reduction of the nuclear-weapons stockpile
- Clean-up of nuclear research and production sites
- Storage and disposal of nuclear waste
- Technology for intelligence gathering and non-nuclear weaponry

Societal needs
- Energy
- Environmental protection and restoration
- Infrastructure rehabilitation
- Affordable health care
- Basic scientific research
- Education
- Space exploration and exploitation

Industrial needs
- Cost-shared, market-driven research and development partnerships
- User facilities
- Technology assistance
- Start-up of new technical businesses

process. In return, the customer—the government—had staying power and patient capital. It has invested in this institution for fifty years.

By contrast, in the domestic and economic arenas the government is at best a stakeholder or one of many different customers. It can serve as catalyst or partner. It also serves as requirement setter, regulator, auditor, or often, merely as the barrier to getting things done. In fact, in issues like energy, environment, and economic development, all of which have a strong local component, it makes much less sense for the government to play the central role.

Nevertheless, there is no question that Los Alamos can develop technologies for the civilian sector, and I think we can do it very well. But making a major impact with that technology will be very difficult and will require forging new partnerships and relationships, not just with the DOE but also with agencies throughout the government, with industry, and with universities. We will have to be quick, responsive, and flexible, and we will have to bring together the best talent. This need is no less critical today than at the beginning of the Manhattan Project, when the government created Los Alamos as a contractor-operated, government-owned (GOCO) institution and asked the University of California to run it. The GOCO concept proved to be incredibly successful. Unfortunately, over the past fifty years our institutional agility has been severely compromised by the growth of bureaucracy both in Washington and in our own institution.

We do not face this problem alone. In fact, many have recognized that the government must change its relationships to become more effective. Osborne has argued for no less than reinventing government. Secretary of Energy Hazel O'Leary has included reinventing the Department of Energy as part of her high-priority agenda. We at Los Alamos are taking steps to reduce our internal bureaucracy and to make our operations more responsive to the challenges ahead. And we have a president who firmly believes that the federal government must play a strong role in domestic and economic matters and who also recognizes that technology holds the key to our nation's welfare.

Having presented this preamble, I wish to address the three principal missions I see for Los Alamos in the post-Cold-War era: defense technologies, civilian technologies, and commercial technologies.

Defense Technologies

Our defense needs have changed dramatically. This country, with help from its allies, has tamed the big bear—and I have proof of that. Last night, our colleagues from the Russian weapons institute gave us a beautifully carved bear as a symbol of friendship and, even more symbolic, a plaque containing a piece from one of their dismantled nuclear warheads. The inscription reads, “From Russia, with love.” So we’ve tamed the big bear, but still many dangers are lurking in the woods. People around the world face threats resulting from fractious nationalism, regional conflicts, proliferation of high-technology weapons, the breakdown of national law, increased terrorism, and increased influence of organized crime. Clearly our nation will continue to need new technology for defense. Here the federal government has the unquestioned central role, and Los Alamos must continue to play its special part in nuclear defense as well as some other defense missions.

In the nuclear-weapons business, we have four major priorities and challenges: (1) Stewardship of a much-reduced stockpile of nuclear weapons and, just as pressing, stewardship of nuclear competency—of the people and the capabilities needed to answer the questions that will inevitably come up as long as there are nuclear weapons on this planet. (2) Countering proliferation of weapons of mass destruction, an incredibly important challenge in today’s world. Only the nuclear-weapons laboratories—Los Alamos, Livermore, Sandia—have the full sweep of technological capabilities and the vertical integration required to evaluate such threats and develop

Advanced Conventional-Defense and Intelligence Technologies

Though the Cold War has ended, “The world is still a dangerous place,” as President Clinton has said. Political changes and advancement of technology everywhere may lead to advanced-technology threats and weapons, threats from countries that do not now threaten us, and terrorism on a scale we have not seen before. Maintaining a strong defense R&D effort that emphasizes effectiveness and quality over quantity of military hardware will help to dissuade potential future conflicts or, if necessary, to conclude future conflicts decisively and with low human casualties on both sides.

Areas of present and future contributions

- “Smart” weapons that can hit maneuvering and concealed targets
- Effective defenses against ballistic and theater missiles and other weapons
- Computing and communications hardware and software
  Command, control, communications, computation, and intelligence. The “forward edge” in future military actions will be information and command networks.
  Simulations of battles for training and tactical planning and simulations of the performance of new hardware for design.
- Intelligence, including global surveillance, and weapons expertise to avoid being surprised by advanced-technology foreign weapons.

Technologies for advanced systems (nearly all have civilian uses)

- Integrated modeling, simulation, and gaming techniques
- System-level integration (especially for command, control, communications, computation, and intelligence)
- Machines with useful levels of intelligence
- Powerful software-generation systems
- Other aspects of computing
- Communications
- Electro-optics and optical electronics
- Space technologies
- Sensors
- New materials for strucural use, electronics, and storage and conversion of energy, including biologically generated or copied materials
- Nanotechnology based on electronic, mechanical, and biological techniques
- Flexible manufacturing
- Unmanned automated vehicles for air, sea, and land
- Nonlethal weapons
- Stealth and counterstealth
- High-performance missiles

the means to counter them. (3) Facilitating the nuclear drawdown, which starts with warheads, the other nuclear materials out there in the system, and nuclear waste, but also includes the drawdown of the production complex itself, which has grown to enormous size over the years. Today the complex must be cut back, and we must make it more efficient and environmentally benign. (4) Cleaning up the legacy of fifty years of production of nuclear materials and nuclear weapons.

Just a few years ago, the superpowers had 75,000 weapons out there ensuring the peace. I contend that it was a rather uneasy peace. Now we will be dismantling tens of thousands of weapons, so all of us can sleep better. But nuclear weapons are still with us, and we at Los Alamos can't rest until each and every weapon that we have designed is actually retired and dismantled. We need to revamp the nuclear-weapons program to meet a dramatically changed situation, which, I should emphasize, requires much more than an oil change and a lube job! It requires science. Although the country is not terribly interested in nuclear weapons, our responsibilities have not gone away. It will be up to us to provide the intellectual challenges needed to retain the best people and to maintain their experience and judgement. The latter goal is our highest priority.

Two weeks ago in our classified seminar, Edward Teller and Dick Garwin were here participating on the same panel. Edward suggested that we develop very small, very-low-yield, tactical nuclear weapons. Dick Garwin believes our focus should be on figuring out a way to disable the plutonium pits that are going be stored by the tens of thousands over the next few years. I don't know who's right. But we must be prepared to respond quickly and appropriately to the changing needs of the nation. We must develop the capabilities to disable the pits, or to create small nukes, or to do both. We can afford to have fewer nuclear weapons, but we can't afford to be less smart. And we have to configure our jobs so that we are prepared to meet all eventualities. It's not up to this institution to decide how many weapons the nation ought to have—or how or whether they should be used. But it is up to us to support whatever comes along in national policy—and to provide technological options for whatever the country needs.

It's also our job to contribute to conventional-defense and intelligence technologies. This country will continue to rely on technology to gain through quality what we won't spend on quantity. Los Alamos is in an excellent position to help translate the latest scientific accomplishments into benefits to the nation's defense posture. We are active in almost all the areas needed for the development of the smart precision military technology of the future, and many of those technologies have the distinct advantage of being dual-use—that is, they are also applicable in the civilian sector.

Civilian Technologies

Now I will turn to the domestic and economic front. Societal needs that will benefit from better technology include clean, affordable, abundant energy; a cleaner environment; a refurbished public infrastructure; affordable health care available to all; continued innovation through research; a better educated work force; and finally the spirit and desire to explore the unknown. Our president believes that government must play a role in these areas, that technology is a key component of progress, and that progress is essential for improving the economic performance of the nation.

For Los Alamos to contribute in these areas, we need to forge new relationships, what Lewis Branscomb referred to earlier as "linkages." We must also stick to our strengths—those areas in which, as a result of missions in defense and basic research, we have developed special skills, facilities, and approaches to getting things done, approaches that are not found in universities or in industry. The talents of our scientists and our ability to form interdisciplinary teams have worked powerfully in the past and must now be applied to pressing domestic problems.

Our ability to translate science into applications was certainly demonstrated by the Manhattan Project, but there are many more recent examples. Just a couple of days ago Doyle Evans talked about our work on space sensors. We've designed over 300 of them that have worked. We have operated an accelerator in space, to the dismay of some, but to the delight of many of us. During the Gulf War we put together a LIDAR system for tracking chemical and biological agents with lasers. We accomplished that task in seventeen days, much of it during the Christmas holidays. It was a stunning example of the dedication and technical strength of the staff. Fortunately, we didn't have to use the system in the Persian Gulf, but we turned around and used LIDAR in Mexico City and in Barcelona to monitor air pollution and in the central Pacific to make some crucial measurements for global climate modeling.

Our strength in nuclear science and technology is unparalleled—and although things nuclear are a rather small part of the overall economic agenda, behind that strength lies a whole spectrum of expertise in mathematics, physics, modeling of complex physical systems, and large-scale computer simulation. We devote between $250 and $300 million a year to the broad subject of high-performance computing, which includes hardware, software, applications, and basic research. Having made that kind of investment, the country can expect us to be the best at applying computers to solve real problems, and we are. In the nuclear-weapons business, we've always had to outcompute everybody else in the world—particularly Livermore. That competition is still there, and it has made us world leaders.

We invest in excess of $100 million a year in materials science and technology. Of course, some of that work is very specific to uranium, plutonium, and other materials that people hope they never have to work with, but we're also working on materials problems for novel electronic and photonic devices, for nanotechnology, for application of high-temperature superconductors, for efficient fuel cells, higher-temperature structural materials, and much more.

It may be surprising to some, but environmental research is also a major activity at Los Alamos. Because of the legacy of fifty years of operations here, we are now supported to the tune of $200 million a year for environmental restoration, waste management, and environmental R&D. Our basic-research program means that we have the chemists, biologists, materials scientists, and computer scientists to contribute innovative solutions to environmental problems, and so we are very good at it.

Other areas of expertise include accelerators, lasers, sensors, and dynamic experiments. And, as I mentioned earlier, we are very strong in theory and the modeling of complex systems.

I am underscoring our strength in basic research because that strength underlies our ability to contribute to civilian technologies. Many in this country believe that we need less basic research and more applications. But as Charles Herzfeld pointed out yesterday, if one takes a rational look, even in the defense arena, it's clear that this country needs to cast the net as broadly as

Translating Basic Research into Practical Technologies

The laboratory's success in translating basic research into practical technology is demonstrated by the following examples.

- The KIVA computer program for modeling internal-combustion engines. A spinoff from groundbreaking developments in numerical hydrodynamics, KIVA is now used by all the Big Three automobile makers to design engines.
- The side-coupled cavity used in high-power radio-frequency commercial accelerators. Originally designed to create intense particle beams at the LAMPF accelerator, it is now used in high-energy x-ray machines for cancer therapy and industrial radiography. Such machines have a worldwide market of $400 million per year.
- High-temperature superconducting cables and electronics. Building on considerable expertise in the physics of high-temperature superconductors, the Laboratory is helping a total of seventeen U.S. companies develop the technology base required for competetiveness in thin-film electronics and in electric-power transmission.
- Flow cytometers for biology and medicine. The flow cytometer was developed at the Laboratory in the 1960s to study the effects of radiation on cells. This instrument, which uses lasers to separate cells or chromosomes according to their characteristics, is widely used in hospitals to diagnose diseases such as AIDS and leukemia, to monitor transplants and the effects of cancer therapy, and to assist biological research in the Human Genome Project and related work. The total market for three U.S. companies is $800 million per year.
- Resonant ultrasound spectrometry for nondestructive testing. Invented at Los Alamos to study basic structural properties of high-temperature superconductors and other new materials, the resonant ultrasound spectrometer is now available from Quatro Corporation as a tool for nondestructive testing of high-precision objects such as ball bearings.

High-Performance Computing at the Laboratory

Large-scale computing was a critical element in the the development at the Laboratory of the first fission weapons and the first thermonuclear weapon. Some of the best mathematical minds of that time, among them John von Neumann, Richard Feynman, Hans Bethe, Stan Ulam, Edward Teller, and Nick Metropolis, helped establish the foundations of what is today the most sophisticated computing center in the world.

Our extraordinary computing capabilities can help improve the economic position of the nation in many areas, including:

- exploration for and extraction of oil,
- efficiency of internal combustion engines,
- design of new materials,
- environmental restoration,
- modeling climate,
- medical data banks and diagnostic tools,
- manufacturing processes and materials.

The Laboratory's computing capabilities are currently being applied to "Grand Challenges" in science and technology such as:

- simulating properties of the global ocean over a hundred-year period at forty depth levels and a horizontal resolution of 0.25° latitude and longitude;
- simulating the three-dimensional flow of two immiscible liquids (such as oil and water) through porous media (such as oil-bearing rocks);
- simulating the behavior of materials on an atomic level at a spatial resolution of 1 cubic micrometer and a temporal resolution of 1 nanosecond;
- assessing the safety of nuclear weapons in various hypothetical accident scenarios.

These problems are grand challenges in the sense that their solutions require enormous numbers of computer operations and access to enormous amounts of data. To put the numbers below in perspective, consider that forty years of computing time on a Cray YMP 8/8 are required to carry out 10^{18} operations and that the Library of Congress contains the equivalent of 25 terabytes of data (1 terabyte = 10^{12} bytes). Solving the grand challenges will help to drive the leading edge of computational science just as designing nuclear weapons did in the past.

	Operations Required	Terabytes of Data Required
Global ocean features	10^{17}	20
Flow through porous media	10^{18}	4
Atomistic behavior of materials	10^{18}	6
Nuclear-weapon safety	10^{18}	20

possible—investments in research must remain broad and basic.

At Los Alamos we have some of the best people, and we have some very special and unique capabilities. Consequently, investment in basic research at Los Alamos results in multiple payoffs. We do not simply publish ideas that are picked up and applied by other countries. We have the people who can translate those ideas into technology, and we've done just that over and over. Basic research is also crucial to the health of the Lab itself. It is the fountain of ideas for technology, and it is our link to the academic community. For example, aside from the good physics done at LAMPF, the Los Alamos Meson Physics Facility, that facility has provided a most important connection to the academic community. Over a thousand scientists from around the world have come to do experiments at LAMPF. Many visiting scientists come from universities to work in other parts of the Laboratory. We also have 1300 students and 200 post-docs who are our link to the future.

Los Alamos always has advanced and must continue to advance the frontiers of science. Nuclear physics was *the* exciting frontier when this laboratory began and remains a challenging and productive field. But today we're seeing an explosion of knowledge in the biosciences, materials sciences, and computing/information sciences. For that reason we hope to refocus LAMPF from a nuclear-physics facility to one aimed at two of these areas. This change will depend on upgrading the accelerator at LAMPF and creating an advanced spallation neutron source, a facility that will make the U.S. once again a world leader in the fast-growing area of neutron scattering.

Environmental research, an expanding area at Los Alamos, is one of the best examples of a field in which civilian and defense needs are served simultaneously. It also has great potential for industrial spin-offs. The government will be its own customer—and the Department of Energy, in particular, a big customer. At the same time the technological developments will surely spur competitive industry in the environmental arena.

As an example of a specific, large civilian technology project suitable for Los Alamos, I would mention first the clean, or green, car. You might ask why. There is a real possibility of designing nonpolluting automobile engines that are twice as fuel-efficient as present combustion engines. Such a development would clearly benefit the entire nation, not just the automotive industry. Another major project is the application of accelerators to the efficient destruction of plutonium, the elimination of high-level nuclear waste, and the production of energy. Los Alamos is already exploring specific systems, and they look quite promising.

The building of electronic highways across the nation that integrate computing and communication hardware and software is a realistic goal and one that will be of great benefit to business, industry, education, and healthcare. Los Alamos and its sister national-security labs have the in-depth expertise to develop and test prototypes of such systems, and I expect we will be called upon to do so. Finally, I'd like to mention our growing contributions to the biosciences. Our work on the Human Genome Project, structural biology, and medical diagnostics has already demonstrated the value of the Laboratory's combined strength in biology, chemistry, physics, mathematics, and engineering.

Many of these civilian technology projects will contribute to the economic performance of U.S. industry. But as the government increases support of civilian (in contrast to defense) mission-oriented research, it should not rely simply on spin-offs. Such research must be deliberately planned so that it will contribute to the industrial technology base. A good start would be to fund all such research jointly with industry. In the past industry has been uninterested in or even hostile to the government's attempt to help. Today we are seeing a marked change in those attitudes.

Commercial Technologies

Los Alamos and its sister laboratories (both defense and energy multiprogram labs) can make substantial contributions to long-term industrial competitiveness by devoting up to 20 percent of their budgets to working directly with industry. But to make this work, it must first be acknowledged that the labs cannot "save" industry. We should also replace the concept of technology transfer with that of industrial partnerships—deliberate collaborations with U.S. companies driven by the needs of industry.

The Laboratory's relationship with industry is part of a much larger issue, the proper role of the government in economic competitiveness. Progress has been hindered by the spectre of a national industrial policy that places the government in the position of picking winners and losers. The federal government has always influenced the private sector through macroeconomic factors such

A New Framework for Government-Assisted R&D

Technical output doubles every ten to fifteen years. To keep U.S. industry competitive, the government must judiciously support R&D and facilitate access to knowledge and innovative capacity. In *Beyond Spinoff* Alic et al. suggest public investment in a range of technologies in the vast gray area between basic research and commercial-product process development. Technology diffusion must also be specifically encouraged and supported.

Appropriate areas for government investment

I. Pathbreaking technology—arising from new science and potentially leading to new industries or transformation of existing ones.
- Government funding: pivotal at early stages because of high technical risk, uncertain practical payoffs.
- Examples: biotechnology, satellite communications, nuclear power, nuclear medicine, massively parallel computing.
- Payoffs: typically after ten years.

II. Strategic technology—of great importance to sectors of existing U.S. industry, typically requiring industry-centered consortia.
- Government funding: necessary because of high business risk and difficulty of sustaining the technological edge
- Examples: semiconductor process tools (the SEMATECH consortium is a model for the support of strategic technology), high-performance computing, machine tools.
- Payoffs: typically after five years.

III. Infrastructural technology—for improving the productivity of a broad spectrum of firms by making the design and development of products and processes more efficient.
- Government funding: necessary because of high cost of infrastructure, provides institutional and technical support, but must be arranged so benefits cannot be captured predominantly by any one firm.
- Examples: national computer networks, national facilities (such as wind tunnels, light sources, and supercomputer centers), research emphasis in areas such as solid-state chemistry and manufacturing sciences and engineering.
- Payoffs: typically begin immediately.

Mechanisms of technology diffusion

- Better access to foreign technical knowledge and to technical information in the United States
- Technical services and industrial extensions
- Collaborative technical activities among firms
- Investment in human resources.

as tax policy, trade policy, and antitrust laws. It has also had a direct impact through mission-oriented research in agriculture, health, space, and defense, although those initiatives were not articulated as explicit technology policies.

Today, the major shift in world military- and economic-power balance requires a new paradigm—one in which government is more aggressive. The American public has asked the government to add economic performance to the well-accepted government responsibilities in defense, energy, environment, infrastructure, and healthcare. Furthermore, President Clinton has made economic development the nation's number-one priority. The authors of *Beyond Spinoff*[1] provide a useful framework for how the government can help industry. In the federal laboratory system, the DOE laboratories offer the most potent vehicle for helping industry because together they represent approximately one-third, or $6.5 billion, of the government's $21 billion investment in that system.

I envision four principal mechanisms for the DOE laboratories to work with industry on commercially useful R&D: collaborative R&D partnerships, user facilities, technology assistance, and small business start-ups.

Currently the principal mechanism for collaborative R&D partnerships is the Cooperative Research and Development Agreement (CRADA), a vehicle created by legislation. The collaboration is cost-shared, so no money need change hands. The work is driven by the needs of industry, and the industry's right to intellectual property is protected. The CRADA is much maligned these days, and that's unfortunate, because I think it's a superb vehicle. Industry not only gets a match for their R&D dollars but also buys into the Laboratory's capabilities. Moreover, our experience demonstrates that the agreements can address each of the three high-priority areas for government assistance outlined in *Beyond Spinoff*; that is, pathbreaking, strategic, and infrastructural technologies.

Xerox, for instance, is interested in working with us on pathbreaking technology. They want to develop new paradigms in computing, along the lines of the lattice Boltzmann technique that we developed for solving nonlinear differential equations. Mobil and Schlumberger are not primarily interested in developing the next technique, but they'd like to apply lattice Boltzmann to very complex problems involving three-dimensional, two-phase fluid flow, an example of a strategic technology. They have massively parallel computers, so they don't need our hardware. They do, however, want our help in modeling complex flows. As an example of infrastructural technology, Mark Murphy, who spoke earlier this week, wants us to help his independent oil company with specific experimental capabilities in microseismic detection and the calculations needed to interpret the data. Los Alamos has already established thirty-eight CRADAs, and the main problem has been overcoming the red tape that bogs down their implementation. If the Laboratory had more decision-making authority, we could simplify and speed up the industry interface.

User facilities provide the second, very effective avenue for helping industry. Early on, national user facilities, such as accelerators and reactors, were primarily tools for nuclear and high-energy physics. More recently, nuclear reactors have been used for neutron scattering studies in materials science and bioscience. Accelerators have been constructed as sources of neutrons and x rays for studies of materials. Transmission electron microscopes, combustion-research facilities, materials-processing facilities, and DNA-sequence databases have all been made available to users. These facilities are very attractive to private companies and will enhance our ability to work with them. The Computational Test Bed at Los Alamos is an example of a new type of user facility designed specifically for industry. It

Cooperative Research and Development Agreements

The Laboratory has executed thirty-eight CRADAs in a wide variety of fields. The following is a sample:

- High-speed sequencing of DNA by detecting individual base molecules with laser-induced fluorescence (Life Technologies).
- Removing uranium and plutonium from soil using high-gradient magnetic fields (Lockheed).
- Developing the next generation of models of electromagnetic processes in semiconductor chips, of large molecules (containing several thousand rather than several hundred atoms), and of global climate change (Cray Research).
- Constructing random-access computer memories using new techniques so that the memories do not lose information when power is interrupted (Radiant Technologies).
- Developing ways to produce very stiff materials for the aircraft and automotive industries by coating materials with diamond or diamond-like carbon (DuPont and Sandia National Laboratories).
- Optimizing complex metal-forming operations by expanding models of tool-workpiece friction and material behavior, with applications to forming aluminum sheet (Alcan) and corrosion-resistant pipe (Exxon).
- Developing high-temperature-superconducting materials, fabrication technology, and device applications: electronics (DuPont), microwave communication devices (Neocera).
- Adapting advanced pattern-recognizing neural networks for use in simplified and inexpensive quality-control systems (Ethicon).
- Isolating fetal cells from the mother's blood in order to test for congenital diseases without invading the womb (MediGene).

The Los Alamos Computational Test Bed for Industry

The DOE-sponsored High-Performance Research Center at Los Alamos's Advanced Computing Laboratory keeps the Laboratory at the leading edge of computing. We have established the Computational Test Bed for Industry to provide U.S. firms with access to the latest scientific computing environment. In particular, the Test Bed

- allows U.S. companies to use high-performance computer hardware, software, networks, storage devices, and visualization tools on a cost-shared basis;
- promotes interaction of U.S. companies with computational scientists and engineers at Los Alamos who have extensive experience with the most recent hardware and software;
- allows U.S. companies to test and improve their own programs;
- hosts industrial internships as well as conferences and workshops for industrial scientists and engineers;
- facilitates communication and collaboration between the Laboratory and industry on state-of-the-art hardware, software, and applications.

Educational workshops

- Nuclear Criticality Safety Workshop (completed fall, 1992)
  Applications of Monte Carlo transport techniques to the storage, environmental impact, transportation, and siting of fissile material
- Technology Commercialization for the Petroleum Industry Workshop (summer, 1993)
  Modeling of oil exploration, environmental impact, seismic imaging, refining, and remediation
- Environmental Modeling Workshop (under discussion)

Examples of industry-sponsored internships

- DuPont is participating in design and construction of a Gigabit Testbed.
- Electronic Data Systems is studying workstation clusters as well as the gasoline combustion/emission problem and is participating in benchmarking the Connection Machine 5.
- Schlumberger-Doll plans to use the CM-5 to study bio-remediation.
- The oil industry plans to implement seismic-imaging codes on the CM-200 and CM-5.
- Rocket Research plans to study design of arcjet-rocket thrusters.
- Xerox plans to model xerography.
- Texas Instruments plans to model semiconductors.
- BIOSYM Technologies plans to develop commercial materials-modeling software.

provides education and training as well as direct use, and it should serve as a model for other such facilities.

Technology assistance is the third avenue of collaboration. As you all know, much of the innovation and the job creation in this country is done by small companies. They incorporate new technology more quickly than large companies because their survival depends on it. Yet they often do not have their own research capabilities. For instance, the machine-tool industry in this country is only approximately 25 percent computerized and they need help to take better advantage of computers. We can provide that help. We could get on board with the National Institute for Standards and Technology (NIST) to work within the manufacturing extension centers. Through the nuclear weapons program and its legacy, many of our people have worked as liaisons in the DOE production plants. They developed the CAD/CAM systems for those plants and could do that for industry today.

Assisting small business start-ups, or creating them, is the fourth avenue and the most direct way of introducing new technology into the marketplace. It's even better than helping existing small companies. Although we have spun off thirty-eight companies in the past ten years, such start-ups have not been a large focus of ours in the past. They have, however, been successfully encouraged at universities in the areas of computer software and biotechnology. We have extensive software and biotechnology capability, and now we have a substantial environmental capability. So we view small business start-ups as a promising avenue for getting technology into the marketplace.

Clearly, there is no single magic bullet for improving the nation's economic performance. In the next few years the nation must experiment with several approaches. Progress will have to be monitored, and future funding of collaborations will have to be based on success with industry as well as the ability to demonstrate public good. But this is a very new area for the Laboratory and the government. Our emphasis should be on the creation of long-term relationships rather than on the production of short-term payoffs. We should continue to expose our industrial partners to the best of science, but we must also listen to them and allow their problems to drive our collaborative work. In the meantime, the Laboratory and the government must sharpen the national missions that will account for the bulk of our work. We should also involve industry in these missions so that as we accomplish the government's goals we also strengthen the nation's industrial science and technology base. Through fulfilling those missions, the Laboratory will also be able to sustain its core technical competencies, which, in turn, will provide the source of innovative contributions to commercial technologies.

Scientifically and technically we can rise to the challenge before us. Los Alamos has superb facilities and is still able to attract the best talent in the world. We are very strong in the vast area between basic research and product design, which many claim needs shoring up in the nation's science and technology base. Most of our bench-level skills are interchangeable among defense, civilian, and commercial missions, and we are capable of applying them to all three.

Our superb scientific capabilities notwithstanding, the management practices that have evolved over decades of defense dominance demand a major overhaul. As we maintain our emphasis on science and innovation, we must streamline the bureaucracy. I view this challenge as similar to that faced by most of U.S. industry over the past decade. We've spent a lot of time in the last few years studying institutions and corporations who've gone through their institutional renewals, companies such as Motorola, which started that process in 1979 and today is one of the most competitive companies in the world. We are beginning to simplify our organizational structure, change the way we manage, increase our focus on productivity, and become more responsive to a wider agenda. We are also working with the government to develop a partnership that will restore the institutional flexibility and agility necessary in a fiercely competitive environment with multiple missions and multiple customers.

Our world has changed, our missions are changing, and we must work together to change our institution. I'll close with the message Charles Herzfeld gave us yesterday: "There is plenty to do—let's go do it." ■

Further Reading

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