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Pacific Northwest National Laboratory Institutional Plan FY 1997-2002

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Pacific Northwest National Laboratory
Richland, Washington 99352

Disclaimer

Pacific Northwest National Laboratory

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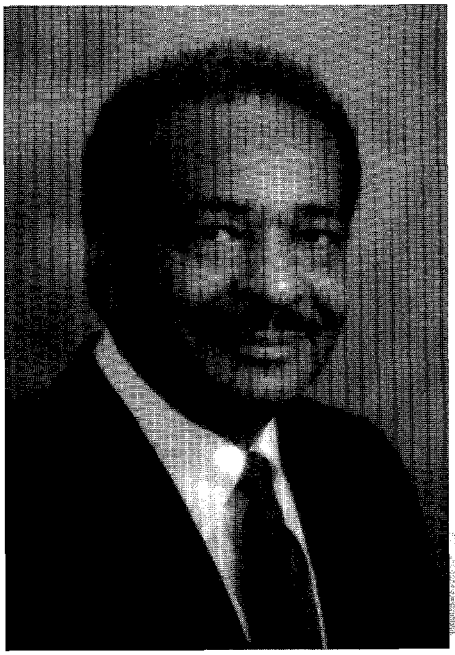
The FY 1997-2002 Institutional Plan is dedicated to the memory of

Dr. William R. Wiley

1984-1994, Laboratory Director



"We have moved from the age of atoms to the age of molecules."

—Bill Wiley

On October 16, 1996, Secretary of Energy Hazel R. O'Leary dedicated the William R. Wiley Environmental Molecular Sciences Laboratory. The new U.S. Department of Energy facility was named in honor of Wiley, who championed basic molecular science research during the 10 years he served as Pacific Northwest National Laboratory's director. Wiley's foresight, determination, and leadership inspired many to unite in turning his vision into reality.

Contents

1 Director's Statement

On October 16, 1996, Secretary of Energy Hazel R. O'Leary dedicated the William R. Wiley Environmental Molecular Sciences Laboratory and wrote the opening pages of a new, exciting chapter in the history of the Pacific Northwest National Laboratory. By the fall of 1997, we expect EMSL to be in full operation as the first major Department of Energy user facility located in the Pacific Northwest.

The EMSL is the latest addition to the family of DOE scientific user facilities that is so central to our nation's research enterprise. Like the Advanced Photon Source at Argonne, the Advanced Light Source at Lawrence Berkeley, the National Synchrotron Light Source at Brookhaven, and the materials science facilities at Oak Ridge, the EMSL will bring the nation's research community together around critical scientific challenges and provide powerful new instruments with which to meet those challenges. As the newest addition to the nation's scientific infrastructure, the EMSL is focused on science that will make a difference on critical environmental and national issues.

Many of the environmental problems DOE faces at the Hanford Site are shared problems—shared with other DOE sites, military installations, industrial complexes, municipalities, etc. Groundwater contamination is one such problem. At sites across the United States and around the world, groundwater is contaminated with toxic chemicals. Existing solutions are piecemeal and expensive and often merely contain rather than solve these problems. The research conducted in EMSL will expand our basic understanding of the transport, fate, and effect of contaminants in the subsurface. This understanding will enable us to better judge the risks posed to ecosystems and human health by groundwater contamination and to develop genuine solutions to critical problems.

At EMSL, chemists and biologists will work together to develop and improve bioremediation technologies that help clean up the environment naturally. For instance, at Hanford and around the world society faces tremendous environmental and health challenges from cancer-causing solvents and other chemicals. Sunney Xie, a chemical physicist at EMSL, is collaborating with Professor Luying Xun, a molecular biologist at Washington State University, to study how enzymes break down these chemicals. Using an advanced optical microscope developed at EMSL, Xie and Xun will be looking at the emissions from the active site of an enzyme. They expect to take a first look at a single enzyme blinking on and off as it completes a reaction to break down chlorinated hydrocarbon.

Environmental cleanup is a vitally important mission both for Hanford and DOE, but it will also be of limited duration. Indeed, part of our job is to hasten the day when DOE sites no longer pose significant risk to our people or the environment. Beyond the cleanup missions at Hanford and other DOE production sites we also look toward pollution prevention, waste minimization, zero-discharge manufacturing, and inherently clean process technology. We have an obligation to future generations to ensure that our production or use of energy creates no new sites like Hanford nor any comparable large-scale environmental problems.

We expect EMSL to play a significant role in the development of pollution-preventing technologies. For example, the petrochemical industry uses gaseous hydrogen fluoride as a catalyst to break down crude oil into more refined products such as gasoline for our automobiles. Indeed, the waste streams produced by these processes are so hazardous and difficult to treat that California has banned the use of gaseous hydrogen fluoride as a catalyst in any new petrochemical refinery. Researchers in the EMSL are collaborating with scientists at Catalytica, an industrial firm, and at Texas A&M University to investigate the potential for a "solid-acid" catalyst that would eliminate these hydrogen-fluoride-containing waste streams.

Dr. William J. Madia, Director, Pacific Northwest National Laboratory

In the area of human health, research conducted in the EMSL can help us better understand the effects of environmental pollutants on DNA and answer questions such as: What are the health consequences of exposure? Is there DNA damage? Can it be repaired? To answer some of these questions, researchers in the EMSL will use a suite of high-field magnetic

resonance spectrometers to study the molecular basis for damage recognition in DNA. Such information will have applications in the strategies used in cancer research. This work, headed by EMSL's Paul Ellis, will be done in collaboration with researchers in our Health Division, the Los Alamos National Laboratory, the University of Washington, Washington State University, the University of Idaho, and Washington University at Saint Louis.

In addition to its environmental mission, we expect EMSL will support DOE in pursuing a science-based energy strategy that will provide clean, safe, economic energy for the future. We need to make dramatic improvement in the economic and environmental performance of our energy technology, and this improvement depends on developing and applying new scientific and engineering knowledge.

Here too, EMSL capabilities have a role. By advancing our ability to design materials at the nano-scale and to combine these nano-structures in the form of films and membranes with engineered micro-structures, we and our collaborators hope to strongly impact energy applications such as selective gas separation, efficient material transformation, high-performance heat exchangers, high-density energy storage, and improved batteries.

The EMSL also will have a substantial role in national security. For instance, EMSL capabilities in chemical sensor design are being used in the development of micro-sensors for arms control and nonproliferation. Under funding from the Advanced Concepts Program in DOE's Office of Nonproliferation and National Security, EMSL researchers have developed selective coatings for chemical field effect transistor detector arrays to detect a solvent typically used in the large-scale reprocessing of special nuclear material.

Art Janata and his collaborators are taking the Microfabricated Sensor Arrays Project into the development phase and extending it to the detection of effluents indicative of the spread of weapons of mass destruction, particularly chemical and nuclear weapons. EMSL researchers also are using advanced laser spectroscopy techniques to detect trace amounts (on the order of parts per trillion) of gases resulting from chemical and nuclear processing in weapons programs. Both sensors have dual applications in environmental cleanup and in national security, where they can be used on the ground or in aircraft as part of monitoring surveys to detect treaty violations.

Throughout this statement, I have mentioned opportunities for collaboration with other research institutions, and indeed, an important component of the EMSL is its collaborative research environment. "The Collaboratory," as it is often called, is an electronically enabled mechanism for EMSL researchers to share their expertise and data, and the facility's unique scientific instruments, in real time with colleagues around the world. This mechanism also enables EMSL researchers to access remote scientific information and capabilities that can be applied to their own environmental and molecular science research. More than 200 collaborative working agreements have been established between EMSL staff and scientists at research universities, other federal laboratories, and private-sector institutions worldwide.

It is also important to remember that one of the primary missions of the EMSL is to provide opportunities to educate and recruit young scientists to meet the demanding environmental challenges of the future. Through student internship programs, collaborative research with university scientists, postdoctoral appointments, and outreach activities targeting local educational institutions, EMSL staff will encourage young men and women to pursue careers in science. In addition, many EMSL scientists are already serving dual roles as researchers and as instructors in regional colleges and universities.

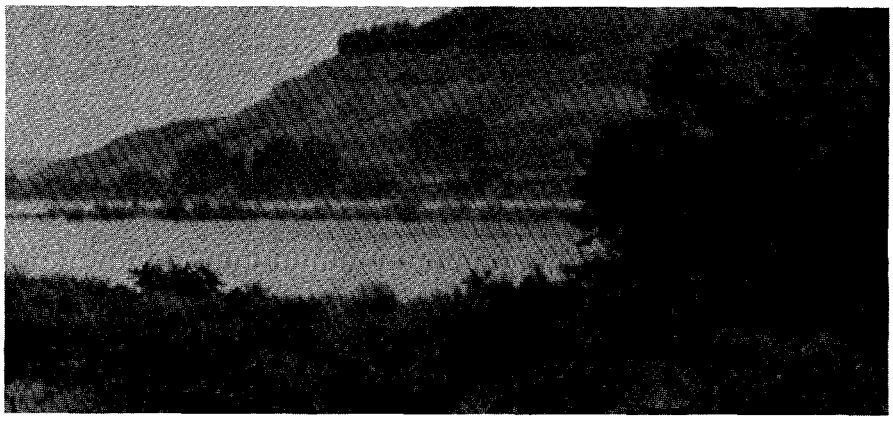
We are all proud that EMSL was dedicated to Bill Wiley. He introduced and championed the concept of a scientific user facility dedicated to molecular science during the ten years he served as Laboratory Director. In the final analysis, however, this was a team effort, and literally hundreds of people played crucial roles in transforming Bill's vision to reality: the men and women here at Pacific Northwest, our colleagues at DOE Headquarters and in the Richland Operations Office, and our collaborators at universities and other laboratories. Together they established an unparalleled new scientific resource for our nation.

Bill's sudden death earlier this year was a shock to all of us, and while we regret that the dream outlived the dreamer, we take great pride in the legacy he has left this Laboratory and this nation.

Let me end with this. The William R. Wiley Environmental Molecular Sciences Laboratory is an investment in science with real, tangible products—a cleaner environment, enhanced human health, a science-based energy strategy, and improved national security—with the added benefits of a state-of-the-art collaborative user facility and major educational resource. In the years ahead, scientists in EMSL will fulfill the destiny Bill Wiley envisioned for this laboratory by making our world a better place for future generations.

2 Laboratory Mission and Core Competencies

As part of our planning, we regularly reevaluate our mission and review the technical capability portfolio of the Pacific Northwest National Laboratory. We realize that in a time of limited resources, we must make careful choices both about what problems we will solve and the technical capabilities we will maintain. This need for reevaluation was confirmed by similar activities conducted by the Department of Energy, such as the Task Force on Alternative Futures for the Department of Energy laboratories, the Department of Energy's Strategic Plan, and, most recently, the Department's Strategic Laboratory Mission Plan, Phase I. We believe our mission must be closely coupled with the DOE Strategic Plan, consistent with the Strategic Laboratory Mission Plan, and appropriately matched to our technical capabilities.



Pacific Northwest's core mission is to deliver environmental science and technology in the service of the nation and humanity. Laboratory researchers are addressing today's environmental needs with technologies that prevent pollution and minimize waste.

Mission

We have articulated our mission as follows:

Pacific Northwest's core mission is to deliver environmental science and technology in the service of the nation and humanity. Through basic research we create fundamental knowledge of natural, engineered, and social systems that is the basis for both effective environmental technology and sound public policy. We solve legacy environmental problems by delivering technologies that remedy existing environmental hazards, we address today's environmental needs with technologies that prevent pollution and minimize waste, and we are laying the technical foundation for tomorrow's inherently clean energy and industrial processes. We also apply our capabilities to meet selected national security, energy, and human health needs; strengthen the U.S. economy; and support the education of future scientists and engineers.

This mission is in line with the DOE Strategic Plan and draft Strategic Laboratory Mission Plan, where Pacific Northwest is designated as a Principal Laboratory in the Environmental Quality mission, a Major Contributing Laboratory in both Science and Technology and Energy, and a Participating Laboratory in National Security.

The mission is also consistent with the technical work carried out at our Laboratory. Fully two-thirds of the Laboratory's work is in environmental science, environmental technology, or both. Further, our projects in support of DOE's national security and energy missions often draw heavily on capabilities we have developed in support of our environmental mission.

Core Competencies

The concept of "core competencies" has become increasingly central to the management of the Laboratory over the last few years. The distinguishing feature of the Laboratory is the ability to bring multiple technical and support capabilities together to solve complex problems. Although we are proud of our strength in a number of technical disciplines, our core competencies must be more broadly defined. We view core competencies as those few broad, integrated capabilities that allow us to deliver robust solutions to the most complex environmental challenges facing the Department of Energy and the nation.

Pacific Northwest has developed and maintains the following three core competencies:

- *Integrated Environmental Research* encompasses the capabilities necessary to provide a whole-system approach to environmental issues, including sensing and measurement of environmental contaminants; characterization of physical processes in the earth's interior, ocean, and atmosphere; the transport and fate of contaminants in the environment; the interaction of biological or ecological systems with their physical environment and their response to contaminants in that environment; and the technical, economic, and regulatory analysis of policy alternatives.

- *Process Science and Engineering* encompasses the capabilities necessary to develop process technology for both environmental remediation and for pollution prevention and waste minimization, including advanced chemical separations, the mechanics of complex fluids, selected aspects of catalysis, selected aspects of materials science, and process design and testing.
- *Energy Systems Development* encompasses the capabilities necessary to design and efficiently operate environmentally benign energy generation, distribution, and utilization technologies, including automated diagnostics and controls, buildings science, power system engineering, and selected aspects of materials engineering and specialty component fabrication.

Each of these three core competencies is a synthesis of the technical and other capabilities necessary to deliver complete solutions to broad classes of problems. Our strategies for capability development are based on the health of these competencies and on our understanding of the future problems to which they will be applied.

To ensure that our core competencies remain on the leading edge, we actively manage and plan around a larger set of underlying technical capabilities, which we define along more traditional disciplinary lines. Technical capability leaders maintain active networks to ensure a high level of internal and external communication, and prepare assessments of the capabilities and development plans that are designed to ensure continued excellence and relevance in each of the technical capabilities. These more detailed technical capabilities are also a key building block in our effort to strengthen and make more uniform our technical peer review practices.

3 Laboratory Strategic Plan

For the Department of Energy laboratories, this remains a time of rapid change, unprecedented in recent times. The nation's security needs have been redefined by the end of the Cold War, the potential proliferation of nuclear and other weapons technologies, and the need to respond to incessant regional conflicts around the globe. We face fierce competition from developed and developing nations as the economic predominance that we took for granted only a few years ago has eroded. Economic growth in the developed nations and population growth and the drive toward increased standards of living in the developing world are intensifying our environmental challenges. As a result, domestic priorities are being rethought in light of economic and fiscal constraints. The social contract under which the nation's taxpayers have broadly supported scientific research, formed at the end of the Second World War and renewed in the space race era, is being reexamined.

The nation's review of our commitments to science and technology includes a reevaluation of our scientific institutions. As with other federal laboratories, the mission, size, governance, and even existence of the Department of Energy laboratory system is in question. The Task Force on Alternative Futures for the Department of Energy National Laboratories, led by Robert Galvin, released its report in February 1995. This report recommended sweeping changes in governance and management practice. The task force also urged an increased focus on national security, energy, and environmental missions, and on related basic research, and identified what it believed to be overcapacity in the laboratory system. Similar reviews of other major elements of the federal laboratory system have been completed under the purview of the National Science and Technology Council. In response to these reviews, DOE and the national laboratories have undertaken an array of initiatives to strengthen mission focus and improve productivity. However, there is continuing discussion within both Congress and the Administration on roles, missions, and budgets for the laboratories.

How can we best respond to these dynamic times? Our fundamental goal is to make the Pacific Northwest National Laboratory the most relevant (i.e., we will focus on the highest value needs of DOE and the nation) and productive supplier of science and technology in those areas where we concentrate our efforts. Our work must be understood, valued, and supported by not only the scientific community and policymakers, but also by the public. Our view of productivity encompasses four key elements: quality, timeliness, cost-effectiveness, and stewardship. If we provide timely delivery of high-quality products at a reasonable cost while exercising stewardship for our staff, intellectual capital, research equipment and facilities, community, and the environment, then this Laboratory will have a bright future.

Primary Planning Assumptions

During the last year, we reexamined our primary planning assumptions in light of the continuing national debate over the direction and magnitude of the federal science and technology investment. We concluded that we needed to take into account the great uncertainties around short-term political decisions and the longer-term uncertainties surrounding the drivers that determine national needs. Accordingly, we chose a planning scenario, which allowed us to examine the consequences of a variety of outcomes of the current political debates and the various drivers that determine national needs for science and technology. The figure lists the major trends or issues considered in our planning scenarios.

As part of our planning, we developed four scenarios that allowed us to address the issues. The scenarios were built around different threads in the current U.S. policy debates and led us to recast some of our fundamental planning assumptions.

With regard to *science and technology policy and budgets*

- There will be continued tension between two highly divergent views of the role of federal investment in science and technology, and we must be prepared for either to dominate policy and budgets for a period of time. There is the belief that federal investments should be largely restricted to basic science. Alternatively, there is the view that in a time of limited resources and pressing problems federal research and development investments should be explicitly tied to the most pressing technology and policy needs, including industrial competitiveness. With the former view, we expect flat basic research budgets and sharp decreases in funding for applied research, perhaps with the exception of the national security area. In the latter view, an increased share of the available resources will be allocated to needs-driven research programs in areas such as health care, transportation, environmental remediation and protection, national security, and energy reliability, and to collaboration with industry in commercially important technologies.
- Resources of all types will be limited. The total national investment, public and private, in science and technology

Trends and issues considered in scenario development (partial list)

External Drivers

Population trends and changing demographics (U.S. and world)
Pace and impact of environmental deterioration on local and global scales
Trends in food production, water supply, and availability of agricultural lands
Reliability, adequacy, and cost of energy supplies
The nature and degree of international tensions and conflicts
The proliferation of weapons of mass destruction
The nature and likelihood of a defining crisis or event

U.S. Government

Degree of international engagement on both security and trade matters
Possible devolution of responsibilities from federal government to states
Science and technology policy, priorities, and funding
Future role and missions of the Department of Energy and of the laboratories
Changes in regulatory practices
Alternative approaches to weapons complex cleanup

U.S. Economy and Other Domestic Issues

Health of the U.S. economy
Health of U.S. cities and urban policy
Evolution of the U.S. health care system
Trends in industrial research and development funding levels and orientation
Evolution of the U.S. energy industry

will grow slowly over the next few years. Federal investment will be sharply constrained for the foreseeable future by the ongoing attempt to balance the federal budget. Although we believe that the declines in science and technology funding may not be as severe as proposed in the current year's budget balancing plans, significant reductions in inflation-adjusted funding are highly likely over the next 5 years. As a result, there will be unprecedented technical and political competition for scarce investment resources.

With regard to *national needs* that will drive science and technology policy in the intermediate and longer term

- The tension between economic development, or meeting human needs, and protection of our environment will be a primary long-term driver for science and technology investments. Technology that allows economic growth while maintaining our environment will be critical.
- Although industrial research and development investments should show continuing modest growth, the well-documented trend in industrial investment toward short-term, product-related research will likely continue. Many industries will, therefore, look to government-supported research in the universities and federal laboratories to provide the new knowledge from which breakthrough commercial technologies can arise.
- We expect that the current high level of social and political instability and consequent regional-scale conflicts will continue for the foreseeable future. The U.S. role in peacemaking or multilateral peace-keeping efforts, and in nonproliferation and arms control, will be a significant driver for national security needs.

With regard to the *Department of Energy and the laboratory system*

- A reduction in the overall size of the federal laboratory system remains likely, and further reductions in the DOE laboratory work force are also likely. Closure of federal laboratories remains possible.
- The Department of Energy and its national laboratories will remain under fierce pressure to improve management practices and increase productivity. In response, DOE and the laboratories will continue the trend toward use of best commercial practice, outcome-oriented performance measures, and identification and elimination of low-value-added activities.
- Advances in scientific instrumentation, computing and information technology, scientific knowledge, and engineering practices will be very rapid by past standards. Continual reinvestment in the knowledge and expertise of our staff and in our research equipment and supporting infrastructure will be required if we are to remain relevant, productive, and competitive for research funding.
- We will face substantial challenges in attracting, retaining, and motivating staff through the next few years as we deal with the combined impacts of continued funding uncertainties and our recent work force restructuring.

The Laboratory Agenda: Our Role in the Department of Energy Strategic Plan

As part of our ongoing planning, we have revisited our strategic objectives in light of both our progress toward our stated goals and evolution in DOE guidance and strategy. This has led to modest refinement of several of our objectives. This year we have organized our high-level objectives into a framework that will enhance communication and provide a more strategic view of our plans. This framework called the *Laboratory Agenda*, has four components, as illustrated in the figure.

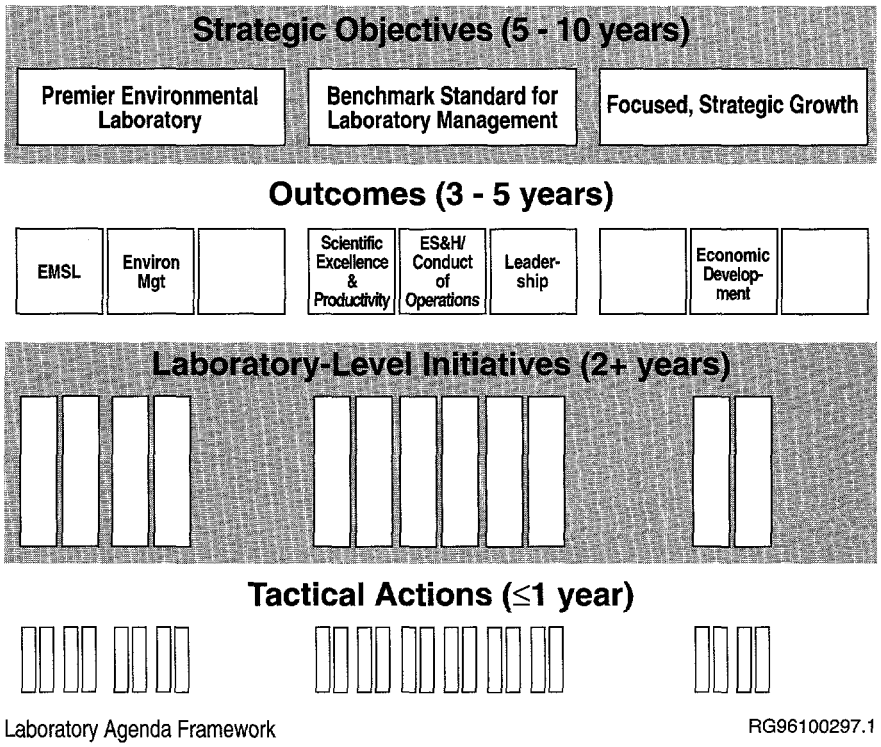
Strategic Objectives are our broad, long-term (5 to 10 year) goals for the future of the Laboratory. These Strategic Objectives provide an organizing framework for the programs and

management initiatives that we undertake in response to the DOE strategic plan. Critical Outcomes are our highest level intermediate-term (3 to 5 year) tangible results that we deliver for DOE, and are the principal building blocks by which we achieve our strategic objectives. Progress toward these outcomes is the heart of the Department's performance assessment for the Laboratory. Laboratory-level Initiatives usually have a lifetime of 2 to 5 years and are specific programs that we put in place to achieve some element of our outcomes. Our full agenda includes the tactical or shorter-term implementing actions that we undertake.

The Department's Strategic Plan establishes goals in each of its core missions: Science and Technology, Environmental Quality, Energy Resources, and National Security. In addition, the plan articulates DOE's role in strengthening the nation's economy as a derivative outcome of success in these core missions. The plan also discusses a number of critical success factors that define the principles by which DOE conducts its work.

The Strategic Laboratory Mission Plan describes the role of the national laboratories, as a group and individually, in carrying out the Department's strategic plan and in each of the Department's major programs. The figure shows the relationship between these documents and our Laboratory Agenda.

We have organized our Laboratory agenda around three long-term strategic objectives. Our first, becoming a **premier environmental laboratory** through our science and technology contributions, provides the long-term framework for our primary objectives in support of the Department's missions. Becoming the **benchmark standard for laboratory management** provides the framework for our response to the critical success factors articulated in the DOE strategic plan, and to the improvement efforts that have derived from the Department's response to the Galvin Commission report and other studies. Our final strategic objective, achieving **focused, strategic growth**, represents our



Laboratory Agenda Framework RG96100297.1

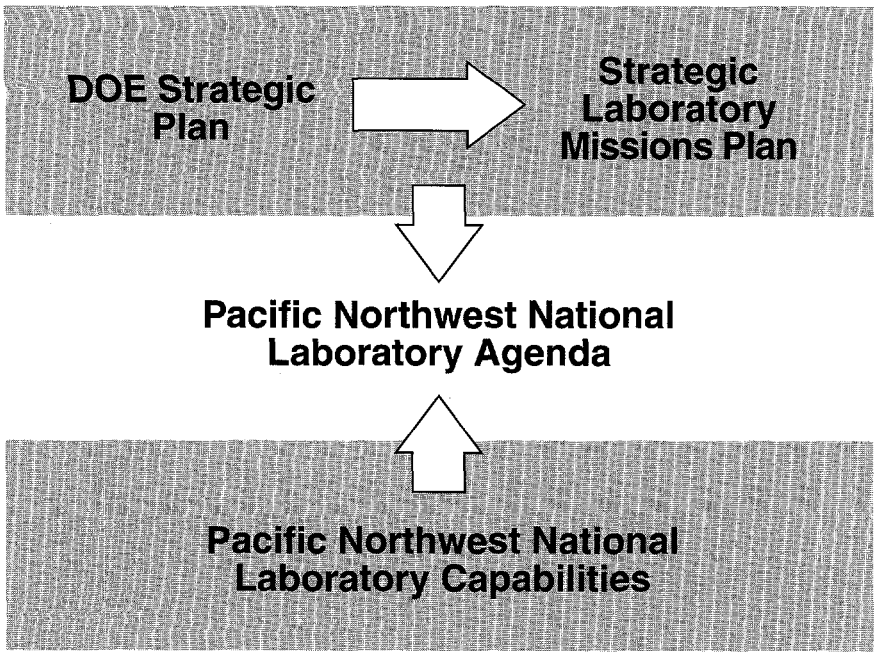
commitment to ensure that the Laboratory remains a vital resource to the Department over time, and incorporates our efforts in support of the Department's commitments to local economic development and diversification of its host communities.

Creating a Premier Environmental Laboratory: Our Role in DOE's Core Missions

We intend to be a premier national laboratory as measured by the science and technology we produce, focused around our core environmental science and technology mission, and with significant contributions in our energy, national security, and health work. We will achieve this strategic objective as the long-term result of outstanding technical contribution in each of the missions we serve: Science and Technology, Environmental Quality, Energy Resources, and National Security.

Science and Technology In keeping with our environmental mission, our science portfolio has two primary components. We are heavily engaged in the environmental sciences, including the investigation of the processes by which contaminants are transported and transformed in the environment and the impacts of those contaminants on ecological systems. We also maintain leading-edge programs in those aspects of the chemical, material, and life sciences that underlie creation of environmental technology, or that are required to understand the interaction between natural and biological or engineered systems. Through these programs we support four of DOE's five Science and Technology goals (we have no significant role in DOE's high energy and nuclear physics programs).

Our Critical Outcome in support of DOE's Science and Technology mission is to deliver the Environmental Molecular Sciences Laboratory as a preeminent collaborative research facility, and in so doing, bring the nation's best scientific talent to the Department's critical environmental challenges. We are committed to provide the maximum possible scientific capabilities in this Laboratory. With the construction project nearing completion, our emphasis over the next



Laboratory Agenda

2 or 3 years will be on initiating operation as a user facility and developing the high-quality programs and collaborations necessary to realize the full benefit from this unique facility.

In line with the Energy Research strategic plan, we are also continuing our emphasis on fundamental science related to human health and to the development of applied medical technologies that derive from our technical capabilities in imaging, information technology, materials science, and other areas. We will improve the condition of human health through the development of fundamental scientific understanding and deployment of technologies that facilitate the assessment and management of health risks, the analysis of the safety and effectiveness of pharmaceuticals, and that reduce the time and resources required to develop drugs and chemicals and microbes for bioremediation.

Over the next 5 years we also intend to continue our emphasis on bringing new scientific knowledge to bear on DOE's environmental, energy, and national security missions. For example, the programs housed in the EMSL will be fully successful when the resulting knowledge has significant impact on DOE's environmental remediation programs at Hanford and across the complex, and more broadly, on the environmental management challenges facing the nation. Similarly, our energy programs increasingly reflect the application of basic scientific and engineering work, such as our microtechnology investments, to the creation of new, environmentally benign, pollution preventing technologies. Our nonproliferation and arms control programs must remain well-connected to our environmental science and technology base in areas such as radiation detection and chemical sensors.

We will continue our contributions to systemic reform of scientific and mathematics education in support of DOE's efforts to provide a technically trained, diverse work force of the future and to ensure a technically literate citizenry. We will continue to concentrate on curricular reform, on regional outreach, and on strengthening our ties with historically black colleges and universities and other minority institutions. We intend to increase the fraction of our research that is carried out in partnership with the university community and to continue providing research participation opportunities to visiting students, teachers, and university faculty.

Environmental Quality Pacific Northwest is designated as a Principal Laboratory for the Environmental Quality mission in the Strategic Laboratory Mission Plan. In keeping with that designation, we have strong leadership roles in the two principal science and technology goals asserted in the DOE Strategic Plan: reduction of the health and environmental risks associated with both legacy production sites and current operations, and development of environmental technology. Our Critical Outcome here is *that we and* our research partners will deliver knowledge required to make scientifically sound risk-based decisions and deliver technology that reduces the cost and improves the timeliness and effectiveness of environmental remediation at Hanford and across the entire DOE complex. We will support DOE in achieving a scientifically defensible, risk-based remediation strategy and schedule, and deliver technology that helps DOE meet that schedule at affordable cost. To fulfill this intent, we have added a fundamental molecular sciences capability to our long-term strength in the environmental sciences. On the engineering side, we are strengthening our system engineering skills to complement our long-standing capability in the design of complex processing systems.

To fulfill the Department's strategic intent and to meet the expectations of the nation's taxpayers, the environmental remediation program requires intense effort over the next few years. In the long term, however, a strategy of pollution prevention and environmental protection must replace the strategy of waste management and environmental restoration. We must protect our environment through use of inherently clean processes rather than through costly post-pollution remediation. Pacific Northwest, in partnership with our sister laboratories and with U.S. industry, will be a national resource of environmentally acceptable technology and, again in partnership with our laboratory and university colleagues, will provide the underlying science required for future advances. Our principal focus areas, in line with the DOE Strategic Plan and as reflected

in our current initiatives, are industrial process technology and commercial and residential energy end-use technologies.

Energy Resources We believe that DOE's Energy Resources mission will be of increasing importance to the nation for the foreseeable future. Our programs support three of the goals specified in the DOE Strategic Plan: enhancing energy productivity; ensuring reliable, secure energy supplies; and reducing the environmental impacts of energy production.

Two of our objectives in the energy area are

- for the near term, improving the utilization of the current national and international energy infrastructure through development of technologies that save energy and control costs
- for the longer term, developing the next generation of science and technology to increase our nation's energy security in an environmentally acceptable manner consistent with an increasingly competitive energy marketplace.

Accordingly, we will continue our focus on enhancing the resource efficiency and performance of existing energy assets (and most particularly transmission and distribution systems), and our work with government and the utility industry to develop a new generation of distributed energy systems. We will also continue our investment in the capabilities required to develop and deploy resource-efficient pollution prevention and waste minimization technologies that enhance the economic, energy-efficiency, and environmental performance of government and U.S. industry. The development of effective partnerships around major Northwest energy issues, such as management of our watersheds to accommodate the often conflicting multiple objectives of power generation, habitat preservation, and supply for agricultural uses, is an important element of our strategy.

Finally, we are supporting the Department's efforts to help developing and rebuilding countries create a balanced, coordinated, and sustainable portfolio of energy sources; efficient or sustainable energy consumption practices; and a reliable energy infrastructure. Over the last 3 years, we have become increasingly engaged in Eastern Europe, the Far East, and Central and South America through the creation of independent Energy Efficiency Centers, and we expect to continue to play an active role. We believe that this outreach effort will be of increasing importance to DOE.

National Security Of the five primary national security goals asserted in the DOE Strategic Plan, we focus on support of DOE's nonproliferation and arms control goal. The rationale for our involvement is straightforward. The Laboratory's core technical capabilities and key technologies, developed through our environmental science and technology programs have direct application to critical nonproliferation and arms control challenges facing the Department as well as meeting national security needs in defense-related activities. Also, we support the goal to continue enhancement of the technology infrastructure and core competencies for the execution of the national security mission. In addition, and of particular current interest, our expertise in nuclear power and related technologies is highly relevant to current U.S. policy goals to reduce the danger associated with power producing reactors in the former Soviet Union. We are not, and have no intention of becoming involved in maintenance of the DOE national security infrastructure, in weapons science and technology, or in weapons dismantlement.

Our primary objective is to leverage our environmental science and technology base to develop arms control, nonproliferation, and intelligence technologies that enhance national security and reduce the danger from weapons of mass destruction. We also pride ourselves on the ability to respond rapidly to urgent technology needs in our areas of expertise and plan to maintain that capability. Finally, in the last 2 years, we have assumed significant programmatic and technical responsibilities in DOE's effort to reduce the danger associated with power reactors in the former Soviet Union. Over the next 5 years we will devote substantial staff and management resources to meeting those responsibilities.

Benchmark Standard for Laboratory Management

Our Strategic Objective is to be the benchmark standard of excellence for laboratory management, providing the Department of Energy and the nation with the greatest possible research product for each dollar invested in our laboratory while fully meeting our responsibilities for the health and safety of our workers and the public, and for protecting the environment. This Strategic Objective provides the long-term framework for our response to the Critical Success Factors laid out in the DOE Strategic Plan, and to the set of improvement initiatives that DOE has launched over the last 2 years.

The DOE Strategic Plan establishes goals associated with each of four primary Critical Success Factors: communications and trust; human resources; environment, safety and health; and management practices. Broadly speaking, these critical success factors and the associated goals and initiatives represent a commitment by DOE to be "best in class" in meeting the performance expectations of the public.

We have established three Critical Outcomes in the areas covered by DOE's Critical Success Factors that we believe are essential to the continued success and vitality of the Laboratory. First, we recognize that the heart of the Laboratory is made up not of facilities or equipment, but by our research and administrative staff. Accordingly, we are committed to building a tradition of interactive personal and institutional leadership, encompassing the entire staff of the Laboratory. Our Critical Outcome is that we will recruit, develop, and retain a diverse staff recognized for scientific, intellectual, and personal leadership for the integrity of our research and business practices, and for our contributions to the community and the nation. This commitment takes on particular importance in light of the programmatic and staff reductions that we experienced in

1995 and the continuing funding and other uncertainties that challenge our staff through 1996.

Second, the Department's Strategic Plan communicates a strong and unambiguous commitment to operations to ensure the health and safety of our work force and the public and with respect for the environment. Our Critical Outcome is that we will manage our facilities and conduct our work in a manner that protects the environment and the health and safety of our staff and the public. We and the Department jointly established this commitment in our planning for 1995 as one of our Critical Outcomes by the recognition that, although our environment, safety, and health statistics were good as compared to industry standards, our operating practices did not yet fully conform to the standard of excellence expected by DOE and the public. We have evolved as rapidly as possible through implementation of a Laboratory-wide operations improvement program to an improved level of performance. In carrying out this effort, we are working with DOE to establish the appropriate standards for each aspect of our operations, and designing management systems to ensure that we cost-effectively meet those standards. While making these significant changes, we remain committed to maintaining or exceeding our past performance on traditional measures of environment, safety, and health outcomes.

Third, we must meet DOE's and the public's expectation for cost-effective operation. We must significantly improve our productivity and cost-effectiveness, becoming one of the highest value providers of science and technology in the world. Accordingly, we have established a Critical Outcome in the areas of Scientific Excellence and Productivity. We are committed to becoming the benchmark case for management of national laboratories in terms of value of the work we do; the quality of the working environment; our organizational effectiveness; the stewardship of our human, physical, and intellectual assets; and our cost-effectiveness. In 1995 we initiated a major, multiyear productivity enhancement initiative, Achieving the Competitive Edge (ACE). During 1996 we have implemented many of the improvements identified in the diagnostic phases of this initiative, during which we examined in detail the value of our products, both those we deliver to customers and those we produce in our management of the institution or in response to DOE requirements. We are achieving a significant increase in the fraction of total staff time devoted to research and development, accelerating the delivery of new technical products, decreasing the cycle time associated with administrative and management functions, and ensuring effective stewardship of the Laboratory's people, facilities, and programs. We have also initiated efforts to strengthen our peer review practices in line with DOE guidance. Last, we have begun an effort to redesign all of our management systems to ensure that each system effectively supports our scientific and engineering projects.

Because of the fierce cost pressures to which we are all responding, we must take care not to lose sight of the stewardship and scientific excellence aspects of this Critical Outcome. Apparent increases in productivity obtained by reducing cost through failure to reinvest or failure to develop new capabilities are counterproductive. Efficiency improvements in needed activities and elimination of unnecessary or low-value activities will provide the needed productivity increase. However, in making these improvements we must take great care not to compromise our ability to respond to current and future national needs. We are, therefore, committed to increasing our investment in Laboratory Directed Research and Development.

Finally, we must respond to what is a key theme in the Department's Strategic Plan. We recognize that our high-level objectives require a foundation of effective communication and trust, both within our institution and between us and our customers, partners, and the public. Continuous, rapid change in the world to which we respond and in our own business and management practices is inevitable. If our staff are to successfully respond to these changes, they must have confidence that the Laboratory is home to open, honest communication. If our customers and partners are to continue to entrust us with significant resources and shared responsibility for their future, they, too, must have confidence in both our character and our competence. Each staff member, whether working in research, in administrative functions, or in management, is accountable for, and entitled to, this foundation.

Focused, Strategic Growth

As our third Strategic Objective, we intend to achieve focused, strategic growth, through which we will provide stability and opportunity for our staff, continually renew and strengthen our technical capabilities, and increase our contribution to the nation.

This objective reflects a new emphasis on growth as an essential element of our overall long-term strategy. Although we recognize that it may seem paradoxical to assert the need for growth at a time when resources are so obviously constrained, we have concluded that this objective is a crucial element of our long-term stewardship for this laboratory. There are four factors that have led us to this conclusion:

A modest level of overall growth will significantly increase our ability to provide stability and opportunity to our staff.

To maintain the vitality of any research institution, it is necessary to have a continuing infusion of new ideas and new talent. Growth will ensure that we are able to offer opportunities to highly capable scientists and engineers.

To fully realize the benefits of the reductions we've made in overhead and fixed costs we need to spread the remaining costs over a larger research base. Given the improvements we've made, even modest growth in our research business will give us very substantial leverage in reducing charge-out rates and increasing the fraction of our staff working directly on projects.

> Today's capabilities will not meet tomorrow's DOE needs. We must continually strengthen the technical capabilities and performance of this Laboratory if we are to remain relevant to evolving national needs.

The level of growth we envision is modest, perhaps increases of a few percent per year in both funding over inflation and in the size of the technical staff. In selecting opportunities through which we will achieve this growth, we will continue to emphasize the fit of those opportunities with both our mission strategy and our technical capabilities, the importance of that work to our clients and the nation, and the quality of opportunities provided to our staff. Finally, we recognize that growth in capability and impact may as readily come through collaboration as through additions to staff count, and strengthened outreach to university, government laboratory, and industrial collaborators is a key part of our growth strategy.

Only one of our six Critical Outcomes is associated with this Strategic Objective. As a derivative of the Department's core missions, the DOE Strategic Plan lays out a broad set of goals in the economic area, including helping industry make the transition to pollution prevention and waste minimization, becoming a more reliable partner for industry, speeding technology deployment, and developing "dual-benefit" technology that meets both DOE mission needs and is of commercial value to U.S. industry. In supporting these goals, we must keep in mind the strong commitment that DOE has made to local economic transition to the post-cleanup world, in which thousands of DOE-supported jobs will disappear and must be replaced by private-sector activities over the next two to three decades. Accordingly, our sixth Critical Outcome is in the area of Local Economic Development. We and our partners will develop technologies, primarily in the environmental area, that measurably help modernize America's manufacturing and process industries, thus creating new high-wage jobs and increasing U.S. export potential.

Our emphases will continue to be on job creation in the local area and provision of technical assistance to local businesses. Our response to the Secretary's request that we associate a local economic development initiative in the next revision of the contract for management of the Laboratory will result in new activities and even stronger emphasis. With regard to the Northwest region and the local economy, we believe that we have a critical role to play in supporting DOE's commitment to economic transition. This commitment is central to the Hanford Strategic Plan that has been released by the DOE Richland Operations Office, and must be met to ensure that completion of Hanford cleanup does not result in massive economic dislocation. Our intent is to ensure that a vital Pacific Northwest National Laboratory can serve as an economic anchor for the community and an integral part of the Northwest science and technology infrastructure. In addition, we are setting ourselves the objective of increasing the number of successful mid-Columbia companies created by spin-off from our Laboratory, producing products based on our technology, or otherwise catalyzed by our actions. Finally, through an expanded portfolio of outreach programs, we intend to be a productive and increasingly sought-after technology resource to local and regional small businesses.

Fundamental Strategies

We close by articulating a crosscutting set of fundamental strategies that we will use to achieve the Critical Outcomes described above. We believe that there are five broad, closely linked, and enduring strategies critical to our future.

- *We will maintain a clear mission focus.* Over the last few years we have more tightly focused the Laboratory's programs around our core environmental mission, and those elements of DOE's other missions that best match our core competencies. With the publication of the Strategic Laboratory Mission Plan, this strategy has been reinforced as a fundamental expectation that the Department has for each of the laboratories.
- *We will build and maintain an outstanding fundamental science capability, directly and effectively linked to the nation's highest priority environmental needs and policy issues.* When we made the transition to being an Energy Research laboratory, we made the commitment to establish a fundamental science capability fully on par with our traditional engineering and applied science strengths. Through Laboratory Directed Research and Development and our programmatic investments, we have developed leading-edge fundamental science programs and capabilities in selected areas of molecular, environmental, and life sciences that we believe are particularly relevant to the Department's environmental mission. The Environmental Molecular Sciences Laboratory is the cornerstone of this strategy.
- *We will maintain and enhance a focused set of core competencies, relevant to both current and emerging national needs.* Over the past few years, we have begun to manage the Laboratory around a set of three integrating or core competencies: Integrated Environmental Research, Process Science and Engineering, and Energy Systems Development. These are based on a larger set of underlying, largely disciplinary, set of twenty technical capabilities. We continually review the health of these capabilities and their relevance to current and anticipated national needs. Changes to our capabilities portfolio will be made in line with our understanding of those needs.
- *We will bring the full technical resource of the nation to critical problems through broad partnership with our sister national laboratories and with universities and industry.* The breadth and complexity of DOE's missions make it unlikely that any single institution will maintain the complete set of core competencies required to respond fully to mission needs. We believe we can best meet the Department's needs for comprehensive solutions to complex problems by building partnerships that draw on the most appropriate resources of the laboratory system,

Pacific Northwest National Laboratory's Strategic Objectives

- **Premier Environmental Laboratory**
  - **Critical Outcome: EMSL**

    Construct, equip, and staff the EMSL on budget and on schedule, provide the maximum possible scientific capability in that Laboratory, and have the available capacity fully subscribed by users.
  - **Critical Outcome: Environmental Management**

    Deploy new environmental technologies that allow environmental cleanup to be done faster, at lower cost, or more effectively and that minimize waste and prevent pollution.
  - **Critical Outcome: Energy**

    Advance sustainable energy production and use, economic growth, and a healthy citizenry through research and technology transfer, leading to new and improved energy technologies.
  - **Critical Outcome: National Security**

    Improve national security through deployment of technologies that reduce the risks associated with weapons of mass destruction, specifically in nonproliferation and arms control, and security in the New World Order.
  - **Critical Outcome: Health**

    Improve the condition of human health through the development and deployment of medical technologies that facilitate assessment and management of health risks, analysis of safety and effectiveness of pharmaceuticals, and reduction of the time and resource requirements for successful development of drugs, chemicals, and microbes for bioremediation.
- **Benchmark Standard for Laboratory Management**
  - **Critical Outcome: Scientific Excellence and Productivity**

    Deliver more and better R&D for each dollar, becoming the science and technology provider of choice in the markets we serve.
  - **Critical Outcome: Environmental Safety and Health/ Conduct of Operations**

    Conduct our work in a manner that fully protects the environment and health and safety of our staff and the public.
  - **Critical Outcome: Leadership**

    The Laboratory has visionary leaders who develop their staff, influence the national science and technology agenda, and earn national recognition for our science and technology accomplishments.
- **Focused, Strategic Growth**
  - **Critical Outcome: Economic Development**

    Create new businesses, expand existing businesses, and attract outside businesses to the Tri-Cities to support transition of the Hanford Site to the post-cleanup era.

our universities, and U.S. industry. Major programs that we have participated in initiating over the last several years, such as the Atmospheric Radiation Measurement program, The AMTEX Partnership, and several of our major environmental remediation programs reflect this practice. We have also made significant progress in simplifying the mechanisms by which we can create suitable partnerships, particularly with academic researchers. We will continue to make partnerships a way of life.

- *We will dramatically enhance our technical productivity while protecting the health and safety of our staff, the public, and the environment.* Both DOE requirements and our duty to the public and taxpayers require that we achieve cost-effective excellence in our operations, fully meet the Department's expectations for conduct of operation, and deliver the highest possible return on the nation's investment in our programs. We have completed a thorough, in-depth review of our research, management, and administrative and operation practices, and reorganized to strengthen mission focus and to reduce management costs, and are well on our way to implementing the recommendations developed in that review. In cooperation with DOE, we have achieved dramatic operational improvements within the last year, and will continue to focus in this area.

On the basis of this strategy, we have a bright future. Our science and technology is and will remain highly relevant to important national needs. We are fast becoming one of the most productive and cost-effective laboratories in our country. As a result, we are confident that Pacific Northwest National Laboratory will be making significant science and technology contributions well into the next century and beyond.

4 Laboratory Initiatives

Initiatives are the primary means by which we enhance our scientific and technical capabilities to support the U.S. Department of Energy (DOE). We are proposing six multidisciplinary science and technology initiatives for DOE's consideration.[a] Investment in these initiatives will build new capabilities and strengthen existing core competencies. These initiatives, built on past accomplishment and our accumulated skill, show our focus for the future.

The proposed initiatives described in this section directly respond to the missions of DOE in energy, science and technology, and the environment and the linkages between these missions. Consistent with the Pacific Northwest National Laboratory's mission, most of the proposed initiatives are directed toward the interface between the science and technology and environmental quality missions. The initiatives are

- *Molecular Sciences Research* - This initiative is advancing the state of the art in molecular sciences and applying the knowledge gained from these advancements to DOE missions, particularly the environmental quality mission. It is the focal point of our efforts to enhance the fundamental science base that supports our core competency in integrated environmental research. The principal research thrust areas are chemical structure and dynamics, theory modeling and simulation, materials and interfaces, macromolecular structure and dynamics, computing and information sciences, and environmental dynamics and simulation.
- *Microbial Biotechnology* - The Microbial Biotechnology initiative is developing an integrated scientific and engineering capability in microbial systems and applications. This capability is enhancing our core competency in integrated environmental research and is establishing the foundation for a broader role for the Laboratory in biotechnology. Specific research areas incorporated in the initiative include microbial diversity; microbial genetics; enzyme structure/function enzyme redesign; informatics; bioprocess engineering; and ethical, legal, and social implications research.
- *Global Environmental Change* - Global Environmental Change is directed toward developing an integrated understanding of the global impacts of energy production and resource utilization and related complex environmental and policy issues. The initiative is enhancing interdisciplinary capabilities for understanding and modeling the coupled socioeconomic, physical, and biological systems that make up our environment. Specific research areas include regional climate modeling, modeling the effects of climate change on water resources and unmanaged ecosystems, heterogeneous atmospheric chemistry, modeling of emissions levels for greenhouse gases, and analysis of the economic and other social impacts of global environmental change.
- *Advanced Processing Technology* - The Advanced Processing Technology initiative is focused on enhancing our core competency in process science and engineering. Primary thrust areas include 1) advanced processes, including chemical conversion and separations; and 2) advanced materials, which include advanced coatings and materials synthesis and processing. We are also using this initiative to develop the infrastructure and culture necessary to more rapidly advance processing technologies through the development cycle. Technical thrusts have been selected based on two principal application targets: tank waste processing and environmentally conscious processing.
- *Energy Technology Development* - The Energy Technology Development initiative is designed to enhance the Laboratory's core competency in energy systems development. Current research activities are focused in four interrelated technology areas: microtechnology, transmission and distribution systems, advanced operations and maintenance technology, and transportation materials.
- *Medical Technologies and Systems* - The Medical Technologies and Systems initiative is focused on applying our existing multidisciplinary capabilities to the development of innovative new technologies in health care. The initiative is supporting the efforts of DOE's Office of Health and Environmental Research to contribute to national needs in this area. Current focus areas include advanced ultrasound, medical sensors, medical informatics and computation, targeted therapeutics, medical materials, and medical process improvements.

Molecular Sciences Research

The Molecular Sciences Research initiative is a key component in the Laboratory's effort to develop and provide the fundamental science base necessary to support DOE's environmental missions and is the basis for development of the research programs that will be conducted in the Environmental Molecular Sciences Laboratory (EMSL), a scientific user facility currently under construction at the Laboratory.

(a) Initiatives are provided for consideration by the Department of Energy. Inclusion in the plan does not imply Departmental funding or intent to implement any initiative.

Research undertaken in this initiative will focus on developing the molecular-level understanding of important environmental issues such as:

- the complex chemical, physical, and biological processes that operate in natural and contaminated environments
- ways in which natural processes can be used to assist in the cleanup of contaminated soils and groundwater
- processes and techniques that can be used to safely extract and destroy chemical wastes and to separate and store radioactive wastes
- the ultimate impact of radioactive and chemical contaminants on the health of humans and the ecosystem.

An important aspect of this initiative is to link the molecular information to the actual macroscopic field problems and to innovative solutions to these problems.

These research activities will provide the fundamental scientific knowledge needed to develop permanent, cost-effective solutions to the nation's environmental problems, as well as develop environmentally acceptable energy options for the future. Capabilities and expertise developed in several of the projects under the Molecular Sciences Research initiative have provided the basis for significant contributions to new DOE initiatives, such as the Environmental Management Science Program and the Environmental Technology Partnership Initiative.

Collaborative research involving scientists from other DOE and government laboratories, universities, and industry are key ingredients in the Molecular Sciences Research initiative. Programmatic support for this initiative is sought through various DOE offices as shown in the initiatives table at the end of this section. Multiyear resource requirements also are shown in the initiatives table at the end of this section and are not included in the Resource Projections.

Following are descriptions of the major research programs in the Laboratory's Molecular Sciences Research initiative.

Chemical Structure and Dynamics

The goal of the Chemical Structure and Dynamics program is to obtain a fundamental, molecular-level understanding of the chemical processes occurring at environmentally important interfaces. The research is focused on rigorous studies of fundamental molecular processes in model systems using advanced laser spectroscopies, molecular and ionic beam techniques, and atomic resolution microscopy, together with a powerful combination of advanced optical, photoelectron, and mass spectrometry techniques. This work will result in a detailed, quantitative understanding of chemical processes at complex interfaces, development of new techniques for detection and measurement of species at such interfaces, and interpretation and extrapolation of the observations in terms of models of interfacial chemistry.

Major thrusts include the following:

- investigations of the underlying physical and chemical mechanisms of radiolytic degradation of glasses and ceramics used in long-term storage of high-level nuclear wastes
- study and control of enzymatic reactions occurring at biological membranes in aqueous environments. This work takes advantage of recent advances in near field scanning optical microscopy that make it possible to optically map membrane structures at the nanometer scale in aqueous environments and to monitor or even control chemical changes.

Theory, Modeling, and Simulation

The Theory, Modeling, and Simulation program focuses on combining the elements of theoretical and computational chemistry, solid-state theory, and molecular biology with computer science, advanced mathematics, and advanced computing technologies to provide a comprehensive understanding of molecular processes. The focus is on problems associated with a wide range of environmental issues, including the design of separation materials, the interaction of contaminants with soil minerals, and the enzymatic degradation of pollutants, as well as energy efficiency and the reduction of waste streams from production processes. Research programs have been established in the areas of molecular theory and modeling, solid-state theory and modeling, biomolecular modeling and simulation, software/algorithm design, applied mathematics, high-performance computational chemistry, and an extensible computational chemistry environment. The research efforts in molecular theory and modeling are well established, and the program in solid-state chemistry is showing good progress in the areas of geoscience and catalysis research. Both of these efforts are described in the Basic Energy Sciences and Chemical Sciences sections. The research efforts that are focused on the development of a new generation of molecular modeling software are funded under the EMSL Project. The applied mathematics program is funded from a variety of sources including the EMSL Project. Investments are currently being made to further develop research in the life science area and in the development of new theoretical/computational/mathematical methods.

Major thrusts in Theory, Modeling, and Simulation include the following:

- Modeling the structure and dynamics of adduct-DNA and protein-DNA complexes. The primary objective is to understand the molecular damage to DNA resulting from exposure to hazardous chemicals and the mechanisms by which enzymes recognize and repair damaged DNA.
- Development of innovative approaches for describing electron correlation in molecular systems (e.g., the numerical solution of the Schrödinger equation and other advances in mathematical methods). Of particular interest are approaches that take advantage of emerging computer technologies (e.g., massively parallel computers).

Materials and Interfaces

Chemical and physical processes that take place in boundary regions (i.e.,

between solids and liquids, two immiscible liquids, gases and solids, and gases and liquids) play key roles in solving environmental restoration and waste management problems. They control such phenomena as the rate of transport of chemicals between these phases, the rates of transformation in catalytic conversions, and the dynamics of permeation of species through the environment. A detailed understanding of the interactions that take place between a solid and a gaseous or liquid environment is also essential for rational design of chemical sensors that are critical to monitoring environmentally related activities. Thus, sensor research logically falls into the area of physical chemistry of complex systems.

Major thrusts include the following:

- Synthesis of materials needed to obtain a molecular-level understanding of the adsorption and reaction of contaminants on soils. Model mineral surfaces are being prepared by molecular beam epitaxy and chemical vapor deposition and are being studied by optical and charged particle probes to determine the details of the surface chemistry and physics of these model soil materials.
- Investigation of colloid-colloid interactions using static and dynamic force measurements under tank waste processing conditions. Since interparticle forces determine whether colloids remain suspended in solution or aggregate and precipitate, an understanding of these phenomena is crucial to solid-liquid separations and chemical treatment of tank wastes.
- Studies of the surface chemistry and catalytic properties of metal oxide materials. Surface properties of metal oxides are critical in an enormous number of environmental problems and their potential technological solutions. This work is aimed at understanding how surface chemical bonding influences the character and rates of surface reactions that involve water and adsorbates of environmental interest (e.g., organics and metal ion complexes).
- Development of flow injection analysis techniques for automated miniaturized chemical analysis for a variety of applications, including 1) microscale radiochemical analysis and process simulation for tank wastes; 2) soil and groundwater analysis (e.g., hexavalent chromium); and 3) controlled exposure of biomolecules and cells to radiation and mutagens. These miniaturized techniques dramatically decrease the sample volume needed, the analysis time, and the amount of waste produced, and because they are computer controlled, they eliminate human errors.
- Synthesis and characterization of novel metal cluster/polymer composites important in the design of advanced chemical sensors and separations membranes, molecular electronic devices, and electrocatalytic conversion devices.
- Development of advanced sensing layers for the design of higher order chemical sensor array systems. When supplemented with chemometrics, such systems are capable of operating with superior performance in demanding environments.

EMSL staff are also continuing their participation in the Pacific-Northwest Consortium beam-line proposal for the Advanced Photon Source at Argonne National Laboratory.

Macromolecular Structure and Dynamics

A quantitative understanding of health risks, particularly from cancer, is necessary to establish realistic cleanup standards and priorities. Research in Macromolecular Structure and Dynamics focuses on health and environmental issues of interest to DOE with a strong emphasis on obtaining the fundamental understanding required to quantify the health risks resulting from human exposure to hazardous chemicals. Genomic damage, a molecular phenomenon, is generally accepted to be the underlying mechanism of cancer induction. However, use of molecular data in cancer risk analysis is limited by our knowledge of how normal cellular processes are involved in the expression of DNA damage. Such damage may result from direct interaction of a carcinogen with DNA or by indirect mechanisms that change the level or persistence of endogenous DNA damage from normal cellular processes. Therefore, an understanding of the carcinogenic process can only be achieved through fundamental data on biological systems at all levels of organization (i.e., from macromolecules to mammals).

Major thrusts in Macromolecular Structure and Dynamics include the following:

- Investigations of the time evolution of lesions in mice resulting from transplantation of carcinogenic cell lines or exposure to toxic chemicals. This will be achieved by in vivo magnetic resonance imaging (MRI) and spectroscopy (MRS). These techniques are noninvasive and nondestructive, thus making it possible to follow the evolution of specific lesions in live animals. The results will be used for risk assessment modeling associated with exposures to environmentally important toxic chemicals.
- Development of high-field magnetic resonance microscopes with magnetic resonance imaging capabilities for studying three-dimensional cell systems with a subcellular spatial resolution and magnetic resonance spectroscopy capabilities for studying small cell clusters. Initially, these microscopes will be used to identify viable hypoxic and necrotic parts in tumor cell spheroids, and to follow mitosis in these cell systems.
- Structural and mechanistic studies of proteins, DNA-adducts, and altered-DNA/protein complexes to provide a molecular-level understanding of DNA-protein and protein-protein interactions in DNA damage recognition and repair.

Other research problems under study in the Macromolecular Structure and Dynamics program include

- Studies of the structural details (bond distances, angles, and spatial distributions) and dynamics (rotational and translational diffusion) of small molecules adsorbed to oxide surfaces, metals on supported surfaces, and clay materials. This

information is critical to a host of environmental issues, including the interaction of contaminants with soil minerals, catalytic destruction of pollutants, and the design of stable waste forms.

- Investigations of the structure and function of biodegradative enzymes with potential bioremediation applications. This work is part of a larger Laboratory integrated effort utilizing expertise in Molecular and Structural Biology, the Microbial Genome initiative, and the Microbial Biotechnology initiative.

Computing and Information Sciences

The focus of the Computing and Information Sciences research program for this initiative is on the development of prototype implementations of the next generation of instrument designs and data systems for distributed collaborative research environments. These efforts are designed to take advantage of the continuing advances in computing and communications to create a "laboratory without walls" that enables geographically distributed researchers to work with EMSL equipment and scientists.

Staff in the Computing and Information sciences program work closely with EMSL researchers to develop prototypes for a new generation of on-line instruments that will enable onsite and offsite scientists to monitor or control experiments, and to acquire and analyze data. For the initial prototype, a radio-frequency ion trap mass spectrometer is being modified and enhanced for full remote control, monitoring, and data acquisition. All of the key instrument and sampling parameters can be remotely controlled. Mass spectra data acquisition is integrated with an online experiment database and with other EMSL electronic laboratory notebook development efforts, thus implementing a unified architecture for the EMSL collaborative research environment and providing scientists with capabilities to integrate information across disciplines. Together with other collaboratory development work in the EMSL, the objective is to increase the value of the EMSL as a collaborative research facility and to enhance our ability to engage multidisciplinary science teams directed at critical DOE problems.

Environmental Dynamics and Simulation

The Environmental Dynamics and Simulation program emphasizes the development of molecular-scale information on the structure and reactivity of aqueous and gaseous complexes on solid surfaces and in complex fluids, and focuses on linking knowledge of molecular mechanisms to chemical transport phenomena occurring on the pore-scale and microscopic-scale in aqueous, gaseous, and porous media. The effort develops and uses the capabilities of environmental spectroscopy and advanced computational modeling to elucidate the chemical phenomena that affect contaminant fate and transport in various media. The majority of the research activities are focused on chemistry at the aqueous-mineral interface, with smaller efforts in understanding the flow of complex fluids and solutions, bioremediation and enzymatic reactions, advanced characterization, and atmospheric chemistry.

Major thrusts in Environmental Dynamics and Simulation include the following:

- Synthesis and characterization of model inorganic ion exchange materials. Layered aluminosilicates and hydrotalcite-like minerals are being synthesized for detailed studies of surface reactivity. Research on these materials is important because of their abundance in soils and sediments and/or their possible use as ion exchangers for selective removal of radioactive contaminants from wastes.
- Studies of sorption of organic ligands on mineral surfaces in aqueous environments using state-of-the-art spectroscopic methods, such as laser-induced fluorescence, high-sensitivity infrared spectrometry and laser resonance Raman scattering. These techniques are being used in novel ways to enable characterization of bonding and adsorption/desorption kinetics of organic species at aqueous-mineral interfaces.
- Investigations of the adsorption, desorption, and diffusion of oxyanions on mineral surfaces. This work provides a basis for understanding transport of contaminants through soils. Emphasis is on the role of surface structure and defects, both on the atomic and mesoscopic levels, in the adsorption and chemistry of important groundwater oxyanions.

Processing Science

The Processing Science program is a relatively recent addition to the Molecular Science Research initiative. This program is being designed to link fundamental molecular science research performed in the EMSL to chemical process and engineering applications. This program also will link to existing applied research and development activities involving chemical processes and technology, such as the Laboratory's Advanced Processing Technology initiative. A major focus of the program will be processing issues associated with radioactive wastes stored in underground tanks at a number of DOE sites. Research areas critical to addressing these issues are 1) colloid chemistry and behavior; 2) separation processes for separating radioactive species from the bulk of the chemical waste; 3) chemical conversion processes (e.g., destruction of organic complexants and nitrates); and 4) physico-chemical behavior of waste forms. In addition, computer modeling of the chemical processes and behaviors that govern waste treatment is important for optimizing the overall process.

Major thrusts include

- Ligand design and testing for metal ion separations. The main objective of these theoretical and experimental studies is to develop the fundamental chemical principles that underlie the rational design of organic ligands for separations of metal ions such as actinides.
- Structural and spectroscopic studies of simulated nuclear waste glasses. The objectives of this research are

to 1) determine how species present in wastes enter the glass structure; 2) determine how structural changes affect physical and chemical properties of the glass; and 3) apply structural knowledge to improve waste processing (e.g., accommodation of problematic waste components into glass).

- Exploratory studies to determine the feasibility of using common photochemical oxidation catalysts, such as titanium dioxide, as gamma radiation catalysts for in situ destruction of organic species in tank wastes.

Microbial Biotechnology

The goal of the Microbial Biotechnology initiative is to build a comprehensive biotechnology capability that significantly contributes to DOE's core businesses in the environment, energy, health, and national security. This initiative is initially focused on fundamental investigation of microbial systems through directed research leading to a broad range of applications. Strategic investments in new staff and integrated scientific and engineering teaming are creating new state-of-the-art capabilities in basic research to understand microbiological phenomena and to develop and test novel concepts for advanced bioprocesses based on fundamental knowledge. These investments have led to a rapidly developing funding base addressing a range of DOE needs.

In the next century, biotechnology will dramatically impact all facets of society and the economy as a consequence of the rapid accumulation of fundamental knowledge of biological systems resulting from federal and private-sector investments in molecular and cellular biology, human and microbial genome sciences, computational and structural biology, and advanced engineering processes. Diagnosis and treatment of disease, environmental stewardship, materials, industrial processes, and ultimately, cultural and ethical values will all undergo major transformations. To address these trends, the Laboratory strategy in biotechnology is to enhance its research programs in life, environmental, materials, chemical, and computational sciences through selective investments to build and integrate capabilities in structural biology, microbiology, enzymology, genome sciences, biochemical and bioprocess engineering, and ethical, legal, and social impact research. The resulting theoretical and experimental base, coupled with new capabilities in the EMSL, will result in the successful development of new interdisciplinary programs in fundamental and applied microbiology that are directly linked with DOE missions and the growth and development of the biotechnology industry.

Pacific Northwest's Microbial Biotechnology initiative is building on Laboratory strengths in environmental microbiology and molecular sciences and focusing initially on building capability in fundamental microbiology (molecular biology, microbial genome mapping and sequencing, bacterial enzymology, physiology and metabolism); microbial and molecular applications in key areas (bioremediation, biotreatment of industrial waste streams); and technology planning and analysis (risk management; ethical, economic, and social issues). New collaborations are being developed to augment and fully use this capability to address DOE missions, including collaborations with other national laboratories (e.g., Lawrence Berekely, Argonne National Laboratory), universities (e.g., Washington State University, Princeton University), and industry (e.g., Zymogenetics, Envirogen).

Fundamental research addresses the following issues:

- Isolating and characterizing microorganisms from unexplored and extreme environments to determine their roles in natural biogeochemical processes, to understand their origins, and to examine their potential for new industrial processes. Target microorganisms include deep subsurface bacteria that may have survived for long periods in ancient depositional environments under oligotrophic conditions, as well as thermophiles, halophiles, barophiles, acidophiles, and anaerobes.
- Mapping and sequencing the genomes of industrially and environmentally important bacteria to provide the basis for understanding and enhancing important and novel functions. Laboratory investments have recently resulted in derivation of a physical map for a 180-kilobase megaplasmid in *Sphingomonas*, a bacterium from the deep subsurface. The map was used to locate genes encoding the metabolic capability to degrade a unique range of toxic aromatic compounds. The entire plasmid is currently being sequenced.
- Elucidating the structure and function of important enzymes that act as novel biological catalysts and of biomolecules that control critical biogeochemical processes in the environment through integrated research in computational and structural biology. Nuclear magnetic resonance spectroscopy is being used to determine the structure of tetrachloro p-hydro quinone reductive dehalogenase purified using an *E. Coli* gene expression system from a bacterium capable of degrading chlorinated compounds. Molecular modeling tools are being employed to better understand relationships between the structure of glutathione-S-transferases and thermophilic enzymes (e.g., bacterial subtilisins) and their catalytic activity at high temperature and in nonaqueous solvents.
- Developing interactive links with microbial biochemistry, genetic, and genomic databases on the Internet to provide and access integrated information on fundamental microbial processes and their applications.
- Identifying phylogenetic and functional molecular probes in bacterial dehalogenase and metal reductase systems. This will contribute to a more accurate understanding of biological and ecosystem processes and their response to manipulation of in situ geochemical and hydrological processes for bioremediation.
- Identifying and assessing key social and economic issues, including comparative impacts of competing technologies, environmental stewardship, and ethical and risk perception issues that will accompany the commercialization of new microbial biotechnologies.

Fundamental research is serving as a basis for new technologies which are examined through joint scientific and engineering research. Opportunities under investigation include the following:

- Novel biological methods for improving the range and efficiency of energy production and chemical processing (e.g., high-temperature biocatalysis), for selective concentration and conversion of wastes and environmental contaminants, and for supporting an improved understanding of global climate change (e.g., biogeochemical cycles).
- Microbial systems for cost-effective treatment of metals and radionuclides and chlorinated hydrocarbons in contaminated aquifers and industrial waste streams through advanced bioprocesses based on enzymatic alteration of valence states and reductive dehalogenation. Initial focus is on iron-reducing bacteria for uranium bioprecipitation and chlorinated hydrocarbon degradation (i.e., mechanisms, kinetics, engineering scale-up).
- New concepts for the use of natural processes in environmental restoration (e.g., bioremediation) resulting from the identification of key physiological, enzymatic, and metabolic properties of microorganisms. Laboratory investments are focused on understanding the mechanisms and genetic control of metal reduction, dechlorination, and degradation of aromatic compounds. The Laboratory has recently isolated the first dehalogenase from a bacterium capable of using dehalogenation to derive energy for growth.
- Rational protein analysis to derive novel concepts for genetic engineering to improve industrial enzyme technology, and for the identification and selection of new biocatalysts from nature to enhance efficiency of chemical manufacturing and waste management processes.
- Basic research in molecular ecology is supporting the development of methods for in situ detection of metabolic activity and the construction of gene probes for specific organisms and activities to improve the performance of bioprocesses and field-scale bioremediation research, development, and deployment.

Transferring knowledge and technology to users in the public and private sectors is integral to all aspects of the research. Current efforts encompass transfer to DOE sites, DOE program offices, other federal agencies, universities, and industry. Investments are aimed at 1) development of fundamental capabilities with generic or cross-disciplinary applications (e.g., advances in enzymology with applications in materials, bioprocessing, and bioremediation), 2) integrated research leading to intellectual property and near-term improvements in biologically based tools and processes, and 3) engaging the user community in workshops and colloquia focused on transferring new knowledge and tools and on technological opportunities offered by DOE user facilities, including the EMSL. The growing success of the Laboratory's interdisciplinary approach to technology development and transfer is underscored by a number of research awards and important intellectual property in biotechnology, including four Federal Laboratory Consortium and R&D 100 awards and over 40 patents awarded and pending.

Funding requirements for this initiative are given in the initiatives table at the end of this section and are not included in the Resource Projections section. Programmatic support for this initiative is sought through DOE offices with basic and applied research businesses, including microbial genome and bioremediation (Natural and Accelerated Bioremediation Research) and health effects (nucleotide excision and repair) programs in the Office of Health and Environmental Research (OHER); Energy Biosciences in the Office of Basic Energy Sciences; the DOE-Environmental Management (Environmental Management Science Program and focus areas, including landfill stabilization and contaminant plume containment and mixed waste characterization, treatment, and disposal); bioremediation programs in the DOE Office of Fossil Energy (Environmental Technology Partnerships); DOE-INTEL; and the Advanced Industrial Concepts Program in the DOE Office of Industrial Technology. New interfaces with other federal agencies and industry are also rapidly developing.

Global Environmental Change

The goal of Pacific Northwest's Global Environmental Change initiative has been to develop the understanding necessary to support critical local, regional, national, and international decisions within the context of global environmental change. The initiative is based on the premise that a multidisciplinary laboratory is well positioned to meet these needs and uniquely suited to effectively perform the vital integration function. The Laboratory continually seeks to improve the scientific understanding of the processes and forces shaping the environment and the integration of that knowledge on appropriate spatial and temporal scales to inform government policymakers and guide the development of technology.

Globally linked changes in the environment develop from complex interactions among the physical climate system, the biological systems that inhabit the earth, and the rapidly expanding activities of human civilization. In the past century, the growth of civilization has progressed to the point that human elements are now major forces in this interlinked system. It is clear that the production and use of energy creates one of the strongest interactions between civilization and the natural world. The increasing extent to which energy production is being linked to global-scale effects has made global environmental change a central issue in energy policy.

The Laboratory's initiative featured four elements: 1) the establishment and pursuit of a research agenda on environmental change processes; 2) the development of an initial framework for evaluating technological responses to global environmental change; 3) the communication of knowledge both directly to those charged with formulating policy, as well as to the broader

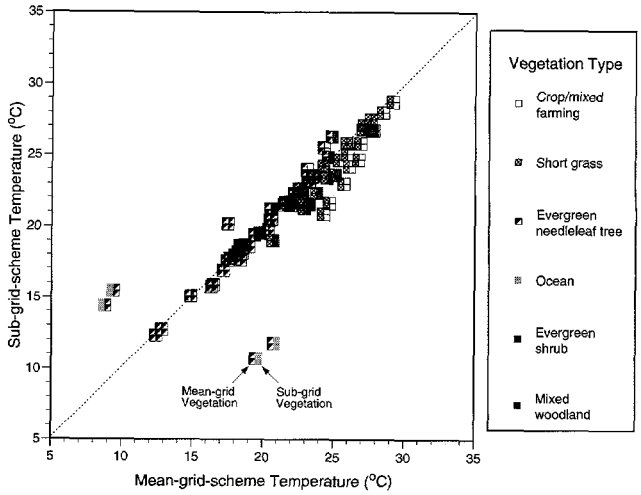
community of researchers and analysts; and 4) the promotion of analyses which ensure that the understanding of science, technology, and policy are appropriately integrated with each other.

The maturation of the Laboratory's Global Environmental Change initiative has resulted in the formation of a new product line that bears the same name. Nearly all of the intellectual activity supported through the initiative continues in the product line, with a few exceptions. Projections of support from various DOE offices and other organizations are shown in the initiatives table at the end of this section and are not included in the Resource Projections.

Building the Scientific Base

The Laboratory's integrated scientific research effort is built around the U.S. Global Change Research Program (USGCRP) objectives, with a particular emphasis on attaining the goals of the DOE component in long-term climate prediction. This federal multiagency program is coordinated by the Global Change Research Subcommittee of the Committee on Environment and Natural Resources, which is an element of the National Science and Technology Council. Elements of the program contribute to the World Climate Research Programme and the International Geosphere Biosphere Program. The USGCRP is described in *Our Changing Planet: A U.S. Strategy for Global Change Research*, an annually updated report outlining the roles that the various federal government agencies will play in research to understand both the continuing change in natural biochemical, water, and energy cycles and the disturbances in those cycles that may be caused by human activities.

As a major player in the USGCRP, DOE has developed research programs around two elements of the national scientific effort: decade-to-century climate prediction and the cycling of carbon in the environment. Through its support for the Environmental Sciences Division of OHER, the Laboratory has assisted DOE by active participation in leadership and research



A scatterplot comparing the daily maximum surface temperature over each weather station in Washington State as simulated by a regional climate model using a mean-grid vegetation scheme which defines one vegetation type for each 90 km grid cell, and a subgrid vegetation scheme which defines one vegetation type for each elevation class within the grid cell.

in the Atmospheric Radiation Measurement and Computer Hardware, Advanced Mathematics and Model Physics climate prediction programs. In addition, the Laboratory contributed significantly to the ocean research carbon cycle element of the Core Carbon Dioxide Research Program. There remains a focus on understanding the formation, removal, and climatic consequences of anthropogenic aerosols and on the development of approaches to detecting impending climate change.

In support of the broad federal objective, as well as the specific DOE business area, the Laboratory has focused its internal investments on the following key areas: regional climate prediction, climate change and its effects on water resources, the effects of climate change on unmanaged ecosystems, and the effect of heterogeneous chemistry on the fate of energy-related pollutants in the atmosphere. More recent emphasis has been on the linkage of these processes with ecological impacts. Each of these efforts is highly integrated. The Laboratory has accomplished its goal of producing a set of linked models and a network of talented researchers that provide a consistent intellectual framework for examining the coupled effects of regional climate variability and change on water resources, unmanaged ecosystems, forests, and agriculture.

Understanding Technology and Global Environmental Change

Technology is an important component of the complex considerations involved in understanding global environmental change. Pacific Northwest has a strong program that provides basic models of the relationship between energy generation technologies, economic growth, and the emission of greenhouse gases. This effort has been intensified with the ongoing development of a second-generation energy/economic model and the development of the Global Change Assessment Model (GCAM).

Global environmental change research integrates the understanding gained from science, technology, and human interactions research, which together define both the global environmental problems and reasonable responses. This knowledge is integrated in the form of models that can represent the essential interactions within, and among, the various components. The use of these models presents opportunities for collaborations with other scientists and institutions.

In addition to developing the second-generation emissions model, the Laboratory is increasing the level of understanding about the role of technology in both cause and mitigation

of global change. New approaches are required to evaluate technologies based on environmental factors to prevent global environmental change from becoming the basis for unfounded technological advocacy. Our research is aimed at producing a methodology that encompasses all of the direct environmental benefits and consequences of a particular technology, as well as effects that flow from the interaction of different technologies in the marketplace.

Analyzing Policy Options

The ultimate customer for understanding the global system, and civilization's role in it, is the policymaker. It is essential that those who consider policy options understand the context in which their decisions are being made. This requires reliable and useful analysis tools to support that decision-making process. The Laboratory has created and acquired a set of state-of-the-art analysis tools related to global environmental issues. Laboratory staff have used these tools to provide integrated policy support to the DOE Environmental Sciences Division, the Office of Policy, the Office of Energy Efficiency and Renewable Energy, and the National Energy Strategy development. These support activities include the following:

- estimating U.S. emissions and modeling global emissions of carbon dioxide as well as other radiatively important gases
- integrating the multiprogram laboratories' participation in several global policy studies mandated by Congress (such as a report to Congress on options for mitigating carbon dioxide emissions) and supporting the review of such documents
- supporting the incorporation of global change issues in the National Energy Strategy
- developing methodologies, such as GCAM, to model the impact of regional climate change on natural and unmanaged ecosystems, the economy, and society
- evaluating strategies for carbon dioxide emission mitigation
- evaluation of policy options in support of negotiations under the Berlin Mandate for the Framework Convention on Climate Change.

In anticipation of supporting analysis of future policy concerns, the Laboratory is developing improved economic evaluation tools and methods for evaluating the effect of climate change on human welfare. In particular, we have made a significant investment in the development of a model to enable assessments of the effects of energy policy decisions and technology developments on the environment and economies of North America.

Promoting Integrated Understanding of Global Change

The final element of the Laboratory's Global Environmental Change initiative was driven by the need for an integrated rather than a piecemeal understanding of the global environmental change issue. A particular emphasis in this area has been on promoting an international perspective of the need for national responses to global change concerns. Individual nations both create and respond to global change issues in ways that are coupled to their state of economic development and their resource mix. In general, we are focusing on national responses in the international context as the most appropriate level of integrating responses to global environmental change. The Laboratory's activities have led to the following:

- national studies of carbon dioxide control strategies in support of the Intergovernmental Panel on Climate Change for such countries as Poland, France, the United States, and the states of the former Soviet Union
- invitations for several Laboratory scientists to participate in the 1995 assessment activities of the Intergovernmental Panel on Climate Change
- establishment of an Advanced International Studies Unit in Washington, D.C., to provide a focus for international participation in policy-related programs
- support of the development of the position statement by the U.S. Energy Association related to the study of climate change
- development of a workshop with private industry on living with uncertainties associated with climate change predictions
- establishment of energy-efficiency centers in Russia, Poland, the Czech Republic, Ukraine, Bulgaria, and China to transfer U.S. technology and demonstrate options for reducing emissions of greenhouse gases
- initiation and leadership of an international assessment of the state of the art in the social sciences in terms of the knowledge needed to deal with the social, political, and economic issues of global environmental change.

Advanced Processing Technology

Process science and engineering is a core competency that supports the Laboratory's environmental and energy missions. The Advanced Processing Technology initiative is enhancing this core competency by making integrated investments spanning basic research through engineering to rapidly develop and deploy new process technologies for environmentally conscious processing. Technical capabilities in materials and chemical science (colloidal science, solution/solvation chemistry, catalyst development and characterization), molecular science (plasma chemistry, materials characterization), and process technology development (reaction systems for nonequilibrium plasma, electrochemical conversion and separations, supercritical fluid treatment) are being strengthened through this initiative. These investments are ensuring the health and relevance of our process science and engineering core competency.

The Advanced Processing Technology initiative is transforming Pacific Northwest's environmental mission by

- *Integrating and focusing the Laboratory's process science and*

engineering investments around two significant national problems: tank waste processing and environmentally conscious processing. Tank waste processing is addressing vulnerabilities associated with radioactive and mixed wastes stored in over 400 waste tanks across the DOE complex. Key technical challenges include the physical/chemical separations of the waste into high- and low-level components and the subsequent immobilization of these waste streams in robust waste forms. The technical vulnerabilities associated with these processes translate into excessive treatment and disposal costs that DOE and the public cannot afford. Investments in the separations and materials synthesis thrust areas are being aligned on this target. Intimate knowledge of tank waste processing needs are obtained through the Laboratory's leadership role in the Tank Focus Area, a national technology development program addressing waste tank remediation issues across the DOE complex.

Environmentally conscious processing is addressing process substitution, resource recovery, and waste treatment as approaches to reduce environmental and energy impacts for governmental and industrial processes. Our efforts are centered around process substitution where the largest gains in waste reduction and energy efficiency can be obtained. Examples include novel chemical reactors which simultaneously convert and separate products, thereby increasing product yields and reducing downstream separation costs, and plasma-assisted conversion, which uses ions and radicals created from a plasma discharge to promote chemical reactions at lower temperatures, thereby decreasing energy costs. We are also investigating recovery of valuable materials from process streams using a variety of separations techniques and advanced separations materials.

- *Implementing and demonstrating methodologies to speed the deployment of process technologies.* Major reductions in process development time at the Laboratory are being achieved by a coupled technology development approach—the effective and concurrent integration of basic and applied research, technology development, and engineering activities. As fundamental knowledge of processes grows, the need for multiple scale-up steps diminishes. New processes can then be integrated and demonstrated at much smaller scales, decreasing development time and resource requirements.

Funding requirements for the initiative are given in the table at the end of this section and are not included in the Resource Projections.

Advanced Processes

Advanced processes in chemical conversion and separations are required to make major advances in our tank waste and environmentally conscious processing targets. Development of these technologies are supported by advanced materials being developed by this initiative.

Chemical Conversion A key objective of chemical conversion is to use fundamental knowledge of conversion mechanisms to develop novel processes to reduce energy consumption and waste generation, leading to more efficient and competitive chemical manufacturing processes.

Conversion is the process by which chemical reactions alter the molecular structure of raw materials into other molecules of higher value or lower toxicity. In many cases, conversion can only be obtained by using high temperatures or pressures or long reactor residence times. This can consume large amounts of energy and create undesirable byproducts. Our research emphasis is on developing novel techniques that improve conversion processes by reducing the temperature, pressure, and residence time. Our activities are focused in two major areas: 1) nonequilibrium plasma and 2) reaction engineering.

A nonequilibrium plasma occurs when electrons are accelerated in an electric field until they reach sufficient energy to break chemical bonds. This can create reactive species that can be used to destroy toxic compounds or synthesize chemical species at significantly lower temperatures than many conventional conversion processes. This ability may enable the development of very energy-efficient and environmentally friendly processes for conversion. Past work centered around high-vacuum applications in the coatings area, such as chemical vapor deposition or surface modification. However, application to large-scale conversion processes was limited because high vacuum was required, reducing throughput. Research performed by the Laboratory led to the discovery of a method to create a volumetric plasma at ambient conditions. This enabled the technology to be used for larger-scale processes. Initial work has focused on the destruction of organic contaminants in process off-gas and liquids. Other potential applications include treating automobile exhaust, treating industrial flue gas, and potentially unique conversion processes for industrially significant products such as oxygenated fuels.

The key to successfully applying nonequilibrium plasma is to understand the electric field and the plasma chemistry and to effectively incorporate this understanding into novel reactor designs. To understand the electric field effects, electric field measurements have been taken for various reactor geometries and packings, and a computational model has been developed to assess critical design parameters. To understand the plasma chemistry, a Flowing Afterglow Apparatus has been developed to measure radical and ionic species generated in various plasma configurations. This state-of-the-art diagnostic system can be used to precisely identify chemical species and determine reaction kinetics; a capability which is applicable not only to low-temperature plasma processes but to many other conversion technologies as well. To date, these efforts have led to a fourfold increase in the capacity to destroy organic contaminants in off-gas and unique designs for liquid treatment of organic contaminants.

Reaction engineering is focused on developing innovative reactor designs

for conversion. Concurrent development and deployment of novel materials (e.g., catalysts, membranes) are major components of this task and are critical to its success.

Research in this area is focusing on the development of a novel small-scale methane reformer using a product-separating membrane reactor. Hydrogen is permselectively removed from the reaction zone to shift the reaction equilibrium toward complete conversion. In situ hydrogen separation adds an extra reaction-driving force and eliminates the need for downstream product purification unit operations. Hydrogen is currently produced in a large three-stage reactor with interstitial cooling to shift the reaction equilibrium. The proposed membrane reactor technology will achieve equal or better yields than a single stage.

New membrane materials with greater capabilities are under investigation. High-temperature permselective facilitated transport membranes are being developed for use in a separative-membrane reactor. Dramatically higher yields per pass will be possible for partial oxidation reactions if coupled with in situ product separation to prevent product over-oxidation.

Separations Research efforts in the separations area are focused on processing aqueous waste streams and using supercritical fluids in separation processes. Separation technologies have been explored for the separation of metal ions (toxic and radioactive elements), organic compounds (neutral and charged), and metal complexes (chelated metals and organometallic compounds). The metal ions, cesium and strontium, were targeted for early efforts because of the need to separate these elements when processing tank wastes at Hanford. Efforts have been expanded to other compounds in support of existing and proposed major DOE initiatives such as the Industries of the Future. The technologies investigated include ion exchange, membrane separations, electro-separations, and supercritical fluid extractions.

Evaluation of the organic ion exchange resins for the separation of cesium from tank waste has centered on elucidation of the primary structure of the resin and examination of synthetic variables affecting the cesium selectivity of the resin. One of the important issues identified during the course of this work that may limit the implementation of these materials is the oxidation of the resin. Current efforts have been focused on preparation and characterization of modified resins that should be more resistant to chemical oxidation. This is being achieved by modifying the backbone structure of the polymer resin. A variety of derivatives are being prepared that may expand the pH range over which the resin will selectively remove cesium from waste streams.

Electro-separation activities have focused on technologies with applicability to the environmental problems of government facilities and private industry. Electro-separations have the advantage of operating at low temperature, generating minimal secondary waste, and selectively controlling the separation by adjusting the applied potential. The technologies developed include electrodialysis, electroconversion, and electroactive materials. Electrodialysis processes have been developed to separate anions such as borate, nitrate, and phosphate. The separation of these ions is important to water-cooled nuclear power plants, spent-acid recovery, selective oxidation in the chemical industry, and environmental cleanup. The application of electroconversion to energetic materials is also being explored. Explosives, such as HMX and RDX, were converted to carbon dioxide, water, or useful byproducts using direct oxidation and reduction. This approach provides an attractive alternative to incineration. Finally, a new capability was developed to prepare, evaluate, and characterize electroactive surfaces. The work focused on preparing thin-film surfaces for selective adsorption and desorption of metal ions by manipulating the electroactive (oxidation/reduction) sites within the film. Electroactive films have been synthesized and demonstrated for the selective removal of cesium from simulated tank wastes. Electroactive films selective for other metal ions and anions are currently under development.

Supercritical fluid extraction research has focused on the basic investigation of metal complexation in compressible fluid solvents. Research efforts have centered on the development of analytical instrumentation and techniques for characterizing the solubility of metal and metal complexes in supercritical carbon dioxide. This supports the development of extraction processes for the removal of metals from aqueous solutions using ligand-impregnated supercritical carbon dioxide. This effort is predicated on the fundamental understanding of metal complex solubility and chemistry in supercritical fluids. Current investigations have entailed the development of high-pressure nuclear magnetic resonance capabilities to study, at the molecular level, labeled ligands and the metal ion as a function of fluid (solvent) properties. Scale-up of these analytical studies can lead to a closed-loop environmentally benign solvent-extraction process based on supercritical carbon dioxide. This research effort has contributed to the development of a waterless process for sizing fibers and dyeing/finishing fabric based on a "green" solvent—carbon dioxide. Supercritical fluid extraction technology has many applications for pollution prevention or in waste-water treatment, such as environmental remediation, mineral recovery, and true "zero-discharge" manufacturing process design. Supporting investigations on the mixing of supercritical fluids essential to the scale-up of any supercritical process are also being conducted.

Advanced Materials

Advanced materials are critical for breakthrough technologies in the environmental and energy missions. Because of their widespread use, new catalysts and catalyst supports can yield tremendous benefits in terms of environmental impact (increased yields and decreased waste streams) and economic productivity (new products). Advanced coatings offer the opportunity for significant energy impacts via large-scale implementation of lightweight, environmentally hardened materials and new products for energy conservation. New classes of materials, including mesoporous ceramics,

organomettalate catalysts, and advanced coatings will be useful for a wide range of DOE applied programs in Energy Efficiency and Fossil Energy, including transportation technologies, industrial technologies, and fuel cell development.

Advanced Coatings The advanced coatings effort is directed toward the development of an integrated capability in thin-film coatings for a variety of applications including energy, environmental restoration, defense, and biomedical. This integration includes state-of-the-art molecular beam epitaxy and chemical vapor deposition capabilities, unique physical vapor deposition, polymer multilayer coatings, and solution-derived, biomimetic thin films. The combination of these coatings technologies provides the Laboratory with a unique range of vapor and solution-based technologies for coating simple and complex geometries—powerful tools to address almost any coating challenge.

The technical and scientific base of the individual coatings components are being strengthened in this initiative. For example, in the biomimetics (solution phase) coatings effort, we are developing a unique scientific understanding of surface-induced thin-film formation. Expertise is being developed in the fundamental understanding of the factors (supersaturation, chelation, solution speciation) controlling film growth in the deposition solutions. Chemical modification schemes that induce biomimetic film growth are being developed for most of the "consumer" plastics (acetal, polycarbonate, nylon, polyethylene, polyvinyl chloride). The ability to deposit ceramic coatings on these plastics has tremendous technical significance.

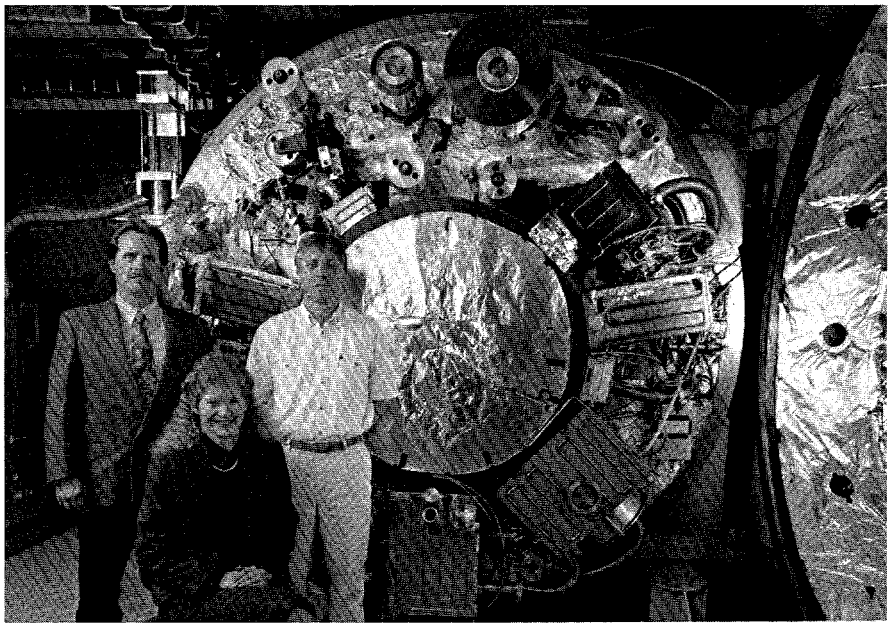
To strengthen our vapor-phase coatings technology base, we developed a new type of vacuum coating technology (polymer multilayer, physical vapor deposition), while adding more traditional coating processes to our capabilities, including large-scale magnetron and ultrahigh-rate sputtering. An in-line, multilayer, deposition process that lent itself to economic manufacturing and rapid prototyping was developed. Polymer multilayer technology offers a new method for integrating polymer film deposition at prototypic rates and has opened up a whole new area of product applications. A vacuum roll coater, capable of multiple, inline deposition processes using physical vapor deposition (e-beam and ultraviolet cure), sputtering, e-beam evaporation, thermal evaporation, plasma enhanced chemical vapor deposition, and polymer extrusion and flash evaporation (e-beam and ultraviolet cure) was also developed for rapid prototyping of advanced coatings.

The development of this unique, single-pass system has resulted in a Cooperative Research and Development Agreement (CRADA) with DuPont to investigate polymer multilayer/silver films, and both a CRADA and a license agreement with Moltech to develop a lithium-polymer battery. In addition, several other collaborative efforts are under way.

1996 R&D 100 Award Winner

1996 FLC Award Winner

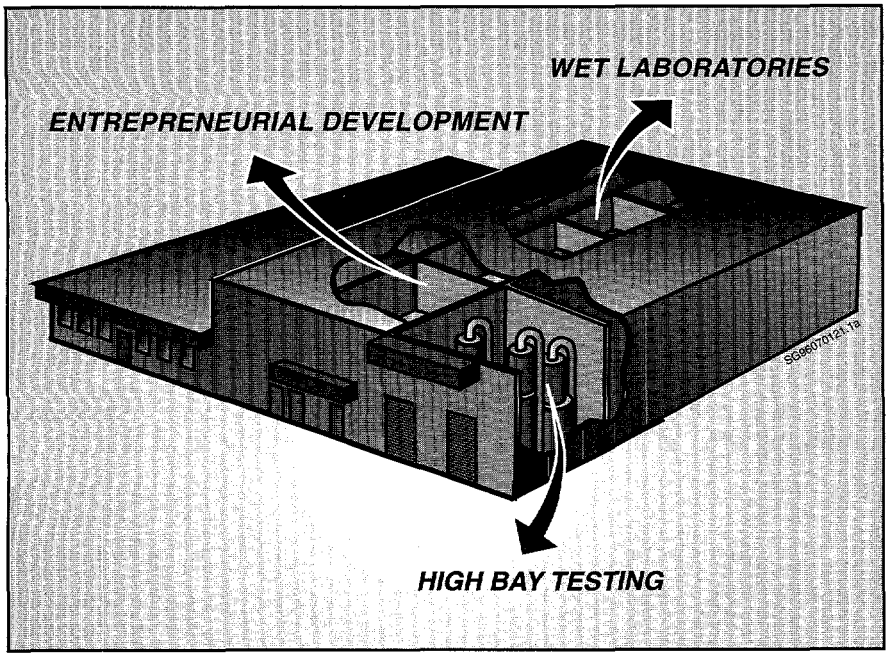
The Liquid Multilayer/Polymer Multilayer processes enable vacuum deposition of smooth, continuous polymer layers on flexible surfaces. Commercialization of the LML/PML processes means easier manufacture and higher quality for many products, including high energy-density, lightweight, rechargeable lithium polymer batteries used in electronic devices such as cellular phones and laptop computers.



The technology was transferred to Moltech Corporation through an innovative package of technology transfer mechanisms including a CRADA, a private development contract, a nonexclusive license and an option for an exclusive license for lithium polymer battery production.

Materials Synthesis and Processing Current efforts center around synthesis and processing of advanced catalytic materials, supports, and devices. Processing of these advanced materials into robust engineered forms is crucial to successful deployment. Projects are also under way on development of new techniques for solid-liquid separations in tank waste processing and in expanding ceramic nanoparticle synthesis to some new composition fields.

In the area of advanced catalytic materials, solid acid catalyst materials are



The APEL provides opportunities for efficient and effective development, validation, and commercialization of environmental and other innovative technologies.

being developed from nanoparticle sulfated zirconia. These materials, having effective pH as low as -14 (Hammett scale), can be safely held in the hand and will replace large quantities of sulfuric acid that are currently used by the petroleum refineries. Solid acid catalysts will yield significant environmental and safety benefits over the hazardous liquid alternative. A unique Laboratory process for synthesizing sulfated zirconia as a single processing option will facilitate deployment of this new technology.

Organomettalate materials are under investigation for potential replacements to aluminum chloride as catalysts for alkylation and acylation reactions. The aluminum chloride catalysts currently used are "once through" types and create a hazardous waste stream, which has raised strong environmental concerns. The new catalysts under development are Lewis acids that can be attached to substrates so they can act as recyclable heterogeneous catalysts.

Through an investment in mesoporous materials, we continue to explore novel processing routes to synthesize mesoporous materials and nanoscale structures based on self-assembly of ordered structures in surfactant solutions and other organic or biological systems. The self-assembled organic structures function as templates for the nucleation and growth of inorganic porous structures and other ceramic materials in a controlled manner. The inorganic materials produced this way have unique structural order and functional sites which cannot be achieved by traditional processing routes. These materials have specific surface areas in excess of 1000 square meters per gram due to monodisperse porosity. The pore diameters can be controlled in the range of 4 to 20 nanometers by selection of surfactants. The materials developed have direct applications as ion exchangers for environmental cleanup and separation and for catalysis and catalyst supports.

An effort to develop supported metal catalysts is under way for industrially important reactions. This effort builds upon technologies that have been or are under development at the Laboratory (e.g., glycine nitrate combustion synthesis, mesoporous materials) for producing high-surface area inorganic materials. These processes can produce either nanoscale particle size or ultrahigh surface area silica, zirconia, and aluminosilicate materials that offer a unique opportunity for application as supports for metal catalysts. These supports are unique because the high surface area and the large pore volume to surface area ratio inherent in these materials afford the potential for highly dispersed metal deposition.

Methods of processing ultrafine ceramic particles into useful engineered forms are critical capabilities being developed to accelerate the deployment of novel materials into industrial processes. Currently, the project is focused on ultrafine powder consolidation for catalytic applications using both nanoparticle and mesoporous powders. Issues include overcoming problems of consolidating powders that have highly hydrated surfaces, maintaining high surface activity, and fabricating mechanically robust components. These components must retain their high pore volume after processing to facilitate mass transport.

Another effort is focused on developing synthesis of hexaaluminates through cation substitution in the crystal structure and structural modification with a view to designing catalyst materials for high temperature processes such as steam reforming, membrane reactor, and gas turbine catalytic combustion. The objective is to provide an understanding of the relationships between synthesis and catalytic activity, selectivity, and durability.

Advanced Process Engineering Laboratory

We are supporting, through this initiative, a new effort to build an engineering-scale user facility to rapidly develop, test, and deploy new technologies. Commercial users, other agencies, and Laboratory researchers will use the Advanced Process Engineering Laboratory (APEL) to demonstrate new technologies and to develop the technical and regulatory databases for permitting, licensing, and otherwise establishing the technical, economic, and regulatory basis for applying the technology to real-world environmental and technical problems. The systems and services in APEL include permits;

effluent treatment systems; modular configurable support systems; data collection, modeling, and analysis; as well as certified analytical laboratories and a waste treatment/packaging system.

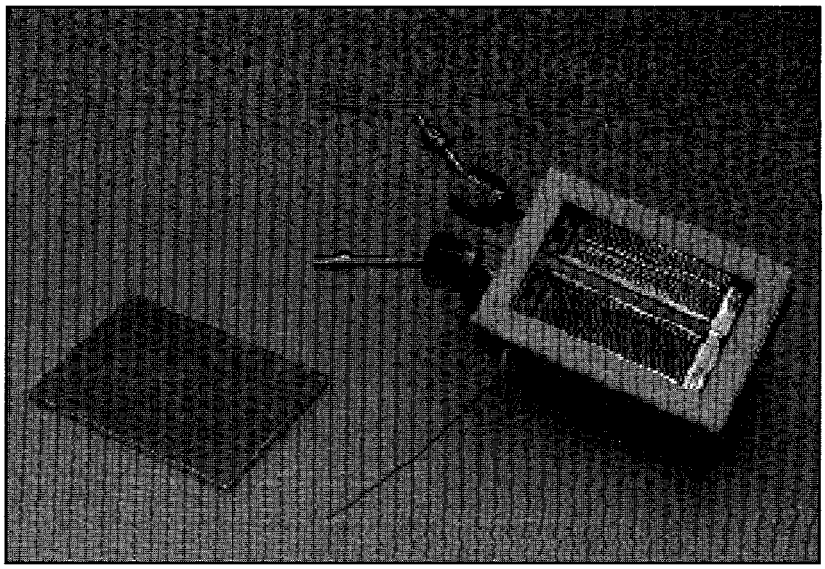
Funding for this user facility will be obtained through an innovative collaborative funding arrangement with DOE (Economic Transition Funds), Port of Benton, the City of Richland, Battelle, and the Washington Public Power Supply System.

Energy Technology Development

The Energy Technology Development initiative is designed to broaden and deepen Pacific Northwest's fundamental core competencies affecting energy systems and utilization. These competencies are the primary foundation for work supporting the Office of Energy Efficiency and Renewable Energy, a major contributor to support for the Office of Fossil Energy, and a key element in the Laboratory's collaboration with American industry. In FY 1994, the Energy Programs Directorate led a series of workshops across the Laboratory to refine the focus for this competency. The goal was to establish an important niche for the Laboratory within the energy technology community; one that can be used to solve important problems, and that readily distinguishes the Laboratory from other research and development organizations. A compelling vision emerged from that effort.

> The Laboratory will develop and deliver innovative technologies and services that will transform the global energy infrastructure leading to a sustainable energy future. We will focus on improving the use of existing energy assets and developing a new generation of distributed energy systems.

The key to this vision statement is the dual investment focus on improving the utilization of existing energy assets and developing a new generation of distributed energy systems. These two focuses are highly complementary and will lead to the development of reliable, cost-effective energy systems that are environmentally friendly and important for maintaining the competitiveness of American industry.



Researchers at Pacific Northwest are developing microchannel chemical reactors, for the conversion of hydrocarbons, which have the potential of providing unique reaction products that otherwise would be difficult to accomplish using conventional reactor technology. A key element is the incorporation of extremely precise temperature control, which is accomplished through the integration of microchannel heat exchangers within the component. In this prototype example (pictured) the goal is the development of a compact heat source that does not produce pollutants such as NOx, and which therefore does not require a catalytic converter unit.

Current research activities are focused in four interrelated technology areas: microtechnology, transmission and distribution systems, advanced operations and maintenance technology, and transportation materials. These areas are briefly described below. The substantial progress to date in developing competencies and technologies through this initiative enables a reduction of investments in FY 1997 and beyond. Funding projections are shown in the table at the end of this section and are not included in the Resource Projections. It is anticipated that continued Pacific Northwest-sponsored research will be conducted in selected areas currently receiving Laboratory discretionary investment under this initiative but with different or enhanced focus.

Microtechnology

The objective of this Energy Technology Development effort is extending high-precision, microfabrication techniques, originally developed for the electronics industry, to preliminarily develop and demonstrate revolutionary thermal and chemical components and systems. Examples include compact, high efficiency, microchannel heat exchangers, fuel processors, and heat engines with the potential for reductions in size, weight, and capital costs compared to conventional hardware.

Microtechnology serves both Energy Technology Development initiative competency focuses: in the near term, microtechnology-based components will prove important for operating and maintaining our existing infrastructure; and, in the longer term, microtechnology-based energy conversion systems (e.g., heat pumps, power generators, etc.), broadly distributed to locations where their services are required, constitute the quintessential distributed energy systems. New microtechnologies could make small-scale, distributed energy processes economically and environmentally attractive when compared to centralized processes normally used today.

There are numerous potential advantages which may accrue from microtechnology systems besides reduced size and weight, including 1) capital cost advantages due to economies of

production, compared to the large capital investments required for large, centralized facilities; 2) employing phenomenological processes that are more powerful at the microscale than at the macroscale (such as heat transfer and mass transport); and 3) the ability to facilitate distributed systems, hence eliminating the energy transmission and distribution losses characteristic of large central systems.

Pacific Northwest activities are focused on design, fabrication, and testing of microtechnology-enhanced thermal and chemical components and systems. We are extending the manufacturing techniques developed for microelectronics to manufacture compact, high capacity components and are combining them into complete energy and chemical systems. We are also developing the basic system architectures for a wide variety of energy applications. For example, we have fabricated and tested the first microchannel evaporators, condensers, gas absorbers, and electromagnetic micropumps. Results show that the performance of microchannel heat and mass transfer devices are outstanding and offer the potential to radically reduce the size and weight of many energy and chemical conversion processes. We are now working on an integrated microchannel combustor/evaporator; advanced microchannel heat exchangers; compact, microtechnology-based compressors; microchannel partial oxidation reactors for hydrogen production; and microtechnology-based heat engines. Our future target is to assemble these components into prototype heat pumps, power generators, and chemical conversion systems.

Transmission and Distribution Systems

This Energy Technology Development effort seeks to develop and deploy technologies to improve the capacity, reliability, efficiency, and safety of the nation's energy transmission and distribution systems. The current focus is on electric power. Since new transmission capacity is difficult to implement, existing systems must be operated closer to their physical limits. Restructuring of the electric power industry will also place many new stresses on operation of the electrical system. In addition, there is a movement toward small, distributed generation and storage devices at the site of the end user (the "distributed utility"). This places strains on the stability and reliability of the nation's transmission and distribution systems that require better diagnostic systems and more effective real-time control of system operations. The distributed utility model requires close coordination of fuel delivery and generator deployment, better integration of independent renewable generators, and a better understanding of how distributed electricity generators and storage devices impact the existing electrical grid. Coordination between control centers and new physical elements of the power system is also required for enhanced grid operation. All of these are important elements in our transmission and distribution investment portfolio.

To meet the need for improved operations, the Laboratory is developing advanced analysis and simulation tools and conversion technologies in four main areas:

- measurement-based analysis techniques for modeling and understanding power system dynamics and development of robust controls
- new theoretical, mathematical, and computational analysis techniques for model-based power system analysis, including evaluation of distributed utility options
- pulse amplitude synthesis and control technology for frequency conversion of electrical power to connect multiple distributed direct current and asynchronous alternating current generation sources to the electric grid
- artificial intelligence-based tools for short-term load forecasting and detecting and diagnosing electrical system problems.

Development work is not being conducted in a vacuum, but rather through close coordination with the Bonneville Power Administration, the Electric Power Research Institute, and Northwest utilities, where technology is being deployed on a trial basis as it is developed to make sure that it meets the needs of the utility industry.

Advanced Operations and Maintenance Technology

With the overriding need for government and industry to be more competitive comes the associated emphasis on cost control and cost-effective operating and maintenance approaches. Thus, a significant element of our Energy Technology Development initiative is the development of technologies and systems to support good decision making in the operation and maintenance of energy systems. Our earlier work has focused on development of automated diagnostic techniques and approaches. Having developed strong capabilities in that area, we are now shifting efforts toward low-cost, higher-reliability sensor systems, another critical barrier to efficient operation of energy systems. The capabilities resulting from investment in this technical area are key to two focuses: 1) extending the life and increasing the reliability and capacity of the existing energy infrastructure, and 2) effectively operating and maintaining a large, complex network of distributed energy systems. Operations and maintenance technologies developed under the Energy Technology Development initiative will, of course, be applicable to a wide range of physical systems, not just energy systems.

Pacific Northwest is pursuing two approaches for reducing the cost of sensor systems, including a generic sensor validation approach that can be used within an operating system to detect system failure and to serve as a virtual sensor to enable continued operation of some systems until the sensor can be repaired. This approach will also provide the logical basis for minimizing sensors needed for any particular system. Concepts for low-cost sensors including sensors that are powered by the system they are measuring and (in later years) moving on to new approaches for remote communication with dispersed sensor suites. The initial targets here will be a low-cost self-powered device for measuring the Btu content and constituency of natural gas in pipelines, and optically

powered sensor platforms for high voltage or hazardous environments.

This development work is being conducted in cooperation with other Energy Technology Development initiative elements, including the microtechnology and transmission and distribution elements.

Transportation Materials

This Energy Technology Development effort seeks to develop materials and material/component manufacturing methods that will improve the fuel efficiency of vehicles and reduce their emissions. We are also focusing on technologies needed for the next generation of vehicles. These technologies, once developed and demonstrated, are often widely applicable beyond the transportation arena, and this element seeks to identify alternative applications and to adapt the transportation technologies to those applications. This area largely serves the second (distributed energy system) focus, since vehicles are distributed systems, although the materials that we are developing will serve to extend the life of, and enhance the efficiency and effectiveness of, the existing energy infrastructure.

In past years, the Laboratory has focused on advanced manufacturing and coatings technologies. Superplastic forming holds the potential to reduce the weight of new generation vehicles and improve U.S. industrial manufacturing competitiveness. The Laboratory's role has been adapting this technology from the aircraft industry, and the development of new, cheaper alloys to make the process feasible in the automobile industry. The Laboratory also developed advanced coatings techniques that can be applied for special purpose glasses, to replace paint, and to coat engine parts to provide compatibility with alcohol-based fuels. Our work in this arena continues, funded by the Office of Transportation Technologies, the Office of Energy Research, and private industry.

Our current focus is development of technology to reduce automobile emissions. Approximately 70 percent of exhaust emissions that exceed standards are generated during cold start of catalytic converter-equipped vehicles. During cold start, the converter is at insufficient temperature for catalytic reactions to occur efficiently, resulting in higher levels of hydrocarbon and carbon monoxide emissions. Although a number of approaches for reduced light-off times and improved converter operation are being investigated, there is an emerging need to have a better predictive understanding of thermal conditions and flow behavior of automotive exhaust systems. The Laboratory is focusing on the modeling of exhaust flow and heat transfer in real exhaust systems, coatings for thermal control and exhaust treatment, and thermal energy storage concepts for enhanced catalytic converter performance. Laboratory staff are also developing new manufacturing approaches that will redesign the engine cylinder to reduce crevice volume, a principal source of emissions generation.

Medical Technologies and Systems

Significant potential exists throughout the DOE system to apply capabilities and technologies developed for other mission areas to the issue of national health care. The DOE Medical Applications and Biophysical Research program, the Basic Energy Sciences Materials Science program, and the Laboratory Technology Research programs are all making direct and indirect significant contributions to advancing the state of medical science and technology. Researchers at Pacific Northwest are developing basic scientific knowledge, breakthrough medical products, and innovative ways to improve health care delivery systems that will reduce the cost and improve the efficacy and accessibility of health care. Our major areas of emphasis are in diagnostics, therapeutics, informatics, and health care delivery systems.

Diagnostics

Rapid, accurate, cost-effective diagnosis is the first requirement for medical treatment. Sensitive, easy-to-use diagnostic tools will play a key role in defining the breakthrough diagnostics products of the future. The Laboratory is supporting the development of noninvasive diagnostic instrumentation in two main areas: advanced ultrasound and high-specificity sensors systems.

The Laboratory is developing the core technology to support real-time three-dimensional visualization of both transmission and reflective ultrasound. Researchers are exploring ultrasound enhancements including two-dimensional array transducers, rapid three-dimensional display rendering capabilities, tissue segmentation techniques, and vector velocity measurement.

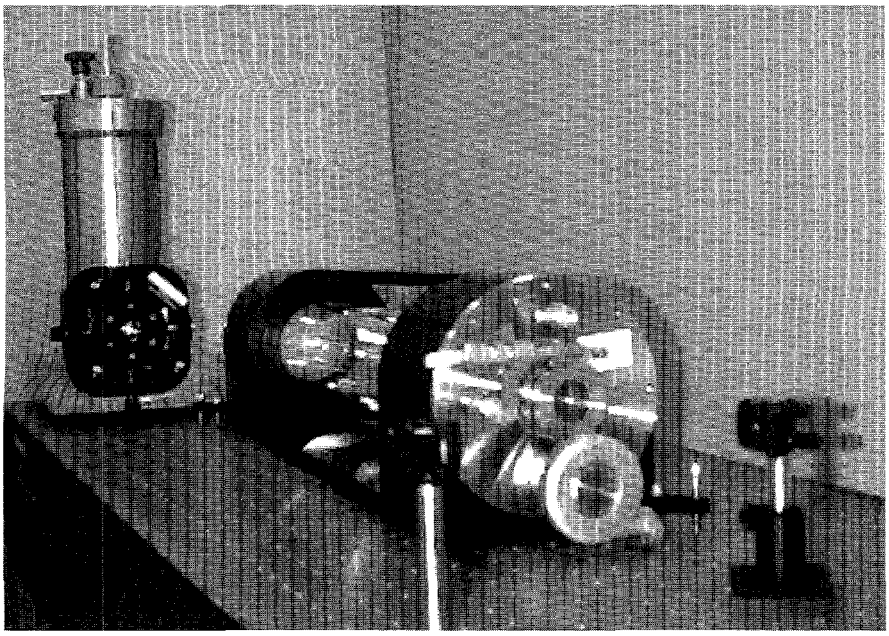
The Laboratory is enhancing its sensor capabilities to develop state-of-the-art sensor systems for detecting chemical and biological toxins, monitoring physiological status, detecting diseased tissue, and recording treatment response. Near-term areas of focus include the following:

- proof-of-principle experimentation to demonstrate the applicability of laser-based breath analysis for real-time detection of disease
- development of probes for in situ, real-time dosimetry of therapeutic radiation during boron neutron capture therapy for cancer treatment
- proof-of-principle experiments to establish the technical basis for the development of ultrasensitive sensors to detect endotoxins in solution (blood, saline, water, etc.)
- exploratory research to determine the feasibility of using optical detection of key analyte levels in blood to enable in vivo sensor development.

Therapeutics

Once disease and damage is detected, rapid targeted therapeutics are needed to stabilize, repair, or reverse the progression of diseased tissue.

Laboratory researchers are working on targeted delivery systems based on radionuclides and high-specificity toxins. Specifically, research is directed toward developing and testing a novel radium-223 radioconjugate for cancer therapy. Prior work established the methodology to produce radium-223 and synthesize modified radium-complexing agents. The current effort



A new method of breath analysis based on ultra-sensitive laser spectroscopy of nonradioactive isotopes developed at Pacific Northwest, is safe, inexpensive, fast, and easy to use. The detection apparatus will be small enough to sit on the corner of a desk and inexpensive enough to be purchased by the physician specialist for office use.

will develop and test, with animal models, immunoconjugates that can be used as therapeutic radiopharmaceuticals for treatment of cancers in humans.

Laboratory scientists are developing biomaterials for tissue replacement, tissue repair, and implant stabilization that have improved longevity and enhanced biocompatibility. One current research effort involves developing novel processing routes that produce bioactive coatings or composite materials for bone replacement applications. Fiscal year 1995 results included the formation of either dense or porous collagen/mineral bioactive coatings. Control of the mineral phase formed was possible with either hydroxyapatite or octacalcium phosphate being precipitated. This work is continuing through the DOE Laboratory Technology Research program. Other biomaterials work is focused on the following:

- proof-of-principle studies to develop polymers that contain amino acid esters, antibiotics, and/or anticoagulant agents attached to a polymer backbone that could be used to develop stents
- investigating the feasibility of using polysaccarides and/or other nontoxic binders in near net shape forming of complex ceramic parts for use in medical applications such as components of joint devices or as resorbable, reconstructive, and restorative tissue enhancement or replacement.

Researchers also are working to develop advanced solid electrolyte materials to use as separation membranes in oxygen electrolyzers. The development of these new materials will allow the operation temperature to be decreased, improve electrolyzer efficiency, and allow for miniaturization. This enabling technology will provide the technical basis for developing a prototype, small-scale electrolyzer for delivery of therapeutic oxygen.

Informatics

Timely access to patient records and the latest information on disease treatment and transmission is crucial to health care decision making. The Laboratory is integrating its expertise in computer science, information management, and telecommunications to better link the decision maker to the data source and provide advanced tools to aid in data analysis and visualization. Current exploratory research efforts will yield neural-network-based prototype systems for personal status monitoring and lung ventilation diagnosis. Several ongoing programmatic efforts, conducted in collaboration with Madigan Army Medical Center and the Army's Artificial Intelligence Center, are focused on developing prototype physician and patient information systems. In the future, we envision integrating our extensive information systems capabilities, remote sensing technology, and our understanding of global environmental and economic factors to provide science and technology solutions to the problem of global infectious disease surveillance.

Health Care Delivery Systems

Pressure to improve the performance and quality of health care delivery continues to mount as health care costs spiral upward. Improving access and delivering medical products and services at a reduced cost requires a holistic approach that balances social/behavioral, technological, and business issues. Current work with various organizations draws on our experience in strategic and business planning, policy analysis, stakeholder involvement, business and work process analysis and reengineering, system modeling, human factors analysis, organizational design, and change management.

Programmatic support for elements of the Medical Technology and Systems initiative is sought through DOE offices that emphasize basic and applied research. Included among these are the Medical Applications and Biophysics Research program, the Basic Energy Sciences Material Science program, and the Laboratory Technology Research program. In addition, several other opportunities are emerging with the U.S. Department of Defense, particularly in the areas of combat casualty care and with industry through CRADAs. Funding projections are shown in the table at the end of the section and are not included in the Resource Projections.

Pacific Northwest National Laboratory Initiatives

(Budget Authorization $ in Millions)

Initiative	1996	1997	1998	1999	2000	2001	2002
Advanced Processing Technology							
Operating	6.7	8.2	15.7	25.7	26.0	28.6	28.9
Capital	0.9	1.4	1.4	1.6	1.6	1.6	1.6
Total Advanced Processing Technology	**7.6**	**9.6**	**17.1**	**27.3**	**27.6**	**30.2**	**30.5**
Energy Technology Development							
Operating							
Energy Efficiency and Renewable Energy	6.0	7.0	9.0	11.0	13.0	15.0	17.0
Energy Research	0.6	1.0	2.0	2.5	3.0	3.5	4.0
Laboratory Technology Transfer	1.0	1.0	1.5	1.5	1.5	1.5	1.5
Private Sector/Other	2.0	5.0	7.0	8.0	9.0	10.0	11.0
Capital							
Energy Efficiency and Renewable Energy	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Research	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Laboratory Technology Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Private Sector/Other	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Energy Technology Development	**10.1**	**14.5**	**20.0**	**23.5**	**27.0**	**30.5**	**34.0**
Global Environmental Change							
DOE Funding							
Biological & Environmental Research[a]	22.9	22.9	22.0	22.0	22.0	22.0	22.0
Policy, Fossil, EE	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other DOE	1.3	0.3	0.3	0.3	0.3	0.3	0.3
Work For Others							
Other Federal Agencies	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	8.7	8.3	8.3	8.3	8.3	8.3	8.3
Total Global Environmental Change	**33.3**	**31.9**	**31.0**	**31.0**	**31.0**	**31.0**	**31.0**
Medical Technologies and Systems							
DOE							
Office of Health & Environmental Research	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Basic Energy Sciences	0.5	0.6	0.5	0.5	0.5	0.5	0.5
Laboratory Technology Transfer	0.5	0.5	0.5	0.5	0.5	0.5	0.5
DoD	2.5	3.7	4.5	6.0	8.0	9.5	9.0
DHHS	0.0	0.4	0.5	0.8	1.0	1.2	1.4
Industry	0.5	0.8	1.0	1.5	2.0	2.5	3.0
Capital Equipment, DOE	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Total Medical Technologies & Systems	**8.0**	**11.6**	**15.5**	**20.1**	**25.5**	**29.9**	**15.4**

Pacific Northwest National Laboratory Initiatives (contd)

(Budget Authorization $ in Millions)

Initiative	1996	1997	1998	1999	2000	2001	2002
Microbial Biotechnology							
Energy Research	1.4	1.5	1.8	2.5	4.0	5.5	7.0
Environmental Management	1.0	1.3	1.8	2.5	4.0	5.5	7.0
Energy Efficiency & Renewable Energy	0.1	3.5	1.2	2.0	4.0	6.0	8.0
Fossil Energy	0.1	0.2	0.5	0.8	1.5	2.5	3.7
Other Federal Agencies	0.5	1.0	2.0	2.2	5.0	7.0	9.0
Industry	0.5	1.0	1.5	5.0	7.5	9.0	10.5
Capital Equipment	0.5	0.6	0.6	1.9	3.0	3.0	3.0
Total Microbial Biotechnology	**4.1**	**9.1**	**9.4**	**16.9**	**29.0**	**38.5**	**48.2**
Molecular Sciences Research							
Operating							
Basic Energy Sciences	7.0	8.0	9.0	9.5	10.0	10.5	11.0
Biological & Environmental Research[b]	3.0	5.5	9.0	9.5	10.0	10.5	11.0
Other Energy Research	1.5	2.0	3.0	3.1	3.2	3.4	3.5
Environmental Management & Other	2.5	5.5	9.5	9.9	10.4	10.9	11.5
Capital							
Basic Energy Sciences	1.0	1.5	2.0	2.0	2.1	2.2	2.2
Biological & Environmental Research[b]	1.0	1.5	2.0	2.1	2.2	2.3	2.4
Other Energy Research	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Environmental Management and Other	0.5	0.5	0.4	0.4	0.5	0.6	0.7
Total Molecular Sciences Research	**17.0**	**25.0**	**35.4**	**37.0**	**39.0**	**41.0**	**42.9**
Total Laboratory Initiatives	**94.6**	**114.8**	**141.4**	**168.8**	**192.1**	**214.1**	**202.0**

(a) Includes Atmospheric Radiation Measurement program funding, which will have significant subcontracts and is included in the resource projections.
(b) Assumes that funding for the EM Sciences Program will be managed by the Office of Energy Research.

5 Core Business Areas

As described in the Laboratory Strategic Plan, the Pacific Northwest National Laboratory is focusing its efforts in order to contribute to selected goals in each of the five core missions: science and technology, environmental quality, energy resources, national security, and economic productivity. Objectives have been established in each area and the Laboratory's scientific and technical programs are directed toward these objectives which are described below.

Science and Technology

Research at Pacific Northwest directly supports the science and technology mission of the Department of Energy. Our basic and applied research produces new knowledge and understanding in a wide variety of scientific disciplines that underpin the Department's technology missions in energy, environmental quality, and national security. Significant educational opportunities also are provided by those research programs. Our visiting scientists programs, graduate and undergraduate programs, and special programs that target all levels of precollege students are designed to stimulate and train the next generation of U.S. scientists. In addition, our science and technology research produces scientific advances that stimulate U.S. economic prosperity. Many of our research programs have direct industrial interactions, e.g., Cooperative Research and Development Agreements (CRADAs), while others have more informal industrial collaborations that transfer new scientific discoveries to industry.

Laboratory scientists contribute to DOE's science and technology mission in a variety of ways. Staff use special skills and facilities that enable them to contribute as part of national research programs. We form teams of scientists and engineers to address complex problems that require a multidisciplinary approach. Perhaps most important, we bring together basic and applied researchers with multidisciplinary skills in collaboration with partners from academia, industry, and other federal laboratories to develop solutions to DOE's most challenging research problems.

The discussions in this section of the Institutional Plan describe our core science and technology research programs. We describe current and future research plans to achieve the following objectives

- bring our basic scientific and technological capabilities to bear on a wide range of applied science programs to enhance the effectiveness of these programs
- complete construction and begin operating the Environmental Molecular Sciences Laboratory (EMSL), a state-of-the-art collaborative research facility that is the key element in our efforts to advance the understanding of environmental molecular science
- understand the behavior of contaminants in subsurface, marine, and atmospheric environments by understanding the chemistry in complex systems
- enhance fundamental knowledge related to important industrial processes, chemical separations, the behavior of complex fluids, and synthesis of new materials
- bring emerging supercomputing technologies to bear on modeling complex systems
- advance the understanding of the health effects of hazardous agents
- improve the understanding of environmentally important microbial systems and applications in bioremediation, bioprocessing, and pollution prevention.

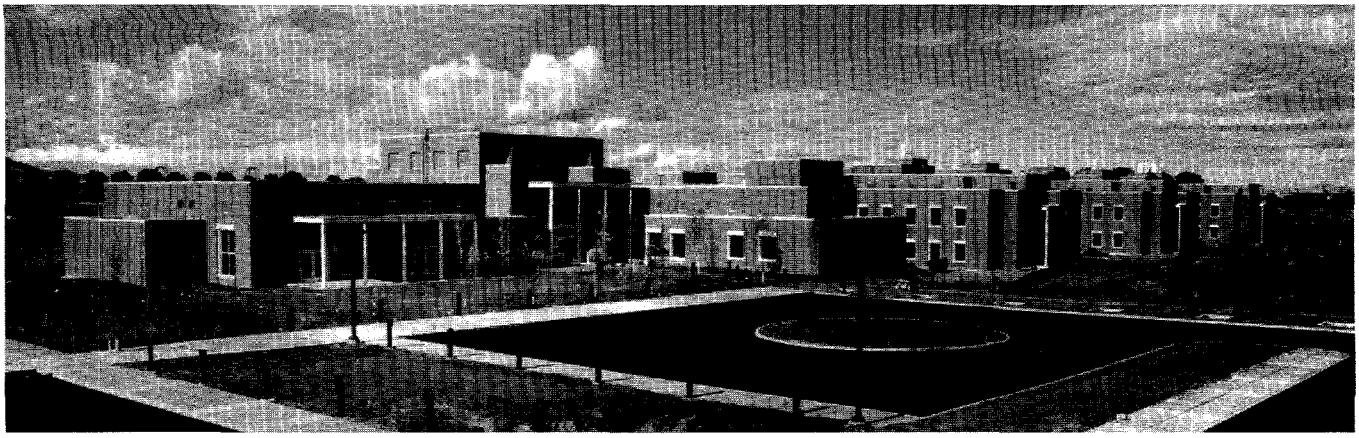
Office of Energy Research

Research at Pacific Northwest for the Office of Energy Research directly contributes to the nation's science and technology leadership. Our Energy Research programs bring together staff, unique research instrumentation, and facilities to address many of the nation's most challenging and complex research problems.

Research supported by Energy Research spans a wide variety of scientific disciplines and brings together collaborators from academia, industry, and other federal laboratories. Below are programmatic descriptions of research conducted at the Laboratory, sponsored by the various Energy Research programs. In addition, the Office of Health and Environmental Research (OHER) is funding the EMSL, a new national collaborative user facility currently under construction with completion scheduled for FY 1997.

Environmental Molecular Sciences Laboratory

The EMSL will be an essential part of our ability to provide the fundamental scientific understanding needed for DOE to successfully achieve its strategic environmental quality and science and technology objectives. The EMSL will support forefront scientific research programs critical to DOE's missions, provide unique resources to the greater scientific community, enhance educational and training initiatives, and facilitate technology development and transfer among federal and state agencies and laboratories, academia, and industry.



Construction of the EMSL was completed by the end of FY 1996. Equipment and systems will continue to be installed during FY 1997.

As a collaborative research facility, the EMSL will be a national focal point for molecular science research with a primary emphasis on DOE's long-term environmental quality mission. The EMSL will capitalize on today's experimental, theoretical, and computational sciences to create an expanded science base, thus enabling the development of new technologies that will not only have a positive impact on national problems but will stimulate the U.S. economy by creating new opportunities in global technological markets.

EMSL research programs that are responsive to the needs of DOE's Offices of Energy Research and Environmental Management are being developed under Pacific Northwest's Molecular Sciences Research initiative. Special attention is given to Energy Research-funded research and how it can be used to provide the knowledge needed to help Environmental Management meet its environmental cleanup challenges. These efforts will be greatly enhanced by the unique facilities and equipment that will be available in the EMSL. These two elements, the EMSL capabilities and the research programs developed under the Molecular Sciences Research initiative, are vital in efforts to address the complex technical issues associated with DOE's environmental mission.

Collaborative efforts undertaken by EMSL staff continue to increase both in number and significance. The EMSL Advisory Committee, which was formed to ensure a voice for external users in EMSL operations and management, recommended formation of a Molecular Science Computing Facility Advisory Committee and a Magnetic Resonance Advisory Committee. These committees will play major roles in guiding the development and successful operation of the EMSL as a collaborative research facility.

An operations plan based on the "best practices" used in top industrial and government laboratories and designed to meet the success criteria established for the EMSL has been developed. The principle guiding development of the plan was to truly define state-of-the-art operations in terms of cost effectiveness and the demands for services in the EMSL. This definition was balanced against EMSL's operational need to focus on research of the highest value while minimizing worker risk and adverse environmental impacts. A review of the plan conducted during the second quarter of FY 1996 concluded that the operational approach meets the intent of the "work smart standards," and that it provides a reasonable basis for conducting operations in a non-nuclear research facility. The operations plan will be fully implemented by the end of FY 1996.

Over the life of the EMSL construction project, the DOE and DoD will spend $229.9 million to design and construct the building and to design, develop, and acquire the advanced research instruments. A total of $194 million has been provided through FY 1996 for these activities. In the FY 1997 DOE budget, $36 million in project funding is required to complete the project. Activities in FY 1997 include project management; completion of procurement activities; receipt, testing, and acceptance of research and computer equipment and systems; completion of facility and equipment readiness assessment; phased turnover of the facility and equipment from construction to operations; closeout of the facility construction contract; and completion of Key Decision 4 requirements. Construction of the facility is scheduled to be completed at the end of FY 1996, and equipment and systems will be installed and turned over to operations in FY 1997 resulting in an overall project completion by the end of FY 1997.

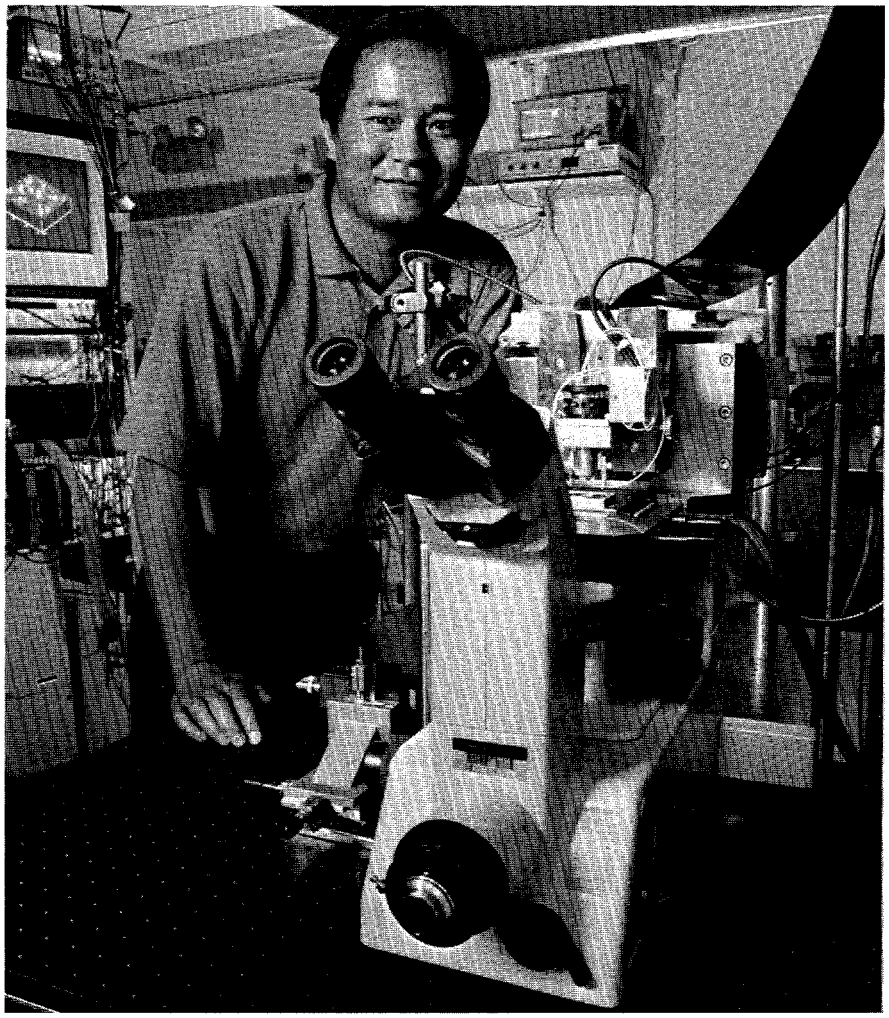
EMSL facilities developed under construction or programmatic support are described below.

Chemical Structure and Dynamics

The Chemical Structure and Dynamics facilities support activities aimed at providing a fundamental, molecular-level understanding of chemistry in a wide variety of environmentally important interfaces. The facilities will provide the means to synthesize unique molecular structures (i.e., surfaces, interfaces, and atomic and molecular clusters), to measure the structures of these model systems (including the ability to study single molecules within these structures), and to observe their

chemical properties (e.g., thermodynamics, kinetics, and dynamics). This approach provides the underpinning for quantitative models of the complex systems found in natural and contaminated environments. The work will also develop novel sensitive and species-specific detection methods required for the wide-ranging site and process characterization/analysis needs of the DOE complex.

- The Surface/Interface Structure and Reactions (SISR) Laboratory houses surface/interface instrumentation (including 10 ultrahigh-vacuum surface science instruments) to study the kinetics of molecules interacting with, and undergoing reactions at, oxide and ice surfaces and interfaces. This facility includes several molecular and ionic beam sources with capabilities for growing ices doped with molecules, radicals, and ions to simulate aerosols important in atmospheric chemistry, to model mineral interface chemistry and heterogeneous catalysis, and to understand the stability of short- and long-term hazardous waste forms. Single-molecule surface structure and photochemistry studies will rely on instrumentation designed to provide direct atomic-resolution imaging of molecules on surfaces, and to follow their reactions, consisting of room-temperature and low-temperature (i.e., 20K) scanning tunneling microscopes with associated sample-handling and interface capabilities. The SISR Laboratory also contains six multi-wavelength laser systems and other energy sources for the initiation of chemical reactions and the state-resolved detection of chemical reaction products.
- The Time-Resolved and Solution Spectroscopy Facility provides the capability for studying relaxation processes in fluids, ultrafast dynamics in biological systems, and time-resolved processes at surfaces and interfaces. It contains laser systems for generating picosecond and femtosecond pulses, including state-of-the-art femtosecond laser systems operating from the infrared through the ultraviolet, as well as picosecond systems for the study of longer time processes. These systems will be used with absorption, emission, infrared, and Raman spectrometers, with a unique collection of sample cells, for analysis of molecular dynamics and chemical reactions at environmental interfaces, such as solid mineral surfaces immersed in solutions, metal surfaces in contact with waste solutions and slurries, and surfaces important in heterogeneous atmospheric chemistry. Recently developed near-field optical microscopes enable the detection and spectroscopic study of single chromophores in solution, at interfaces, and in biological systems.
- The Cluster Structure and Reaction Dynamics Facility contains instrumentation for studying the structure and reactivity of clusters important to understanding contaminant chemistry in solution and at mineral interfaces and in heterogeneous atmospheric processes. It contains optical, mass, and photoelectron spectrometers that form nine independent research stations. These stations are used in conjunction with neutral and ionic sources to provide high-flux beam currents of cold, mass-selected clusters of solvated molecules, metal alloys, metal oxides, minerals, and insulator materials, for the study of cluster structures, dynamics, and reactions. The instruments include custom-designed expansion nozzles and



Research using near-field microscopes has applications in several fields including chemical analysis, materials, and the mapping of biological structures.

provide high-resolution infrared spectroscopic capability using semiconductor diode lasers and a Fourier-transform spectrophotometer. Long-path gas absorption cells are available for studying atmospheric chemistry and for developing sensitive remote detection and analytical techniques. Dynamics measurements will rely upon the short-pulsed laser systems described above. Cluster preparation and spectroscopic detection will utilize a number of tunable laser systems capable of providing high-resolution and/or high-energy nanosecond pulses with wavelengths ranging from the infrared into the vacuum ultraviolet.

Theory, Modeling, and Simulation

Computational modeling of the transport, fate, and processing of environmental contaminants is a challenge of the first magnitude, a so-called "Grand Challenge," because of the complexity, the temporal and spatial scales, and the urgency of the problems at hand. The scope of the many multiple interconnected challenges that must be addressed to make substantial progress in the computational modeling of complex physical, chemical, and biological systems is very large. Computational molecular science, in combination with experimental investigations, provides a fundamental understanding of the complex interactions of anthropogenic materials with the environment. Computational molecular science can provide data that is difficult, or at times even impossible, to obtain in the laboratory. It can also extend limited experimental data into domains in which such data are not yet available and can help provide direction to optimize experimental efforts. Macroscopic environmental and processing models require enormous amounts of data. No matter how comprehensive the model is, if the underlying physical, chemical, and biological data are missing or unreliable, the model will be of limited value. It is the goal of computational molecular science to reliably provide as much of these data as possible.

Efforts to model molecular processes that occur in the environment require fundamental understanding of molecules and their interactions as isolated species in the gas phase, in condensed phases such as liquids and solids, and within a range of interfaces. For several reasons, such modeling is, however, one of the most challenging problems ever faced by computational molecular science:

- the molecules of importance vary a great deal in size, ranging from organic chelates and chlorinated solvents, to inorganic complexes of actinides and other metals regulated under Resource Conservation and Recovery Act (RCRA), to catalytic systems including zeolites, to minerals such as iron oxides and clays, to biomacromolecules including proteins, enzymes, and DNA
- many of the molecular systems involve multiple species and multiple phases (e.g., tank waste solutions as well as heavy-metal-contaminated fluids flowing through the soil)
- the time scale of important events can range from picoseconds for fast reactions in the gas phase to tens of thousands of years for migration of radioactive metals in glasses.

Consideration of the scaling laws for molecular computations of the accuracy required to be of value shows that the modeling studies which are needed will require a level of computing and modeling capability that far exceeds (100 to 1000 times) that available with current supercomputers and molecular modeling software.

To provide the advanced computing capability needed by the staff and collaborative users of the EMSL, a Molecular Science Computing Facility has been established. The MSCF will provide a robust and highly integrated computing environment, with high-speed links to collaborators at other DOE laboratories, universities, and industry. The facility consists of the following:

- The High-Performance Computing Center, which will provide for the high-performance computing needs of the research programs in the EMSL. The center will have a large-scale, massively parallel IBM SP computer system with 472 processors with a peak performance of 200 to 300 gigaflops (50 to 100 gigaflops sustained user performance), 50 gigabytes of user memory, and more than a terabyte of on-line disk storage. The High-Performance Computing Center will also contain a high-performance database and archive computer system for handling the large-scale scientific data management needs of the computational and experimental research programs in the EMSL. The database/archive system will have an initial capacity of 20 terabytes of on-line tape storage and 400 gigabytes of on-line disk. Database/archiving processing will be provided by 4- and 8-processor SGI Challenge computer systems.
- The Graphics and Visualization Laboratory, which will provide high-performance production graphics and visualization facilities for the display and analysis of complex data sets from both experiments and simulations. This laboratory will contain four high-performance graphics workstations with high-speed connections to the computers in the High-Performance Computing Center, a video system integrated with the workstations to facilitate the display and capture of scientific data, and video editing equipment for the preparation of scientific presentations.
- The proposed Experimental Computing Laboratory, which will contain an advanced architecture computer system. During EMSL operation, this system will provide a platform for software research and development efforts aimed at significantly extending the range and reducing the cost of molecular simulations.

The use of advanced parallel computing systems by computational scientists has been inhibited because of the lack of software that takes full advantage of these unique architectures. Software development is the key if there is to be a benefit from the advanced computer systems installed in the MSCF. An aggressive research and development effort in molecular science software has been established as an integral component of the MSCF.

The software development activities are focused in two areas:

- The High-Performance Computational Chemistry effort is focused on the development of a new generation of advanced molecular modeling software for a wide range of parallel computer systems, from clusters of workstations to the high-performance IBM SP parallel computer system to be installed in the MSCF, to the next generation of massively parallel computers with over a teraflop of performance. A key aspect of this work involves the improvement and extension of the state of the art in computational chemistry algorithms. The crucial requirement for scalability of these algorithms, which determines the efficiency of an application for large numbers of processors, will not be met by conventional porting of current software to parallel computers. In many cases, the computer algorithms must be recast; in other cases, new approaches for expressing the fundamental physics will be required. The initial effort is focused on the development of software for calculating the electronic structure of molecules and solids from the first principles of physics, and for simulating the classical dynamics of molecules. The resulting molecular orbital theory, density functional theory, and molecular dynamics codes have been incorporated into the NWChem program system. The associated parallel code development tools including GATools and PeIGS, a parallel eigensolver, have been made publicly available.
- The Extensible Computational Chemistry Environment (ECCE) effort is focused on the development of an extensible, integrated environment for supporting molecular research activities. Productive use of the advanced computational resources becoming available to molecular scientists requires not only a revolution in computational methods, but also a corresponding revolution in the tools for initiating, managing, and analyzing computational experiments, and for dealing with the large amounts of data that are generated. The goal of the research and development efforts in this area is the development of an integrated, comprehensive environment for molecular modeling and simulation activities. Key components of this environment are application systems with graphical user interfaces, chemistry-specific visualization and analysis software, tools for managing the data from molecular computations, and tools for managing the calculations while they are being executed on the computer.

An important result from both of the above efforts will be the optimal use of the computational resources available in the MSCF and at other DOE high-performance computing facilities for computational chemistry problems.

Materials and Interfaces The Materials and Interfaces Research Facility will provide state-of-the-art experimental capabilities for research into the properties of materials and interfaces; the design, preparation, and characterization of environmentally relevant materials; and the development of advanced sensors.

- Capabilities in materials synthesis include novel methods for epitaxial and electrochemical growth and characterization of novel materials. These materials will be used in studies of model mineral surfaces, as conversion and separation materials, and in higher order chemical sensors. A particular focus will be on creation of surfaces with specific properties or types of defects. A flexible "cluster" of sputtering and vapor deposition chambers is being established to allow a wide variety of films to be deposited, including sequential deposition of different films without exposure to atmosphere.
- A spectrum of equipment for interphasial studies is included in the Materials and Interfaces Research Facility. Probes to examine solid-liquid, liquid-liquid, solid-solid interfaces include electrochemical, spectro-electrochemical, scanning probe imaging techniques, and optical methods. Also included are capabilities for determining the structure and composition surfaces and interfaces and capabilities for examining reactions at atmospheric pressure. These capabilities have been developed to facilitate research that will lead to a detailed molecular level understanding of the surface and interfacial properties of complex environmentally important systems. Consequently, the range of experimental information varies from detailed analysis of model systems to characterization of complex real-world specimens. Thus, the capabilities and information are designed to provide a bridge from fundamental theoretical and molecular studies to the physical chemistry of complex systems to"real-world" environmental problems.
- Planned experimental capabilities will include electron and ion based methods that primarily operate in vacuum, as well as optical, scanning probe, energetic particle, x-ray capabilities, and electrochemical methods that allow examination of unexposed interfaces. The materials synthesis and interphasial chemistry capabilities will be linked through a unique specimen transfer capability. The molecular beam epitaxy, chemical vapor deposition, and structural and analytical characterization capabilities will be interfaced to other EMSL equipment via passive and active transfer systems that also will allow samples to be transferred to offsite users. This aspect is particularly important to sustaining the collaborative mission of the EMSL.
- A Chemical Sensor Laboratory is being established to support development of sensors to meet DOE's sensing and site characterization needs. This facility will interact with the synthesis and interphasial chemistry capabilities for the development of new sensors to work in complex environments and to meet specific DOE needs. The sensor development and testing laboratory will be a state-of-the-art resource for the evaluation of chemically selective materials, the fabrication and testing of chemical microsensors, and the development of sensor arrays and microanalytical systems.

paramagnetic spectrometer. Controlled-atmosphere environmental chambers are connected directly to the spectroscopic systems, allowing the direct examination of natural environmental samples under the same ambient conditions in the field.

- Analytical Chemistry, Physical Chemistry, and Radiochemistry Laboratories—These laboratories consist of analytical systems for quantification of contaminants and reaction products, as well as thermochemical and kinetic systems for mechanistic and macroscopic characterization of contaminant-soil interactions. State-of-the-art gas/supercritical phase/liquid chromatography with mass spectrometry will be used in conjunction with pressure-jump kinetics and calorimetry instrumentation to determine rates of complexation of environmentally significant constituents, including radionuclides, on mineral surfaces and in fluids.
- Environmental Graphics and Visualization Laboratory—This laboratory will be equipped with state-of-the-art computer workstations linked to the computational infrastructure of the EMSL. Coupled geochemical reaction-transport codes developed as part of the Environmental Dynamics and Simulation Geochemical Modeling Software Library will be used to simulate complex chemical reactions coupled with flow and transport processes. The laboratory consists of several networked workstations that link into the MSCF, an integrated computing environment developed for the entire EMSL.

Processing Science The Processing Science program is designed to link the fundamental molecular science research performed in the EMSL to chemical process and engineering applications. Core capabilities for this program are centered in four major research areas: Colloid Chemistry, Separations, Chemical Conversions, and Waste Forms. Capabilities in each of these research areas provide resources that help integrate a diverse mixture of complementary expertise and equipment, both inside and outside the EMSL, and provide basic science solutions to applied processing problems.

- Colloid Chemistry - Scientists in the Colloid Chemistry group apply fundamental concepts of colloidal science to understanding the properties of particulate suspensions including radioactive tank sludges, cements, tape casting formulations for ceramic processing, paint formulations, and ordered liquid crystal surfactants that are used as templates for fabricating nanostructural composites. Group facilities focus on understanding interparticle interactions, the role of such interactions in controlling agglomeration and dispersion phenomena, and the impact agglomeration phenomena have on physical properties of suspensions such as rheology, sedimentation, and self-assembly.

  Capabilities include a surface force apparatus for measuring interparticle forces at atomic separation distances; small-angle x-ray equipment for measuring primary particle sizes, agglomerate structures (fractal dimensions), and agglomerate sizes; and field flow fractionation equipment for determining agglomerate size distributions, surface charges, adsorption of organic and inorganic species, and the extent of surface reactions.
- Separations - Researchers in the Separations group develop materials, selective ligands, and processing methods for removing target ions, molecules, gases, or solids from complex reaction mixtures. Research activities include development of new methods for treating tank wastes, e.g., acid-side processing followed by solvent extraction separations; design and synthesis of new ligands for removal of radionuclides via solvent extraction; development of separations membranes for removal of organic species from aqueous solutions; and design of new membranes and processes for gas separations that are important to the chemical industry.

  Capabilities for the group include a Membrane Reaction Test System that includes both liquid- and gas-phase membrane systems. The liquid system is used to study processes such as reverse osmosis, ultrafiltration, and microfiltration, while the gas system can be used to study gas separation and conversion reactions at temperatures up to 1200°C. In addition, an Electrochemical Reaction Test System incorporates a variety of electrochemical techniques for examining separations and salt slitting, as well as electrowinning, organic destruction, electrosynthesis, and corrosion.
- Chemical Conversions - Core capabilities in Chemical Conversions span a broad range of activities that include destruction of organics and nitrates in tank wastes, catalysis, and processing of feed stocks for applications in the chemical industry. Research activities in this group are equally diverse and include basic surface science studies to relate surface reactivity to atomic surface structures; organic reaction pathways and free-radical chemistry; development of new materials to facilitate conversion; and chemical engineering studies for evaluating the effectiveness of new conversion systems.

  Group capabilities include 1) a state-of-the-art system for studying reactions between gas phase reactants and solid surfaces at high temperatures and pressures with diagnostics including FTIR and x-ray photoelectron spectroscopy, and 2) a custom built chemical reaction test stand that provides a computer controlled, automatic laboratory reactor system for studying the mechanisms of catalytic and other chemical processes in solid, liquid, and gaseous environments.
- Waste Forms - The research team in the Waste Forms group focuses on developing new glass, ceramic, and cement hosts for high- and low-level waste disposal. Activities outside the realm of environmental remediation include activities for developing biocompatible glasses, as well as cements, to aid in restoration of

America's aging infrastructure, e.g., highways, bridges, and concrete structures.

Core research activities in this group involve developing structural models for oxide materials; validating structural models using state-of-the art techniques such as solid-state nuclear magnetic resonance and EXAFS; understanding phase relationships as a function of chemical composition and structure; and utilizing an understanding of structure to understand and predict properties such as chemical durability, melt properties, crystallization tendencies, cementation, and precipitation. This group also is involved in fabricating new glasses, ceramics, and cements using both high-temperature processing and solution chemistry techniques.

- Characterization/Analytical Support - Some group capabilities are not unique to one group, but support most of the activities involving the Processing Science Directorate. This group has two nuclear magnetic resonance systems. The first system, a 300-megahertz nuclear magnetic resonance spectrometer, is useful in defining the structure and dynamics of solid samples, while the other instrument, a 500-megahertz nuclear magnetic resonance spectrometer, provides high-resolution, multinuclear spectra of molecules and complexes in solution. Another important capability is laser-ablation mass spectroscopy coupled with ion trapping that can provide nondestructive evaluations of both organic and inorganic species adsorbed on substrate surfaces.

Staffing and Funding the EMSL

The EMSL staff now totals 122, with 73 additional research and support staff matrixed from other Pacific Northwest organizations. In addition, 88 postdoctoral appointees are assigned to the EMSL. Key new hires in FY 1996 included Dr. Michael Dupuis, Dr. Teresa Fryberger, Dr. Shirley Rawson, and Dr. Bruce Bunker. Dr. Dupuis joined the Theory, Modeling, and Simulation program as a Level-5 scientist, the highest level technical position in the Laboratory. He will be a major contributor in EMSL efforts to develop new generations of computational chemistry software for massively parallel computers. Prior to joining the EMSL, Dr. Dupuis was a Senior Scientist with IBM. Dr. Fryberger joined the EMSL as Deputy Director for Applied Environmental Sciences. In this position, she will focus on EMSL activities related to environmental management and processing science. She will also help the EMSL Director integrate programs sponsored by Energy Research and Environmental Management. Prior to joining the EMSL, Dr. Fryberger managed the Efficient Separations Program and the Processing Crosscutting Program in the Office of Science and Technology. Dr. Rawson joined the EMSL as Acting Deputy Director for Environmental Restoration. She will focus on EMSL activities and program development related to the molecular processes that are critical in contaminant fate and transport in the subsurface. Prior to joining the EMSL, Dr. Rawson was Manager of the Earth Systems Sciences Department in Pacific Northwest's Environmental and Energy Sciences Division. Dr. Bunker joined the EMSL as Associate Director for the Processing Science research program. In this position, he is responsible for developing and managing research programs that link molecular-level science to a broad spectrum of innovative chemical and physical processes applicable to DOE's waste remediation efforts. Prior to assuming his new position, Dr. Bunker was a Level-5 Scientist in the Materials and Chemical Sciences Department of Pacific Northwest's Environmental and Energy Sciences Division. In an internal staffing move, Dr. Richard D. Smith and his mass spectroscopy group transferred to the EMSL from the Materials and Chemical Sciences research department. A key hire anticipated in the first quarter of FY 1997 is the Associate director for the Environmental Dynamics and Simulation Program. Additional staff to complete the EMSL's full complement of 209 permanent staff will be hired as programmatic funding support for DOE-ER/EM coordinated research increases.

Biological and Environmental Research (KP)[a]

Pacific Northwest National Laboratory is a major participant in DOE's Office of Health and Environmental Research. Our research portfolio is increasingly focused on complex environmental and health problems that require multidisciplinary teams to address the multitude of time and spatial scales.

Health effects research examines mechanisms by which hazardous physical and chemical agents affect living systems. Emphasis is placed on determining the molecular bases of receptor-mediated processes at the cellular level. Such studies permit the use of model systems to simultaneously study both cell growth control and the biological structures responsible for specific events therein. Included among the capabilities for health-related research are cellular, molecular, and structural biology, and biotechnology (shared with environmental science). The Laboratory's environmental research is broadly based and includes the effects of natural events and human activities on the environment as well as development of technologies to minimize impacts and remediate damage. Our environmental research programs use state-of-the-art facilities to study subsurface science and bioremediation as well as atmospheric and climate research (including global change) critical to understanding the transport and transformation of toxic substances in the environment.

Biological Research Biological research is addressed through a multilevel approach incorporating studies from the molecular level to the whole-animal level. Emphasis is placed on understanding effects at the low doses, which are characteristic of occupational and environmental exposures. This will be accomplished by gaining a quantitative understanding of fundamental mechanisms that underlie the effects of chemical and physical agents using integrated dosimetric, molecular, cellular, and experimental animal

(a) Budget codes are provided in parentheses next to related headings.

approaches. Alterations in the structure and function of genetic material are investigated both in vivo and in vitro as biological indications of the development of subsequent disease processes in living animals. Key aspects of these studies are the analysis of interactions of repair enzymes and other regulatory proteins with damaged DNA. The ultimate objective is to identify the cause of disease states induced by exposure to hazardous agents and to predict human susceptibility to these disease states. This information will provide the scientific basis for improved risk estimation models needed to understand the health risks associated with chemically and radiologically contaminated DOE sites.

Cellular, Molecular, and Structural Biology The Laboratory's health effects research program has undergone a major transformation from one confined largely to the descriptive study of radiation effects in biological systems to one examining mechanisms of biological responses to hazardous physical and chemical agents. To provide the scientific basis for improved risk analysis, research is dedicated to determination of the molecular bases of receptor-mediated toxicological and pharmacological responses at the cellular level. Research results from such studies will provide clients biomarkers for measuring biological effects, safety information, new product development, and approaches to regulatory policy.

In a companion approach, model systems are under development to study complex processes required for appropriate biological responses to external agents. The nucleotide excision repair pathway is one such system that is a crucial component in response to exposure to environmental contaminants. Not only does this system have implications for health effects but it serves as a multicomponent model for sequential nucleic acid-protein and protein-protein interactions that participate in functional responses and cell signaling. Structural alterations accompanying such physiological events as mutation induction, cell cycle disruption, and apoptosis are fundamental components of the neoplastic transformation process. The unmatched EMSL ability to study structures of very large molecules coupled with cellular and molecular biology studies promise to provide previously unavailable insight into the mechanisms of carcinogenesis and human susceptibility thereto.

Structure-function analysis is also being applied to problems in microbial systems and bioremediation. Key enzymes for bioremediation are being identified through biochemical and microbial genomic approaches. Work is currently in progress to determine the solution structure of tetrachlorohydroquinone reductive dehalogenase. This enzyme is not only important as a dechlorinator but also serves as a model for a large class of glutathione transferase enzymes important in bioremediation. Isolation and characterization of metal reductase systems is also under way to provide fundamental information that will lead to improved biological treatment of metal and radionuclides in waste streams and the environment.

EMSL resources that support structural biology include two-dimensional nuclear magnetic resonance, electron paramagnetic resonance, and mass spectrometry together with advanced modeling and computational capabilities. Cellular, molecular, and structural biology capabilities are also exploited in support of biotechnology and medical applications described below.

National Radiobiology Archives The National Radiobiology Archives, developed and managed by Pacific Northwest, consists of a computerized information system for dose-effects data, a repository for documents and other research records, and a tissue archive, integrated by a computerized inventory system. Several DOE laboratories have stored records and selected tissues from a unique program of life-span animal studies conducted over the past five decades. As the program ends, the stored data must either be archived or discarded. Because these studies are unlikely to be repeated and represent a resource for future research, they are being preserved in the National Radiobiology Archives. The Archives will obtain as much information as possible from DOE laboratories and will focus on electronic storage and dissemination of that information. Once complete, the Archives will be reduced to a maintenance level.

Medical Internal Dosimetry The objectives of this program are to 1) provide internal dosimetry support to major medical facilities in their studies on the effectiveness of radiolabeled antibodies in the diagnosis and treatment of cancer; 2) develop improved methods for estimating radiation doses to tumors and normal tissues from incorporated radiolabeled antibodies, hormones, and growth factors; and 3) develop new alpha-particle-emitting immunoconjugates for therapy.

The Laboratory is currently conducting dosimetric assessments in support of the lymphoma and leukemia clinical trials at the Fred Hutchinson Cancer Research Center and the University of Washington in Seattle, and other clinical studies at the Virginia Mason Cancer Clinic (Seattle) and the National Institutes of Health (Bethesda, Maryland).

Pacific Northwest also performs internal dose assessments for animal studies and in vitro cell-irradiation experiments. Methods have been developed for assessing the localized dose distribution of nonuniformly distributed radiolabeled antibodies in solid tumors. Experiments have been undertaken with animal models to test the efficacy of using other radiolabeled compounds for tumor diagnosis and therapy.

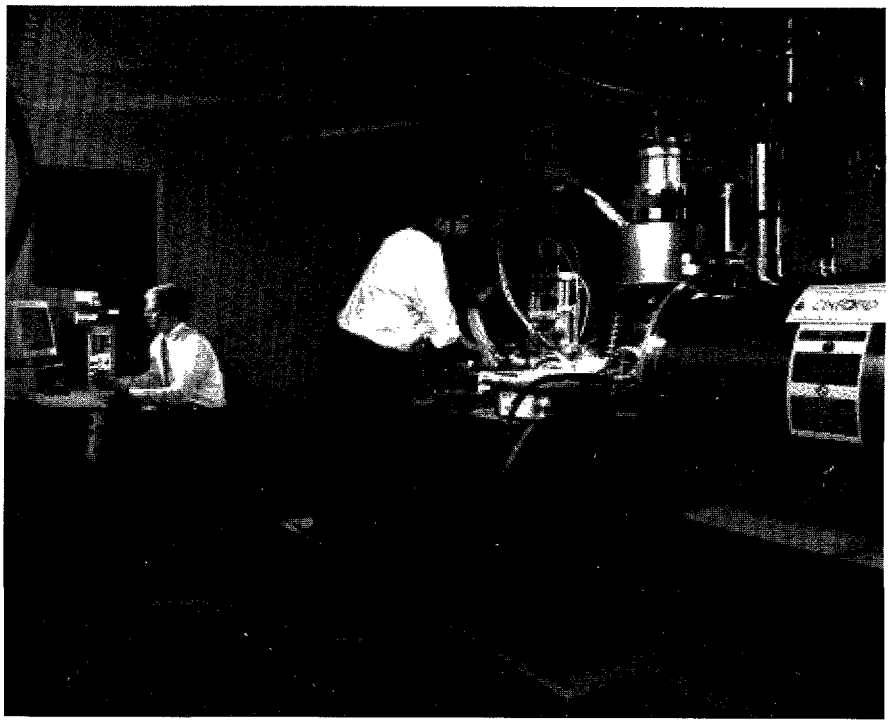
Biotechnology Biotechnology at the Laboratory supports the national Human Genome Project and Laboratory programs in structural biology, health effects research, bioremediation, and microbial biotechnology. Also included in this section are descriptions of analytical capabilities that we consider to be enabling technologies and which are deployed in support of biotechnology.

Human Genome Research New approaches are being developed at the Laboratory with the potential for high-speed DNA sequencing based on mass spectrometry. In one approach, large single-stranded segments (1 to 20 kilobases) are transferred to the gas phase by an electrospray process that produces highly charged molecular

ions. The ions are then trapped in a FTICR cell in a high-magnetic field where a single molecular ion can be trapped, isolated, and nondestructively detected with high mass measurement accuracy. The ability to trap, isolate, and measure the mass and charge properties of an individual ion for as long as hours has recently been demonstrated. The aims of the project are to develop 1) the instrumental methods necessary for such accurate mass determination, and 2) physical or chemical methods for sequentially cleaving individual nucleotide bases from one terminus of the DNA segment. An accurate and high-speed ion cyclotron resonance measurement after each step would therefore allow rapid determination of the oligonucleotide sequence for very long DNA segments.

An alternative approach to high-speed DNA sequencing is also being developed based on the analysis of mixtures of DNA fragments by electrospray ionization mass spectrometry (ESI-MS), which exploits the advantages of electrospray ionization over other ionization methods. This approach involves reducing the charge states of electrosprayed oligonucleotides by manipulating the electrospray ionization process or by subsequent gas-phase reactions. Existing mass spectrometric instrumentation is being modified to determine the maximum oligonucleotide length amenable to this approach. This approach promises to allow rapid molecular weight determination of mixture components and provide DNA sequence information analogous to the conventional electrophoresis methods. Sequencing rates on the order of 100 bases per second are projected, along with improved accuracy compared with existing methods.

Present efforts are developing more rapid and accurate high speed DNA sequencing and improved methods of DNA characterization for support of research applications at the Laboratory and in various collaborations. Such applications include characterization of DNA adduction and damage, studies of the possible site-specific nature of DNA damage, studies of gene-derived proteins and protein-DNA interactions, DNA mapping of uncloneable regions, ultrahigh sensitivity for sequencing of unamplified DNA, direct measurement for identification and analysis of viruses, and study of the binding of "combinatorial-like" libraries of damaged DNAs with DNA repair proteins. We are also exploring the potential for "soft landing" and recovery of selected single DNA segments after accurate FTICR measurements for subsequent PCR amplification and study. The potential for the rapid characterization of PCR products is also being developed due to the wide range of important research and clinical applications (e.g., microorganism identification in support of bioremediation research, mutation detection, etc.).



Research conducted at the Pacific Northwest National Laboratory is paving the way for valuable medical applications using FTICR-mass spectroscopy.

Microbial Genome Research As part of the initiative in microbial biotechnology, laboratory scientists are identifying bacterial genes of environmental, energy, and industrial importance. For example, identification of genes in novel bacteria is important for devising bioremediation strategies. However, finding relevant genes in bacteria often cannot be accomplished by traditional methods since genetic tools and a description of biochemical pathways are often unavailable. To circumvent these shortcomings, genomic research methods have been applied to isolate and characterize genes. Using methods developed at the Laboratory, researchers have isolated plasmids, accessory genetic elements, from deep subsurface bacteria. Through a combination of physical mapping, biochemical analyses, and DNA sequencing, genes on the plasmids have been identified that encode enzymes utilized in the degradation of aromatic hydrocarbons and facilitate microbial survival and function under hostile conditions, such as the deep subsurface.

Analytical Studies - Measurement Science An integral part of health effects, life science, and environmental research is our ability to measure the physical and chemical properties of complex molecular systems. Our researchers are constantly striving to measure the chemical composition, molecular structure, chemical kinetics, system dynamics, and a variety of

physical properties over a wide span of temporal, spatial, and concentration ranges.

Two new projects represent what we feel is a revitalization of measurement science research at the Laboratory. We expect this research to grow in coming years as our scientists gain access to new state-of-the-art instruments in areas such as nuclear magnetic resonance, electron paramagnetic resonance, FTICR, pico-second laser spectrometers, and the extensive computational resources in EMSL. The first new project is a collaborative effort between Pacific Northwest and the Massachusetts Institute of Technology. This research combines magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (MRS) to create a magnetic resonance microscope to be used to probe molecular details of cellular insults. This instrumentation will take advantage of the high-resolution high-magnetic field nuclear magnetic resonance spectrometers (fields > 21 tesla) within the EMSL. Magnetic resonance imaging is a process where spatial information is encoded via a gradient in the magnetic field and subsequently transformed into a three-dimensional image of the object. In a more time-consuming experiment, ^{1}H or ^{31}P nuclear magnetic resonance spectroscopy can be performed on region-specific volume elements of sample. Our new work involves a combination of the two experiments mentioned above to obtain a map of spatial (the image) information and chemical process that are occurring within the particular volume element of the sample of interest. We are developing sample holders (nuclear magnetic resonance probes) with the ability to generate intense gradients resulting in much higher spatial resolution in the magnetic resonance imaging experiment. These intense gradients are achieved, in part, by utilizing small samples. The sensitivity problem engendered by the reduction of the sample volume is compensated by the use of high-magnetic fields. The sizes of the samples are on the order of tens of cells (or clusters of cells). The idea is to perform MRI/MRS experiments on selected numbers of cells which have been exposed to some insult, either chemical in nature or via a radiation source, and then to follow the fate of these cells as a function of time. These results will provide critical molecular data that can be utilized in pharmacokinetics and toxicodynamic (dose and response, respectively) models of cancer evolution in cells.

The second new project is part of the special ER/EM proposal solicitation. The new research is to develop methods for accurate and timely analysis of radionuclides present in waste streams. The basic idea revolves around the notion of flow injection (FI) coupled with sequential injection (SI) methodology and the use of these methods to automate sorbent extraction and chromatographic radiochemical separations processes and deliver the sample to the detector. Radiochemical separation chemistry will be investigated with regard to issues that must be addressed to successfully automate such methods for analytical purposes, including analyte recoveries, reproducibility, rigorous control of speciation, kinetics of on-line reaction chemistry, characterization of separation materials, and the effects of complex sample matrices. Novel methods will be developed for reviewing separations materials on-line, using liquid-liquid extraction with a wetting film and recent methodologies for moving, capturing, and releasing polymer beads. Multiple detection approaches, i.e., both radiation counting and atom counting methods, will be used for the quantification of separated radionuclides. New radiation detecting flow cells will be designed specifically for use with FI/SI systems performing radiochemical separations. In the final phase, we will investigate the possibility of integrating separation and detection operations in a single compact unit. The primary focus will be on radiochemical methods as they apply to the analysis of tank wastes, but the methodology will also be applicable to environmental samples. The radionuclide separations to be automated will be those fission products, actinides, and lanthanides in tank waste that are important in waste characterization and remediation, but which cannot be adequately determined using direct nondestructive methods. It is aptly clear that this methodology can be extended to many different analytical circumstances and the application of FI/SI notions to other systems is currently under development.

Subsurface Science Research and Bioremediation Environmental restoration will constitute a major fraction of the costs of minimizing environmental and public health risks associated with mixed wastes that have accumulated at DOE sites nationwide. Yet there is a paucity of information and tools needed for prediction and remediation of subsurface contamination over the 20 to 30 years required to restore these sites. To help address these needs, Pacific Northwest research for the DOE-OHER Subsurface Science and Natural and Accelerated Bioremediation Research (NABIR) Programs builds on the Laboratory's technical strengths (geochemistry, microbiology, molecular biology, hydrology, and geology), which are applied in interdisciplinary, multi-institutional programs focused on developing a fundamental understanding of key processes controlling contaminant behavior and remediation in subsurface systems. Unique intermediate-scale and field approaches and facilities, in conjunction with mathematical modeling, are used to examine the integrated effects of environmental processes, validate predictive models, extrapolate results to the system level, and drive new concepts for subsurface remediation. These efforts are reinforced by a Laboratory initiative focusing on microbial biotechnology and by the vigorous collaborations with over 40 universities, other national laboratories, and industry that have been fostered by the OHER Subsurface Science Program and coordinated through the Laboratory's outreach activities.

A major focus of the DOE Subsurface Science Program investigations by the Laboratory has been on 1) co-contaminant behavior in subsurface systems and the influence of complex chemical, microbial, and physical properties and processes on

contaminant transport, and 2) developing an understanding of the factors that govern the presence and activity of microorganisms in the subsurface at DOE and other sites. In the past, emphasis has been placed on how these organisms may have adapted, evolved, and survived over millions of years under the austere environmental conditions of the deep subsurface. As the Subsurface Science Program is phased into NABIR, the Laboratory is building on this research and its investments in microbial biotechnology and molecular sciences to establish a premiere program in fundamental research undergirding bioremediation of contaminants at DOE facilities. As part of the Laboratory initiative in Microbial Biotechnology, we are extending research on the Subsurface Science Program to identify important microbial functions that form the basis for developing new industrial, environmental, and energy-related processes. This effort is already leading to new discoveries of value for remediation and other purposes. For example, exploration of the subsurface has identified microorganisms with a unique capability for degrading a range of aromatic organic compounds and chlorinated hydrocarbons under microaerophilic and anaerobic conditions. These organisms may offer unique potential for in situ remediation of deep contamination where oxygen is limited. Other organisms that have recently been discovered are capable of sequestering metals and producing new products, such as dyes and antibiotics.

Examples of other Subsurface Science Program research under way at the Laboratory that are relevant to bioremediation and DOE-EM needs include studies to 1) examine the mechanisms underlying interfacial reactions between mixed contaminants and mineral surfaces; 2) define the factors governing the presence and activity of microorganisms in the deep subsurface and their origins and movement over geologic time; 3) determine the processes underlying physical partitioning of vapors, solvents, and solutes in porous media; and 4) implement advanced experimental concepts for coupling and scaling fundamental molecular, cellular, chemical, and physical processes and their interactions to understand contaminant behavior in large-scale, heterogeneous field environments.

The Environmental Science Research Center plays a special role by exploring new concepts and approaches for understanding and restoring subsurface systems through intermediate-scale and field research to scale fundamental knowledge of natural processes and how they are linked for applications in heterogeneous subsurface environments; and joint research with the DOE sites (e.g., Paducah, Idaho National Engineering Laboratory, Hanford) to help bring fundamental knowledge to bear on resolution of immediate site problems and ensure that this knowledge is available for the timely resolution of long-term environmental problems faced by DOE.

Atmospheric and Climate Research

The objective of the DOE-OHER's Environmental Sciences Division is to provide scientifically defensible information on the long-term consequences of national energy use. Within the Environmental Sciences Division, global environmental change and atmospheric sciences are research components in which Pacific Northwest provides significant technical leadership. The Carbon Dioxide Research program is the DOE contribution to the multiagency, long-term U.S. Global Change Research Program developed by the Global Change Research Subcommittee of the Committee on Environment and Natural Resources.

The Laboratory's Global Change Program directly supports the technical objectives of the Environmental Sciences Division on environmental change. Components of the Environmental Sciences Division objectives represented at the Laboratory include the Atmospheric Radiation Measurement (ARM) program, the Core Carbon Dioxide Research program, the Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) program, the oceans research and Global Change Integrated Assessment Research, and the quantitative links program. These programs have the common goal of improving our understanding of the physical, geological, chemical, biological, and social processes that influence the earth system so that national and international policymaking related to natural and human-induced changes in the earth system can be given a firm scientific basis. The Laboratory continues to lead the planning and organization of the ARM program and the oceans research program, as well as assisting the Environmental Sciences Division with the implementation of CHAMMP. Each program involves a number of DOE laboratories and other agencies and strong participation from the university community.

The Laboratory also plays a leading role in other long-term Environmental Sciences Division research thrusts that provide the scientific foundations on which the global change programs are based, from which energy-related air pollution assessments draw improved models, and with which safety evaluations at DOE sites reduce environmental uncertainties. This work comprises the Atmospheric Chemistry Program and the Atmospheric Studies in Complex Terrain (ASCOT) program. The Laboratory's research within the Atmospheric Chemistry Program focuses on the fate of energy-related pollutants through research on atmospheric gas-phase and heterogeneous chemistry; cloud and aerosol chemistry, physics, and dynamics; and global-scale chemical transport modeling. The Laboratory's work within the ASCOT program focuses on density-driven air circulations, turbulent mixing and dispersion in the atmospheric boundary layer, and microscale to mesoscale meteorological processes that affect air-surface exchange processes.

Global Change Research Global change research at Pacific Northwest focuses on studying basic geophysical processes and developing data that are critical for understanding global and regional climate change. The Laboratory is supporting the DOE goal of increasing the reliability and scientific defensibility of general circulation models (GCMs) that are used for predicting the timing and magnitude of climate change on regional and global scales by energy-related anthropogenic emissions. Our current research

includes the study of atmospheric radiative forcing by aerosols and clouds, the prediction of future emissions of carbon dioxide, the exchange of carbon dioxide and energy between the ocean and the atmosphere, the development of the next generation of computational resources for predicting climate change, and development of a program of research for detecting human-induced climate change.

A new focus is the use of molecular techniques to examine specific mechanisms that control ecosystem responses to environmental change. Research is directed toward understanding how energy exchange and biological (microbial, plant) processes affect mineral, water, and gaseous fluxes within arid ecosystems. These investigations are being used to determine the biotic feedback linkages that control radiatively important gaseous emissions from the environment.

The ARM program represents a major effort to improve the treatment of processes that control the redistribution of energy and water in the climate system. Recent research has revealed that radiative forcing and feedback by clouds are the most important processes governing the response of the atmospheric component of the climate system to the perturbations resulting from human activity. The results of the ARM program will lead to improved GCMs by improving the treatment of cloud radiative forcing and feedbacks and the direct and indirect effects of aerosols. ARM is focused specifically on two aspects of that improvement: 1) the treatment in GCMs of radiative transfer under clear sky, general overcast, and broken cloud conditions; and 2) cloud formation, maintenance, and dissipation in GCMs. Pacific Northwest is responsible for coordinating and integrating the field and laboratory measurement programs, modeling studies, and data analysis activities of ARM.

The experimental objective of the ARM program is to characterize empirically the radiative processes in the earth's atmosphere with high spatial, temporal, and spectral resolution and accuracy at three climatologically important sites distributed worldwide that capture and represent the full range of climate conditions that must be represented in global climate models. At these sites, and in a surrounding area approximately as large as a general circulation model grid cell, observations are being made to characterize the radiative and meteorological properties of the atmospheric column above the site. These sites, called Cloud and Radiation Testbed (CART) sites, provide ARM with the experimental infrastructure needed to couple a measurement program with the data requirements for the development, testing, and refinement of the treatment of cloud life cycles and radiative transfer processes in GCMs. These improvements are expected to greatly enhance the accuracy of long-term general circulation models predictions at the important regional scale.

The first ARM field measurement site was established in 1992 and comprises 28 individual instrument sites distributed over a 275 by 325 km rectangle in south-central Kansas and north-central Oklahoma including a highly instrumented central facility near Lamont, Oklahoma. The first data was transmitted from the site in May 1992, only one month later than planned at the inception of the program in 1990. The second ARM field site will be located in the Tropical Western Pacific Ocean, oriented along the equator. The first instrument facility there will be on the island of Manus in Papua, New Guinea, and is planned to begin operations in the fall of 1996. The second instrument facility will be established on the island of Nauru in 1997. In all, five island-based instrument sites are planned in order to acquire data across the oceanic "warm pool" that is one of the most significant energy sources for the atmospheric heat engine. The third ARM field site will be at the opposite climatic regime and in the radiative "cooler" atmosphere, the Arctic, near Point Barrow. The initial instrumentation for this site will be operating by the end of 1998.

The operation of each of the ARM field sites is planned to be about 10 years, or until the scientific community concludes that adequate advances have been made. During the next several years following 1996, the Laboratory will engage in a series of research projects that address key ARM issues. Research will continue on the development and testing of improved procedures for parameterzing the radiative properties of clouds, and on a study of the impact that the southern Great Plains low-level jet has on cloudiness over that region. Research will also improve methods by which point measurements can be extrapolated to give spatially averaged surface flux values and will improve modeling methods to account for the efforts of subgrid-scale variability. Data from a network of multi-spectral rotating shadowband radiometers will be used with satellite remote sensing data to determine quantitative relationships between clouds and their effects on radioactive energy transfer.

As the ARM program expands in the coming years to include satellites and unmanned aerospace vehicles, the efforts at the Laboratory will expand as well. A key element will be the integration of these new data streams with data from the CART sites and other atmospheric programs. The major focus for these efforts will be at the ARM Experiment Center at the Laboratory, along with the ARM data archive at Oak Ridge National Laboratory.

Oceanic convective processes, including deep convection, and sea ice-convection, are important transfer processes in the climate system. Oceanic deep convection is currently parameterized in ocean circulation models by physically unrealistic algorithms. These parameterizations limit the ability of ocean general circulation models (OGCMs) to predict the altered circulation regime that could exist in significantly different climatic conditions. A new deep-convection parameterization, developed by scientists at the Laboratory as part of the CHAMMP project, will be evaluated in a massively parallel OGCM. A surface mixed-layer parameterization, which will work together with the deep-convection parameterization, is presently under development.

Under the carbon dioxide ocean research program, high-resolution, three-dimensional process modeling

is being performed by Laboratory researchers to support the development of parameterizations. This research provides a necessary link between understanding key ocean processes and ensuring that they are properly simulated in climate models. Future work on deep convection will be directed at producing empirical relationships between the forcing and deep convection. These relationships will provide a basis for an improved understanding of how variations in forcing factors affect deep convection. Experiments using the coupled ice-ocean turbulence model will provide the first detailed look at processes important in determining the ice margin extent and large-scale ice melt in the polar oceans.

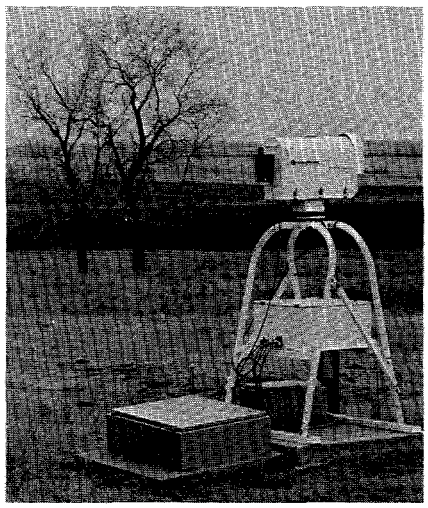
Additional modeling research is being performed to examine how wind, waves, and surface heat flux affect the structure and growth of the ocean mixed layer. Turbulence in the mixed layer is directly responsible for the transport of heat, momentum, and carbon dioxide from the atmosphere into the interior ocean. Results from these detailed numerical studies will be used in the CHAMMP project to improve the representation of the surface mixed layer in ocean general circulation models. As with much of the Laboratory's global change research, this work is intended to produce improved methods for parameterzing these processes in global-scale models.

Laboratory research in the ocean sciences component of the basic carbon dioxide program is also advancing our understanding of gas exchange processes that control carbon dioxide uptake at the air/sea interface and of the exchange mechanisms between the oceanic mixed layer and waters below the thermocline. The influence of whitecaps on the rate of exchange of carbon dioxide at the ocean surface is being studied in large-scale laboratory experiments and will be examined in future field studies. A principal objective is to develop empirical algorithms for translating satellite remote sensing observations into global-scale estimates of air/sea gas exchange.

More precise estimates of the magnitude of oceanic uptake of carbon dioxide from the atmosphere are needed to estimate future (10 to 100 years from present) concentrations of atmospheric carbon dioxide that are used in calculations of radiative transfer in climate models. Through the organization of a science team to guide the conduct of a global survey of carbon dioxide in the oceans, the Laboratory is assisting the DOE in coordinating its ocean carbon dioxide research activities with other ocean programs with a goal to assess the results of ongoing research and the establishment of priorities for future research in this area.

The Laboratory's carbon dioxide emissions research is aimed at providing the scientific basis for forecasting future emissions of carbon dioxide and other radiatively important gases. The extent of future global emissions of carbon dioxide and other radiatively important gases is one of the dominant uncertainties confronting research in global climate change. A database is being developed on traditional energy supplies and energy uses in countries within and outside the Organization for Economic Cooperation and Development, with particular focus on large countries such as China and the former Soviet Union. The current scientific understanding of the relationship between energy production and the emissions of radiatively important gases other than carbon dioxide will be advanced. A second-generation, global greenhouse gas emissions model is being developed to provide predictions of the emissions of carbon dioxide and other gases as a function of time and nation of origin.

Based on our long-standing work on greenhouse gas emissions modeling, the Laboratory has been pioneering the development of global-scale integrated assessment models. Current efforts focus on the development of the Global Change Assessment Model (GCAM) and on the development of regional-scale offshoots of this model. The GCAM integrates an emission model that represents several important sectors of the global economy with reduced-form models of agricultural production, ecosystem response, and climate change (including sea-level rise) to simulate coupled economic and ecosystem response to climate change. The model can also simulate the effect of future technological innovations, as well as energy and environmental policy decisions, on the buildup of greenhouse gases, subsequent climate change, and on the global energy, industrial, and agricultural economy.



Engineers from Pacific Northwest have worked with instrument manufacturers to improve the use of multifrequency microwave radiometers to measure path-integrated water vapor and cloud liquid water.

In another aspect of our research on the socioeconomic effects of global environmental change, the Laboratory is leading an international group of social scientists in the development of a comprehensive, state-of-the-art assessment of the ability to understand and affect social responses to global environmental change. This effort is comparable in scope to the Intergovernmental Panel on Climate Change (IPCC) assessments of the state of scientific understanding of the response of the physical climate system to increasing concentrations of greenhouse gases in the atmosphere. The social science assessment was scheduled for completion in time for the March 1995 meeting of the IPCC in Berlin.

During the past year, the Laboratory has completed the design of a program of research to determine if the expected greenhouse gas climate signal could be detected in the climate data set. The primary objectives of this research are

Researchers from Pacific Northwest and Battelle Columbus unload equipment used on Long Island from the Gulfstream 1 airplane.

to 1) determine if current anthropogenic perturbations to the climate system are large enough and sufficiently different from other natural climate variations to be detectable in the climate record, and 2) determine the extent to which current climate models are capable of simulating the broad response of the system to a gradually increasing anthropogenic forcing. This program of research, called the Early Detection of Induced Climate Trends, is the product of an international group of distinguished climate researchers. The program has been submitted to the U.S. Global Change Research Program for possible future implementation.

Atmospheric Sciences Research

Atmospheric research at the Laboratory is in three areas: atmospheric chemistry, boundary-layer meteorology, and regional climate modeling.

The Laboratory's atmospheric chemistry research has been focused largely on the tropospheric chemistry of ozone and its precursors. While this will remain an active area of research, there will be a shift from its present emphasis on gas-phase processes to understanding the role of aerosols and clouds in ozone chemistry and to understanding the processes by which aerosols are formed and modified by gas- and aqueous-phase processes in the atmosphere. Process-oriented research into the fundamentals of gas-particle reactions will be needed to support larger-scale simulations. This work will depend on the analytical and computational resources in the EMSL. Our research in atmospheric chemistry will steadily expand as activities over the next several years move to increasingly complicated experimentation that is integrated with other national and international efforts. Field studies will rely heavily on the G-1 aircraft and its complement of chemical and physical sensors, including a mass spectrometer for measuring trace gases. Future developments in chemical transport modeling will include explicit treatment of heterogenous chemistry and aerosol and cloud formation as well as conversion of codes for operation on parallel processing computers.

Boundary-layer meteorological research is also undergoing change within the Laboratory. The emphasis is shifting from a focus on air flows in complex terrain toward a closer coupling of research in atmospheric boundary-layer dynamics and atmospheric chemistry. This is in recognition of the important role that vertical mixing has on initiating the reaction of fresh emissions, both natural and energy-related, with aged pollutants. Ground work has been laid by the Laboratory for the development of a new multilaboratory research program within DOE that has as its central theme vertical transport processes. This program will refocus the boundary-layer meteorology capability presently found within the national laboratory system on this topic and emphasize its importance to understanding and predicting the impact of energy-related emissions on air quality. Regional and local air quality modeling used for the analysis of emissions control scenarios to meet federally mandated air quality standards will benefit from an improved capability to simulate these processes. We will apply our capabilities to measure and characterize the structure of the boundary layer to site-specific investigations in which vertical transport exerts a significant control on the dispersion of pollutants.

The Laboratory's participation in a new regional climate modeling research program within DOE's atmospheric sciences program is expected to grow. In regional climate modeling, output from global-scale climate change models is used to drive other models that simulate the regional expression of global climate. Regional hydrology and water resource availability are driven by large-scale climatic patterns of precipitation and temperature. Further extension of the regional response to climate will be obtained by coupling the water resource and climate simulations to regional agricultural production and economic models. Through past Laboratory Directed Research and Development (LDRD) investments, the Laboratory created the capability to link global climate models to regional models that simulate climate and hydrology. Agricultural and economic models for global integrated assessments also developed with LDRD resources will contribute to this research program.

A significant strength of the Laboratory's atmospheric research is the extent to which its scientists participate in multilaboratory research programs and collaborate with scientists in other laboratories, universities, and agencies. Laboratory staff are active leaders and contributors to the major atmospheric research programs within the Office of Energy Research. The Laboratory's atmospheric research equipment and facilities, such as the well-equipped G-1 aircraft that is operated as a DOE Research Facility, radar and acoustic profilers, balloon-borne sounding systems, turbulence and flux measurement systems, and high-performance data acquisition systems have been and will continue to be used to benefit research activities within many DOE-ER programs.

Basic Energy Sciences (KC)

Research at Pacific Northwest supported by the Office of Basic Energy Sciences (BES) is key to the Laboratory's commitment to establish a world-class science base in chemical, material, geochemical, and computational sciences. Programs supported by BES provide strong contributions to DOE missions in basic science. Our DOE-BES programs are increasingly focused on achieving a fundamental understanding of complex, multidimensional environmental problems associated with the production and consumption of energy and the cleanup of our past environmental practices and the development of new knowledge required to promote economic prosperity and minimize future environmental insults.

Chemical Sciences Research programs funded by Basic Energy Sciences provide an underpinning for all of DOE's technology mission. Our research studying fundamental chemistry and chemical physics focuses on new ways to quantify problems and make informed decisions regarding DOE objectives in energy, environmental quality, environmental restoration and waste management, and national security.

The Laboratory receives programmatic funding from the Fundamental Interactions Branch for research on fundamental molecular processes. We focus our research on developing molecular-level understanding of scientific issues that will lead to improvements in the technical base for remediation of DOE's environmental problems associated with its contaminated sites. We conduct both theoretical and experimental studies of the chemistry at the liquid-solid interface and the condensed phases. Pacific Northwest receives support from the Process and Techniques program for research in the areas of supercritical fluids, analytical chemistry focusing on new laser spectroscopy, and the fundamental chemistry of coal combining both experimental and theoretical techniques.

In FY 1996, Pacific Northwest initiated a new research project using modern computational chemistry to develop a new understanding of fundamental interfacial reactions important to chemical catalysis.

Molecular Theory and Modeling

Developing the knowledge base needed to address the environmental restoration issues of the DOE requires a fundamental understanding of molecules and their interactions in isolation (gas phase) and in liquids, on surfaces, and at interfaces (condensed media). The scope of the research program in Molecular Theory and Modeling is defined by three field-scale problems: fate and transport of contaminants in the subsurface, chemical separations of metals from liquid wastes, and stability of nuclear waste forms. To address these field-scale problems, research is conducted in the areas of Groundwater Chemistry, Separations Chemistry, Chemistry at Aqueous/Mineral Interfaces, and Chemistry and Physics of Nuclear Waste Forms. In addition, to meet the goals of extending the current state-of-the-art theoretical methods and developing models for large complex systems, there is an effort in Theory Development.

Groundwater Chemistry Research in this area is focused on properties (structure, energetics, etc.) of aqueous clusters and aqueous solutions containing inorganic and organic species that occur in natural and contaminated groundwater. The goal of this research is to understand the correlation between molecular-scale processes—solvation, association, and reaction—and the composition and behavior of aqueous systems in the environment. Research activities in this area include studies of the properties of aqueous clusters, the thermodynamics of aqueous ionic clusters, the thermodynamics of organic solutes, properties of clusters of chlorinated hydrocarbons (CHCs) and water, chemical reactions of chlorinated hydrocarbons, and structure and dynamics at water/chlorinated hydrocarbon interfaces.

Molecular clusters offer a unique opportunity to examine the transition from the gaseous phase to condensed phases. In addition, to the extent that clusters model the solution phase, studies of molecular clusters provide an opportunity to ascertain the detailed effects of solvation on chemical reactivity. Finally, the intermolecular potentials derived from cluster calculations lay the foundation for accurate simulations of solution processes.

Ab initio methodologies developed to model gas-phase molecules and molecular processes are being applied to the study of the aqueous clusters. This approach provides an accurate description of aqueous clusters and is currently feasible for clusters involving as many as six water molecules. In addition, these accurate methods are being used to provide benchmark calculations of cluster properties for testing the methods used to simulate solution-phase processes. Current activities are focused on the structure and energetics of water clusters and aqueous clusters of anions (H^-, F^-, Cl^-, OH^-, CN^-), cations (alkali and alkaline earths), salts (LiF, LiCl, NaF, NaCl), chlorinated hydrocarbons (carbon tetrachloride and chloroform), and formaldehyde.

Monte Carlo and molecular dynamics simulation techniques are being applied

to studies of equilibrium properties (e.g., average structural properties such as radial distribution functions and coordination numbers) and average energetics (e.g., enthalpies and free energies of formation) of ionic aqueous solutions. Molecular dynamics simulations are also used to obtain some time-dependent properties (e.g., residence time of solvent molecules in the first solvation shell and correlation functions). Methods that combine quantum mechanics (for solutes) with molecular mechanics (for the solvent) have been developed and are being used to model thermodynamics and chemical reactivity of halogenated organic species in solution. Current activities are focused on the aqueous solvation of atomic and polyatomic ions and the energetics of ion association in water.

Ab initio methods are being applied to CHC and CHC-water clusters to understand the interactions needed to model the liquid-liquid interface of water with CHCs. This information is then used in molecular dynamics simulations to obtain information about the structure and energetics of these environmentally important interfaces and to examine the molecular process of transport of ions across them. Current projects include studies of carbon tetrachloride and chloroform dimers and of aqueous interfaces with carbon tetrachloride and chloroform.

Separations Chemistry Research in this area concentrates on the structure and energetics of ion-ligand complexes and the dynamics of complex formation in aqueous solutions. The goal of this effort is to discover the factors that control the selectivity and efficiency of ligating species important in the separation of metal ions and radionuclides in order to develop improved separation technology. Research activities in this area include studies of ion-ligand binding properties, ion selectivity of 18-crown-6 ether, ion-ligand interactions in solution, and properties of supercritical fluids.

Research in this effort is focused on the crown ethers. Three different, yet complementary approaches are being used. The first uses ab initio electronic structure techniques to compute the binding energy of metal ions to crown ethers and water. The second approach is based on the standard molecular dynamics simulations with classical force fields to model the ion-crown-ether association in aqueous solution. The third approach combines the electronic structure and empirical methods in a hybrid QM/MM approach that is coupled with molecular dynamics to simulate aqueous solutions of ions and ligands. Current activities are focused on the binding of alkaline earth cations to 18-crown-6.

Chemistry at Aqueous/Mineral Interfaces Research in this area is focused on properties of liquid-mineral interfaces important in the subsurface. The goal of this effort is to develop a fundamental understanding of interfacial molecular processes that control the fate and transport of contaminants through the vadose and saturated zones. Research activities in this area include studies of mechanisms and kinetics of water/mineral interfaces, ion solvation at mineral interfaces, and structure of water adsorbates on molecular ionic solids.

The study of aqueous-mineral interfaces is a joint project with staff in the Solid State Theory and Modeling Group (with support from DOE-BES Geosciences) and is important to understanding the binding of contaminants to minerals in the soil. Ab initio periodic Hartree-Fock theory is being used to study the structure, physical properties, and energetics of minerals and the binding of molecules to minerals. Current activities are focused on modeling the solvation of cations (Na^+ and Cs^+) at the MgO-water interface based on the ab initio calculations.

Chemistry and Physics of Nuclear Waste Forms Research in this area is focused on studying the properties of amorphous materials involved in waste processing and storage. The goal of this effort is to provide insight into the dissolution and degradation of materials proposed for long-term isolation of radionuclides. Research activities in this area include studies of structure and thermodynamics of glasses, and surfaces and interfaces.

The study of aqueous-glass interfaces provides insight on the dissolution and degradation of materials that are proposed for long-term isolation of radionuclides. Network materials, such as glasses, are treated using a semiempirical methodology designed for treating covalently bonded materials. This simulation methodology is used to specifically address the questions related to the geometric structure of networked liquids and amorphous materials. Current activities are focused on extending these methods to simulate the surfaces and interfaces of silicon oxide and include the development of a dissociating water model.

Theory Development In addition to the research efforts in the applications areas, there are also efforts in the development of new theoretical and modeling methods. A significant activity in this area is the development of a new generation of basis sets for use in correlated molecular calculations. These sets provide unparalleled accuracy for calculating the thermochemical properties of molecules. Other research activities include the development of rate theories for reactions in solution, hybrid QM/MM methods, improved methods for modeling aqueous/ion interaction potentials, electrostatic potential models for mineral interfaces, and semiempirical methodologies for networked systems.

Methods for computing the rates of activated chemical reactions in solution are based upon well-established gas-phase theories. Because of the importance of reactions involving light atoms (such as hydrogen atom, hydride ion, or proton transfer reactions) that occur in aqueous solutions (e.g., acid and based catalyzed reactions), the accurate treatment of quantum mechanical effects is a focus of this work. One goal of the present work is to extend variational transition state theory methods to include solvent effects. Current activities are focused on the effects of nonequilibrium solvation on activated chemical reactions.

Chemical Structure and Dynamics

As a major component of the EMSL, the purposes of this program are to

1) extend the experimental characterization and theoretical description of chemical reactions to encompass the effects of condensed media and interfaces, and 2) develop a multidisciplinary capability for describing interfacial chemical processes within which the new knowledge generated can be brought to bear on complex phenomena in environmental chemistry. The success of this program will result in the achievement of a quantitative understanding of chemical reactions at interfaces. This understanding will form the basis for the development of a priori theories for predictions of macroscopic chemical behavior in condensed and heterogeneous media, adding significantly to the value of field-scale environmental models. The EMSL Chemical Structure and Dynamics program is conducting research in the following areas.

Reaction Mechanisms at Solid Interfaces To impact important problems such as soil and aquifer contaminant transport rates and persistence, the roles of atmospheric aerosols and dust in pollution and global change, and waste processing (separations, catalytic destruction, etc.), we must understand the mechanisms of interfacial reactions, and how surface structures dictate those mechanisms. Specific areas of interest include the catalyzed destruction of contaminants, complex surface kinetics and reaction mechanisms, high-temperature/high-energy reactions, and cluster chemistry in the transition region between individual molecules and extended condensed and interfacial phases.

Solutions and Solution Interfaces The Chemical Structure and Dynamics program has a strong focus on the dynamical aspects of aqueous solutions. No solvent is more important than water, and few have such a profoundly strong interaction with dissolved molecules, the energetics of which often control aqueous reactions. The acid-base properties of water and of dissolved molecules are important in many groundwater, tank, and remediation reactions. To study how a proton (H^+) transfers from one molecule to another, we are investigating the early time behavior of the H^+ motion, and how the donor and acceptor molecules begin to reshape to accommodate the H^+ transfer. Proton-transfer reactions are also being studied in water clusters and ultrafine aerosols. Another area of interest is the solid-liquid interface; for example, probing rare-earth/metal-ion complexes to explore redox mechanisms at aquatic mineral surfaces, and spectroscopic studies testing current hypotheses regarding the binding of complexes to metal oxide surfaces. Small clusters of water surrounding a molecule or ion are also being studied, for their properties are determined by the same physics that determine solvation effects in real solutions. Experimental studies of these model systems, in conjunction with detailed calculations, provide important input to theoretical models.

Structure and Dynamics of Biological Systems A Chemical Structure and Dynamics research program in laser spectroscopy will enable direct measurements of protein motions to improve the predictability of molecular dynamics calculations. In particular, time-resolved spectroscopic measurements can be carried out to study protein conformational motion, testing the validity of the methodology used in molecular dynamics simulations. Such a coupling between experiment and theory can provide insights into the enzymatic reactivity needed for engineering enzymes far more effective at degrading recalcitrant pollutants. Another area of emphasis is atomic force microscopy and scanning tunneling microscopy, which have been combined with a new near-field optical microscope having sufficient sensitivity to detect single protein molecules. These combined capabilities will allow the mapping of proteins, DNA, and other macromolecules.

Analytical Methods Development Central to the Chemical Structure and Dynamics research programs is the development of frontier analytical techniques: detecting single atoms/molecules; controlled vaporization of complex solids; highly efficient and specific laser-induced fluorescence, Raman scattering, and ionization methods; high-sensitivity optical and mass spectroscopies; and surface analysis probes. The scope of work ranges from providing specialty analytical services to the development of instruments for remote field use. Optical methods under development, including Raman, laser-induced fluorescence, and multiphoton excitation, are being combined with sampling methods ranging from molecular-beam to high-pressure techniques.

Atmospheric Chemistry The Chemical Structure and Dynamics program has the capabilities needed to address critical areas of atmospheric chemistry, such as chemistry in aqueous media, the chemistry of aerosols, and heterogeneous chemistry. Current activities focus on the kinetics and thermodynamics of sorption and desorption of gas-phase species on water surfaces, and on spectroscopic probes of small cluster molecules and ultrafine aerosols. Recent experiments have measured the sticking probability of water on ice at low temperatures in ultrahigh vacuum. Experiments studying the photochemistry and stimulated desorption of adsorbates from ice surfaces are in progress.

Analytical and Process Chemistry Research programs supported by the Process and Techniques branch develop fundamental understanding of complex chemical phenomena that underpin the energy and environmental restoration and waste management business areas of DOE. A long-range goal of research in the areas of chemical separation and analysis is to improve present state-of-the-art capabilities in analytical measurement and separation of complex chemical mixtures. Our analytical chemistry research is focused on studies of the fundamental processes in laser-based vaporization/ionization and other low- and high-temperature ionization processes. Our chemical separations research examines fundamental processes in a wide variety of supercritical fluid systems. Our physical organic chemistry of coal research examines free radical chemistry reactions, which will lead to new methods for conversion of coal to liquid products.

Laser-Based Analytical Chemistry

The objective of the laser-based analytical chemistry program is to provide an improved understanding of the basic physical processes that control sample interrogation by laser irradiation. The ability to directly ablate samples using this approach may obviate lengthy sample preparation times for more traditional analysis schemes. Use of one laser to vaporize the sample and another laser (system) to efficiently ionize the ablated material will allow optimization of both steps. Ever-improving laser technology is resulting in smaller, more monochromatic sources of laser light for analyte excitation and ionization purposes. The scope of this research includes 1) design of new approaches to laser detection methods, 2) development and understanding of the mechanisms and limitations of the techniques, and 3) demonstration of the analytical utility for developed laser analysis techniques. Ultimately, application of this knowledge will result in improvements in rapid, remote, multicomponent analysis of solid samples.

New work in this area is using high-resolution lasers to perform detailed studies of atomic line shapes within laser ablation plumes. These studies provide fundamental information on the physical conditions such as effective temperatures, velocity distributions, and charged and neutral particle density distributions within the plumes. In addition to characterizing the conditions within the plume itself, these measurements can also be used to provide a better understanding of the initial light-solid interaction that creates the plume. Understanding of these processes is critical for laser ablation to be optimized and used as a quantitative analysis tool.

In addition to the fundamental studies of the laser ablation processes, approaches for ultrasensitive and selective isotopic analysis are being evaluated. These involve coupling multistep high-resolution resonance ionization with mass spectrometric detection. The use of multiple laser excitation steps is particularly important in improving both sensitivity and selectivity in measurements performed in the complex high-temperature environment of laser ablation plumes where the Doppler effects significantly broaden spectral lines. Double-resonance excitation has already been demonstrated to reduce Doppler broadening to that corresponding to the difference frequency of the two lasers. These methods will be extended to triple-resonance excitation where, by appropriate choice of excitation geometry, it is possible to achieve complete wave-vector cancellation and hence complete removal of Doppler broadening. The gains in isotopic selectivity and overall sensitivity are expected to allow the application of these methods to the measurement of long-lived radionuclides such as strontium-90, technetium-99, cesium-135/135, and transuranics at levels useful for environmental and waste processing/containment assessment.

Research is also conducted to develop a basic understanding of high-temperature surface chemistry in chemical analysis. The work seeks to provide understanding of high-temperature surface processes which control vaporization, atomization, dissociation, and ionization so that the sensitivity, selectivity, and reliability of analytical methods can be improved. In addition to the studies of laser ablation discussed above, electrothermally heated graphite furnace sources are also being evaluated by similar laser spectroscopic studies.

Supercritical Fluids Research The goal of the supercritical fluids project is to provide a basis for improved molecular-level understanding of condensed-phase interactions by bridging the gap between the gaseous and liquid states and to describe the molecular interactions underlying separations in supercritical fluids. The scope of recent studies includes 1) solvation properties and their dependence on supercritical fluid density; 2) structure, formation, and stability of organized assemblies in such fluids; and 3) the basis of selective separation processes. Understanding these phenomena will lead to improved supercritical fluid separations and chemical reactions and will suggest ways of improving existing processes.

Expansion of supercritical fluids research is planned to take full advantage of the novel characteristics of these systems. Part of the newly proposed work will center on the study of reverse micelles and microemulsions in supercritical and near-supercritical fluids and their uses in more complex chemical separations and in catalysis. Practical application of this work is already materializing, with the development of reverse micelle technology for the textile industry, the use of micelle systems to model formation damage in petroleum reservoirs, and the incorporation of micelles in producing nanoscale particulate materials for industry.

Supercritical water has important potential applications in 1) oxidative destruction of hazardous waste, 2) salt separation and solubility, and 3) organic synthesis and oxidation reactions. Due to the difficulty of experimentally probing this extreme solvent environment, there is a severe lack of fundamental solvation information. Research in this area involves utilizing methods such as XAFS (x-ray absorption fine structure) to study the molecular structure of supercritical water. The XAFS technique is a powerful method to determine the local solvent environment around an ion in terms of the number of nearest solvent neighbors and the hydration distance. Ion hydration information of this type is virtually nonexistent and thus we now have a powerful method to improve models for supercritical water solvation dynamics.

Free Radical Chemistry of Coal

Research under the free radical chemistry of coal program develops fundamental properties of reactive intermediates important to high-temperature conversion of hydrocarbon resources to fuels and feedstocks. The primary objective of the program is to improve the base of knowledge of the fundamental reactivity of complex hydrocarbons such as coal in order to provide an improved predictive basis for liquefaction and hydrorefining processes. The project involves the study of hydrocarbon and heteroatom (sulfur, nitrogen, and oxygen)-containing hydrocarbons and related free radicals. Approaches include the study of

kinetics of free radical-mediated rearrangement, decomposition, and hydrogen transfer involving organic structure; the application of advanced methods in quantum chemistry to characterize the potential surfaces of important molecular rearrangements and atom transfer reactions; the development of new methods for measurement of bond strengths in organic molecules; and the study of novel reaction channels for hydrogen transfer between organic molecules and reactive intermediates that become accessible at high temperatures. In addition, advanced nuclear magnetic resonance methods are developed to improve the state of knowledge of heteroatom structure in coal and related complex hydrocarbons. Finally, the catalysis of hydrocracking reactions by a novel suite of nanometer-scale hydrocracking catalysts developed at the Laboratory is under study.

Present studies of novel reaction channels for hydrogen transfer involving organic free radicals have led to a revision of conventional understanding of key chemical reaction mechanisms operative in coal conversion processes. Recent efforts have provided a repertoire of kinetic data for organosulfur-containing free radicals supporting the understanding of coal and hydrocarbon conversion and providing rate standards of broad utility in studies of the kinetics of reactions of organic structures. Future efforts will further enhance the state of knowledge of the structure and reactivity of complex hydrocarbons and will focus advanced methods in kinetics of reactions of reactive intermediates and nanocatalysts, nuclear magnetic resonance spectroscopy, and quantum chemistry to develop a molecular-level, global predictive basis for coal and resin conversion chemistry.

Theoretical Heterogeneous Catalysis Work in this research area focuses on understanding the atomic level details of how the geometric and electronic structure (including topological and electronic defects) affect the reactivity of transition metal oxides and pyrophosphates and zeolites. The ability of metal atoms to influence the reactivity and selectivity on and within these materials is also a subject of interest. There is a close coupling of the predictions from the quantum mechanical calculations with state-of-the-art experimental studies. The goal in this context is to exploit the complementary nature of modern theoretical and experimental tools to understand the fundamental interactions at the molecular level which govern heterogeneous catalytic reactions.

Materials Sciences Materials research at Pacific Northwest is primarily focused on 1) the development of unique synthesis techniques for producing new or improved materials in an environmentally conscious manner and 2) the reaction of materials with their environment. These activities are the scientific underpinning for many of the applied programs that address DOE mission areas and relevant technological issues. New capabilities will build on a substantial base of expertise and experience in 1) thin-film optical materials and protective coatings; 2) synthesis and characterization of advanced nanoscale composites, ceramics, and intermetallics; and 3) mixed conductors for low-temperature gas separation. Current research on environmental effects on ceramic stability and on stress corrosion and corrosion fatigue of metals and ceramics is an internationally recognized area of expertise for the Laboratory. The effects of aqueous, gaseous, irradiation, and temperature environments are being evaluated.

Stress Corrosion The goal of the stress corrosion research is to study and model the fundamental processes controlling environment-induced crack growth processes in metals and ceramics, including early stages of stress corrosion crack growth in metallic materials in aqueous environments and high-temperature gaseous environments for ceramic matrix composites. Emphasis is on interfacial chemistry effects in metallic and ceramic composite materials.

A major emphasis of the stress corrosion cracking research area is to relate the grain boundary chemistry of materials to the initiation and growth behavior of cracks in various environments. This effort involves 1) measuring the grain boundary chemistry by Auger electron spectroscopy, 2) computer modeling the grain boundary segregation kinetics, 3) measuring the fracture mode and rate using straining electrode and fracture toughness specimens, and 4) modeling the interaction of the environment with grain boundary impurities. Crack-tip chemistry modeling is being used to identify and predict mechanisms of crack growth related to stress and corrosion. Acoustic emission monitoring is being used to evaluate crack growth processes during intergranular stress corrosion cracking. Determination of the effect of crack-tip stresses and strains on surface adsorption is also determined with in situ Auger electron spectrometer measurements as part of this effort. A new effort is focused on evaluating environmental effects on the mechanical behavior of ceramic-ceramic composites. The emphasis is on environmental interactions on the composite interfaces and how they degrade properties.

Irradiation Effects in Metals Mechanisms of irradiation-induced environmental degradation of materials are being identified, elucidated, and modeled. Emphasis is placed on irradiation-induced microstructures and microchemistries, and their influence on fundamental corrosion and stress corrosion processes. Chemical and mechanical processes at the tip of a stress corrosion crack are isolated and analyzed by selected experimentation and by crack-tip chemistry and deformation modeling.

The effects of radiation on materials microstructure and/or microchemistry and water chemistry are being evaluated with respect to the mechanisms of stress corrosion in a radiation environment. Radiation phenomena affect the stress corrosion behavior of materials in 1) the light-water reactor industry, 2) fusion first-wall and blanket structures, and 3) nuclear waste canisters in deep geologic storage. This research entails a mixture of modeling, critical experiments, and detailed analysis to identify cracking mechanisms and

predict material behavior. Major issues addressed include radiation effects on alloying and impurity element segregation, sensitization, crack-tip solution chemistry, corrosion processes, and deformation mechanics.

There are many shared benefits attained by the close collaboration of related materials programs in fusion energy, BES, and fission reactor areas. Not only does the fusion materials research add value to BES's radiation effects programs, but the BES work adds value to the fusion energy materials programs. This type of leveraging is the key to maximizing resources.

Irradiation Effects in Ceramics

The primary goal of this multidisciplinary research effort is to develop a basic understanding of the production, nature, and accumulation of irradiation-induced defects, microstructures, and solid-state transformations in ceramics. Objectives include identification of defects and damage processes, development of models describing these processes, development and use of in situ techniques for studying defects and damage processes during irradiation, and use of computer simulation techniques to calculate defect stability, energies of formation and migration, cascade geometries, and defect survivability. A secondary goal is to transfer this understanding to both DOE applied mission programs (i.e., fusion, environmental restoration, and nuclear waste and weapons plutonium storage) and to industry, as appropriate.

Ceramic Surface Reactivity The program focus is to obtain fundamental understanding of the chemistry of oxide surfaces, primarily in aqueous environments. The program contains three interactive components: 1) synthesis and characterization of model oxide surfaces containing controlled populations of specific surface sites, 2) surface science investigations of the adsorption and acid-base chemistry of model surfaces, and 3) theoretical modeling of the chemistry associated with specific surface bonding configurations. Program results provide information of relevance to environmental remediation (e.g., waste form stability and dissolution); adsorption on soil minerals; and the development of inorganic materials as sorbants, separations media, and catalysts.

This research is focused on developing the scientific and/or mechanistic understanding that supports the containment of hazardous waste and ceramic materials durability in general. Development of structure/property relationships for ceramic materials in a reactive environment is the focus of this research area, using systematic variations of bulk, surface, and environmental properties. A fundamental understanding of the physics and chemistry at ceramic surfaces is evolved through correlations between experimental measurement and molecular modeling methods. Primary experimental tools for molecular spectroscopy (Fourier transform infrared, Raman, x-ray photoelectron spectroscopy, and magic-angle spinning nuclear magnetic resonance) are being used to investigate initial structures and their evolution in chemically reacting environments. Model systems, electronic structure, and molecular dynamics approaches are emphasized in interpreting molecular-level phenomena. The combination of these techniques is used to extend the molecular information to bulk phenomena. Mechanistic models have been developed to bridge short- and long-term behavior for ceramic durability, which has particular relevance for structural ceramics, optical materials, chemical sensors, and environmental considerations.

Optical Materials Thin-film optical materials have long been an important area for the Laboratory. The basic research that supports this area focuses on understanding the relationship between thin-film structure and optical properties. Experimental and theoretical studies are designed to probe the relationship between intrinsic materials properties (such as stress and microstructure) and the attendant linear and nonlinear optical response of dielectric films deposited using both vacuum and solution-based methods. This program addresses issues related to phase stability; residual stress; the resident microstructure that evolves during deposition; and the associated perturbation to film optical properties when subjected to variations in temperature, pressure, electric field, or chemical environment. Modeling approaches, which provide insight into these structure/property relationships, are used for the design of optical films with targeted properties.

The dependence of film refractive index on thickness is also considered. Several modeling approaches are used to describe the optical properties of thin films. Microstructural parameters, such as void density and crystallite size and shape, can be extracted from empirical models of the real part of the refractive index that are based on composite media approaches. Semiempirical calculations of electronic-level energies in well-defined single-crystal materials use parameterized molecular fragment and extended Hückel (tight binding) methods to determine allowed transition energies that can be related to the optical extinction coefficient. Lattice strain can be quantified from mode frequency shifts in the phonon spectrum. The relationship between localized structural perturbations induced by strain and phonon frequencies will be pursued using lattice dynamical approaches. Results will be correlated with x-ray and Raman measurements of dielectric single crystals and films subjected to high pressures. New optical approaches for interrogating film interfaces are currently under development.

Materials Synthesis and Processing

Materials synthesis research focuses on unique routes to making new materials. One approach involves using inorganic polymers on a submicron scale which allows high-quality nanoscale composites to be made. The second approach involves mimicking biological processes to produce better materials.

Ceramic Processing Interfacial interactions attendant during colloidal consolidation and during the blending of composite materials influence the mechanical properties of compacted ceramics and ceramic-polymer composites. Understanding and controlling these interactions are paramount to the development of advanced ceramic materials. A principal focus of this project involves the design and synthesis of inorganic molecules, which

either can incorporate directly with colloidal compacts formed from particle suspensions or can be completely released during sintering to final density. Slip-stick interactions are evaluated from in situ molecular spectroscopic measurements and particle compaction studies; the evolving microstructure during compaction is characterized by means of atomic force or electron microscopies. The research focuses on studies of particle-dispersant-solvent interactions in aqueous solutions and interfacial binding in ceramic-polymer molecular composites. Activities in this project support the polymers thrust area in the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials.

Inorganic polymers remain largely unexplored. These materials offer several advantages over organic polymers, including direct incorporation into the ceramic matrix during sintering. This project involves a systematic investigation of particle-polymer-solvent interactions using a variety of localized molecular spectroscopic probes. Particle packing efficiency and resulting microstructure following sintering are evaluated from sedimentation and other microstructural probes. Integration of spectroscopic results with microstructure and packing efficiency suggests appropriate functional group changes to the polymer to control these localized interactions.

Polymer Processing Pacific Northwest coordinates this multilaboratory project which is focused on the preparation of advanced polymer and polymer-composite materials based upon fundamental results derived from related BES-supported programs. Ongoing work focuses on the development of advanced processing methods for mesostructural engineering of polymers, polymer blends, and polymer/glass/ceramic composites. This objective is motivated by technological needs that drive the program to establish strong interactions and cross-leveraging with DOE technologies and industry. Resident expertise at the Laboratory in the areas of polymer synthesis, processing, and molecular and physical properties characterization supports several ongoing efforts dealing with colloidal dispersants, nonlinear optical polymers, polymer templates for ceramic synthesis, polymer blends, and robust ion exchange media. The breadth of ongoing polymer synthesis and processing work at the Laboratory allows significant interaction and teaming with staff at other national laboratories and within industry who are pursuing polymer-related research. The BES/DMS program, Microstructural Modification in Ceramic Processing using Inorganic Polymer Dispersants, integrates directly with this effort.

Biomimetic Materials The objective of the biomimetic research is to understand the synthesis and the underlying control mechanisms for the fabrication of ceramic/polymer composites at low temperature using biological principles. New methods of ceramic composite production and new and/or improved ceramic composites will result. Key to reaching this goal is understanding how the "ultrastructure" of biogenic ceramic/organic fiber composites affects the materials properties, how this structure is formed, and how we can mimic this structure and process.

The Laboratory's approach is to combine the input from many diverse fields to understand the role of ultrastructure and mechanism of mineralization. The materials properties of mollusk shell and bone have been determined and related to the ultrastructure, living bone cells have been adapted to mineralize chemically modified substrates, natural and synthetic polymers have been mineralized, and the mechanism for surface-promoted mineralization has been elucidated. The practical emphasis is on deposition of technically important minerals as thin films. Applications in optical, electronic, and mechanical coating are being developed. For basic research purposes, the emphasis is on relating the efficacy of a surface in promoting film nucleation and growth to its structural and thermodynamic properties. Well-characterized self-assembled monolayers are derivatized with various organic functional groups.

Metal Processing/Forming A new area of research at the Laboratory involves microstructural effects on materials deformation that includes superplastic deformation of lightweight materials. This is a new program that lends technical support to the USCAR (U.S. Council for Automotive Research) program on lightweight vehicles.

The objective of this research effort is to elucidate and model basic mechanisms controlling heterogeneous deformation processes at material interfaces. Emphasis is placed on characterizing, modifying, and simulating dynamic events occurring at grain boundary and particle-matrix interfaces utilizing high-resolution analytical and atomistic modeling techniques. Specific interfacial processes such as dislocation emission and accommodation, boundary migration, sliding, sliding accommodation, diffusion, solute segregation, and cavitation will be isolated and evaluated.

These processes control a wide range of material properties from processing and fabrication to structural failure. Initial research will focus on the interfacial dynamics limiting the superplastic deformation of fine-grained metallic materials. High-rate superplastic forming has the potential to produce a significant advance in commercial manufacturing technology (e.g., drastically reduced forming times and die costs, ability to form large complex parts, and ability to form normally brittle materials). The fundamental science required as a basis for the general application of this technology is sorely lacking and will be a focus of near-term research.

Aluminum Forming The objective of this research effort is to establish basic understanding for the development of a new class of inexpensive, highly formable, aluminum alloys. Tailored alloys will be produced and processed using traditional ingot-metallurgy techniques to establish controlled matrix and grain boundary microstructures. Interfacial deformation dynamics will be quantified and linked to bulk mechanical behavior. Emphasis will be placed on characterizing, modifying, and simulating dynamic events occurring at grain

boundary and particle-matrix interfaces. Existing CRADA funding is being used to examine the advanced formability of new alloys and determine constitutive relations for detailed modeling of forming operations. This new research will focus on high-resolution interfacial characterization in multiphase alloys and link interfacial deformation dynamics to multigrain behavior. The mechanistic basis for differences in forming behavior will be established and used to design optimized alloy compositions and precipitate microstructures.

The primary growth areas for materials research are synthesis, processing optimization, and materials/environmental interactions. These growth areas will be pursued in conjunction with the EMSL. Basic Energy Sciences-funded material sciences programs relevant to the research areas of 1) conventional and superplastic metal forming, 2) materials joining, and 3) microstructured engineering with polymers are part of the Laboratory's participation in the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials.

Engineering and Geosciences

Basic Energy Sciences-funded engineering and geosciences research at the Laboratory has recently been completed in the areas of aeronomy, solar-terrestrial energy transfer and interactions, and geoscientific data integration using virtual reality. New research is in low-temperature geochemistry as a result of an intentional strategic expansion of programs aimed at collaborations involving core technical capabilities in molecular science and geochemistry and the development of spectroscopic and computational capabilities within the EMSL. These projects, along with LDRD funds, contribute to the research portfolio of the Environmental Dynamics and Simulation program within the EMSL. These efforts are exploring the geochemistry of the mineral-aqueous interface, the structure and reactivity of minerals, and the nature of complex fluids.

Since FY 1993, researchers from the EMSL and Earth Systems Sciences have been funded by the BES Division of Engineering and Geosciences to investigate the microscopic properties of minerals and mineral interfaces that affect the macroscopic transport of contaminants through the subsurface. Our program in solid-state theory is focused on the mineral/water interface with the goal of identifying critical or controlling aspects of atomic-scale phenomena that influence the behavior of complex geochemical systems on longer length and time scales. First-principles quantum mechanical methods implemented on massively parallel computer architectures are used to investigate such phenomena as adsorption, dissociative chemisorption, diffusion, and desorption on the internal and external surfaces of oxides, silicates, aluminosilicates, and clay minerals.

Research is also under way to develop a molecular-scale understanding of the surfaces of ferric oxide and oxyhydroxide minerals. Quantum mechanical calculations and experimental data are used to compute interaction parameters for large-system atomic-scale simulations of Fe-O-H systems. These simulations are then used to compute observables such as the infrared spectrum, pH of zero charge, and the surface charge-pH curves. This information, along with information about atomic structure and surface speciation of the hydroxylated Fe-oxide-water interface, will be used to obtain improved, more realistic thermodynamic models of adsorption on ferric oxide surfaces.

Another area of research is our interdisicplinary theoretical and experimental effort designed to gain a fundamental molecular level understanding of carbonate mineral surface structure and chemistry. Our focus is on how different surface sites influence crystal growth and dissolution and on interactions with impurities and contaminants found in the environment. An atomic force microscope equipped with a flow-through cell is used to measure dissolution and growth rates in solution. The experimental measurements in combination with empirical and first-principle quantum mechanical methods are used to build and test models of the structure and chemistry of the carbonate surface. This information provides input and boundary conditions for a kinetic Monte Carlo model description of step and pit evolution. Results of this research provide insight to the important processes and surface properties affecting the overall reactivity of carbonate surfaces.

Office of Computational and Technology Research

Mathematical, Information, and Computational Sciences Pacific Northwest has three major research programs ongoing for the Office of Mathematical, Information, and Computational Sciences (MICS): the High-Performance Computational Chemistry Program; the Wavelet Numerical Methods with Initial Application to Computational Chemistry Program; and Distributed, Collaboratory Experiment Environments (DCEE) Program.

The High-Performance Computational Chemistry program is a multilaboratory collaboration (Pacific Northwest National Laboratory, through the EMSL, and Argonne National Laboratory) with participation from the U.S. chemical and petroleum industry (Allied Signal, Amoco, DuPont, Exxon, and Phillips). The objective of this program, which is funded by the Mathematical, Information, and Computational Sciences Division of DOE's Office of Computational and Technology Research, is to develop the computational technology required to solve Grand Challenge-class problems in computational chemistry. New algorithms, software, and diagnostics required to fully exploit the new generations of massively parallel computers capable of teraflops performance are being developed in the program. In particular, algorithms are being developed that scale to larger numbers of processors, use hierarchical memory much more effectively, and have more appropriate input/output demands than current methods. The work is being done by an integrated team of computer scientists, applied mathematicians, and computational chemistry applications developers. The work focuses on a suite of computational chemistry modeling methods appropriate to three specific problem areas of urgent interest to the DOE and the

chemical and petroleum industries: 1) the disposal and replacement of halogenated hydrocarbons including the CFCs, 2) the chemistry of clay materials, and 3) the rational redesign of biodegradative enzymes.

Significant progress has already been made in the following areas:

- Identification of nonuniform memory access (NUMA) costs as the major issue to be confronted in both designing scalable parallel algorithms and in improving ease of program development and maintenance.
- Minimizing memory requirements by use of distributed, rather than replicated, data structures to achieve scalability and to make massively parallel processors cost-effective.
- Development of a tool kit (Global Arrays) to support the NUMA programming model. Global Arrays has been transferred to the public domain.
- A highly efficient parallel eigensolver (PeIGS) for matrices of dimensions common to chemistry problems. The diagonalizer has been transferred to the public domain.
- The development of several scalable algorithms to compute the electronic structure of molecules
  - self-consistent field (SCF) or Hartree-Fock
  - second-order many-body perturbation theory (MBPT-2)
  - multiconfiguration SCF (MCSCF)
  - multireference configuration interaction
  - local and nonlocal density functional theory.
- Development of a set of large-molecule calculations drawn from industrial and laboratory research problems. These calculations help in establishing design goals and in tracking performance.

The development of the software tools and computer codes will be critical to solving the large environmental challenges facing the DOE and the U.S. chemical industry. Based on the accomplishments of the previous High-Performance Computation Chemistry Initiative Grand Challenge effort, a follow-on proposal has been submitted to the new Grand Challenge call in the area of relativistic chemistry. This effort will focus on developing methods to calculate the electronic structure of actinides for nuclear waste characterization and processing. This effort will be performed by a multisite, multidisciplinary team and will focus on developing a massively parallel processor implementation of the codes. Development efforts include spin-free relativistic effective core potential methods; spin-free, all-electron methods; spin-dependent relativistic methods; and MCSCF and multiconfiguration relativistic perturbation theories.

A second program sponsored by MICS is "Wavelet Numerical Methods with Initial Application to Computational Chemistry." This program is focused on developing new, computationally efficient methods for the solution of differential equations. The equations of electronic structure theory such as the Hartree-Fock equation are nonlinear eigenvalue problems. In order to provide a more computationally efficient approach to the solution of such equations, recent advances in the development of multiresolution strategies for elliptic integro-differential eigenvalue problems are being implemented in the multi-wavelet representation. Wavelets have the potential to provide an order-of-magnitude or more improvement in computational efficiency and accuracy when compared with current basis set implementations. These methods are being implemented for a one-dimensional prototype atomic self-consistent field equation developed specifically for use as a benchmark for the extension of these methods to the three-dimensional problems common to molecular electronic structure problems.

Wavelet representations have the possibility of providing highly efficient algorithms, a unified representation of disparate length scales, and increased accuracy over current approaches. This project aims to bring recently developed multi-wavelet numerical methods to bear on three-dimensional free-space Poisson-like equations and nonlinear eigenvalue problems in a manner that is different from previous numerical approaches to this problem. Specifically, development is in progress for multi-wavelet formalisms and algorithms and appropriate sparse data structures, to produce efficient and practical computer programs that implement the Green's function to the three-dimensional Poisson equation and non-oscillatory Helmholtz equation, evaluation and compression of functions in the multi-wavelet basis, and other necessary linear and nonlinear operations.

This research will also contribute to the development of numerical wavelet methods for general problems in other application areas that exhibit multi-scale phenomena and thus benefit from a multi-resolution approach to their solution. The free-space Poisson problem is widespread and this method can be immediately transferred to other applications. This problem can also be considered a paradigm for more general elliptic problems, and the development of this method is essential in laying ground work for the development of numerical wavelet methods for anisotropic equations, bounded domains, and nonlinear equations.

Pacific Northwest is developing the concept of an Environmental Molecular Sciences Collaboratory which establishes a collective research environment to enable more effective research directed at the missions of the EMSL. A Collaboratory is an open meta-laboratory that spans multiple geographical areas, with collaborators interacting via electronic means—"working together apart." Collaboratories are designed to enable close ties between scientists in a given research area, to promote collaborations involving scientists in diverse areas, to accelerate the development and dissemination of knowledge, and to minimize the time-lag between discovery and application.

The DCEE program is part of DOE's High Performance Computing and Communication Initiative (HPCCI). A unique aspect of DOE's DCEE program is the role of collaboration among all of the investigators and their collaborators, in defining the architecture

of key elements of the next generation of collaboratory tools. The EMSL Collaboratory effort is developing one of the five testbeds for this program. This program extends Pacific Northwest's exploratory collaboratory technology development work by implementing authentication and authorization, extending cross platform dynamic screen sharing capabilities, and demonstrating the use of a collaboratory software environment.

The DCEE program is currently in its second phase. Pacific Northwest's main focus in this phase is on the development of two key collaboratory components, the EMSL Televiewer and an Electronic Laboratory Notebook. The televiewer enables remote colleagues to share in an experiment or analysis session by watching the remote application on their computer screen. The screen view is repeatedly updated as the remote screen changes. The EMSL Televiewer supports screen sharing between different kinds of platforms, e.g., PC, UNIX, Macintosh, and across great distances, including overseas locations.

An electronic laboratory notebook combines the flexibility and familiarity of the paper notebook with the organizational power of computer databases and the distributive capabilities of computer networks. The Electronic Laboratory Notebook prototype project is a joint effort involving Pacific Northwest and collaborators at The Evergreen State College, and the Concurrent Engineering Research Center at West Virginia University. The main objective is to develop an architecture and a usable prototype with a range of notebook information/annotation types, data access and sharing capabilities, and the ability to integrate with data acquisition and analysis applications.

Collectively, this DCEE project and other Collaboratory projects at Pacific Northwest are developing the basis for a revolution in the way that expertise and facilities can be applied to demanding scientific problems in environmental molecular science. These same techniques, and many of the same capabilities, can be directly applied to an array of endeavors in science and industry.

Laboratory Technology Research Program (KU)

This program has produced exceptional results in conducting technology research projects in cooperation with industrial partners that bridge the gap between basic and applied science. The majority of the technology research projects supported by the program at the Laboratory have linkages with other Energy Research-funded activities. Example highlights of some on-going Laboratory projects conducted under the technology research program include the following:

- A project to develop a near-field optical microscope has produced high-quality near-field/shear-force images of photosynthetic membranes. In addition, a new technique for "near-field optical tweezers" has been developed that shows promise for manipulating single proteins in order to control enzymatic reactions, and single-molecule excitation spectra were recorded for the first time. The principal investigator on this project received the internationally recognized Coblentz Award, which recognizes outstanding achievement by a young molecular spectroscopist.
- A project to develop a new generation of elemental mass spectrometers has resulted in the development of two new plasma source ion-trap instruments that have been successfully operated for several months and demonstrated exceptional sensitivity. A patent has been filed on design concepts incorporated in the prototypes and four technical presentations, two invited papers, and two journal articles have been published on work conducted in the project.
- A project to develop bioactive and porous metal coatings for improved tissue regeneration has demonstrated the feasibility of using Void Metal Composite materials with a unique pore structure to allow for in-growth of tissue. A unique ability to use a solution deposition method to deposit a mineral coating in small, porous materials also has been demonstrated.
- A project to develop new technologies for the reduction of automobile exhaust emissions has resulted in the development of a corona discharge flow system that has demonstrated the efficient destruction of hydrocarbon at space velocities approaching 20,000 hr^{-1}. Nearly complete destruction of nitric oxide under anhydrous conditions was also demonstrated.

Despite these and other successes, the future of the Technology Research Program is in doubt because of Congressional budget reductions. Our current plan is to support the program through a continued commitment to producing positive results and further strengthening of the linkage of the program to achieving the scientific and technical missions of the Laboratory and DOE. The Laboratory fully supports the program's on-going efforts to identify and fund projects in technical focus areas that are critical to both the fulfillment of DOE and Laboratory missions and to U.S. industrial competitiveness. Currently, these areas are defined as

- intelligent manufacturing
- tailored materials
- sustainable environments.

We believe that the Laboratory can play a key technical role in each of these areas through the development and conduct of cooperative research projects that bridge between basic and applied science.

The Technology Research Program also plays a vital role in the Laboratory's efforts to provide technical assistance to small businesses, particularly those in the local and regional area. The program funds quick response projects, including staff exchanges and small technical assistance projects, that enable the technical capabilities of the Laboratory to be used to assist small business. Feedback from small business participants in this aspect of the program has been extremely favorable. Further details on these efforts is provided in the Scientific and Technology Partnerships section of this Plan.

A third major role of the program has been to support major industry

partnerships, such as The AMTEX Partnership with the textile industry. While we continue to believe in these major partnership efforts, the current environment does not favor their formation or implementation. Although the efforts of Pacific Northwest and other Energy Research laboratories in The AMTEX Partnership were funded by the Technology Research Program in FY 1996, responsibility for these efforts has been transferred to the Office of Energy Efficiency and Renewable Energy in the FY 1997 budget submission. So long as The AMTEX Partnership remains viable, we plan to play a major role within it. The only major industry partnership that remains a responsibility of the Technology Research Program is the Advanced Computational Technology Initiative (ACTI), in which the Laboratory presently has no on-going projects. If additional opportunities to compete for ACTI funds are made available, the Laboratory will likely submit proposals.

If key stakeholders in the program can be convinced of the value of the Technology Research Program, we believe that our efforts in support of the program will stabilize or even grow slightly over the next 3 to 5 years compared to their present levels.

Energy Research Analysis (KD)

Pacific Northwest National Laboratory's Basic Science Analysis Program works with the Director of the Office of Planning and Analysis within the Office of Energy Research to provide scientific and technical analysis to improve the understanding of science, technology, and policy issues that impact energy research decisions. The Laboratory's research is focused on planning and economic analysis to support science policy, development of strategic or technical plans for basic science, and development of background to facilitate the analysis of science policy issues.

Magnetic Fusion (AT)

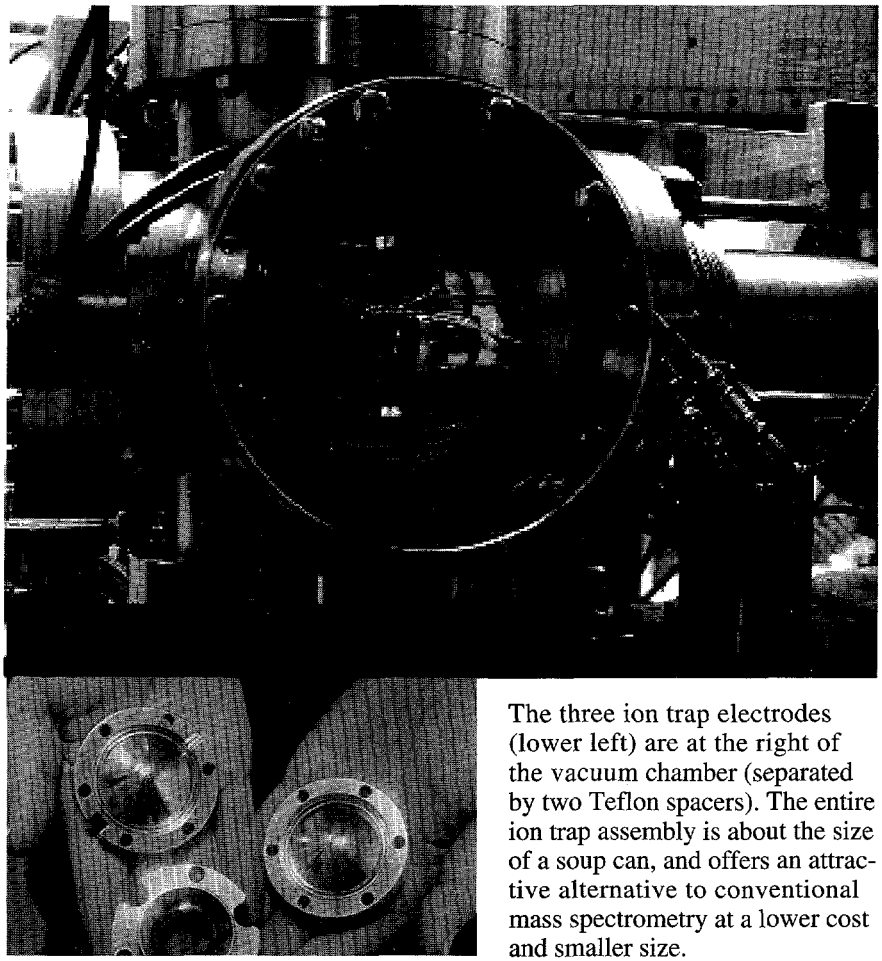
The Magnetic Fusion program at the Laboratory is focused on advancing first-wall and blanket technology. The long-term objective of the program is to enhance the economic and environmental attractiveness of the fusion energy option. This is accomplished by research aimed at developing reduced activation materials that provide the needed performance in the chemical and nuclear environment of a fusion reactor. The near-term objective is to meet the needs for a materials database for experimental devices such as the International Thermonuclear Experimental Reactor (ITER).

The scope of the Laboratory's work includes determining the behavior of reference candidate materials in a radiation environment, developing new materials with improved properties, developing reduced activation materials, and developing predictive capabilities through theory and modeling of radiation and chemical effects on material properties. This predictive capability is needed to account for differences in the neutron spectrum between available fission reactors and the fusion neutron environment.

The primary materials under investigation are for structural and tritium breeding applications. Research is in progress on ferritic/martensitic steels,

1996 R&D 100 Award Winner

The Plasma Source Quistor mass spectrometer was developed by Pacific Northwest and an industrial partner, Finnigan Corporation of San Jose, California. Their collaboration focused on incorporating on-line and real-time chemistry capabilities into the spectrometer. These attributes are very important in overcoming the classic limitations caused by interference problems and ion repulsion effects.



The three ion trap electrodes (lower left) are at the right of the vacuum chamber (separated by two Teflon spacers). The entire ion trap assembly is about the size of a soup can, and offers an attractive alternative to conventional mass spectrometry at a lower cost and smaller size.

vanadium alloys, SiC/SiC composites, copper alloys, and beryllium. The tritium breeding performance of lithium ceramics (solid breeders) is also being evaluated.

This material development program requires a research staff with expertise in radiation effects, facilities for handling and testing radioactive materials, and reactors for irradiating materials. The Laboratory has a dedicated team of research engineers and scientists with considerable expertise in radiation effects and excellent facilities for handling and testing radioactive materials. Reactor facilities to achieve the U.S. and international fusion goals have become a problem not only for the Laboratory but also for the U.S. and international fusion community. Radiation experiments with joint Pacific Northwest and Oak Ridge National Laboratory participation currently are in progress in the HFIR at Oak Ridge National Laboratory and the SM 3 reactor in Russia.

Fusion energy development continues to be a very international program. The Laboratory's international involvement includes participation in the ITER program and official international collaborations with the Japanese MONBUSHO program and with researchers in Russia. Funding for Phase III began in April 1995 and will be 30 percent more than Phase II. The structural materials effort at the Laboratory is expected to remain constant for the next 5 years but at a reduced level compared to the last 5 years. There is some uncertainty regarding the future of the solid breeder task.

High Energy Physics (KA)

The measurement of the double-beta decay of germanium-76 is considered by most physicists to be the experiment having the highest potential for setting the world standards on lepton nonconservation, neutrino mass, and grand unification. We designed and built the most sensitive experiment in the world for making this measurement. In Phase I, three 1-kilogram detectors were fabricated from 5 kilograms of enriched germanium-76 supplied to us by the former Soviet Union. We made the first confirmed measurement of the two-neutrino double-beta decay of germanium-76 and the first measurement of the double-beta decay of molybdenum-100 to the first excited 0+ state of ruthenium-100.

An international consortium, the International Germanium Experiment (IGEX), has been formed including Pacific Northwest National Laboratory; the universities of Minnesota, South Carolina, and Zaragoza, Spain; the Institute for Theoretical and Experimental Physics in Moscow; the Yerevan Physical Institute; and the Russian Academy of Sciences' Institute for Nuclear Research, to produce several more germanium detectors enriched to 86 percent in germanium-76. The former Soviet Union delivered 20 kilograms of this enriched germanium (worth $30 million) to the United States for fabrication into very large ultralow-background detectors by the Laboratory. The first two of these detectors, weighing more than 2 kilograms each, have been installed in the Homestake Mine in Lead, South Dakota. The third detector has been installed in a newly completed underground laboratory in Canfranc, Spain. A total of at least five such large detectors are planned. The current program has virtually eliminated all controllable sources of background, and only cosmic-ray-induced radioactivities in the construction materials remain. A pulse shape discrimination technique is under development to electronically eliminate events from these cosmogenic activities. Preliminary results indicate pulse shape discrimination can reduce the remaining background in the endpoint region by another factor of 20. This should lead to a remaining background of 0.01 counts/keV/kg/yr: sufficient to measure a neutrino mass of ≈0.1 eV. The goal of the Laboratory and IGEX is to measure, or place meaningful limits on, the zero-neutrino double-beta decay mode of germanium-76 for resolution of Grand Unified Theories.

Science, Mathematics, Engineering, and Technology Education

Along the educational pipeline, from elementary school through postdoctoral studies, education programs at the Pacific Northwest National Laboratory aim to increase the quantity, quality, and diversity of students preparing to participate as scientific and technical professionals in areas related to DOE and Laboratory missions; to assist in the reform of the education system so that all citizens are educated to understand science and technology and the need for high quality science, mathematics, engineering, and technology education; and to support DOE and the Laboratory's missions in energy, the environment, and economic competitiveness through interactions with universities.

The Laboratory's educational activities include an array of programs and interactions for students and faculty at the precollege, 2-year institution, and university levels. The programs are based on the premise that the national laboratory system and the core competencies and unique capabilities of the Laboratory provide a rich technical and human resource for enhancing the education of students and improving the education system.

The Laboratory's education programs support four overarching goals:

- supporting promising students in a successful transition from school to work
- developing the diversity of students in the education and work force pipeline
- promoting systemic reform of mathematics, science, and technology education
- building strong Laboratory-university partnerships.

Supporting the School-to-Work Transition About 20 percent of the nation's students drop out before they finish high school. Of those who graduate, less than 40 percent make the transition from high school to college. Overall, less than 25 percent remain to complete a 4-year degree. Currently, 75 percent of students in this state and nation attempt to enter the work force directly from high school or following 1 to 2 years of college. Many are not successful in their transition

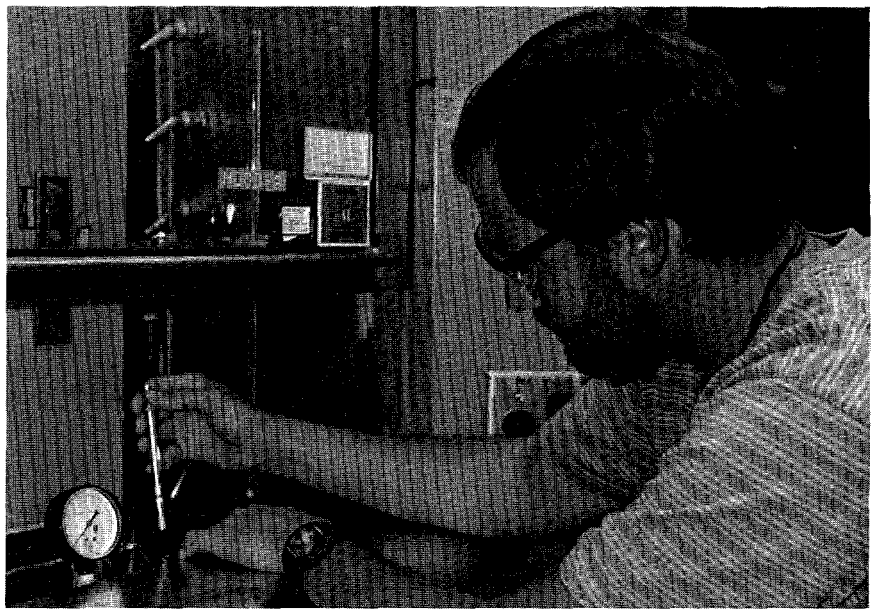
from school to work, particularly in work areas requiring knowledge and skill in science, mathematics, and technology. They lack the basic academic and entry-level occupational skills necessary to succeed.

The President's School-to-Work Opportunities Act of 1993, passed by Congress and signed by the President, is a critical component of the nation's response to the challenge to prepare every American for employment and productive citizenship.

Hands-on, performance-based training and mentoring at the work site for students participating in Laboratory education programs supports the establishment of instructional programs in schools, colleges, and universities, that meet high academic and occupational standards and reflect the technology and training needs of a Laboratory work assignment. The Laboratory works with educational institutions to connect school-based learning with work-based learning.

The Laboratory's school-to-work efforts assist schools, colleges, and universities with curricula and instruction that reflect the integration of the disciplines in the scientific and technical work place. Opportunities will be provided for teachers and faculty to develop content knowledge and instructional strategies that successfully integrate the teaching of science, mathematics, and technology. Such interdisciplinary curricula will reach not only the majority of students who never complete college, but will also enrich programs designed for all students including those who pursue careers in science and engineering.

Foundation at the K14 Level A foundation exists at the Laboratory for supporting the school-to-work transition. At the precollege level, the Laboratory supports career awareness presentations and workshops for students. At the community college level, the Laboratory assisted in the development of the hazardous materials technician training program at the local community college which builds on curricula at the high school level. During FY 1996, the Laboratory continues to participate in the development of the Tech Prep Consortium which includes local academic partners at the high school and community college levels dedicated to providing continuity in specific science and technology curricula between the high school and community college. OPTIONS scholarships and internships provided to multicultural and nontraditional community college students also support the school-to-work transition. The Laboratory is participating in the efforts of a local high school to design a materials science and technology "academy."



A university senior working in a hands-on research environment through the SERS program.

Undergraduate and Graduate Links to the Laboratory Workplace At the college and university level, the school-to-work transition is supported by existing programs for students. Outstanding undergraduate students spend time at the Laboratory during the fall or spring academic semester through the DOE Science and Engineering Research Semester (SERS) program. SERS provides students the opportunity to work in a hands-on research environment under the guidance of Laboratory scientists and engineers. During FY 1996, 68 students participated in SERS.

Through Associated Western Universities, Inc., the Laboratory hosts college and university undergraduate and graduate students for high-quality summer education and training opportunities at the Laboratory as part of the DOE Laboratory Cooperative (Lab Coop) program. Laboratory research staff strongly support the goal of the Lab Coop to enhance the training of outstanding university students. During FY 1996, more than 250 undergraduate appointees participated in the program. The Lab Coop program is expected to continue healthy growth in the coming years.

In FY 1997, a proposal to the National Science Foundation will be developed to provide undergraduate faculty training at regional universities using the Environmental Molecular Sciences Laboratory "Collaboratory," a highly interactive computer and communications network for research and education. A faculty enhancement course in one or more technical fields is being developed to assist faculty with curriculum development.

At the graduate level, the Laboratory supports Energy Research Fellowships for highly qualified students from nine regional universities. The fellowships allow students to conduct course work on campus during the academic year and spend 3 months each year conducting research at the Laboratory. During

FY 1996, six graduate fellowships were awarded to Ph.D. candidates studying a variety of research topics.

The Laboratory hosts recipients of DOE's many graduate fellowships including Industrial Hygiene, Operational Health Physics, Nuclear Engineering, Environmental Restoration and Waste Management, and Fusion Energy Technology. Graduate students spend 3 months conducting research at the Laboratory and complete their academic requirements at the university.

The Laboratory has recently initiated the DOE-funded Environmental Science and Engineering Education Coordination and Assistance Project (ESEECAP). The purpose of this program is to assist Washington State University at Tri-Cities (WSU-TC) to provide relevant and timely educational programs in environmental science and engineering to Hanford staff and the local community. A bachelor's degree program in Environmental Science was initiated several years ago, and a master's degree program began in 1996. These programs provide an applied approach to education designed to equip students with the technical background and hands-on knowledge to address environmental problems that are related to Hanford as well as to regional, national, and worldwide concerns.

Developing Diversity in the Pipeline

The need for increasing the diversity of students in the pipeline is twofold. Jobs requiring scientific and technical knowledge and skill are increasing, at the same time, traditional sources of scientific and technical professionals are decreasing in relation to the populations of those who traditionally do not enter scientific and technical fields. Demographic trends indicate that 85 percent of new workers entering the work force between now and the year 2000 will be those from nontraditional groups such as women and ethnic minorities. Unless an increased number of individuals from nontraditional groups are attracted into scientific and technical fields, the future need for qualified scientific and technical professionals, particularly in selected disciplines, may exceed the available supply.

Equally compelling is the need to diversify the work force because diversity contributes to excellence in our work. The distinctive perspectives found in the complex richness of a diverse work force engender creativity and innovation important to solving complex problems related to energy, the environment, and economic competitiveness.

To develop diversity for a future work force, education activities at the Laboratory that target the traditionally underrepresented form a seamless pipeline from the precollege through the university level. Resources will be applied to ensure that segments of the pipeline currently weakest will be strengthened to sustain promising students at every stage of their progress. Strategies will be employed to ensure that students, once selected to participate, are supported from year to year as they progress through the pipeline and make the transition from precollege to college and university to employment.

Following are descriptions of education programs dedicated to increasing diversity in the education and work force pipeline.

High Schools and Two-Year Institutions At the high school levels, incentives and opportunities continue to be provided for students who participate in MESA (Mathematics, Engineering and Science Achievement), a statewide program to encourage minority students to prepare for careers in science and engineering. Laboratory staff continue to participate on the advisory boards of the local MESA center and as Chair of the MESA State Board of Directors. This Laboratory investment has been leveraged by Battelle, which awarded financial support to assist MESA in ensuring that the legislated education reform in Washington State takes into account the needs of a diverse population of students. In the future, MESA will be closely linked providing specific pathways for young women and underrepresented minority students to pursue scientific and technical studies.

Begun in 1979 and once exclusively a high school level program, the Student Research Apprenticeship Program, an 8-week summer program for traditionally underrepresented students in eastern Washington and Oregon, has been extended through the college and university years to provide continuity from grade to grade beyond the high school level of the entering students. This program is a cornerstone of developing diversity in the Laboratory's education and work force pipeline. It addresses a major weakness in the pipeline for minority students, that is, the transition from high school to higher education.

The Columbia Basin College OPTIONS Scholars Program for multicultural and nontraditional students forms a 2-year college segment of the pipeline. The program provides awards to multicultural, nontraditional students each year for academic tuition and fees and a summer internship at the Laboratory. Students who participate are from ethnic minority groups, or are among those who are returning to school after having dropped out of the mainstream of students whose academic pathway is direct and continuous.

Higher Education Under a Memorandum of Understanding, the Laboratory continues to support Heritage College, adjacent to the Yakama Indian Reservation, whose student body comprises mainly nontraditional or place bound students from the surrounding Native American and Hispanic American communities. Heritage College science and education faculty, in collaboration with the Laboratory, are developing a basis for expanding the environmental science course offerings to students.

Other Institutions with Predominantly Underrepresented Populations In addition to Heritage College, the Laboratory has partnerships with Historically Black Colleges and Universities (HBCUs). The Laboratory has Memoranda of Understanding with the following: Howard University, North Carolina A&T University, Prairie View A&M University, Tuskeegee University, Alabama A&M University, Clark Atlanta University, Florida A&M University, Southern University, and Xavier University. The Memoranda of Understanding allow the Laboratory and the institutions to develop joint programs in science and

engineering that include collaborative research projects, scientist and faculty visits and exchanges, and student internships. In addition, the Laboratory has provided seed monies for developmental research, supports Laboratory staff to serve as lecturers and workshop presenters, and assists HBCUs in designing precollege programs to attract and retain students in science and engineering studies.

Plans for FY 1997 and beyond include maintaining support for education and training at HBCUs as well as developing stronger ties to regional institutions of higher education that have predominantly Hispanic or Native American students.

Programs for Women To recruit and retain women in science and technology, the Laboratory continues to develop programs that link the Laboratory's resources with women students. In 1996, the Laboratory again conducted "Take Our Daughters to Work Day," inviting young women in grades five through nine to spend a day learning about their options in the world of work, particularly in science and technology. Again in 1996 as in past years, Laboratory staff met with groups of young women as part of Expanding Your Horizons conferences conducted in the state of Washington. These conferences attract hundreds of young women and provide an opportunity for their interaction with women of achievement.

At the college level, the Laboratory provides financial and in-kind support for students participating in the Women in Engineering Program at the University of Washington.

In the fall of 1997, the Laboratory will host the U.S. Department of Energy's Annual Review of Women's Programs.

Programs for Disabled Continuing in FY 1996 is an effort to share science and scientists with students who are disabled or otherwise place bound. In partnership with a National Science Foundation-funded program at the University of Washington, Laboratory scientists tutor students and communicate electronically with disabled students across the state who participate in the program.

Promoting Systemic Reform The Department of Energy and its national laboratories are the customer and the patron of a large segment of the nation's scientific and technical work force and have a direct stake in the quality of science, mathematics, engineering, and technology education. Further, the missions of DOE can best be achieved within a community educated to understand and value scientific research and development.

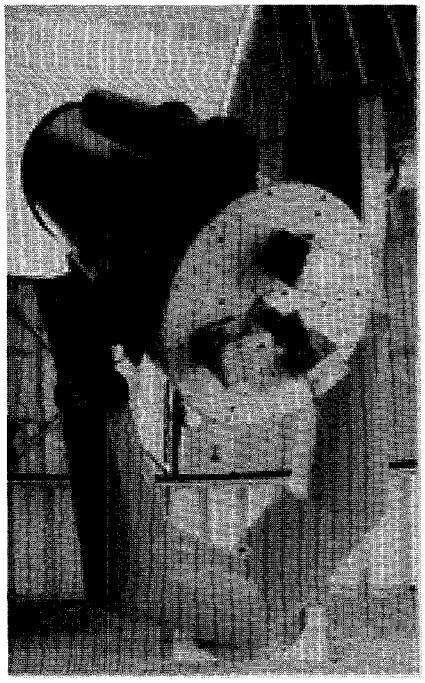
Therefore, the Laboratory's education programs support the national priority for a systemic approach to educational reform, an approach not based on efforts to change discrete parts of the system, but an approach intended to change the whole system so that all parts together support students achieving at the highest possible levels. The Laboratory's participation in systemic reform is aligned with the national education strategy, Goals 2000: Educate America Act, passed by Congress and signed by the President, which centers on systemic reform and calls for partnerships that link the schools with the community, business, and government stakeholders.

Laboratory staff serve on national, regional, state, and local advisory boards and working groups to establish and implement content and assessment standards for mathematics, science, and technology education. The Laboratory continues to work with public- and private-sector organizations in the state of Washington to implement statewide systemic reform in mathematics, science, and technology education, including serving on the state's committee to develop science education standards. Overall efforts include teacher enhancement and preparation, curriculum and instruction, assessment of learning, accountability, and resource development.

Curricula Reform The Laboratory continues to promote curricula reform supported by DOE by conducting the National Teacher Institute in Materials Science and Technology. The intensive 2-week summer institute trains teams of teachers and administrators from across the country to implement in their school districts the materials science and technology curriculum developed over the past 10 years by Laboratory scientists in collaboration with teachers. Since 1986, the development of this applied academics curriculum has been supported variously by DOE, the U.S. Department of Education, the Northwest Regional Educational Laboratory, and the state education offices of Washington and Oregon. More than 22 school sites in Washington and schools in 17 states and U.S. territories are implementing the curriculum. This hands-on, minds-on approach to learning aligns with education research and best practices and parallels the way scientists and engineers uncover knowledge and solve problems.

Teacher Enhancement Because teachers are key to reaching students at all levels, the Laboratory continues to provide high-intensity training and research experiences for elementary, middle, and high school teachers using Laboratory scientists, engineers, and equipment. At the elementary school level, the Laboratory received a second round of funding from the National Science Foundation and DOE to implement the Science Alive program, a component of a DOE multilaboratory elementary school teacher enhancement program. The second round focuses on developing teacher-leaders who can implement change in their schools and districts. Teams of teachers from the Yakima Valley and Tri-Cities participate in summer institutes at the Laboratory and academic year workshops dedicated to producing long-term, sustained systemic change.

Teacher Research Participation Teacher Research Associates (TRAC), a DOE program for middle and high school teachers, has provided 8-week summer research experiences at the Laboratory for more than 300 teachers since 1986. This program has become a model for other federal agencies, universities, and industrial laboratories. Laboratory science education staff have assisted in the dissemination of the model program. The program strengthens the content knowledge and instructional strategies of teachers, providing an avenue for rapid transfer of frontier science to the classroom.



The Rattlesnake Mountain Observatory telescope will help students explore the galaxy.

In summer 1996, the Laboratory continued a component of the TRAC program begun in 1994 to provide research experiences for teachers who are part of a National Science Foundation-funded master's degree project through Washington State University to enhance the abilities of chemistry teachers who are teaching out of their field of academic preparation. Also as part of TRAC, the Laboratory continues to host a teacher from the University of Washington's Math and Science Project (formerly Ford Fellows) program. The Laboratory also expanded a teacher program begun in 1994 and funded under DOE's nuclear nonproliferation program to provide research experiences for teachers of science paired with teachers of the humanities. The outcome will be model instructional strategies based on the science, technology, and humanities content inherent in the teachers research experience.

Student Incentives and Opportunities The Laboratory continues to conduct programs at all grade levels to provide students with incentives to study mathematics, science, and technology, and opportunities to participate in hands-on laboratory activities and interact with Laboratory scientists. Major precollege and university level programs for students are conducted at the Laboratory in Richland. The Laboratory also continues to participate in DOE's regional and national Science Bowl, providing judges, training for the regional judges, and questions produced by scientists. Most student programs are described under other headings within this section of the Institutional Plan.

Educational Technology Initiatives Beginning in the 1996-97 school year, the Laboratory will work with the Richland and Kennewick School Districts to improve student achievement in reading, writing, communications, and science at the high school level using technology. Schools will be connected to the human and technical resources of the laboratory using Internet-based technologies.

The Extensible Computational Chemistry Environment Pilot Project is a project that gives high school students the opportunity to work with computational chemistry databases as part of their advanced science studies at Kennewick High School. The project will link the high school students with the EMSL. Students will perform molecular modeling calculations and submit them for inclusion in the official EMSL database.

Beginning in 1994, the Laboratory entered a partnership with the Kennewick School District which provided Internet access to Kennewick elementary and secondary teachers on a pilot basis. In 1995, Kennewick Schools and the Laboratory submitted a successful proposal to the Washington State Office of the Superintendent of Public Instruction (OSPI) to improve learning through the use of electronic technologies. The partnership, one of five selected from Washington State, will initially be directed toward providing Kennewick students and teachers remote access to and control of the Battelle telescope on Rattlesnake Mountain. Subsequent efforts will address other domains of science and technology at the Laboratory, including the EMSL. The overall effort is supported by the National Science Foundation and coordinated by OSPI. Other partners in this initiative are Columbia Basin College, Heritage College, and the Alliance for the Advancement of Science Through Astronomy.

Researchers in the EMSL are developing a suite of technologies to create a Collaborative Research Environment that allows real-time remote collaborations, interaction with remote instruments and software, and access to remote data and visualization. The entire system is launched and coordinated using familiar World Wide Web interfaces. The Collaboratory is a mechanism for EMSL to easily share its expertise, data, and unique scientific instruments with remote colleagues, and this idea is being extended into the undergraduate classroom. The University and Science Education Programs office is playing a strong role in developing the Collaboratory tools for faculty enhancement and undergraduate student learning by developing a workshop for select regional universities that will begin the process of linking university students and faculty to the Collaboratory's resources. This workshop will also assist EMSL staff with development of Collaboratory tools that are efficiently implemented and used in the undergraduate classroom.

Building Strong Laboratory-University Partnerships The Laboratory has a substantial and growing commitment to education and research partnerships with colleges and universities that spans nearly three decades. Through this broadly based initiative, the unique resources, staff, and facilities of the Laboratory are shared with colleges and universities throughout the northwest region and across the nation.

Integral to building strong Laboratory-university partnerships are the more than 1100 students and faculty who participate each year in educational appointment programs at the Laboratory. Faculty research and education expertise is enhanced through such appointments which serve also to strengthen the academic institutions. Moreover, diverse research partnerships with academia enable the Laboratory to collaborate with a number of recognized experts in fields consistent with the business areas of the Laboratory and DOE.

Agreements and Memoranda of Understanding Collaborative Agreements and Memoranda of Understanding provide a firm foundation for the Laboratory's partnerships with universities and are primarily intended to enhance collaboration between the Laboratory and universities by providing simplified and expanded administrative mechanisms. Partnerships strengthen the quality of research at participating universities through collaborative research, joint use of facilities and equipment, sharing of scientific equipment, appointments of university faculty as Pacific Northwest National Laboratory Affiliate Staff Scientists (PASS) appointees, and appointments of Laboratory staff as Adjunct and Affiliate Professors as well as guest lecturers at the universities.

The Laboratory has formal Collaborative Agreements with the following regional universities:

- University of Idaho
- University of Montana
- Montana State University
- University of Oregon
- Oregon Graduate Institute of Science and Technology
- Oregon State University
- Portland State University (Oregon)
- University of Washington
- Washington State University.

Memoranda of Understanding are currently in place with the following universities throughout the U.S. and Canada:

- California State Polytechnic University at Pomona
- Clarkson University (New York)
- Colorado School of Mines
- East Tennessee State University
- George Mason University (Virginia)
- Heritage College (Washington)
- Indiana University
- Mesa State College (Colorado)
- Pacific Lutheran University (Washington)
- Reed College (Oregon)
- Rutgers University (New Jersey)
- Saint Mary's College (Indiana)
- Sheldon Jackson College (Arkansas)
- SUNY Buffalo (New York)
- Texas A&M University
- University of Alberta
- University of British Columbia
- University and Community College System of Nevada
- University of Florida
- University of Kentucky
- University of South Carolina
- University of Texas at El Paso
- Utah State University
- West Virginia University
- Western Washington University
- William Marsh Rice University (Texas)
- Yale University (Connecticut).

Master Agreements University partnerships are defined and executed jointly by the Laboratory and the college and university partners, and 5-year Master Agreement subcontracts have been developed with 29 universities throughout the United States to facilitate collaborative research and prequalify the universities in one or more of 15 technical work areas. Since Master Agreements were first instituted 8 years ago, joint research projects between the Laboratory and universities have increased significantly. During FY 1996, the Laboratory undertook more than $10 million in subcontracts with universities, and the rate of growth is expected to increase steadily during FY 1998 and beyond.

Areas of joint activity under the Master Agreements include meteorological monitoring modeling and analysis, global change environmental monitoring and modeling, waste site characterization, waste treatment, computational sciences, sensor development, molecular and structural biology, chemical and materials science, toxicology, health physics, risk assessment, energy systems, infrastructure modernization and productivity enhancement, and technology planning and analysis.

Within the Master Agreement framework, the Laboratory supports the establishment of new professorships at regional universities. In past years, the Laboratory assisted in establishing new faculty programs in surface science, chemical engineering, and environmental engineering at Washington State University and the University of Washington. During FY 1998 and beyond, the Laboratory expects to establish faculty programs and support curriculum development in advanced areas of environmental science and molecular science at regional universities.

Postdoctoral Fellowships Postdoctoral fellows play a key role in Laboratory research activities, particularly in the environmental and molecular sciences. The Laboratory's activities at the postdoctoral level have grown significantly during 1996, and represent the largest growth in university programs at the Laboratory. The DOE Lab Coop program provided 1- and 2-year fellowships to more than 175 outstanding postdoctoral researchers during FY 1996.

Also participating in research under the guidance of Laboratory scientists and engineers are those outstanding researchers who have received national DOE postdoctoral fellowships including Alexander Hollaender, Human Genome, and the Distinguished Postdoctoral Fellowship. These highly competitive DOE fellowships provide the Laboratory an opportunity to work with some of the best new researchers in the country, while also expanding the Laboratory's contact with universities connected to the past work of the fellowship recipients.

Faculty Preparation and Enhancement The Laboratory, jointly with Associated Western Universities, Inc., actively promotes opportunities to advance the knowledge and skills of university faculty in science and engineering. The intent of these programs

Science, Mathematics, Engineering, and Technology Education

Pre-University Programs	Fiscal Year 1996 Total	Women	Minority
Pre-University Programs			
Student Programs			
Student Research Apprenticeship Program	31	16	31
Inquiry Into Science	5	1	1
Marine Ecology Institute	10	0	10
CBC OPTIONS Scholars	12	6	7
Expanding Your Horizons/Career Conference	330	330	99
Sharing Science with Schools	10,550	5,275	1,144
Pacific Northwest National Laboratory Disabilities Opportunities	3	2	2
HESEC Summer Institutes (run by HBCUs)	78	40	78
Teacher Programs			
Teacher Research Associates	24	9	0
Science Alive II (National Teacher Enhancement Project)	77	67	48
Summer Research Internship Program for Teachers	7	3	0
Materials Science and Technology Institute	19	5	4
Special Programs			
OPTIONS Systemic Initiative	4,455	1,976	2,686
Subtotal Pre-University Programs	**15,601**	**7,730**	**4,110**
University Programs			
Undergraduate Programs			
Advancing Minorities Interest in Engineering (AMIE)	2	1	2
Science and Engineering Research Semester (SERS)	61	24	8
Laboratory Cooperative Program	254	94	29
GEM (minority)	1	0	1
HAMMER Scholars Program (minority)	10	5	10
HESEC (scholars/scholarships, minority)	7	3	7
WSU-TC OPTIONS	1	1	0
Graduate Programs			
Laboratory Cooperative Program	150	51	24
DOE Graduate Fellows	3	1	0
National Physical Science Consortium (minority)	5	3	3
Pacific Northwest National Laboratory Energy Research Fellowship	6	4	2
Postdoctoral Programs			
Laboratory Cooperative Program	176	28	70
DOE Postdoctoral Program	1	0	0
Faculty Programs			
Laboratory Cooperative Program	90	16	21
Pacific Northwest National Laboratory Affiliate Scientists	219	18	37
Subtotal University Programs	**986**	**249**	**214**
Grand Total	**16,587**	**7,979**	**4,324**

is to bring fresh ideas into the Laboratory and to stimulate the development of updated curricula that draws on interdisciplinary approaches used at the Laboratory.

The PASS program under went significant changes during FY 1995 and has become a premier program during FY 1996. The PASS program allows Laboratory researchers to nominate university faculty collaborators for PASS membership, thus helping to formalize and enhance collaboration. PASS members are allowed access to Laboratory facilities, as well as travel support provided by education programs and the host researcher. It is expected that the PASS appointments will continue to open the Laboratory's doors to university researchers and stimulate new ideas and research opportunities.

A counterpart to the PASS program, Laboratory staff members hold faculty joint appointments at university campuses. More than 240 affiliate professorships and lectureships, approximately one-half of which are held at university campuses around the country, are held by Laboratory staff. The remaining one-half are held at regional universities including WSU-TC located in Richland.

Evaluation and Capacity Building

Building on the past 4 years of participation in DOE's project to assist the laboratories in evaluating the quality and assessing the impact of their education programs nationwide, the Laboratory expects to formalize a multifaceted approach to ensuring that goals and objectives are met for the full array of the Laboratory's education programs. This opportunity for capacity building has added value to the education programs at the Laboratory, strengthened our role through the state and region, and improved the abilities of education staff to conduct effective programs. In addition, the outcomes and results of program evaluation and impact assessment provide tools for the nation to identify effective programs that connect students and faculty with the resources of DOE laboratories or similar science and technology organizations.

Environmental Quality

Management and staff at Pacific Northwest National Laboratory have a major role in DOE's Environmental Quality programs. The dominant part of our research and development activities are devoted to resolving environmental issues faced by DOE and other public and private organizations. Our work in the technology applications area is largely devoted to meeting the demanding technical requirements for waste management and environmental remediation at Hanford and across the DOE complex, but we also provide solutions for a number of domestic and international customers. Our systematic approach to science and technology results in comprehensive solutions to environmental needs for DOE and others.

Our science programs provide the knowledge and understanding required to effectively manage waste and remediate environmental contamination at Hanford and across the DOE complex. The EMSL capability will add significantly to providing this understanding. Our technology development programs provide technologies that reduce the cost and/or risk, or improve the timeliness and effectiveness of DOE's cleanup program. The Advanced Process Engineering Laboratory (see Designated User Facilities under the Science and Technology Partnerships) will provide a resource to support development and deployment of technology by the Laboratory and its partners. We also work to supply the knowledge, methods, and systems engineering capabilities required to support DOE in the risk-based decision making necessary to set priorities and select technical approaches. Finally, we are committed to providing the scientific understanding and the technical methods that enable DOE to ensure protection of its workers and the public in DOE operations and that support establishment of risk-based environment, safety, and health standards.

In meeting these responsibilities, we recognize the necessity for partnerships with other laboratories, industry, and academia. No single institution brings the full suite of capabilities necessary to resolve the complex problems facing DOE. Our major environmental programs involve the broad collaborations necessary to deliver comprehensive solutions.

The Environmental Quality section provides details on Laboratory support to DOE-EM and the Office of Environment, Safety, and Health. Support to the management of the National Technology Development Program as well as the Laboratory's technology development and deployment roles within that program are described first. Work on integrated risk-based environmental planning and decision making for Hanford as well as most of the DOE-EM Program Offices is discussed. The section also discusses the Laboratory's role in supporting the application of environmental technologies to the environmental restoration and waste management programs within Environmental Management. The application of these technologies is primarily targeted to the Hanford Site, but also includes support to DOE-Headquarters and other DOE sites. Pacific Northwest's Environmental Management facility activities and its specific activities supporting Hanford Site operations follow. The Environmental Quality section concludes with a discussion of our support to the Office of Environment, Safety, and Health.

Office of Environmental Management

The majority of the Laboratory's support to DOE in the Environmental Quality Mission area is to the Office of Environmental Management. This support includes a broad range of technological work such as basic studies on waste interactions, systems engineering, development of risk management approaches, regulatory and policy analyses, environmental monitoring, technology development and deployment, and actual cleanup operations.

While the Laboratory's primary support is to Environmental Management programs at Hanford, we also support environmental activities at other DOE sites, as well as a number of components of Environmental Management's National Program. The Laboratory is a major participant in DOE's Office of Science and Technology Program.

We recognize the necessity and importance of linking our Energy Research activities to programs supporting Environmental Management. We expect that the fundamental research the Laboratory is conducting will increase our understanding of complex environmental systems, thereby leading to new technologies that will fill technological gaps in the current cleanup program or provide new solutions which can reduce costs or risks and increase effectiveness. The Laboratory is working to focus its EMSL research programs on DOE's environmental restoration and waste management needs. This effort will strengthen the contextual framework for this state-of-the-art facility and is expected to result in breakthrough solutions for critical environmental problems.

We also recognize that there will be significant contributions to Environmental Management's program from other relevant scientific programs, such as the Environmental Management Science Program, the Environmental Technology Program, and the Natural and Accelerated Bioremediation Research Program. The Laboratory has had several of its submitted proposals selected allowing it to participate in these programs in areas that we feel will significantly benefit the Environmental Management program. Our selected projects and future proposals are based on our strong understanding of Environmental Management needs, gained through many years of support to the Hanford Site, our leadership roles in DOE's Science and Technology Program (e.g., Tanks Focus Area), and our strength in linking environmental technology to environmental science.

The estimated funding for Environmental Management is shown in the Resource Projections section. The funding levels indicated also include work done by Pacific Northwest for the other contractors at Hanford, and the funding projections for the Environmental Management and Energy Research joint initiatives, such as the Environmental Management Science Program and relevant operating portions of the EMSL.

Environmental Management Science and Technology

One of the Laboratory's primary objectives is the development and ultimate deployment of new technologies that can significantly benefit DOE environmental programs. The Laboratory has been able to make significant contributions toward this objective through its involvement in Environmental Management's National Science and Technology Program. The Laboratory is responsible for leadership roles in several of the technology development focus areas, and for the conduct of a number of technical tasks to provide new technologies. These tasks include the responsibility to ensure that these technologies are deployed in Environmental Management programs and broader domestic and commercial markets. The Laboratory has been assigned, jointly with DOE-Richland Operations Office, the lead for the Implementation Team supporting the Tanks Focus Area. The Laboratory and other Hanford staff are working with Idaho National Engineering Laboratory to identify how Hanford technical and human resources can support the Mixed Waste Focus Area, which Idaho National Engineering Laboratory is leading. Pacific Northwest remains responsible for coordinating the Efficient Separations and Processing Crosscutting Area. This section describes the Laboratory's support to the National Science and Technology Program, its recent and planned deployment successes, and its approach to technology implementation.

Tanks Focus Area As lead for the Implementation Team, the Laboratory coordinates the functions of the focus area and provides technical management, decision support, and reporting functions associated with the technical program. The other members of the Implementation Team, which began operation in October 1994, are Idaho National Engineering Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, Sandia National Laboratories, and Westinghouse Savannah River Company. The DOE-Richland Operations Office serves as the lead operations office and administrator of this team. The overall program objective is to deliver a tanks technology program that is applicable, integrated, acceptable, and accountable. Pacific Northwest's Tanks Focus Area staff work with others on the team and the various Site Technology Coordination Groups (representing users and stakeholders) to ensure that the resulting technology development program meets DOE's user needs, has a sound technical basis, and meets stakeholder expectations.

While remediation baselines and systems engineering concepts differ across sites, the high-level waste tank remediation problem can be broken down into common remediation functions: safety, characterization, retrieval and closure, pretreatment, and immobilization with crosscutting activities in safety and characterization. The Tanks Focus Area Implementation Team is organized around these functions, with a Technology Integration Manager, selected from each one of the member organizations, assigned to each function. To ensure that the resulting technology development program meets users' needs, a User Steering Group composed of senior managers of the tank remediation programs at each of the major sites has been established and reviews Tanks Focus Area products at regular intervals. To ensure that the program has a sound technical basis, a Tanks Focus Area Review Group composed of technical experts from industry, universities, and national laboratories has been established and will review the program from a technical perspective. To ensure that the program meets stakeholder expectations, each site has established a Site Technology Coordination Group to help establish a listing of prioritized needs and to review technical products.

To define the technical program, the Tanks Focus Area Implementation Team collects and validates each site's

tank remediation needs, prioritizes the needs with the customers, develops a technical strategy for responding to them, and defines a responsive technology development program that can demonstrate clear return on investment. These activities have produced a national, comprehensive database on tank remediation technology needs and technical activities that address those needs. In FY 1996, the multiyear program plan, which presents the needs-based program, will be updated. The Tanks Focus Area will broaden its scope to integrate more fully across other Environmental Management programs and beyond (i.e., the Environmental Management Science Program).

Work in the Tanks Focus Area currently supports, or could support, several projects within the Spent Nuclear Fuel Program. This support includes information useful to systems study for the sludge path-forward; characterization, vitrification, and repository waste form development; and waste acceptance processes. The anticipated long-term benefits of Tanks Focus Area support to the Spent Nuclear Fuel Program will be in the processing required beyond the interim storage period. In addition, technology cross pollination is expected in the remote handling/robotic development areas. Improved remote handling systems in the stabilization facility are also expected to optimize ALARA (as low as reasonably achievable) exposures and processes. Laboratory staff supporting both the Tanks Focus Area and the Spent Nuclear Fuel Program will be working together to bring about these and other joint benefits. Laboratory activities supporting the Spent Nuclear Fuel Program engineering and operations organizations are described in the Waste Management section.

Efficient Separations and Processing Crosscutting Area

Laboratory staff are providing key technical and coordination support to the Efficient Separations and Processing Crosscutting Area, which supports each of the current problem-directed focus areas. The program's original emphasis on high-level waste separations is expected to continue in close collaboration with the Tanks Focus Area. Over the next 5 years, more emphasis will be placed on separation processes for low-level waste and hazardous chemicals. Efficient Separations and Processing will develop separations technologies for a spectrum of radioactive and hazardous defense wastes with a goal of transferring the technologies to industry. In addition, advanced separations technology development is a major focus at the Laboratory and is a key component of the Advanced Processing Technology initiative.

Hanford's Site Technology Coordination Group Implementation

DOE's National Science and Technology Program will link its efforts with DOE-EM's operating programs in the field through Site Technology Coordination Groups (STCG) located at each of the Department's major operations offices. These STCGs consolidate the site's technology needs, enhance communications, and provide technology transfer functions. The STCG structure implemented at Hanford consists of a Management Council and four subgroups: 1) Subsurface Contamination, 2) Tanks, 3) Mixed Waste, and 4) Decommissioning and Decontamination. The STCG will directly link the Focus Areas to specific site cleanup needs and involve regulators, stakeholders, and potential users in the technology development selection and implementation process.

Pacific Northwest, along with each of the other Hanford contractors (Fluor Daniel Hanford Company and Bechtel Hanford Inc.), has an ex officio member on the STCG Management Council. In addition, Laboratory staff and other contractors will participate in the focus area subgroups to provide specialized technical expertise. Because the Laboratory is also closely involved with most of the Environmental Management Technology Implementation Teams, its STCG members can also provide the Management Council with technical input on how to best respond to Hanford's highest-priority technology needs and how to leverage the results of Environmental Management's planned development and implementation activities. The Laboratory's STCG support staff will also be able to provide Hanford's two management contractors, which have limited Office of Science and Technology (EM-50) involvement, information on the status of the EM-50 program, including STCGs at other sites, Focus Areas, and technologies available for demonstration and deployment.

In FY 1996, the DOE-Richland Operations Office directed the Site's contractors to establish an integrated contractor approach to manage the Site's involvement in the National Science and Technology Program. The Laboratory serves as the central point of contact for this team, coordinating its efforts in supporting the STCG and managing the Site's technology development activities. The Laboratory will work closely with the Technology Management functions within each of the management contractors. In both cases, Laboratory staff will be detailed to these contractors to contribute directly to these functions. The management contractors' primary tie to the National Science and Technology Program will focus on identification, assessment, adaptation, and deployment of technologies coming from that program. Management contractor staff may conduct operations support to selected Science and Technology tasks managed through the Richland Operations Office or by the Laboratory, but they will not conduct technology development per se. Most of the continuing technology projects assigned to Westinghouse Hanford Company have been transferred to the Laboratory for completion in FY 1997.

Development of Environmental Technologies The Laboratory is performing technology development tasks for all of the program areas within EM-50. Specific technologies under development include new analytical techniques for rapidly analyzing the highly radioactive tank wastes, development of new separation agents for treating tank wastes, new characterization devices for mapping the distribution of contaminants in the soil, subsurface manipulation processes to form containment or treatment barriers for contaminants in the soil and groundwater, enhanced contaminant

Laser Ablation/Mass Spectroscopy is installed in a glovebox at the 3708 Laboratory. The system was used to analyze radioactive tank waste samples. The data were compared against standard methods with good results.

extraction combined with new surface destruction techniques, soil and groundwater treatment with biological methods, membrane technology to remove tritium from groundwater, plasma arc technology for treating excavated solid wastes, integrated robotic systems for decommissioning and decontamination or tank operations, and models for assessing subsurface performance and risks. The Laboratory's preferred approach is to conduct these tasks jointly with users, concerned stakeholders, and industrial partners. Approximately one-third of the Laboratory's EM-50 dollars go to universities and industry. The goal of these partnerships is to accomplish implementation of the solutions as quickly as possible. The Laboratory has, or is now developing, through the EM-50 program and other programs, over 130 environmental technologies.

The following technologies are under development and are expected to be deployed over the next several years:

Waste Tank Retrieval and Closure removes the solid "heel" that remains in tanks after soluble waste has been removed. Water-efficient scarifiers break up the solid waste, and a vacuum or water jet pump conveyance moves the chunks out of the tanks without significantly increasing the volume of waste water. Demonstrations are planned at four DOE waste tank facilities.

Light-Duty Utility Arm is a flexible, portable robotic system that can be used to deploy a number of different end effectors in underground waste tanks to characterize the tank or waste, take samples, or even retrieve wastes. This integrated system will be deployed at three DOE sites.

Graphite-Electrode Arc Furnace vitrifies solid, liquid, and off-gas wastes. Graphite electrodes create an arc used to heat up to 10,000 pounds per hour of feedstock to over 1700°C. The resulting slag cools to a glass-like matrix that is extremely durable. A number of diagnostic tools developed for this task can be broadly applied by industry for emission monitoring and unique temperature measurements.

In Situ Redox Manipulation creates a permeable treatment barrier in the subsurface by the injection of reagents and/or microbial nutrients. The reagents or nutrients alter the reduction/oxidation (redox) potential of the aquifer to destroy, immobilize, or mobilize contaminants migrating through the manipulated zone. Further field demonstrations will be completed in FY 1996. This technology is included in the Hanford Site cleanup plan.

Chemically Reactive Subsurface Barriers are permeable barriers that act as selective filters to remove contaminants such as strontium-90 from flowing groundwater. These barriers are being developed as an effective, low-cost method to remediate contaminated subsurface environments.

Laser Ablation/Mass Spectrometry is a prescreening system that gives elemental analysis and molecular speciation information on core samples of tank waste. This technology greatly reduces sample analysis costs.

As noted, over the next 5 years Pacific Northwest's Science and Technology Program expects to bring the major systems listed above as well as a number of other smaller technologies into deployment. Other expected future accomplishments include having one or more monitoring/characterization technologies routinely supporting the characterization of Hanford's high-level waste tanks, several in situ subsurface barrier technologies demonstrated as suitable interim stabilization measures, and an integrated set of technologies identified for deployment through industry in the decontamination and decommissioning of nuclear fuel storage basins.

Deployment of Environmental Technologies A major objective of our technical tasks is to rapidly transfer technologies to DOE-EM's operating programs. The Laboratory is attempting to foster deployment by establishing strong partnerships with industry and implementing a more disciplined approach to technology development and deployment. Our objective is to ensure that our technology projects address all technical, policy, regulatory, and economic issues early and in sufficient detail to make early determinations on the viability of the new technology in the DOE and broader marketplaces, to increase the speed

and lower the cost of development efforts, and increase the percentage of technologies from the Laboratory that are ultimately deployed.

The Laboratory has implemented or is transferring a number of technologies, and other technologies are being closely coordinated with the operating programs to ensure rapid transfer. For example, EM-30 and EM-50 are jointly funding development of in situ and ex situ technologies for analyzing Hanford tank wastes and for use by environmental restoration programs. In each case, the researchers who developed the technology for EM-50 are working with the operating contractor to transfer the technology or to develop the joint partnership arrangements. Over the last year, we saw a number of the Laboratory's technologies deployed in actual environmental operations or accepted by industrial organizations for implementation. Following is a listing of recent deployment successes:

Six-Phase Soil Heating simultaneously heats and ventilates soils to enhance removal of volatile and semivolatile organic compounds. This technology cleans soils to regulatory requirements outlined in RCRA and CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act). It was demonstrated full-scale at Savannah River.

In Situ Vitrification electrically heats and melts soil contaminated with radioactive, chemical, and organic waste. Organics are destroyed by the heat, other contaminants are immobilized in the solid block of obsidian-like glass that remains after cooling. This technology is being used both at DOE and commercial sites, and EM-50 support helped expand the operating envelope and resolve technical issues limiting technology deployment.

Ground-Penetrating Holographic System generates in real time high-resolution, three-dimensional images of buried waste. This system is currently being used to define several subsurface structures at Hanford before remediation work starts.

High Energy Corona can be applied to many liquid or gas wastes containing hazardous organic compounds. A high-energy electrical field creates reactions that destroy the contaminant molecules or reduce them to nontoxic materials.

Waste Acid Detoxification and Reclamation removes metals and recovers reusable acid from industrial applications. Viatec Recovery Systems of Richland, Washington, has licensed the technology, and multiple commercial orders have been placed.

BetaScint Detector is an optical fiber-based sensor that monitors, characterizes, and quantifies uranium-238 and strontium-90 contamination in surface soils and similar media within minutes with no need for soil disturbance, collection, or transport. This detector system was deployed at DOE's Inhalation Toxicology Research Institute in Albuquerque, New Mexico, in 1996, and is being implemented in several operations.

Mediated Electrolytic Oxidation is an alternative to incineration for combustible low-level mixed waste forms and waste streams. This technology uses low-temperature oxidants in an electrochemical cell to oxidize hazardous organics. The technology has been licensed and is targeted for use at several sites.

Microbial Surface Modification of Waste Tire Rubber is a technique to treat shredded waste tires in a way that allows the material to be used directly in the manufacture of new tires and other rubber products. Several demonstrations of the Rubbercycle™ technology are planned, and rubber and tire companies are expressing interest in deploying this technology.

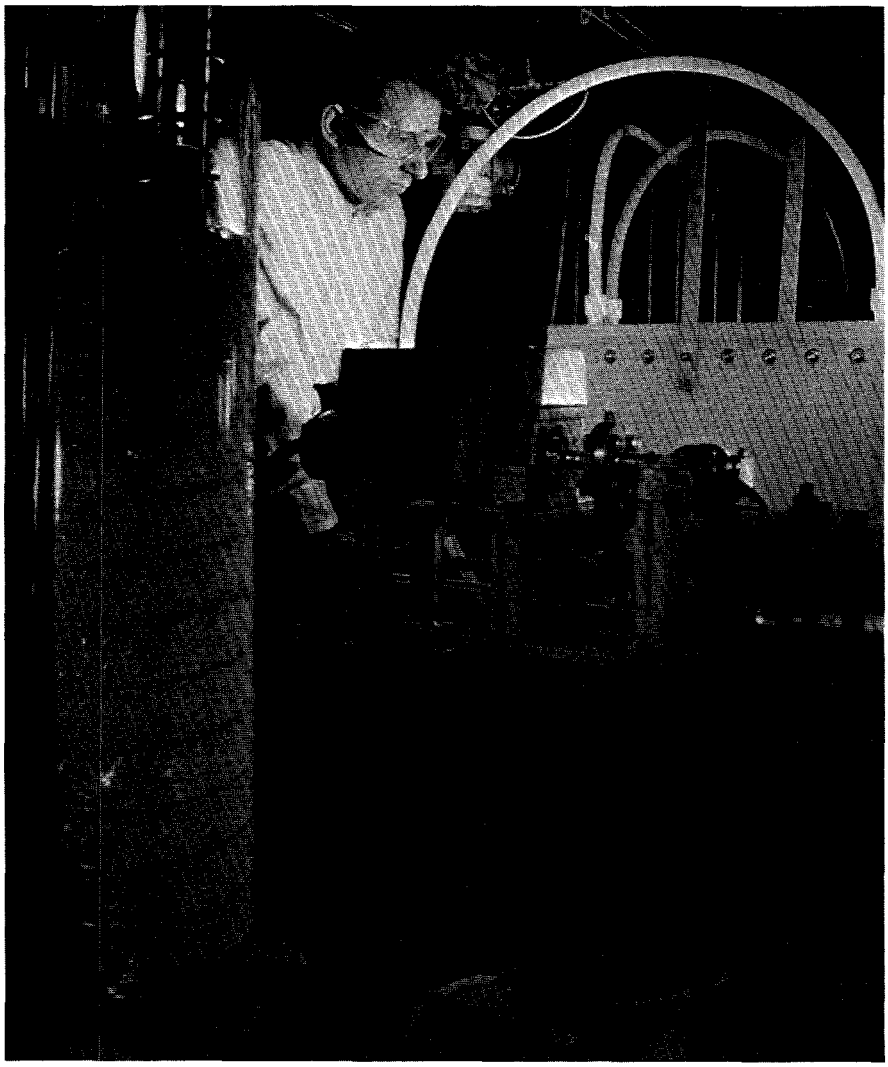
Sonic Vibratory Drilling is an advanced drilling technology for application in poorly consolidated and rocky soils. It has the additional benefit of generating minimal waste. The technology was developed with EM-50 support and is now provided to the Hanford Site through a private vendor.

Leveraging DOE-EM Technology Development through Related Laboratory Programs An important aspect of the National Science and Technology Program is being able to leverage or build from activities in programs for other parts of DOE and other federal agencies. Staff responsible for the Laboratory's Science and Technology Program also track the work for the Strategic Environmental Research and Development Program, Laboratory Directed Research and Development, other DOE-EM offices, and the new Environmental Management Science Program. These staff are also responsible for coordinating the Laboratory's international environmental technology activities. Results from this coordination effort will be provided to EM-50's International Technology Exchange Program and are expected to lead to new international outreach activities or partnerships.

Leveraging with programs outside of DOE is beneficial but is relatively small compared to the benefits of leveraging with the Laboratory's fundamental research activities. Specifically, the Laboratory is leveraging programmatic funding from both Environmental Management and Energy Research with internal LDRD funds to build capability and seed activities bridging the gulf separating fundamental research supported by Energy Research and the highly directed work supported by Environmental Management. The Laboratory has been selected to play a prominent role in the Environmental Management Science Program in FY 1997, and we expect this to continue for the duration of this valuable program. The Laboratory's role will begin with ten projects within this program. Work will include understanding the fundamentals of transport, studying the interaction of contaminants with selected media, evaluating the long-term degradation of waste forms, understanding health effects from selected contaminants, and documenting some of the fundamental mechanisms affecting radiochemical processes. Collectively, these activities will form a broad and substantial scientific basis for examining waste remediation problems outside of any prescribed baseline.

Starting with fundamental science, we are leveraging Energy Research-funded programs, such as the Physics and Chemistry of Ceramic Surfaces, Surface Structure and Reactivity of

1996 R&D 100 Award Winner



The Catalyzed Electrochemical Oxidation process uses electricity to fully destroy a wide variety of hazardous wastes, breaking them into inert materials such as carbon dioxide and water. Catalyzed Electrochemical Oxidation is more cost-effective and environmentally friendly than incineration methods for destroying organic waste. Hazardous waste produced by hospitals, research laboratories, chemical and pharmaceutical producers, and electronics manufacturers can safely be destroyed by this process.

Carbonate Minerals, Molecular Theory and Modeling, and Chemical Structure and Dynamics Programs to develop fundamental, molecular-level understanding of the chemical and physical phenomena important to tank waste remediation. For the future, a range of fundamental research programs is being developed to address environmental management issues. These programs will be part of the EMSL.

At the opposite end of the technology development spectrum is the process science and engineering work supported by DOE-EM. For tank waste remediation, this work has been funded by DOE's Office of Waste Management through the Tank Waste Remediation System (TWRS). Changes in the Environmental Management approaches to managing tank waste remediation are expected to impact the Laboratory's science and engineering programs. However, the need for fundamental understanding of the scientific and technical issues remains. Most work is directed at supporting the technical baseline and its enhancements. There are, however, efforts that are not explicitly tied to baseline technologies. These are aimed at providing the fundamental technical information necessary to make scientifically sound and technically defensible decisions regarding tank waste processing. One example in waste pretreatment is the task that is examining the fundamental chemical and physiochemical behavior of the waste sludges and liquid supernatants, the separations materials used to treat the wastes, and the interactions between waste species and separations materials.

The last piece involves the development of programs that bridge the gulf between the fundamental and process science and engineering research. The Laboratory is investing discretionary funds in seed programs taking fundamental research ideas and concepts and transforming them into viable process science and engineering activities. The two primary activities include: the Advanced Processing Program of the EMSL and the Advanced Processing Technology initiative.

Key core capabilities being developed in the EMSL Advanced Processing Program that crosscut these program elements include colloid chemistry, experimental and computational fluid dynamics, catalysis, chemical and surface analysis, reaction chemistry, analytical chemistry, and process control. Current research of the Advanced Processing Technology initiative is focused in advanced processes and advanced materials. Advanced processes include efforts in separations, conversion, and fluid dynamics. These efforts are strongly coupled with emerging efforts in the EMSL's Advanced Processing Program and are developing linkages

to the Advanced Technology Development, Tank Waste Treatment science, and sludge processing activities.

Application of Environmental Technologies

The backlog of innovative environmental technologies that have not yet made their way into application has grown substantially within the DOE complex from the large investments by EM-50 in recent years. Pacific Northwest is committed to helping get these technologies applied. Numerous studies, workshops, and group discussions over the past several years have sought to isolate and resolve what is popularly regarded as barriers to the application of innovative technologies, including

- regulatory uncertainty/inconsistency/complexity
- poorly defined pathways to market
- fragmented and insufficient markets
- risks versus incentives
- inadequate development and verification.

A consistent theme that emerges from these independent analyses is a need to strengthen the business focus over the research focus. The Laboratory's response to this identified need is to build stronger relationships with industrial partners, equipment vendors, and end users at an early stage in the development process and to install a more formal review process for critical stages of the technology life cycle. We are currently defining the various stages and developing criteria for measuring acceptable progress toward deployment at each stage. End users of technology will help validate our progress by becoming engaged in the technology development planning and progress review. These partners will also help the Laboratory focus on market-driven, high-impact technologies that have broad application to both DOE and industrial needs. Barriers to deployment that include fragmented and uncertain markets can be addressed through concentrating our resources on technologies which have the broadest impact to both DOE and the private sector. By so doing we hope to create stronger incentives for industry to make investments in the late-stage development and deployment of new technologies, which will ultimately benefit both the public and private sector. Our experience has shown that early industry involvement forces the market development phase to occur concurrently with the technology development phase and consequently creates sufficient market to warrant the late-stage investments. Lastly, we continue to search for other mechanisms that substantially reduce the time from initial discovery to commercial deployment of new concepts by better integration of fundamental and applied research. The Laboratory has developed interdisciplinary internal review teams with a balance of scientists and engineers to identify and respond to new program opportunities like the Environmental Management Science Program and the NABIR Program. The purpose of these interdisciplinary internal review committees is to ensure that all submitted proposals are designed with the applied endpoint in mind and with an integrated science and technology research team at the onset.

Risk Management

The complex environmental challenges facing DOE cannot be dealt with one at a time. The problems are interrelated, and the solutions carry different probabilities of success and different tradeoffs among fundamental values such as cost reduction, risk minimization, land use, and compliance. To evaluate these factors, the Laboratory has developed systems engineering methods to integrate the planning activities supporting the different components of the DOE-EM program and risk management approaches to systematically address the different aspects of risk and environmental decision making. This section addresses the integrated planning and support to Hanford as well as national DOE-EM Program Offices. It also discusses risk management approaches and the associated methods and tools for assessment of management and information.

Hanford Planning and Integration

The Hanford Site represents one of the most complex environmental cleanup tasks faced by this country. Transition from Hanford's former production mission to its present cleanup-oriented mission has not been easy. Among the challenges that must be overcome are 1) unclear endpoints for cleanup; 2) a complex regulatory environment with many federal, state, and local agencies having authority over cleanup; and 3) highly complex tasks that are beyond the capability of existing technology or the nation's willingness to pay.

The Laboratory is supporting the DOE-Richland Operations Office in managing cleanup as an integrated project. We are working with other Site contractors to develop the formal systems engineering methods that define what work must be accomplished by each element at Hanford. Decision and risk analysis methods are being applied to evaluate the impacts of both alternative endpoints for cleanup and alternative approaches for reaching those endpoints. The objective is to provide DOE and the Site's management contractors with the concepts, tools, data, and processes to plan, manage, and operate the Site as an integrated system. In June 1995, the Laboratory provided the first assessment of public, worker, and environmental risks from a total site perspective. This assessment provides a basis for understanding the contribution to risk from different elements of the cleanup program (e.g., high-level tank waste, buried solid waste, existing soil and groundwater contamination), and provides the basis for setting endpoint cleanup targets that are driven by credible scientific information. The report identified central tradeoffs between risk, land use, and cost; articulated fundamental decisions related to those tradeoffs; and offered strategies for managing those tradeoffs.

A key product of this activity is identification of alternative planning baselines that fit with increasingly constrained budgets. This includes identifying unacceptable programmatic, technical, human health, ecological, or economic and cultural risks of those options. The Laboratory uses these insights to focus technology development efforts into areas that are likely

to provide DOE with the greatest flexibility and confidence in managing cleanup decisions and success in implementing those decisions. Continuing the Laboratory's strong role in Hanford integrated planning over the long term will help ensure that technology and science investments are focused on real needs and that cleanup dollars are applied to achieve real progress.

Stakeholder Participation at Hanford Pacific Northwest, along with representatives from the Site's management contractors, is providing strategic support to the DOE-Richland Operations Office in the management of the Hanford Advisory Board (formed in January 1994), a regional group of citizens representing local governments, Indian nations, and environmental groups examining Hanford cleanup issues. The Laboratory also is providing primary support to the Health, Safety and Waste Management Committee, one of three issue committees formed by the Hanford Advisory Board. The Laboratory is supporting broad-based public involvement activities at the Site through its participation on the Hanford Public Involvement Network. Finally, the Laboratory is supporting the Hanford Site Technology Coordination Group, formed in January 1995, by EM-50, to advise Environmental Management on DOE-RL's technology needs and facilitate implementation of DOE-EM-funded technologies. The Laboratory's public involvement efforts have increased the visibility of DOE's efforts to clean up the Site; the open sharing of information will continue to improve the credibility of the Department and the successful deployment of proposed technologies.

Integrated Risk Management The Laboratory has been at the forefront of promoting integrated risk management as a key method for establishing priorities and managing DOE's environmental activities. The Laboratory was involved in the initial effort to establish the Office of Integrated Risk Management (EM-6) and continues to support such efforts. The Laboratory also continues to work to establish programs at Hanford that will assess risk from alternative strategies for remediation activities in terms of risk to workers, the public, and ecosystems. The benefit of a risk management approach to planning is to demonstrate what each Environmental Management action, policy, regulatory driver, or new technology does in terms of cleaning up sites and impacting human health or the environment and then to apply that information to key DOE decisions. The Laboratory has been actively involved in this process, providing primary support to the completion and review of Risk Data Sheets and their application to the budget allocation process at Hanford. We are also developing tools to support these initiatives at DOE-Headquarters, including methods for assessing risks and costs of strategic options for cleanup at the complex level of analysis.

Assessing Remedial Actions The Laboratory has developed a computer-based advisory tool that identifies, screens, links, and evaluates established technologies and unit processes for the remediation of operable units and waste management units. The tool, Remedial Action Assessment System (RAAS), was designed primarily to support feasibility studies under CERCLA (or corrective measures studies under RCRA). RAAS is currently being deployed at multiple DOE sites to assist in selecting and implementing appropriate environmental remediation technologies.

Technology Planning and Evaluation Support The Laboratory has historically provided substantial support to DOE-EM headquarters activities, both in planning and evaluation activities within specific offices and in crosscutting activities intended to set the future direction of the office. This type of analysis and information development support has gained the Laboratory a reputation for understanding the detail of Environmental Management operations across the complex and using that knowledge and our capabilities to provide analytic results to help the highest levels of Environmental Management make key policy decisions. Examples of this type of crosscutting activity include the Laboratory's support to the Programmatic Environmental Impact Statement, the Baseline Environmental Management Report, and the report to Congress addressing the risk, cost, and stakeholder issues associated with compliance agreements to which DOE has agreed.

The Laboratory has also been supporting specific offices within DOE-EM to develop forward-looking plans. For example, we supported the former Office of Oversight and Self-Assessment (EM-20) through the development of comprehensive strategic plans, individual office implementation plans, and office-specific program/activity plans. These plans ensure that project activities are implemented in a coordinated fashion to meet DOE-EM objectives. Other project activities included regulatory analysis, technical document review, work on the national compliance plan, stakeholder involvement (particularly with respect to the revision of DOE Order 5820.2A), strategic change management, emergency management assessments and reviews, and analysis and implementation of DOE American Indian policy relative to transportation and emergency management issues. In related work, the Laboratory is also conducting planning, data collection and analysis, and preparation of communication products to support Environmental Management's international outreach efforts.

Environmental Restoration

The Laboratory is providing technology evaluation, acquisition, adaptation, and demonstration services and certain Site operations support to the Hanford Environmental Restoration and Decontamination and Decommissioning programs. The objective of the technology portion of this work is to link Office of Environmental Restoration user requirements to the development efforts of the Office of Science and Technology.

The evaluation portion of the effort involves evaluating and "challenging" the technology baseline and suggesting new technology and innovative approaches for incorporation in environmental restoration and decontamination and decommissioning projects. Environmental restoration efforts are

evaluated on an operable-unit by operable-unit basis to identify restoration requirements that can be met more effectively by new and emerging technologies and innovative approaches. The overriding driver of the program is to provide alternative technologies and approaches that exceed program risk reduction and cost goals, and meet schedule milestones. To date, operable units related to groundwater, soils, and decontamination and decommissioning have been initially evaluated for technology needs.

Identified technology needs will be met through acquisition, adaptation, and demonstration of new technology developed by the Office of Science and Technology and others. Technology acquisition involves partnering with developers throughout industry, the federal agencies, as well as foreign sources. This synergistic approach stretches the value of funding agencies, encourages broad innovative application of technologies, and ensures that activities do not overlap and that modification of existing capabilities takes preference over new starts. Technology acquisition means development of new technology, transfer of the technology from the Office of Science and Technology, or adaptation of industrial knowledge.

Linkages are also established and maintained with other federal agencies that have similar environmental restoration and decontamination and decommissioning programs to share lessons learned, technical approaches, and solutions; and to reduce redundancies in developing technologies required to meet common problems. This promotes development and exchange of technologies for common problems and leveraging of capabilities and resources.

The current program includes diverse projects such as advanced characterization capabilities, adaptation of commercially available borehole geophysical capabilities, application of the Hanford permanent isolation barrier system, application of permeable treatment barriers, and adaptation of several in situ treatment techniques to Hanford-specific problems. Although all projects are for site-specific requirements, DOE complex and industrial applications are also possible. These programs capitalize on the Laboratory's expertise in analytical chemistry, geosciences, materials and process science, and systems integration and engineering.

Pacific Northwest is also supporting the Environmental Restoration Contractor Team in several operations and Tri-Party Agreement-driven actions. Examples of Tri-Party Agreement actions include treatability studies to determine and select remediation technologies at field sites, and the evaluation of ecological and health risks at specific sites. In FY 1996, the Laboratory was assigned the responsibility to perform or direct nearly all groundwater and vadose zone monitoring and modeling for the Hanford Site. This assignment consolidates a number of separate groundwater efforts that were being conducted. Specifically, the Laboratory is responsible for surveillance, RCRA monitoring, postclosure CERCLA monitoring, and modeling most of the vadose zone and the groundwaters. The Laboratory is not directly responsible for characterization leading to remediation and the soil column directly associated with the tank farms, although Laboratory experts will be supporting these operations.

Technology developed by the Laboratory is being demonstrated and applied at other DOE sites. For example, In Situ Vitrification is being demonstrated at Oak Ridge National Laboratory for application to pits and trenches there. In support of this demonstration, an off-gas treatment hood was fabricated incorporating special features to enhance its usefulness including the ability to be mobile, a provision for addition of fluxes or soil amendments during the melting process, and an enhanced particulate recovery system to retain contaminants in the hood. The first area to be treated is pit 1 in WAG 7. Following successful demonstration at this site, treatment of future pits and trenches will be privatized with the Laboratory providing continuing engineering analysis and technical support. The success of this demonstration will also result in continued evaluation of in situ vitrification for buried wastes at Oak Ridge National Laboratory.

Laboratory resources have also been applied to non-DOE facilities. For example, the University of California at Davis operated the Laboratory for Energy Related Health Research for DOE that was used to investigate the effects of x-ray radiation, strontium-90, and radium-226 on dogs. Pacific Northwest continues to support a project to assess the contamination, decontaminate and decommission facilities, remove and dispose of radioactive sludge and a cobalt-60 source, remediate groundwater and soil, manage waste disposal, and verify cleanup of the site. This activity has been a model for other decontamination and decommissioning activities.

Waste Management

Pacific Northwest waste management work encompasses management of high- and low-level radioactive waste, hazardous waste, and mixed radioactive and hazardous wastes in all physical forms and from all sources. Laboratory technical organizations and staff involved have substantial expertise and significant current business in the principal phases of waste management operations including characterization, retrieval, treatment, transportation, storage, recycling, and disposal. Although the Laboratory's expertise is broadly applicable to all phases of waste management, development and deployment of waste treatment technology is a core capability. Maintenance, enhancement, and commercial application of this core capability is central to our plans for future development.

The waste management work is organized into three principal elements: 1) the Spent Nuclear Fuel Program; 2) Tank Waste Remediation System and other waste management science and technology support, including work-order-funded projects and tasks from Fluor Daniel Hanford Company; and 3) the National Analytical Services Program.

Spent Nuclear Fuel Program Support

The Laboratory currently provides substantial support to the DOE National Spent Nuclear Fuel Program and the K Basins Spent Nuclear Fuel Project at Hanford. In addition, to varying lesser degrees, it supports activities at

other DOE sites including Idaho Falls, Savannah River, and Oak Ridge that deal with management of spent nuclear fuel, special nuclear materials, and associated storage facilities left from past defense materials production programs.

For the National Spent Nuclear Fuel Program, Laboratory researchers provide technical support to several technical committees and manage a number of spent nuclear fuel characterization projects to evaluate the performance of K Basins spent nuclear fuel under anticipated repository storage conditions. Laboratory staff work collaboratively with DOE-Richland Operations Office, Fluor Daniel Hanford Company, and DOE-Headquarters in supporting this program, which is currently managed for DOE by the Idaho National Engineering Laboratory.

During FY 1994-1995, the Laboratory prepared the Hanford sections of the DOE Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Environmental Impact Statements, which were prepared for DOE by the Idaho National Engineering Laboratory. The Record of Decision for the Programmatic Spent Nuclear Fuel Environmental Impact Statement was completed June 1, 1995. During FY 1995-1996, the Laboratory had lead responsibility under DOE-RL for preparing the Management of Spent Nuclear Fuel from the K Basins at the Hanford Site, Richland, Washington, Environmental Impact Statement. The Record of Decision for the K Basins Environmental Impact Statement was completed ahead of schedule in record time on March 4, 1996. This Environmental Impact Statement provided the National Environmental Policy Act (NEPA) documentation needed for the K Basins Project to proceed.

The Laboratory's Spent Nuclear Fuel Technology Support Program currently manages a set of tasks supporting the K Basins Spent Nuclear Fuel Project, which is managed by Fluor Daniel Hanford Company. The primary current activities include the Spent Nuclear Fuel Characterization and Spent Nuclear Fuel Sludge Analysis tasks. The data being collected in these tasks are key inputs to development of the design and safety bases required to implement the K Basins Project. Laboratory staff work collaboratively with Fluor Daniel Hanford Company and DOE-RL management in planning and management of these tasks to keep pace with the tight schedules and evolving directions in the parent K Basins Project.

Key issues being addressed in the Spent Nuclear Fuel Characterization Task are the condition and content of spent nuclear fuel, and its behavior in response to drying and conditioning processes, especially the potential for pyrophoric behavior of damaged fuel. Key parameters being investigated in the Sludge Analysis Task are the radiochemical contents and physical state of the sludge relative to its potential acceptance for storage in the TWRS tanks and its drying characteristics. To date, the spent nuclear fuel tests have concentrated on small samples, with progression to large sections and possibly full element testing in FY 1997-1998. The characterization and analysis tasks are being performed by a multidisciplinary team from the Laboratory in the Postirradiation Testing Laboratory in the 327 Building and in the Analytical Chemistry Laboratory of the 325 Building. The Spent Nuclear Fuel sludge characterization and testing work currently is expected to be completed in FY 1998.

The Laboratory's Spent Nuclear Fuel Technology Support efforts also provide technical support to other aspects of the Spent Nuclear Fuel Program, including basins operations, retrieval, transportation, and related projects. Current Laboratory technical support tasks include a safety assessment supporting the sludge retrieval and transport process, an assessment of water quality issues, and development of a software system to document and organize the numerous regulatory requirements of the Spent Nuclear Fuel Program. Previous Laboratory technical support to the project has included evaluation of structural integrity, leakage, ion exchanger hydrogen generation, and other safety issues concerning the K Basin storage pools. These technical efforts are expected to continue on an as-needed basis to support the Spent Nuclear Fuel Project engineering and operations organizations through its implementation phases past the turn of the century.

A Pacific Northwest manager also manages the Applied Technology Program Office for the Site's Management Contractor to independently coordinate assessment and/or development of appropriate technology and to support establishment of the technical basis for the Hanford Spent Nuclear Fuel Project. The Applied Technology Program Office is responsible for developing an integrated test plan for the Project and for managing the process verification program that addresses options for fuel retrieval, drying and conditioning, packaging, transportation, and long-term storage and disposal. Our technical staff support the Applied Technology Program Office in numerous ways providing analyses, assessments, and expert technical consultation. Coordination is maintained between activities supported and directed by the Applied Technology Program Office and tasks managed within the Laboratory's Spent Nuclear Fuel Technology Support Project.

Hanford Tank Waste Remediation System and Technology Development The Laboratory has assumed modifications in its roles in supporting the cleanup of Hanford tanks as the DOE strategy has changed. The Laboratory focuses on three primary roles: 1) support to the integrated disposal program through the Integration Support Team, 2) support to the science and technology needs of the TWRS through the Tanks Focus Area national program (previously described in this section), and 3) continuing technical support to the safety and storage programs.

Laboratory staff support DOE in the development and implementation of the new contracting strategy for the cleanup of the Hanford tanks. The Laboratory has assisted DOE in the formulation, feasibility analysis, and now the implementation of this new strategy. This strategy uses the principles of privatization and competition to stimulate innovations and efficiencies, achieving cost reductions in

waste cleanup. Interactive facets of the cleanup program that needed to be addressed in developing and implementing this strategy included regional and national stakeholder concerns, multiple regulatory agencies, public and private financing, contractual reform, and complex technical issues associated with retrieval and processing as well as the long-term potential for environmental release from a disposal system. To deal with this challenge, we assembled a multidisciplinary team from Pacific Northwest National Laboratory, Fluor Daniel Hanford Company, Argonne National Laboratory, and Los Alamos National Laboratory, as well as a number of private organizations.

During FY 1996, the Secretary of Energy decided to proceed with implementation of the strategy, and a request for proposals for the first phase of privatization was issued. Successful bidders would process 6 to 13 percent of the Hanford tank waste to produce waste forms suitable for storage and ultimate disposal. The Laboratory has been asked to both continue and broaden its support of the Hanford TWRS Program as implementation of the new strategy proceeds.

The new cleanup strategy is a phased approach and the present activities are primarily supporting the first phase. Determination of the goals, objectives, and scope of subsequent phases of the cleanup will require the use of systems engineering and risk analyses and must be integrated with site-level systems planning. We anticipate providing this service to DOE.

Pacific Northwest expects a significant role in the continuing need for technical innovations and scientific insight to support the program mission. Longer-term research and development will be required to address issues such as treating difficult-to-process wastes and waste form disposal performance. Such issues represent high risk to the government that the private sector may not assume. Our role will be in the identification and prioritization as well as support of these needs.

As the privatization initiative goes forward, the Laboratory's support to the Site Management Contractor will change to focus on support of safety, characterization, and retrieval. It is anticipated that we will also continue some technology-related activities in the areas of treatment and immobilization to reduce the risks associated with these activities. The extent of this support is not known at this time. As required, we may also provide technical data directly to the privatization contractors to support design decisions.

Analytical Services Program Support to the Analytical Services Program involves two major activities: methods compendium support, and data quality objectives training and support. Pacific Northwest supports the preparation and distribution of DOE Methods for Evaluating Environmental and Waste Management Samples. In addition, the Laboratory reviews and updates collected information, and reviews the technical data status of methods in the compendium. The Laboratory also supports DOE's efforts to ensure that data collection activities are decision-based and that uncertainties are managed appropriately through implementation of data quality objectives planning methods. This scope encompasses data quality objectives training, statistical methods research, sampling and analysis tools development, DOE statistical clearinghouse, and data quality assessment.

Hanford Site Support

The DOE-Richland Operations Office has assigned responsibility to the Laboratory for the safe and efficient operation of several critical research facilities and for environmental surveillance and oversight activities supporting the entire Hanford Site. These include surface and groundwater surveillance, meteorology and climatology, wildlife resources monitoring, cultural resource protection, and dosimetry coordination; preparation of major environmental documents, including environmental impact statements; occupational dosimetry; operation of the whole-body counter; radiological calibrations; occupational radiation exposure records; and the Hanford Technical Library. The Laboratory provides significant support to Hanford and its environmental restoration and waste management businesses, as described in the previous sections. The Laboratory will continue to seek well-recognized research staff from universities to participate in Hanford environmental programs and to initiate and coordinate peer review of these programs by nationally recognized experts. Funding for Hanford Site support activities is included in the appropriate sections of the Resource Projections.

Radiation Protection Services

As part of Hanford's program to protect the health and safety of workers, the Laboratory provides Hanford Site-wide radiation protection services. These services include the complete assessment of employee and visitor occupational radiation exposure to ensure compliance with DOE Orders and federal regulations. The Laboratory conducts a comprehensive program of occupational dosimetry, including measurement and assessment of external dose and internally deposited radioactive material; calibration, repair, and testing of radiation monitoring devices; and documentation and reporting of this information. The Laboratory retains, in a readily retrievable configuration, all of the 50 years of Hanford's occupational radiation exposure and radiation protection policy records. These services strengthen our physics research programs by providing the means for identifying problems and areas for improving radiation dosimetry and measurement.

Over the last 2 years, the cost of providing these high-quality services has been challenged. As a result, Laboratory staff reevaluated the methods used to provide the services and made significant programmatic changes that reduced the overall cost of providing these services to the Hanford Site by more than 47 percent. In addition, each of the projects developed "unit pricing" to better reflect their commitment to providing services at competitive costs while maintaining high quality and technical excellence. As the Hanford Site moves into the 21st century, cost, quality, and technical excellence issues will become more

and more important and the experience of the Radiation Protection Services provides a model for ongoing reevaluation and cost-cutting efforts.

Public Safety and Resource Protection

The Public Safety and Resource Protection Program, assigned to the Laboratory, is conducted to ensure the safety of the public and protect the environment and Hanford resources. This program provides assessments independent of the Site's Management Contractors to evaluate the potential impacts of Hanford's operations on the environment and to ensure the safety of the public and Hanford workers. The program includes

- characterizing and monitoring the radiological and nonradiological status of the environment and identifying significant trends in contaminant levels
- assessing onsite and offsite environmental impacts of site activities, estimating the corresponding radiological and nonradiological risks to the public, and predicting future impacts of known contaminant releases and planned activities
- monitoring meteorological and climatological conditions to support environmental surveillance and dose assessment activities as well as other site operations and emergency preparedness needs
- monitoring cultural and natural resources of the Hanford Site to evaluate impacts of Hanford operations and comply with applicable regulations
- preparing NEPA documentation for the site
- supporting the DOE-Richland Operations Office in public information efforts, including presentations to cognizant regulatory agencies on matters that pertain to environmental activities
- identifying and recommending programs needed for timely and responsive action on present and future Hanford environmental issues.

The Laboratory prepares environmental monitoring plans; conducts environmental monitoring and surveillance; calculates the radiological dose to humans onsite and offsite, reporting the results in the annual Hanford Site environmental report; and conducts programs to keep the public and local, state, and federal agencies informed about Hanford environmental activities. Environmental media sampled included air, surface and groundwater, soils and vegetation, fish, wildlife, and foodstuffs. Cultural and archaeological resources were also characterized.

National Environmental Policy Act Assistance

Pacific Northwest continues to provide assistance to DOE-Headquarters and the Richland Operations Office to implement the requirements of NEPA for DOE's projects, specifically to prepare environmental impact statements and environmental assessments. Recent examples include the Hanford Site portion of DOE's programmatic environmental impact statement on management of spent nuclear fuel, DOE's environmental impact statement on management of spent nuclear fuel in the K Basins at the Hanford Site, DOE's environmental impact statement on the Dual Axis Radiographic Hydrodynamic Test Facility at Los Alamos, DOE's environmental impact statement on the production of the medical isotope molybdenum-99, and DOE's environmental assessments on resiting, construction, and operation of the Environmental Molecular Sciences Laboratory at the Hanford Site. Each of these environmental documents was completed in less than the 15-month time period recommended in the Secretary's policy memo and each was completed under the original budget except for the molybdenum-99 environmental impact statement. Laboratory staff work closely with the appropriate DOE offices to ensure that all reasonable alternatives are considered, that rigorous analyses are conducted in all areas of environmental impact, that applicable regulatory requirements are discussed, and that mitigation plans, when required, are developed. The Laboratory also develops methodologies and computer programs for analyses of environmental impacts that help ensure that the NEPA process is conducted in a timely and consistent manner across the DOE complex.

Office of Environment, Safety, and Health

Pacific Northwest National Laboratory's participation in programs conducted by the Office of Environment, Safety, and Health are outlined below.

Independent Oversight

The Laboratory's program for the Deputy Assistant Secretary for Independent Oversight (EH-2) involves assessing the status and condition of Environment, Safety, Health and Safeguards and Security programs at all major DOE facilities by developing field inspection plans, evaluating trends and problems in specific areas, and reporting to DOE management on the conditions. The Laboratory will continue to provide direct technical and field support to this program by 1) providing technical assistance to support the DOE Accident Investigation Program, 2) analyzing survey results and performing trend analyses, 3) preparing summary reports on findings, and 4) preparing field guides to assist the DOE and field inspectors in performing their duties. The Laboratory will focus on developing new tools, including information management systems, and techniques that can be applied in the evaluation process.

Office of Nuclear Facility Safety

Under the Deputy Assistant Secretary for Nuclear Facility Safety (EH-3), Laboratory staff provide assistance in implementation of radiological programs that implement the DOE Radiological Control Manual and other requirements such as those found in 10 CFR 835, "Occupational Radiation Protection," to enhance worker and public health protection from unwarranted exposure to radiation, radioactive materials, or contamination. The staff works for continuous improvement in radiological control (Radcon) at DOE field sites through activities

such as 1) radiological evaluations that monitor and assess radiological practices, processes, and systems, and 2) dedicated radiological technical coaching to improve DOE field and contractor radiological capabilities. Support to DOE EH-3 includes assistance in the following:

- evaluation of radiological control programs that implement the DOE Radiological Control Manual and 10 CFR 835
- planning and conducting radiological evaluations and technical coaching activities as requested by EH-3
- support of continuing efforts of EH-3 to implement radiological assistance including onsite evaluations, coaching and mentoring of site personnel, participating in meetings, reviewing documents, and providing advice to improve radiological safety.

Environment

Under the Deputy Assistant Secretary for Environment, Safety, and Health, Pacific Northwest primarily supports the Office of Environmental Policy and Assistance (EH-41). Support to the Air, Water, and Radiation Division (EH-412) is provided in areas of environmental radiation protection, air quality and water resource protection, environmental and ecological risk and standards, and environmental management systems. In general, these projects provide the following support and assistance:

- technical analysis support
- review of key environmental legislation, regulations, and policy documents
- development of innovative methods for presenting implementation guidance
- other areas of environmental support and assistance as required by DOE.

Environmental Protection Support and Assistance Under this project, the Laboratory provides support in areas of environmental radiation protection and radioactive waste management. A major area of effort in FY 1996 includes providing assistance in developing implementation guidance for proposed rule 10 CFR Part 834, "Radiation Protection of the Public and the Environment," including a derived concentration guide handbook, an offsite dose calculation manual, and implementation guidance for aquatic and terrestrial biota doses being prepared for DOE-Headquarters.

Air, Water, and Regulatory Support Under this project, the Laboratory provides technical assistance for air quality and water resource protection. For example, Laboratory staff provided assistance by reviewing and preparing composite Department comments on proposed regulations and other documents developed to implement the Clean Air Act.

The Laboratory also provides technical assistance related to the protection of water resources at DOE sites. Technical assistance includes analysis of legislation and regulations, preparation of technical reports on water resource protection issues, and support for technical assistance workshop activities.

Environmental and Ecological Risk and Standards Under this project, the Laboratory provides technical support in the areas of environmental risk assessment, risk management, and standards during the conduct of waste management, environmental restoration, and decontamination and decommissioning activities.

Environmental Management Systems Under this project, the Laboratory provides technical assistance related to the development and implementation of environmental management systems at DOE sites. This area of assistance may include analysis of various environmental management standards, systems, reports and related documents, white papers on technical subjects including technical analyses involving cost savings and regulatory flexibility, and preparation of informational materials and support for technical assistance workshops.

Laboratory staff also provide technical support to the Office of Environmental Policy and Assistance's RCRA/CERLCA Division (EH-413) in fulfilling its mission of ensuring that DOE facilities have thorough, accurate, and understandable guidance in complying with DOE environmental orders and federal environmental requirements. Support provided by the Laboratory's environmental guidance project includes reviewing technical documents, preparing technical reports, and assisting in the development of guidance strategies, technical approaches, DOE Orders and other written policies, documents, workshops, and tools to help EH-413 accomplish its mission.

The Laboratory has also supported DOE-EH's Office of NEPA Policy and Assistance (EH-42) and its predecessors for many years. Assistance has been provided in areas of implementation guidance, NEPA documentation review, headquarters assistance, and technical support. The Laboratory has recently focused on preparing environmental impact statements for high visibility projects for DOE operations offices and will continue to support DOE NEPA compliance issues.

Worker Health and Safety

The Deputy Assistant Secretary for Worker Health and Safety develops and recommends policies and standards related to radiation protection, industrial hygiene, and occupational medicine for application in DOE's facilities. The Laboratory assists in efforts to implement policies and standards, to evaluate their impact, and to monitor for compliance.

The Laboratory is continuing to develop capabilities to support new programs in the Office of Worker Health and Safety. We are expanding our efforts in nonionizing radiation and we are developing new capabilities to assist DOE in providing comprehensive chemical protection for workers and members of the public. These efforts include monitoring worker exposure to chemicals and evaluating the outcome of such monitoring. This has been expanded through the initiative titled "Health Protection and Standards for Hazardous Chemicals," described later in this section.

The Deputy Assistant Secretary for Worker Health and Safety is responsible for managing and directing comprehensive programs to ensure nuclear and non-nuclear safety in all the DOE's activities. The Laboratory conducts the programs described in the following paragraphs.

Field Technical Assistance for DOE Operations Office and DOE Contractor Personnel The Laboratory provides technical assistance in the field to DOE Operations and DOE contractor personnel in worker health and safety functional areas such as issues management, conduct of operations and maintenance, facility site representative training and program development, unreviewed safety questions, hazardous waste operations, and emergency response program development and training. The purpose of this is to provide expert technical assistance to DOE Operations Office personnel and contractor personnel to strengthen existing programs or assist in the development of additional safety functional areas.

Technical Support for Chemical Risk Studies and Chemical Safety Guidance A chemical safety vulnerability review of the DOE complex was conducted between February and July 1994, at the request of the Secretary of Energy. This review identified generic vulnerabilities and management weaknesses that were indicative of failures of safety management systems to adequately address chemical hazards throughout their life cycle. In response, the Management Response Plan for the Chemical Safety Vulnerability Working Group Report was developed to provide a coordinated set of corrective actions. This plan took advantage of ongoing activities under existing chemical safety initiatives. In 1994, a survey was conducted of chemical processes within DOE which were covered by OSHA's Rule for Process Safety Management for Highly Hazardous Chemicals. The DOE Process Safety Management program developed training and guidance for people responsible for approximately 40 processes covered by the Process Safety Management Rule. In FY 1995, the Technical Assistance for Risk and Safety Analysis and Process Safety Management programs were integrated into the new Technical Assistance for DOE Chemical Safety Program. Under this program, the Laboratory provides the technical support necessary to assist DOE, the DOE Action Team for Chemical Safety, and DOE contractors to successfully implement the recommendations of the Management Response Plan. The ultimate goal of this program is to ensure that DOE has effective management systems in place to address the chemical vulnerabilities noted and thus ensure the safe use of hazardous chemicals in the DOE complex.

Hazardous Waste Operations and Emergency Response Pacific Northwest is providing support to the Office of Worker Health and Safety in the development of their Hazardous Waste Operations and Emergency Response manual and its field implementation. In addition, the Laboratory assisted in the development of the Manager's Hazardous Waste Operations and Emergency Response Guide and the Worker's Guide.

Health Physics and Industrial Hygiene Programs The primary objectives of the Laboratory's health physics programs are to 1) develop guidance to support requirements and good practices in operational programs, 2) develop performance criteria and methods for implementing laboratory accreditation programs for radiation protection measurements and provide technical support in the operation of such programs, 3) operate a secondary calibration laboratory for ionizing radiation for DOE, 4) provide technical support to address key national and international issues affecting DOE, and 5) provide technical support to protect workers from chemical exposures.

Currently, three ongoing health physics projects are conducted by the Laboratory:

- Worker Dosimetry Accreditation
- Radiation Protection Guidance
- Technical Support for Worker Health and Safety.

Worker Dosimetry Accreditation
This project provides a mechanism for the development of improved calibration and quality assurance in radiation protection dosimetry for DOE workers. The breadth of problems associated with radiation measurements and methodologies requires developments in diverse areas such as whole-body dosimetry, extremity dosimetry, bioassay measurements, and radiation protection instrumentation testing. To assist in this effort, the Laboratory has developed a world-class radiation calibration facility and is expanding capabilities to include the measurement of quantities of interest to worker protection other than ionizing radiation. This calibration laboratory has been accredited for the second time as a Secondary Calibration Laboratory for Ionizing Radiation (SCLIR) by the National Institute of Standards and Technology. It is the only SCLIR within DOE.

Radiation Protection Guidance
The purpose of this project is to provide health physics technical support to the DOE Office of Worker Protection and Hazards Management in the implementation of DOE regulations (10 CFR 835), guidance (DOE RadCon Manual), and DOE Orders (Notice 441.1; "Radiological Protection for DOE Activities"). Assistance includes review of field implementation difficulties, resolution of ambiguities, development of technical background information, and development of Implementation Guides and Technical Standards to assist in implementing 10 CFR 835, the RadCon Manual, and DOE N 441.1. Technical assistance is provided by the Laboratory in the form of specific priority tasks or through special studies identified and scoped by DOE in connection with their overview and policy functions. Program objectives are achieved by using the capabilities and expertise of the Laboratory, other DOE laboratories, universities, and private industry. Objectives are met primarily by transferring new techniques and program guidance to the field through the development of health physics guidance documents and performance standards. These documents will lead to improved worker

protection and uniformity in facility compliance with DOE regulations and orders or guidance for radiation protection.

Technical Support for Worker Health and Safety The goal of this project is to develop and integrate a new comprehensive industrial hygiene program for assessing the chemical exposure, internal dose, and potential adverse health risk to an individual worker involved in waste cleanup activities within the DOE complex. Worker exposure histories can be determined by measuring a panel of biomarkers to describe previous exposures (i.e., urinary, fecal, and/or blood analysis of the parent, metabolite, or macromolecular adducts) and evaluating these biomarkers using a physiologically based pharmacokinetic model designed to simulate each individual's chemical exposure. The information is then combined with the daily monitoring of exhaled breath to assess recent exposures and to continue to understand each worker's risk status. The expected benefits of this project include reducing health and environmental risks, improving remediation operations, improving remediation schedules, limiting future liabilities, and reducing costs.

Health Studies

Pacific Northwest supports the Deputy Assistant Secretary for Health Studies (EH-6) in the development of a comprehensive data resource on workers to measure the effectiveness of health protection programs. Three areas of technical support are currently provided by the Laboratory:

- technical support for epidemiology and health surveillance
- technical support for Comprehensive Epidemiologic Data Resource (CEDR)
- health protection standards for hazardous chemicals.

Technical Support for Epidemiology and Health Surveillance The Laboratory will continue to emphasize molecular approaches to epidemiology and health surveillance. In particular, the Laboratory will focus on identifying biomarkers of exposure, disease, or susceptibility that are predictive of consequences of exposure to radiation and chemicals and on understanding issues regarding application of these biomarkers to worker surveillance activities. A waste cleanup worker surveillance study with a biomarker component has been proposed for DOE sites.

Technical Support for Comprehensive Epidemiologic Data Resource The mission of the CEDR program is to make readily available a public-access repository of data that supports DOE epidemiologic and associated health and environmental studies. Current CEDR holdings consist of information pertaining to current and former workers (unidentified) at DOE sites, or facilities, who were included in one or more of nearly 50 studies. Results from community-based environmental studies are also available. The Laboratory will continue to contribute to this program by preparing detailed documentation for remaining Hanford data to be submitted to CEDR; by participating in activities of the CEDR Working Group, particularly those involving data management and dosimetry; and by assisting CEDR users as necessary. The Laboratory will also explore ways of providing results from the Hanford Environmental Dose Reconstruction to CEDR users.

Health Protection Standards for Hazardous Chemicals Initiative DOE sites share the problem of hazardous chemicals that have been disposed of improperly with many industries in the United States. Basic toxicological information is available for many of these chemicals and this data has been properly used for hazard identification purposes. Although data showing that these chemicals are carcinogenic are frequently used for risk assessment purposes, the data are so crude they can only be fit by the most simple linearized models. Thus, the quantitation of risks are in considerable doubt. The cost of cleaning up these chemicals is quite high, in the range of tens of billions of dollars nationally. Thus, it can be very cost-effective to obtain the experimental data necessary to improve the estimates of risk. This can prevent diversion of resources away from other radionuclide and chemical hazards of established importance.

The amount and kind of hazards to workers in the field is an extremely important question for DOE. Inhalation of volatiles is the most likely type of exposure. Because of the short biological half-life of these chemicals and their uneven dispersal in the work environment, it is essential to measure individual workers in the field. Real time monitoring can follow the magnitude and temporal variation of an exposure and ensure that unacceptable levels of exposure are not encountered.

With these two problems in mind, the Health Protection Standards for Hazardous Chemicals Initiative (HPSHC) was begun in FY 1993. The activities began with a focus on evaluation of existing data for several chemicals of importance on DOE sites and to develop methods for measuring worker exposure to volatile chemicals. In FY 1995 the focus shifted to developing an experimental capability for addressing issues of risk assessment at low exposures.

To determine if research is likely to result in regulatory relief for carcinogenic chemicals, it is most important to consider the chemical's probable mode of action. Four modes need to be considered. The first is a chemical that increases the mutation rate within the target organ. This is the mode considered in default methodologies, so only in circumstances where mutation is thought to play a minor role is it worth considering doing research. The other three modes of action, 1) cytotoxicity followed by reparative hyperplasia, 2) selective stimulation of the growth of preneoplastic lesions, or 3) prevention of preneoplastic cells from dying (programmed cell death or apoptosis), are most likely to produce nonlinear dose-response relationships. Theoretical calculations indicate that risks from agents acting by these modes of action would be 2 to 3 orders of magnitude less at low exposures than calculated from linear models more properly applied to mutagenic carcinogens.

Relatively minor modifications in the research methods allow the same approach to be taken with a variety of other chemical hazards such as developmental toxicities, effects on reproduction, and neurotoxicity. The approach is consistent with the new risk-based methodology for prioritizing environmental hazards that has been articulated by the Environmental Protection Agency.

The major experimental focus in FY 1995 and FY 1996 has been to develop methods for quantitating growth and development of tumors induced by chemicals acting by different modes of action. These methods focus on measurement of rates at which cell division and cell death are occurring in normal cells versus tumor cells and how the chemical influences them. Magnetic resonance imaging techniques are also being developed that can be used to make the determination of a chemical's mode of action more rapid and direct. Molecular biological methods are being applied to understanding how and why a chemical acting by one mode of action produces a tumor with significantly different genotypic and phenotypic characters. The chlorinated solvents have received the most attention in these studies. However, the approach is broadly applicable to chemical carcinogens of any chemical or physical class.

Work on the development of an instrument for breath analysis that can be applied to workers exposed to volatile chemicals will be successfully completed and taken to the field in FY 1996.

Energy Resources

Global competition is driving radical changes in the energy industry worldwide. In the U.S., decades-old government regulations are being rewritten to allow market-based decision making to replace regulatory-driven central planning. Energy industries are responding with radical restructuring and cost cutting to permit them to survive in this more competitive business environment. Yet, at the same time that industry is reducing private-sector investment in energy technology, the nation is growing ever more dependent on imported oil, and ever more sensitive to the environmental damage of many traditional energy systems. These inherently public-sector problems can most effectively be addressed with more, not less, investment in energy technology. These legitimate—but differing—public- and private-sector interests challenge our nation to maintain a balance between growing the economy, maintaining national security, and protecting the environment. Where an unnecessary over-reliance on insecure sources of imported oil threatens the U.S. economy, or where necessary environmental regulation raises costs to our citizens or industry, DOE energy technology development has an important national role.

DOE faces huge challenges in enhancing national energy security and lowering the energy-related cost of protecting our environment. In addition, DOE's development of advanced energy technology helps to advance U.S. science and technical leadership, and success in many of its programs will help to strengthen the international competitiveness of our industries. In pursuit of smaller, more effective government, DOE must accomplish its goals with fewer resources and greater efficiencies. Specifically, DOE's Energy Resources area is working to better link and integrate its energy technology development and deployment activities with DOE's basic science programs to take advantage of the full range of capabilities within the Department.

Pacific Northwest is committed to helping DOE in both responding to its current challenges and charting its future. To do so, the Laboratory has focused its energy strategy in two broad areas

- for the near term, improving the utilization of the current national and international energy infrastructure through development of technologies that save energy and control costs, while
- for the longer term, developing the next generation of science and technology to increase our nation's energy security in an environmentally acceptable manner consistent with an increasingly competitive energy marketplace.

The first of these focus areas, improving our current infrastructure, is rich with opportunities for DOE to reduce our energy dependence by improving the efficiency of energy use. The Laboratory for many years has been helping DOE to analyze and evaluate the savings potential of more energy-efficient buildings and appliances. Our evaluations have led to software and hardware development programs that the Laboratory helped implement for use in federal facilities. The Laboratory has demonstrated new energy savings technologies to encourage their use, and has helped train government agents in how to use the new software and hardware. The Laboratory also helped DOE to bring about reasonable and logical codes and standards promoting cost-effective higher energy efficiencies. Our strategy is to continue to help DOE mine this area, which is still rich in opportunity, and to use the capabilities that resulted from this past work to advance us into the more fertile area of the "built environment," where buildings are considered as a fundamental part of a broader infrastructure in which we work and live.

The second of these focus areas represents our vision of the nation's and DOE's future. The Laboratory has been making LDRD investments in technology that it believes will enhance the public interest as the energy industry responds to the energy revolution currently under way. Evolving distributed energy systems, both in energy end-use technologies and generation, are more adaptive to the new competitive marketplace, and are usually cleaner and more versatile than more traditional technologies. Such systems could improve the resiliency of the U.S. energy system. However, they will have to be developed and integrated into the energy delivery system to realize their benefit. In the less predictable open access energy market that is emerging, the energy delivery system will be stretched to the limit to provide reliable energy services. The Laboratory has been investing in and working with government entities like Bonneville Power Administration to

develop the monitoring and control tools and algorithms that will be needed for the integration of new technologies.

And finally, we have been investing in the development of microtechnology-based devices that take the concept of distributed energy systems one step closer to reality. Components such as micro-sized heat pumps could improve the efficiency of heating and cooling our homes in a cleaner, more reliable and efficient manner. This scale of technology also allows improvements in chemical and fuel processing that may open the door to a revolution in economic and desirable transportation—a major consumer of imported oil. With these investments in advanced technological capabilities, the Laboratory plans to be ready to serve the DOE of the future.

In addition to developing new technologies and products, we are also leading several innovative DOE efforts to improve the value of DOE's programs. Specific examples include

- Supporting DOE-EE's Office of Industrial Technologies' Chemical Industry of the Future, where we collaborated with the Office of Industrial Technologies and industry to understand industry's vision for the 21st century. We are helping to develop a public-sector research and development agenda that focuses on reducing energy consumption and the costs of meeting environmental regulations consistent with this vision.
- DOE-EE's Office of Building Technology, State and Community Programs is developing innovative ways of introducing and deploying new technologies to the market. The Laboratory is leading the Energy Saver Program, which has been instrumental in developing these numerous new partnerships and initiatives.
- The Laboratory has played a leadership role in working with the Russians and Ukrainians through the DOE-NE International Nuclear Safety Program, designed to protect the environment and contribute to a more secure world through the safe operation of the Soviet-designed reactors.

With our vision for the future grounded in our efforts to improve the current infrastructure, the Laboratory has focused its capabilities toward the following objectives:

- reduce emissions and weight in motor vehicles through a new generation vehicle
- improve energy and resource efficiency and reduce wastes produced in industrial processes
- improve energy efficiency and use in buildings
- improve transmission, distribution, and utilization of electricity and gas and facilitate a transition to a utility system of the future
- support international agreements and facilitate energy efficiency, safety, and reliability improvements in the former Soviet Union
- understand the technological and policy issues that impact energy policy and global environmental change.

Pacific Northwest's scientific and technical activities in each DOE program contributing to the energy resources core business are described below. The descriptions also explain proposed expansion of the Laboratory's role within these organizations' initiatives.

Office of Energy Efficiency and Renewable Energy

In our efforts for the Assistant Secretary for Energy Efficiency and Renewable Energy, the Laboratory draws upon its core competencies to help DOE-EE respond to its new challenges, both through current programs and through selected new initiatives. Through the Energy Technology Development initiative, which was described previously in this Plan, we are enhancing Laboratory capabilities to address our nation's emerging energy issues and to better serve DOE-EE. We expect to continue to participate in developing collaborative efforts with DOE and industry that access the capabilities of the laboratory system.

Selected Laboratory initiative highlights include

- a new program to apply microtechnology-based devices to building system technologies that could revolutionize the way we heat and cool our buildings
- expansion of the Laboratory's participation in the Partnership for a New Generation Vehicle initiative
- expansion of the Laboratory's role in the Industries of the Future initiatives and active support for the Laboratory Coordinating Council in bringing industry and the laboratories together
- expansion of Laboratory support to DOE-EE's Federal Energy Management Program that invests in federal energy efficiency
- expansion of support to DOE-EE programs that rely on voluntary partnerships with industry, state and local governments, and energy consumers to accomplish mutual objectives
- leadership in working with the U.S. energy industry to help DOE-EE's Office of Utility Technologies define an appropriate federal research and technology development role in utility transmission and distribution systems and the distributed system of the future
- expansion of Laboratory support to DOE-EE's portion of the Climate Change Action Plan.

The projected funding for DOE-EE for the planning period is shown in the Resource Projections. During the period, the level of effort is expected to experience modest growth.

Office of Utility Technologies

Investor and public utilities, power marketing authorities, related energy service organizations, and the utility industry's technology suppliers are facing radical changes in their industry and how they do business. Accelerated deregulation, increased competition, open access, and the trend toward distributed energy systems have thrust them into a market-driven environment

where utilities must move quickly to meet demand and offer a range of products and services to customers.

DOE-EE's Office of Utility Technologies faces similar challenges in the rapidly changing energy environment to define the federal role in the new context. The Laboratory has a tradition and history of working with the Office of Utility Technologies and the utility industry and expects to support the Office of Utility Technologies in helping to articulate technology needs for a reliable electricity supply in the 21st century. In particular, we propose to work with the Office of Utility Technologies and the utility industry in the areas of real-time controls and advanced information technologies to ensure security and integrity in an unregulated utility industry.

The Laboratory has been investing discretionary resources for the past several years to develop engineering and measurement systems deemed important for supporting the engineering requirements of the DOE electromagnetic field research program. A significant effort continues at the Laboratory in the design, development, and characterization of state-of-the-art electromagnetic field exposure systems. This effort also includes building systems for characterizing the electromagnetic field signatures of electrical devices, and creating supporting technologies such as computer-driven, electromagnetic field environment visualization systems.

The Laboratory is also investigating the use of superconducting magnetic energy storage (SMES) for utility load management and system control, working cooperatively with organizations such as Bonneville Power Administration, Defense Nuclear Agency, utilities, and the Electric Power Research Institute to advance the nation's understanding of the potential benefits of this technology. We will work with Sandia National Laboratories and the Office of Utility Technologies to help characterize the appropriate role for SMES vis-a-vis other electric and nonelectric storage technologies.

Electric Energy Systems (AK) The Laboratory will continue its basic research in electromagnetic field (EMF) interactions with biological systems and in the identification of potential health effects in support of DOE's Biological Mechanisms Research Program and the EMF Research Public Information Dissemination (RAPID) Program.

Research currently in progress for the Office of Energy Outreach includes comprehensive studies to assess possible biological effects of electric and magnetic fields related to the use of electric power. This research is expected to provide data to determine the nature of biological responses to electromagnetic fields, evaluate the potential for adverse health effects, and, if necessary, help establish the maximum levels of electromagnetic field exposure that is biologically acceptable for both workers and the general population. The Laboratory's research program also addresses the broader issues of increased electromagnetic fields in the environment from a variety of sources and their health implications for humans and animals.

Current program elements include investigation of possible links between cancer and exposure to electromagnetic fields, examination of neuronal and neuroendocrine involvement in response to exposure, and the study of basic cellular and genetic mechanisms of interaction. Of particular importance currently is our research on electromagnetic field exposure and possible involvement in breast cancer. The work complements related laboratory studies at Pacific Northwest sponsored by the Electric Power Research Institute, the National Institute of Environmental Health Sciences, and the National Cancer Institute. It is expected that we will continue to conduct this core biological and engineering research. In addition, the Laboratory will utilize its scientific expertise as well as considerable experience in public outreach to support the communications goals of the national program.

Work at the Laboratory will continue to complement related laboratory studies conducted under the DOE EMF Biological Mechanisms Research Program by other research organizations. Another important element in the work conducted at the Laboratory will be to continue collaborative studies with scientists from other institutions and to provide a regional exposure facility for electromagnetic field studies.

Office of Building Technology, State and Community Programs (EC)

Throughout most of the world, buildings are an ever-present artifact of human existence. The demand for safe, healthful, productivity-enhancing shelter is a fundamental human need.

The Laboratory's Buildings Energy Program supports the Office of Building Technology, State and Community Program's objective "to improve the energy efficiency of the nation's buildings and to increase their use of renewable resources." Our support includes research, development, and deployment activities designed to target areas with high-efficiency improvement potential that are not addressed by other organizations. The Laboratory seeks the active involvement of other government, industry, and private-sector organizations in planning and conducting program activities to ensure the rapid transfer and application of the knowledge and products developed.

Microtechnology or microtechnology-based devices will play a significant role in many products and processes of the future. Equipment ranging from the width of a human hair to the width of a thumbprint may revolutionize the entire process of heating and cooling buildings. Laboratory scientists are developing a microtechnology-based heat pump so small that hundreds can be fabricated on a single sheet of building material embedded in the walls of homes and buildings. These heat pumps would provide each room its own thermal control without duct work to carry warm or cool air throughout the home. Eliminating the duct work alone could save 30 to 50 percent of the energy produced by conventional heat pumps. The Laboratory is proposing a new initiative for microtechnology-based devices, building on the Energy Technology Development LDRD initiative (described earlier in this Plan) in microtechnologies.

Economics and Systems Analysis Program The Laboratory conducts research and analysis of buildings-related energy-efficiency issues for the Evaluation, Planning and Analysis program activity of DOE's Office of Building Technology, State and Community Programs. Major FY 1996-1997 activities include estimating the programmatic costs and benefits of the Office of Building Technology, State and Community Programs research and implementation portfolio; designing user-friendly visualization interfaces that allow users to access the rich world of buildings-related data; developing a robust protocol for evaluating the benefits of "green" buildings design; and identifying emerging issues with potential significance for the U.S. buildings sector. A particular focus of our future work with Office of Building Technology, State and Community Programs will be improving the access to buildings data and portfolio analysis tools through the application of advanced information technologies.

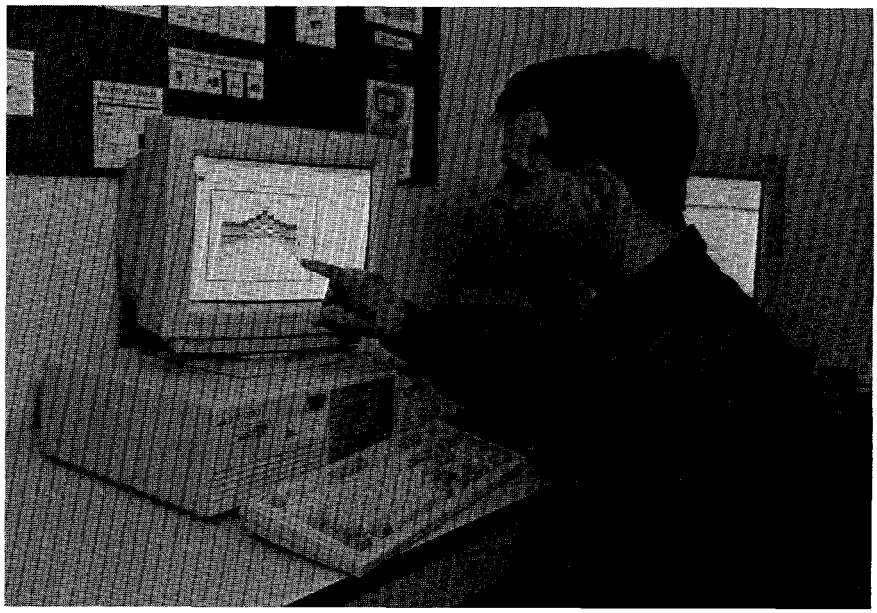
Building Systems Program The Laboratory will also support the Office of Building Technology, State and Community Program's commercial/multifamily research and development efforts through the Building Systems Program. The program focuses on developing knowledge and technologies to improve energy-related decisions made during all phases of a building's life cycle. Current efforts are carried out through the Design Tools (formerly Advanced Energy Design and Operation Technologies [AEDOT]) and Building Operation Research projects. In the design arena, the products of this program will provide guidance to building designers and decision makers for implementing energy-efficient technologies and integrated design strategies. The building operation project focuses on developing and promoting the use of improved practices and advanced technology to ensure efficient, cost-effective, building operation.

Software resulting from collaborative efforts with the private sector in the Design Tools project is putting analytic tools, artificial intelligence, and sophisticated computer graphics in the hands of architects and engineers who make decisions about energy efficiency as they design and construct buildings. A collaborative project, with a private-sector firm and a university, produced the first software tool that integrates a heating and cooling load calculation capability with a computer-aided design system to encourage use of energy analysis as part of the design process. This software tool was first distributed in June 1995 as part of a widely used commercial computer-aided design software package, and in 1996 was awarded a Federal Laboratory Consortium Award for Excellence in Technology Transfer. During FY 1995, another version of the software that is Windows compatible and includes Canadian and U.S. climates, and both imperial and metric units was released. A second private-sector firm also joined the collaboration.

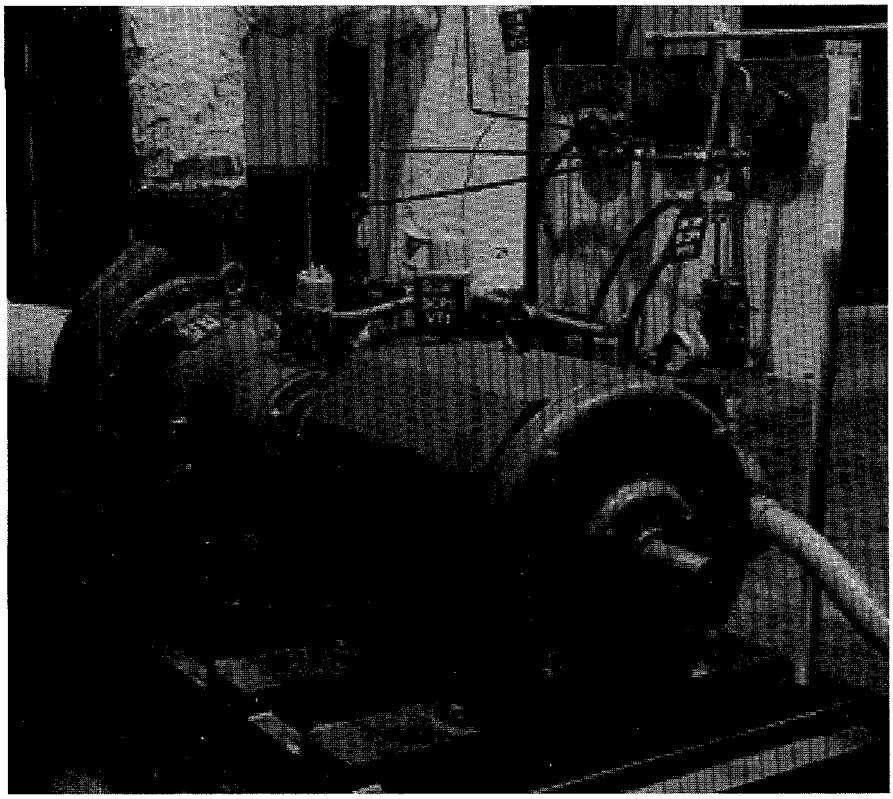
Work done under the CRADA during FY 1996 comprised two primary activities 1) development of an improved version of the software that includes HVAC and code compliance modules and is compatible with new releases of the computer-aided design software; and 2) development of HVAC system scheming, sizing, and selection modules. In addition, efforts continued to expand industrial participation. During FY 1997, the focus will be on delivery of products developed during 1996 and 1997, which will include versions of the software that include the HVAC and code compliance modules. Future directions will be established by the CRADA partners.

During FY 1996, Design Tools project staff joined an alliance of public and private organizations formed to define, promote, and publish industry standards for information sharing through all

1996 FLC Award Winner



Pacific Northwest researchers teamed to pursue their vision of a user-friendly software for energy-efficient building design. They overcame the skepticism of industry and energy software traditionalists and spearheaded an effort that resulted in commercial release of a unique product—Softdesk Energy. To achieve their goals, the researchers recruited an industry partner, ASG, and together they linked with the University of Oregon to provide the expertise needed in software development and energy-efficient design. Softdesk Energy is expected to reach tens of thousands of building engineers and architects.



A generic automated diagnostician developed by Pacific Northwest identifies improperly operating equipment and the root causes of performance degradation in real time. The diagnostician can be applied to pumps, valves, heat exchangers, compressors, filters, generators, boilers, and electrical equipment.

phases of a facility's life cycle. The Laboratory's participation in the alliance gives DOE the unique opportunity to participate in creating a new industry standard that has potential to dramatically change the way things are done by the buildings industries. In FY 1996, the alliance plans to release the first version of the standard, which will contain specifications for architectural, HVAC, and facilities management applications. During FY 1997, the Laboratory will partner with A/E/C industry software vendors (e.g., CAD vendors, HVAC equipment manufacturers, and other equipment manufacturers) to develop energy design tools that employ the initial standard developed by the alliance. The Laboratory team's focus will be implementation of the standard in DOE tools, and expanding efforts on the standard into lighting design and code compliance. In FY 1998, the Laboratory will continue participation in the alliance, implementing plans that will be developed in FY 1997 to further the objectives of information sharing across the industry.

In the Building Operation Research project, the Laboratory is supporting DOE in working with industry and other stakeholders to develop a strategy for improving the actual operating efficiency of the building stock. This effort, involving the private sector, state and local governments, and trade organizations, seeks to encourage better coordination among efforts throughout the nation that focus on developing and implementing ways of making the national building stock operate more efficiently. The product will be a program plan endorsed by important stakeholders, as well as initial projects in which "real players" from the private sector have committed to participate.

A new project was initiated in September 1995 to develop, test, and demonstrate an automated diagnostician/advisor that will detect, diagnose, and recommend solutions to whole-building energy performance problems in commercial buildings. The primary product of this project—a whole-building energy performance diagnostician—will be developed in collaboration with a private-sector firm that brings a major university as part of their team. The approach involves developing three successive prototypes that progressively cover a larger set of problems and provide increasing depth of diagnosis. During FY 1996, the first prototype will be developed and will serve the purpose of eliciting early feedback from potential users. During FY 1997, development of the second and third prototypes of the diagnostician/advisor will be completed and preparations will be made for field testing. In FY 1998, field testing and demonstration will be completed at a site specifically selected to facilitate rigorous testing and maximize visibility. The resulting technology will then be made available to the private sector for embedding in commercial products (e.g., building automation systems) that are widely used in building operation.

Building Standards and Guidelines Program The Laboratory, through the Building Standards and Guidelines Program (BSGP), provides technical support to DOE to support the complex process of development and implementation of building codes and voluntary guidelines at the federal, state, and local levels. The Laboratory works in partnership with the building industry, state and local governments, and other federal agencies to

- help states upgrade their building energy codes and standards, based on a voluntarily achieved consensus among building code organizations
- help states update and implement their building energy codes
- promulgate energy standards for federal buildings
- help the U.S. Department of Housing and Urban Development administer energy-efficient residential loan programs

- support the development and deployment of national voluntary rating guidelines for both new and existing homes.

Through the efforts of this program, occupants of new buildings will save an estimated $1.2 billion in avoided energy costs by the year 2000.

Functionally, the BSGP is divided into two main areas to meet the goals stated above: 1) product development, and 2) outreach and communications. These functions work together to identify the needs of code and guideline users, develop products to meet those needs, make users aware of the availability of these products, and deploy these products both directly and through the interaction with national, regional, state, and local groups. The key components of the program are discussed below.

Upgrading National Standards and Model Codes The BSGP supports improving the technical basis of the voluntary building energy codes by reviewing and introducing code changes that are cost-effective and technically feasible. Consultations with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), national model code organizations, state governments, and others have facilitated the energy code change process. These code upgrades represent the results of engineering and economic analyses that were introduced into a process that involved the private industry, the states, and other stakeholders. The result of this process is a set of voluntary standards for new residential and commercial buildings that is widely accepted.

Promulgate New Standards for Federal Buildings The BSGP supports the upgrading of energy standards for both federal residential and commercial facilities. These upgrades are aimed at making the format of the federal standards consistent with national standards and model codes. The upgrades also improve the energy efficiency of the standards by incorporating provisions that are cost-effective and economically justified. In addition, radon issues are addressed in the new federal standards.

Promulgate Voluntary Guidelines for Home Energy Rating Systems The BSGP provides technical assistance to DOE in carrying out several activities associated with the development and adoption of Home Energy Rating Systems (HERS) guidelines. This includes the development of responses to testimony and written comments to the Notice of Proposed Rulemaking submitted during the public comment period. These responses will be developed through consultation with representatives of other laboratories, DOE program managers, and other sources of technical expertise and knowledge.

Developing Products to Support Code and Voluntary Guideline Implementation The BSGP supports the use of codes and voluntary guidelines through various products and services. These products and services are developed in conjunction with the Department of Housing and Urban Development, the Veterans Administration, and the Rural Economic Development Corporation as well as the National Association of Homebuilders, other building industry representatives, and state energy offices. These range from the development of written materials, videos and training programs to explain the code to code users, to the release of software that assists code users in showing compliance with local codes or federal mortgage guarantee guidelines. Included in these activities is a product awareness activity that includes both marketing and distribution functions. In addition, the BSGP will provide technical input to a users' manual on implementing the HERS guidelines. This manual will be developed by the Technical Committee within the Home Energy Rating Systems Council.

Provide Direct Technical Assistance to States The BSGP provides direct technical assistance to state and local governments to assist them in evaluating, adopting, and implementing building energy codes and guidelines. Included in this activity is the interaction with and support of the DOE Regional Support Offices in their role as DOE's key state liaison in each region. The BSGP will also identify opportunities for DOE to support state efforts and assist the states in defining these opportunities in order to facilitate DOE support requests. In addition, technical assistance is provided to the pilot states that have been selected to implement and test the HERS guidelines. This assistance will focus primarily on interpretation of the requirements contained in the proposed guidelines and on the best ways to implement them.

During the next 2 to 3 years, the BSGP will focus on four major areas. First, the program will move toward the integration of the voluntary and federal residential standards. Future accomplishments in this area include the development of a set of implementation tools, including software and manuals, that can accommodate the requirements of both federal agencies and the private sector.

Second, the program will continue to improve the technical and economic basis upon which the voluntary standards and model codes rely. Future accomplishments in this area include using actual technology performance data to develop standards, improve information available on equipment and component costs, and expand the list of technologies covered by the standards and guidelines in order to improve their cost-effectiveness.

Third, the BSGP will continue to make software products an accessible tool for standards developers, code users, code enforcers, and the users of DOE's voluntary guidelines. Future accomplishments include additional development, refinement, and integration of software tools for specifying standard requirements; development of software tools that can assist builders and designers to comply with requirements; and development of software tools that can provide building design guidance while taking into account builder constraints, occupant needs, and code requirements. These may also include working with lending institutions to allow the software tools to produce the proper documentation for energy-efficient mortgage application.

Fourth, the program will support states in the adoption, implementation, and enforcement of codes and standards.

This will include enhancing the delivery of product to code users, working with DOE regional offices to enhance their role in supporting states, directly supporting the federal and state agencies in the implementation of codes and standards, and serving as technical experts to parties involved in the development, deployment, and use of codes.

EPAct Standards Program The Energy Policy Act of 1992 (EPAct) provides a mandate for the DOE to establish minimum performance standards, test and rating procedures, and labeling requirements for certain categories of commercial heating, air-conditioning, and water heating equipment. EPAct is unique in that it establishes initial minimum performance standards in law based on the ASHRAE/IESNA Standard 90.1. EPAct ties the DOE actions to those of ASHRAE/IESNA. Additionally, in FY 1996, DOE issued the Interpretive Rule to formalize a process for stakeholder input to its rule-making process.

Initiated in April 1994, the EPAct Standards Program (formerly the Commercial Equipment Standards Program) objective is to develop improved commercial heating, cooling, and water heating equipment efficiencies, test procedures, and labeling requirements, in concert with industry, that improve the energy efficiency of the nation's commercial buildings. Activities include the following:

- an analysis determining the energy savings of different equipment options
- an assessment of current and needed test procedures for covered products
- an energy savings analysis on selected pieces of equipment
- implementation of the economic methodology to develop estimates of consumer and manufacturer impacts to provide "... clear and convincing evidence ..." of the economic justification of proposed standards options
- updating the EPAct-covered equipment test procedures, addressing the overlap of test procedures for heating equipment, and recommending how to address intelligent controls
- an assessment of the needs for certification programs and recommendations on the certification requirements and appropriate labeling for commercial markets
- investigations to gather baseline information on current industry practices and identify issues of future concern among industry groups, customers, and stakeholders
- development of a comprehensive program for certification and labeling of commercial equipment identified in Section 122 of EPAct 1992 (Public Law 102-486).

During FY 1997, the Laboratory will continue two major activities in support of the EPAct program. The first is to support the ASHRAE/IESNA consensus process, and the second is to continue the independent analysis for assessing equipment performance and manufacturer and socio-economic impacts.

The ASHRAE/IESNA activity provides for the establishment of efficiency levels and test procedures in conformance with the EPAct legislation. In ASHRAE/IESNA, a Laboratory staff member chairs the full 90.1 subcommittee that is updating the efficiency levels and test procedures for commercial building equipment covered by EPAct. In addition to supporting the committee chair, Laboratory staff will input to various subcommittees efforts that focus on specific equipment efficiency levels and test procedures. Anticipated ASHRAE/IESNA actions are to 1) respond to comments generated by the first public review draft and revise the standard, and 2) issue a second public review draft of Standard 90.1-1989R by midsummer 1997.

The independent analysis supports the DOE rule-making process by examining a range of conditions and impacts not considered by the ASHRAE/IESNA process and/or required by the Interpretive Rule. Laboratory staff will continue the technical analysis of specific equipment types being considered in the ASHRAE/IESNA process. The technical analysis addresses a wider range of equipment types and operating conditions than those considered in the ASHRAE/IESNA process. In addition, effort will be directed toward determining the associated manufacturer and socioeconomic impacts of the equipment types considered in the ASHRAE/IESNA process. Analysis of these impacts is required by the Interpretive Rule and not covered within the ASHRAE/IESNA process.

During FY 1998, ASHRAE/IESNA may issue portions of Standard 90.1-1989R as amendments to the current standard, rather than waiting for the entire revision to be completed. Standards for covered HVAC equipment may well be among the amendments that will be issued. If this occurs, DOE will be in a position to commence the rule-making process for the covered products. Particular attention will be paid to working with DOE to plan and execute the steps necessary to properly and efficiently support DOE in meeting their regulatory responsibilities.

Future work will focus on developing the maximum technical potential for commercial air-conditioning, heating, and water heating equipment, refinement of the equipment cost database to include specific measure costs, and the assessment of consumer and manufacturer impacts of implementing manufacturing standards.

Energy Savers Program The Energy Savers Program promotes high-efficiency home appliances and building equipment and builds on DOE-EE's traditional role in cooperative research and development of highly efficient building equipment by using innovative approaches for developing and introducing new technology. These approaches rely on working closely with the private sector to develop innovative partnerships to help introduce and speed the deployment of new technology into the market. Approaches include high-volume purchases, utility incentive program coordination, product testing, labeling, sales training, and providing technical information to key market segments.

DOE's goal is to achieve annual energy savings of approximately 120 trillion Btu by the year 2000. To help accomplish this, Energy Savers seeks to increase the market penetration of advanced, energy-efficient equipment for space heating and cooling, water heating, lighting, refrigeration, laundry, cooking, and other services in residential and commercial buildings. The decision makers affected by the program include building owners, designers, specifiers, and occupants; building equipment manufacturers, distributors, retailers, installers, purchasers, and financiers; and government agencies involved in regulation, building operation, and public policy.

Partnerships have been established with the following: the hotel and motel industry, the Consortium for Energy Efficiency, the manufactured housing industry, appliance retailers, the National Association of Energy Service Companies, a laundry equipment consortium, states and other public agency procurement officials, gas appliance manufacturers, and a collaborative dedicated to applying an innovative lighting technology.

Since its inception in 1995, the program has assessed the costs and performance of several available and emerging technologies and has established voluntary, industry-led consortia with a desire to purchase and install highly efficient appliances. The program is now conducting field tests of key technologies, organizing large-scale purchase commitments, and conducting other market pull activities, including product labeling, retailer training, and consumer education to draw new technologies into the marketplace.

Pacific Northwest is managing or participating in several Energy Saver initiatives

- The E-Rated Appliance program - In 1996, the Laboratory worked with the manufactured housing industry in Oregon to encourage manufacturers and dealers to offer energy-efficient appliances as a package in new manufactured homes. In 1997, we hope to expand the program to include additional appliances and to target manufacturers and retailers throughout the Northwest.
- High-Volume Purchases of Energy Efficient Equipment - Energy Savers worked with the New York Power Authority to identify large-scale buyers for a highly efficient apartment-sized refrigerator the Authority is procuring. Laboratory staff are working with procurement officials in the military, at the state level, and in the U.S. Department of Housing and Urban Development.
- Hospitality Industry Forum on Energy Conservation - Energy Savers helped establish a consortium of national hotel and motel chains to accelerate improved efficiency in hotels and motels. The Laboratory is conducting metering and evaluation of the Forum's first demonstration project, a water-recycling heat recovery filtration system at the Red Lion Central Laundry Facility in Portland, Oregon.
- Advanced Lighting - Laboratory staff are working on partnerships with private- and federal-sector end users as well as with major lighting manufacturers. Early efforts under way include evaluation of sulfur lamps in a U.S. Postal Service Facility and an Air Force hangar building.

Pacific Northwest is working with a DOE-sponsored consortium of national hotel chains to speed the introduction of resource-efficient technologies into the hospitality industry. The consortium's first demonstration project is a microfiltration unit that recycles water and saves energy at a central laundry facility for a large hotel chain. The water filtration system enabled the laundry, which washes 25,000 pounds of towels, sheets, and tablecloths each day, to reduce its water consumption by 50% and cut its gas bill in half.

Federal Energy Management Program Pacific Northwest, along with the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, and Oak Ridge National Laboratory, are key participants in the Federal Energy Management Program (FEMP). FEMP's goal for 2000 is to lower federal operating costs by annually facilitating implementation of energy and water conservation measures in federal facilities through policy action, coordination, assistance with technology and financing tools, and leveraging private investment. The Laboratory supports FEMP's goal in all main areas of focus including

- providing direct technical support to federal energy managers in the identification and implementation of specific projects at their sites
- facilitating demonstration of new technologies at specific sites across the federal sector to encourage rapid acceptance of the technologies

- developing and presenting training courses on FEMP-developed analytic tools and topics of interest
- supporting the facilitation of partnership working groups with electric utilities with large federal customers to encourage leveraging of financial support for project implementation
- providing technical assistance in the development of quality metrics and evaluation of program activities.

The Laboratory continues to support FEMP in the development of the Facility Energy Decision System (FEDS) screening model that provides a comprehensive approach to fuel-neutral energy resource planning and acquisition. The current release is a user-friendly, Windows-based, menu-driven software tool for assessing the energy-efficiency resources at large federal installations. The tool has been used in completing resource assessment at numerous large DoD facilities. In FY 1996, FEDS Version 3.1 will be released for distribution to federal energy managers. This version will provide additional functionality in terms of the environmental benefits resulting from implementation of projects at a site.

The Laboratory also supports FEMP's efforts to demonstrate, in partnership with equipment developers, utilities, trade associations, and other federal agencies, the reliability and cost-effectiveness of advanced energy technologies at various federal sites. Demonstrations completed to date include

- Evaluation of the performance of two 15-ton natural-gas-powered rooftop air conditioners. Results from the demonstration program indicate that over the estimated 15-year life of the equipment the net savings is estimated to be $120,000.
- Evaluation of a Seahorse gas hot water conversion system for installation in federal family housing units where direct conversion to natural gas systems is not possible. Measured energy savings (life cycle) for each unit was $827. If the national average electricity cost was used, the savings would increase to $1,585 per unit.
- Evaluation of natural-gas-engine-driven heating/cooling equipment for federal residential facilities. Measured savings was $121 per unit per cooling season.
- Evaluation of a 15-ton natural-gas-powered split system for a multipurpose library and office space. Results are still pending.

A broader list of new leading edge technologies will be evaluated in future years.

Because it takes over a year before the results of New Technology Demonstrations are available and shared with federal energy managers, in FY 1995 FEMP launched a publication series call *Federal Technology Alerts*. *Federal Technology Alerts* complement technology demonstrations, inform federal energy and facility managers of technologies in the private and federal sectors currently in use, and provide quick and cost-effective data for procurement decisions. To date, a total of six *Federal Technology Alerts* have been produced by Laboratory staff. These deal with the following technologies: residential heat pump water heater, ground source heat pumps for commercial facilities, polarized refrigerant oil additive, refrigerant subcooling, natural gas fuel cells, and ozone treatment for cooling towers.

Laboratory staff also assist in the development and delivery of selected training programs for federal energy managers, including water resource management, use of the FEDS software tool, and successful operations and maintenance practices. Workshops are also scheduled to be held under direct reimbursable agreements with federal agencies.

In the future, some of the emerging issues that will be addressed include productivity changes resulting from installation of more efficient lighting systems and ways to increase direct involvement in implementation of energy-efficiency technologies earlier in the new construction and refurbishment process. Efforts also are under way to commercialize the FEDS model so it will be readily available in the commercial market and revenues could be used to support additional software enhancement activities.

Building Equipment The Laboratory is working with Office of Building Technology, State and Community Programs Building Equipment Division to investigate the feasibility of applying microtechnology-based devices to building equipment and systems. These devices represent an opportunity for improvements in building heating and cooling systems. An initial effort involves use of a microtechnology-based ammonia concentration sensor for a gas absorption heat pump system to optimize design of the absorber and to control system operation. Fiscal year 1995 investigations identified ion sensitive field-effect transistor (ISFET) technology as being most appropriate for this application. A prototype ISFET ammonia sensor was fabricated at the beginning of FY 1996 and will be tested through the end of the fiscal year. The Laboratory will work with the Building Equipment Division to increase its research activities in microtechnology-based devices. Fiscal year 1997 activities may involve application of the final sensor design in the generator-absorber heat exchange heat pump.

The Laboratory is also working with DOE to investigate promising desiccant-based cooling technologies, in support of a new desiccant program initiative. Despite the fact that desiccant-based equipment has long existed, many fundamental characteristics of its operation have never been well understood. Program work involves computer modeling of various desiccant-based system configurations and performance comparisons with standard vapor-compression units. Development of an ASHRAE short course entitled "A System Designer's Introduction to Commercial Desiccant Equipment" was also supported through the program, to convey some of the information developed by the program (along with other, more introductory material) and to increase industry familiarity and comfort levels with desiccant-based technologies.

The Laboratory also supports the development of communication

materials for distributing information about Building Equipment Division-developed technologies. A CD-ROM computer animation of the generator-absorber heat exchange heat pump was developed, for example, for distribution at industry trade shows and other meetings that describes and illustrates the fundamental generator-absorber heat exchange design and operation. The purpose of such multimedia materials is to educate industry and other personnel on the technologies in a format that is more visually interesting/informative than traditional "hard copy" materials. A future CD-ROM may include animation of a desiccant-based cooling system, targeting HVAC equipment manufacturers, system designers, and users.

Finally, the Laboratory assists the Building Equipment Division in evaluating the status of various technologies or external research for its own planning needs. For example, a recent study performed a literature review of several non-DOE analyses of water heating loads to identify algorithms that could be used to predict hot water consumption based on demographic characteristics of the building. Such efforts help DOE make the best use of its own funds by, among other things, avoiding duplication of research. These analyses are conducted on an as-needed basis.

Office of Industrial Technologies (ED and EF)

The Laboratory's role in supporting the Office of Industrial Technologies (OIT) covers a broad range of activities from program planning and technical evaluation to technology development and demonstration. Current technology development programs draw upon our process science and engineering competencies to recover energy from dilute industrial wastes and to develop renewable-based routes for chemical manufacture. Other programs include the development of leading edge software tools for cradle-to-grave life cycle assessment applications, as well as Office of Industrial Technologies efforts to provide support to innovators and inventors.

Programs emphasize formal/informal collaborations with the private sector and across the national laboratory system. In support of the Office of Industrial Technologies focus on seven energy-intensive and waste generating industries (aluminum, chemicals, forest products, glass, metal casting, petroleum refining, and steel), the Laboratory has joined with 16 other DOE national laboratories and facilities to form the Industries of the Future Laboratory Coordinating Council. Under a Memorandum of Cooperation, this group facilitates access to capabilities that can be applied to solve technology challenges identified in each industry's vision of the future. Collaborative efforts in the Office of Industrial Technologies Industries of the Future initiative will lead to broad national benefits of efficient energy and resource use, economic competitiveness, and enhanced environmental quality.

Chemicals Industry of the Future

Pacific Northwest is providing lead technical support and analysis for the Office of Industrial Technologies for developing a framework for its current and future chemicals-related programs that meet industry's needs and are best conducted via government/industry partnerships. The approach for this project is to engage the chemical industry sponsors and leadership of the visioning process (*Technology Vision 2020*) in developing appropriate technology road mapping and implementation efforts. This is accomplished in part through linkages with the Chemical Manufacturers Association, American Chemical Society, American Institute of Chemical Engineers, Council for Chemical Research, and the Synthetic Organic Chemical Manufacturers Association. The Laboratory is also developing appropriate analytical methodologies for the Office of Industrial Technologies' use as a tool in prioritizing technology investments.

Industrial Waste Program Development of the Thermochemical Environmental Energy System (TEES®) technology continued this year. TEES uses a metal catalyst in a high-temperature, pressurized liquid water environment to convert wet organic industrial wastes to a useful fuel gas product and clean water. Current research and development efforts are directed at the use of a continuously fed bench-scale tubular reactor system to test catalyst effectiveness and stability with further tests to evaluate specific industrial applications in a scaled-up (half-ton per day) engineering development unit.

Efforts in FY 1996 are focused on confirming catalysts lifetime and locating a host site for an onsite demonstration of the transportable unit. The unit will be used through FY 1997 for technology demonstrations and site-specific tests of industrial applications of TEES.

Alternative Feedstocks Program

Pacific Northwest also participates in a joint effort with other national laboratories (Argonne National Laboratory, Oak Ridge National Laboratory, National Renewable Energy Laboratory, and Idaho National Engineering Laboratory) to find renewable-based routes for chemicals to displace the use of petroleum. Both biochemical and thermochemical conversion routes are considered in the program. During FY 1995, Laboratory staff generated four invention reports on catalytic upgrading of the succinic acid product produced from fermentation. These invention reports, along with two pieces of intellectual property from Argonne National Laboratory and Oak Ridge National Laboratory on fermentation processes, form the basis for a CRADA and license agreement which will be signed with Allied Carbo Chemical in FY 1996. Work in FY 1996 is focused on completion of bench-scale tests to provide design data for a pilot-scale unit in support of the CRADA.

Life-Cycle Computer Aided Data Project The Office of Industrial Technologies is funding the Laboratory to work with industry to develop a computer tool that could help standardize life-cycle assessments. Life-cycle assessment is a process for evaluating the cradle-to-grave energy and environmental consequences associated with a technology (i.e., a product, process, or service). The life-cycle concept is

growing in worldwide acceptance as a practice to incorporate new environmental management practices.

The specific goals of the Life-Cycle Computer Aided Data (LCAD) project are to develop and deploy to industry a computer system that supports management, control, and manipulation of life-cycle data on commodities (such as primary metals, bulk chemicals, forest products, plastics, glass and cement) to support the conduct of life-cycle assessments. The effort is closely linked to industry participation through in-kind financial participation such as data collection or review and a formal advisory group providing guidance and help defining the software requirements. Trade associations and research organizations representing several industries are involved: aluminum, cement, chemicals, electric utilities, forest products, petroleum, plastics, and steel. Progress in FY 1997 will include bringing the LCAD software to commercialization.

Advanced Industrial Concepts Program The Laboratory also supports the Office of Industrial Technologies in precompetitive research and development to provide industry with the computational, analytical, and theoretical tools needed to make dramatic improvements in industrial energy and materials efficiency. In this vein, fundamental work aimed at the development of highly selective industrial catalysts is being carried out by Laboratory staff in support of Office of Industrial Technologies Advanced Industrial Concepts Division. Staff at the Laboratory are also working to develop new computational models for predicting fluid behavior in industrial power systems. These models will permit more realistic modeling of fluid properties (such as viscosity, thermal conductivity, and density) and of bubble dynamics. Information gained from this research will be applied in the development of improved heating and cooling systems, as well as in industrial power plants.

Innovative Concepts Program Pacific Northwest has managed the Innovative Concepts Program for DOE-EE since the program was established in 1983. The Innovative Concepts Program is designed to move technology more quickly from the conceptual stage to the marketplace by encouraging innovation and invention.

The Innovative Concepts Program provides "seed money" to innovators to conduct preliminary research into the technical and economic merit of concepts that have the potential to save energy, increase productivity, or reduce adverse environmental effects. An Innovative Concepts Program project cycle includes identifying a focus area, soliciting concepts, providing funding for several concepts, and introducing the concepts at a technology showcasing event such as a trade show or technology fair. Innovators are also given nonfinancial benefits such as the development of a one-page "tech brief" of their concept and new product development training through a commercialization workshop. Over half of the 100 concepts that have been sponsored by this program have received substantial follow-on funding from industry and other government programs.

States Inventors Initiative The Laboratory began managing the States Inventors Initiative in FY 1991. The States Inventors Initiative is designed to encourage a wider participation of inventors in helping solve the nation's energy problems. This initiative encourages and supports the formation of inventor organizations and provides information and assistance to others at state and local levels helping the commercialization process such as Small Business Development Centers. The States Inventors Initiative also facilitates the development of better methods for the inventor organizations to communicate with and provide assistance to inventors. One of the deliverables for this program is a compilation of nonprofit organizations and state and federal programs that encourage and support innovation.

Program Analysis The Laboratory plays an important role in providing technical planning and engineering analysis for Office of Industrial Technologies research, development, demonstration, testing, and evaluation programs. This includes assisting the Office of Industrial Technologies in the strategic planning of its research and development programs and research initiatives, and supporting its technology transfer and tracking efforts.

Through the Industrial Energy and Environmental Analysis Program, the Laboratory is developing or evaluating engineering, economic, or policy information regarding industrial energy use and related environmental impacts. Key activities for FY 1997 include improving Office of Industrial Technologies use of industrial energy models and databases; developing a computerized energy technology analysis data system; characterizing the energy and environmental features of advanced technologies; developing performance indicators for the energy, economic, and environmental impacts of advanced industrial technologies; and assessing the economic productivity impacts of the Office of Industrial Technologies energy and waste minimization technologies.

In support of the Office of Industrial Technologies technology maturation and tracking program, the goals for 1995-1996 included identifying commercialization opportunities; developing collaborations with other federal and state agencies, private industry, utilities, and trade associations; developing seminars and training programs; and sponsoring in situ demonstrations of technologies. In addition, the Laboratory will support the Climate Change Action Plan as well as identify both primary and secondary impacts of the Office of Industrial Technologies commercialized technologies.

Technology Access Continuously since 1979, we have contributed to the Office of Industrial Technology Access Division's goals of gathering and disseminating information to potential users of technology; and collaborating with other federal, state, local, and private partners to establish the technical and financial attributes of Office of Industrial Technologies-supported technologies. Our efforts are focused in two major areas: technology deployment and market analysis. While the Laboratory assists individual Vision Teams with specific technology deployment goals for each of their ongoing programs, Laboratory staff also work closely with industry and

industrial consortia to enhance the market penetration for Office of Industrial Technologies-developed technologies. The Laboratory also provides market assessments, success stories, and case histories of technologies, all designed to mitigate the technical and information risk associated with industrial acceptance of advanced technologies.

Climate Wise The Laboratory's primary focus for the Office of Industrial Technologies Climate Wise program is to recruit industrial partners and assist with their Action Plans, and to perform an assessment of tools that may be useful to partners. The Laboratory has the lead role in the food processing and textiles industries and will support the lead teams in pulp and paper, aluminum, and other industries of the future. We will provide technical assistance to companies that request it through the Denver Support Office's Technical Assistant Program. To help facilitate the recruitment of Climate Wise members, we will develop or enhance potential Climate Wise tools. These tools will provide industry with specific information on energy and environmental impacts of technologies as well as provide "rules of thumb" for converting specific actions into its energy and environmental components.

NICE3 The goal of the National Industrial Competitiveness through Energy, Environment and Economics (NICE3) program is to partner with states and industry for demonstrations to advance energy-efficient and clean production technologies. Laboratory staff work with the Office of Industrial Technologies to ensure that NICE3 technologies are replicated once they have been demonstrated. This requires an in-depth technical and market assessment of each of the technologies that the program supports. The assessments are used to identify opportunities to pursue for alternative applications for the technologies and to identify barriers that we can address and overcome. In addition, the Laboratory will provide coordination and training with state offices to encourage that quality proposals are submitted, reviewed, and implemented.

Technology Tracking Laboratory staff analyze the market penetration of completed Office of Industrial Technologies-sponsored technologies through direct industry contacts. Data from this effort is maintained on a central database and is analyzed to identify what factors have led to the success of Office of Industrial Technologies-supported technology. For each technology, this effort identifies the number of units and the energy savings associated with its operation on a yearly and cumulative (across years) basis. It identifies factors within the marketplace that are impacting the technology's diffusion, obtains unit pricing information, and identifies secondary (nonenergy saving) benefits associated with the operation of these technologies. The goal of the analysis is to enhance the success rate of Office of Industrial Technologies.

Office of Transportation Technologies (EE)

Pacific Northwest is a key contributor to the Office of Transportation Technologies Transportation Technology Program. The objective of the Transportation Technology Program is to develop and commercialize technologies that can radically reduce petroleum consumption in the transportation sector. The program is expected to reduce U.S. reliance on imported oil, reduce environmental impacts from transportation, improve the balance of trade, make resources available to invest in other sectors of the economy, and improve international competitiveness of U.S. firms. The Laboratory is contributing to all of these major elements of the Transportation Technology Program, working in close partnership with the U.S. Council for Automotive Research (USCAR) and the other DOE laboratories. We are applying our core capability in materials sciences and materials processing technology to develop advanced forming technologies for lightweight metals suitable for rapid forming processes and composites. Primary emphasis is on aluminum alloys. Programs to reduce emissions for internal combustion engines are also being developed. These programs focus on both reducing hydrocarbon generation in the engine cylinders and on trapping and destroying hydrocarbons and NO_x coming from the engine. To help us better understand the needs of the automotive industry, we have used the staff exchange program to assign one of our staff members to the General Motors R&D center.

The Office of Transportation Technologies has identified the development of an effective fuel reformer as a critical technology need for the fuel cell program. Through our LDRD program in microtechnology-based devices, we have developed a potential solution to this problem. We expect to initiate the development of a microtechnology-based fuel reformer in FY 1997.

The Laboratory continues working with the National Renewable Energy Laboratory to conduct environmental support research jointly sponsored by DOE-EE's Office of Transportation Technologies (biofuels) and the Office of Utility Technologies (biomass power). The support includes several task areas related to thermochemical biomass conversion. Laboratory analysis is being done on process effluents, and cleanup methods for the products are being developed, as required. Regulatory assessment is also an ongoing portion of this support. Scale-up based on these processing tests will be dependent on economic assessments of the results.

Office of Budget, Planning and Customer Service (CE) Pacific Northwest provides technical assistance to the Office of Budget, Planning and Customer Service (OBPCS) in planning and applied analysis. In the area of planning, contributions include support in developing and implementing strategic scenario and multiyear program planning activities and conducting assessments of issues affecting DOE-EE programs and stakeholders.

The Laboratory is providing technical support to DOE-EE in developing the data and analytical capabilities needed to assess the potential environmental, energy saving, and economic impacts of energy efficiency and renewable technologies and programs. This includes developing a consistent total energy cycle methodology for use within DOE-EE along with supporting computer tools, and participating in an

interlaboratory total energy cycle analyses of electric vehicles. We are also conducting analyses of issues of interest to DOE-EE related to natural gas.

As part of assessing the benefits associated with DOE-EE programs, Pacific Northwest is helping to develop and apply methods to estimate the environmental, productivity, economic, and equity impacts associated with DOE-EE technologies. These activities help DOE-EE understand and compare the benefits associated with its competing programs and technologies and also facilitate comparisons between DOE-EE technologies through its activity called Quality Metrics. The Quality Metrics information is used by DOE-EE to help prioritize its programs for budgeting and for communicating the benefits of its technologies and programs to the public, DOE-EE's stakeholders, and the Congress. Finally, we are working with the OBPCS and other DOE-EE offices in developing an integrated information management system to facilitate access to the data, models, and other database and analytic tools needed to conduct Quality Metrics and other policy and program analysis.

Bonneville Power Administration

Bonneville Power Administration faces significant challenges that will dramatically alter its focus and business approach over the next 2 to 5 years. These challenges stem, to a large extent, from dramatic deregulation of the energy utility industry in general, and the electric utilities in particular. The result will be continued pressure upon all utilities to reduce costs and increase customer service. This pressure affects Bonneville Power Administration more than other utilities because Bonneville sells 100 percent of its power to the wholesale market, whereas the average utility only sells 20 percent.

In response to these dramatic changes, Bonneville Power Administration has embarked upon a restructuring initiative that would ultimately lead to Bonneville becoming three separate business units under a common corporate umbrella. Although Bonneville hopes to remain as a single organization, preferably a government corporation similar to the U.S. Post Office and AMTRAK, this decision will be made through regional review under the direction of regional governors. The regional review will result in a report and recommendations to Congress by year-end. Ultimately, Congress will design the new Bonneville through legislation over the next year or two. At present the final result is uncertain. Nevertheless, the clear message is that Bonneville will undergo dramatic change in the next 5 years.

Pacific Northwest expects that the Bonneville Power Administration of the future will comprise separate business groups for power, transmission, and energy services, and that all these functions will operate with reduced numbers of staff and with increased emphasis on cost competitiveness. The Laboratory plans, therefore, to provide research and development support to lower costs and increase the value of services offered by each of the entities. First, we will continue to invest in building our capabilities to serve the new Bonneville transmission group in real-time power system control and operation. Second, we will continue our current programmatic support in energy resource and environmental programs to serve the power and energy services entities. Finally, we will seek to deliver advanced operations and maintenance technologies to both the power and transmission entities to further Bonnevilles goal in lowering the cost of power to the region. The benefits to the nation will be an improved power marketing function in the Northwest as well as new technologies that can be applied to the nation's public and private power transmission and hydroelectric generation infrastructure.

Selected highlights of programmatic initiatives and priorities that implement these strategies are summarized below.

Real-Time Power System Control and Operation

Bonneville operates one of the most complex and sophisticated transmission systems in North America. Maintaining high reliability while meeting load growth without addition of substantial new transmission lines will be the major challenge to be faced in the years ahead. Reliably increasing the capacity of the present transmission system will require development and incorporation of new technologies and operational infrastructure for monitoring, analysis, control, and operation of the western interconnected power system. The Laboratory is currently assisting Bonneville in the integrated development of all such elements for a Dynamic Information Network spanning the entire western system. Sophisticated monitoring networks will help gather much needed, time-synchronized data enabling development of improved system models and examination of dynamic behavior not presently well understood. New information tools are being developed to share data among collaborating utilities, to convert data into useful information, and to automatically route information to those needing it. Much of this, but not all, is being performed under the DOE Wide Area Measurement Systems (WAMS) Project. At Slatt substation we are strongly involved with dynamic information systems for the FACTS-related Thyristor Controlled Series Capacitor, the Electric Power Research Institute - General Electric flagship device for power system control. We are also developing improved logic for automatic generation control at Bonneville Power Administration's Dittmer Control Center.

It is anticipated that technology development and deployment by the Laboratory in association with Bonneville will continue for at least the next 5 years. Electric Power Research Institute has recently bought into WAMS as a full partner, launching five new "placeholder" tasks in wide area monitoring and testing. The Laboratory leads three of these, and has potential involvement in all five. There is a very strong likelihood that this program will be officially selected for the Electric Power Research Institute-DOE SEP alliance, leading to still greater industry involvement. This will be followed by analysis of monitored behavior, development of improved analysis tools, and utilization of these tools to

improve performance of existing power system stabilizers, progressively including improved control of the major elements of the transmission system such as the HVDC transmission line to California.

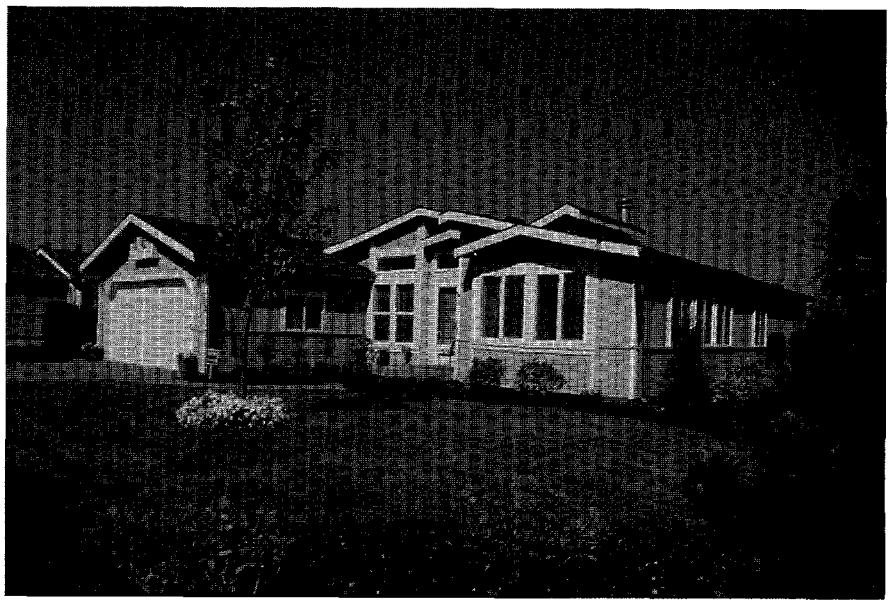
Fish and Wildlife Programs

The protection and enhancement of fish and wildlife is closely tied to impacts of energy production and other water uses in the western United States. The Bonneville Power Administration is charged by Congress to protect and enhance the fish and wildlife of the Columbia Basin while providing power to the region. In addition to Bonneville efforts, the U.S. Army Corps of Engineers is modifying hydroelectric dam structures and operations to mitigate losses of fish and wildlife. The Laboratory is an important scientific and technical resource to Bonneville (and its sister federal agencies) for planning and implementing the Bonneville Power Administration Fish and Wildlife Program.

Today, many of the fish and wildlife resources in the Western U.S. continue to decline. The Laboratory is supporting Bonneville's efforts in many areas to reverse these trends, including fisheries habitat restoration and mitigation planning. To support these emerging fish and wildlife needs, we are targeting research in integrated environmental monitoring; integrated resource planning; computer based controls for natural resource monitoring facilities; hydroaccoustic and video image acquisition, processing, and data management; fisheries physiology; experimental design and hypothesis testing; facilities certification; fisheries genetics; ultrasound and infrasound technologies; and evaluation of electromagnetic exposures.

Regional Energy Resource Programs

Pacific Northwest has supported a broad range of Bonneville Power Administration resource programs over the past decade that include strategic support of energy efficiency and renewable generation research and development, development of resource planning data and methods, and efficiency program design and evaluation. Bonneville's restructuring and its renewed emphasis on power marketing and energy services will lead to new roles for the Laboratory, primarily in the areas of market transformation for end-use technologies, new Bonneville marketing tools for efficient manufactured housing, and technology scanning for the new Bonneville strategic research and development planning process.



Researchers at the Pacific Northwest National Laboratory analyzed energy consumption, obtained and analyzed industry data, and identified technology improvement opportunities for electrically heated manufactured housing. Results were used to establish requirements for a regional Manufactured Housing Acquisition Program, which saw utilities invest $100 million to ensure many manufactured homes meet strict energy efficiency requirements.

Market transformation programming is a relatively new market approach to encourage efficient energy utilization in the residential and commercial sectors. The Laboratory is a leading contributor to the national DOE market transformation program, and Bonneville Power Administration is leading new regional initiatives as well. We anticipate working with Bonneville to establish a link between the regional and national programs to add value to both programs. In particular, we anticipate working with Bonneville in FY 1997 to support the regional initiative to encourage the availability of efficient compact fluorescent lights and fixtures.

About one-third of the new homes in the Northwest region are HUD-code manufactured homes, built to a relatively loose national thermal code. Through technology and information transfer, the Laboratory has assisted Bonneville in sharing information on its energy-efficient manufactured homes program with the states, manufacturers, and other interested parties. The saved energy was acquired at a cost which is about half that of building a new power plant. More than 25,000 homes have been built to MAP (Manufactured Housing Aquisition Program) standards. The Laboratory has completed the evaluation of MAP and initiated efforts to further develop Bonneville marketing tools for the program. The Laboratory will work with Bonneville in 1996 to develop a joint program with energy-efficient product suppliers to continue regional marketing efforts.

Finally, Bonneville Power Administration comes to the competitive electricity market with two characteristics that currently distinguish it from other power marketers. First, as a federal agency, Bonneville has a legacy as a

protector and sponsor of activities that yield public, rather than strictly commercial, benefits. Second, and in a related manner, Bonneville has historically led the region, and in some cases the nation, in utility research, development, and demonstration activities. Bonneville sees these characteristics as competitive advantages in a restructured industry. However, Bonneville can no longer afford to invest in programs that provide it with no direct benefits. As part of its internal restructuring, Bonneville is trying to find way to internalize these two characteristics as a form of "institutionalized innovation." Bonneville Power Administration has asked the Laboratory to assist it with a process for monitoring technological change and using this knowledge to position itself to take advantage of new technologies. This need is expected to remain regardless of Bonneville's future organizational form. The Laboratory is a natural for this mission as it is local, is a DOE laboratory, and provides Bonneville Power Administration with access to federal research and development as well as that in the private sector.

Office of Civilian Radioactive Waste Management

Pacific Northwest National Laboratory programs supporting the Office of Civilian Radioactive Waste Management (RW) cover several activities.

Program Management and Integration (DB)

The Systems Integration Program supports the DOE-RW Office of Program Management and Integration by ensuring that components of the nuclear waste management system are integrated into an efficient, safe, and timely waste management system. Components may include a mined geologic repository, waste generators, near-term storage, transportation, and a monitored retrievable storage facility. The Systems Integration Program technology and program scope were successfully transferred to the Management and Operations Contractor. The Laboratory role is currently directed toward providing the Office of Program Management and Integration with limited independent technical review and consultative support.

Waste Acceptance, Storage, and Transportation (DB, DC)

The Laboratory has provided planning and technical management to DOE for the national Commercial Spent Fuel Management Program. Although the program came to an end, efforts begun by the Laboratory under the Commercial Spent Fuel Management Program are continuing as independent projects. Focus of continuing research and development being done with the Laboratory's involvement is on establishing technology that nuclear power utilities can use for interim spent fuel storage efforts.

The Laboratory provides technical management for cooperative programs between DOE and utilities, including participation of the Electric Power Research Institute. Included in cooperative program activities is the establishment of an agreement to design and demonstrate a licensed system for the dry transfer of spent nuclear fuel between two licensed store-now/transport-later dry storage systems.

Under the Heat Transfer Code Evaluation/Qualification Project, the Laboratory is responsible for evaluation, qualification, maintenance, and user support for COBRA-SFS and HYDRA-II which are "best estimate" thermal-hydraulic computer codes for spent fuel dry storage systems. The codes have been extensively validated and have undergone technical evaluation by the Nuclear Regulatory Commission for use in licensing analyses of spent fuel storage systems.

The Laboratory Utility Interface Programs assist the DOE-RW's Office of Waste Acceptance, Storage, and Transportation and the DOE-RW management and operations contractor in performing the waste acceptance function. We support preparation of two annual DOE reports to implement the DOE contract with utilities to accept their fuel. The Acceptance Priority Ranking represents the DOE contractual commitment to accept spent nuclear fuel for disposal. The Annual Capacity Report, required by the contract, sets forth receiving capacity for the waste management system and allocates the appropriate share of the capacity to the contract holders. The Laboratory assists the Office of Waste Acceptance, Storage, and Transportation with the development and implementation of the control systems for managing delivery commitment schedules.

In addition, the Laboratory helps in reviewing, reconciling, and disseminating the data on spent fuel inventory and projections that are collected for the utilities. These data form the basis for planning the waste management system.

The Laboratory currently provides support to DOE-RW under programs that characterize activated metals from nonfuel-bearing reactor core components and reactor vessel internals that would be disposed of in the federal waste management system. Project activities included radiochemical analysis, waste classification, component machining in hot cells, neutronics analyses of reactor components to determine activation levels, and dose rate/shielding calculations. Ongoing activities include management of the legacy waste remaining in the hot cells from these projects.

Policy Office

Pacific Northwest provides assistance to the Policy Office (PO) in the area of economic and policy analysis, both on major long-range studies and on short-turnaround issues as they emerge. The main strength of the assistance the Laboratory provides to the Policy Office is its policy relevance. The Laboratory has examined the role of the social sciences in global climate change issues and policies. This work has been funded jointly by the Policy Office and OHER. As an example, the Laboratory embarked on an ambitious project to increase international understanding of the challenge to and understanding of the role of social sciences as global climate change is addressed. Under the working title,

Human Choice and Climate Change: A State-of-the-Art Report, the SOAR project has been working with an international team drawn from a wide range of the social sciences. The interdisciplinary team will analyze current social science contributions to climate change information to determine what is known, unknown, and uncertain; to evaluate the strengths and weaknesses of social science knowledge; and to identify new areas of potentially fruitful research. The project is supported by an International Advisory Board, composed of scholars and practitioners in the area of global climate change.

The Laboratory's extensive modeling capability provides another valuable input to the policy decision process.

- The Edmonds-Reilly-Barns Model, which we maintain and update, continues to be used extensively in scenario analysis for numerous studies of possible greenhouse gas control policies.
- Significant improvements in the forecasting of greenhouse gas emissions are being realized as our efforts to develop the Second Generation Model come to fruition. Currently, we have completed eight of the planned modules, including the United States, Western Europe, Korea, Japan, Canada, former Soviet Union, Australia, and India. The global version is expected to be functional by the end of 1996. The Second Generation Model program is founded on the principle that a fully international program can achieve more than even the best national program.
- The Second Generation Model is a principal part of a larger integrated assessment framework, the Global Change Assessment Model. This framework also utilizes models of atmospheric chemistry, and climatic, hydrologic, and agricultural effects. The ability to perform integrated assessment has provided insights not obtainable in research studies that consider each element separately.

The Laboratory assisted the U.S. government in the efforts of the Intergovernmental Panel on Climate Change (IPCC) in developing the Second Assessment, which has been completed. Specifically, the Policy Office provided funding to lead authors and contributing authors on Working Groups 2 and 3 in the areas of Energy Supply and Human Settlements.

The Laboratory is also supporting the Policy Office in developing policy options and strategies to use in negotiations under the Framework Convention on Climate Change. Laboratory scientists are contributing to the revised compendium of policy instruments and to various committees and workgroups associated with the negotiating process. The work on efficient timing of emissions reductions has been cited and used extensively.

The Laboratory provides scientific and technical assistance to the U.S. Initiative on Joint Implementation to both DOE-PO and -EE. The Laboratory provided input to the design of the Pilot Program and each of the three proposal phases, including technical assistance in evaluating proposals and developing programmatic guidance and rationales.

Related to current work on greenhouse gas emissions is a project that examines the energy (and hence carbon) embodied in international trade. This project, titled *Energy Embodied in Trade: A 4-Region Model* is currently being undertaken for the PO-64, Office of Economic Policy and International Competitiveness. This project is motivated by the fact that energy used in the production and transportation of goods and services is a major source of atmospheric greenhouse gas emissions. Concerns about the growth of greenhouse gas emissions are a major factor in the development of policies through international negotiations to reduce these emissions. These negotiations are primarily focused on the site of the production of greenhouse gases and are designed to reduce that production. The objective of this project is to show that there are alternative ways to account for the production of greenhouse gases that would provide a stronger incentive to reduce worldwide greenhouse gas emissions, so that the implications of this work can feed into the international negotiations process.

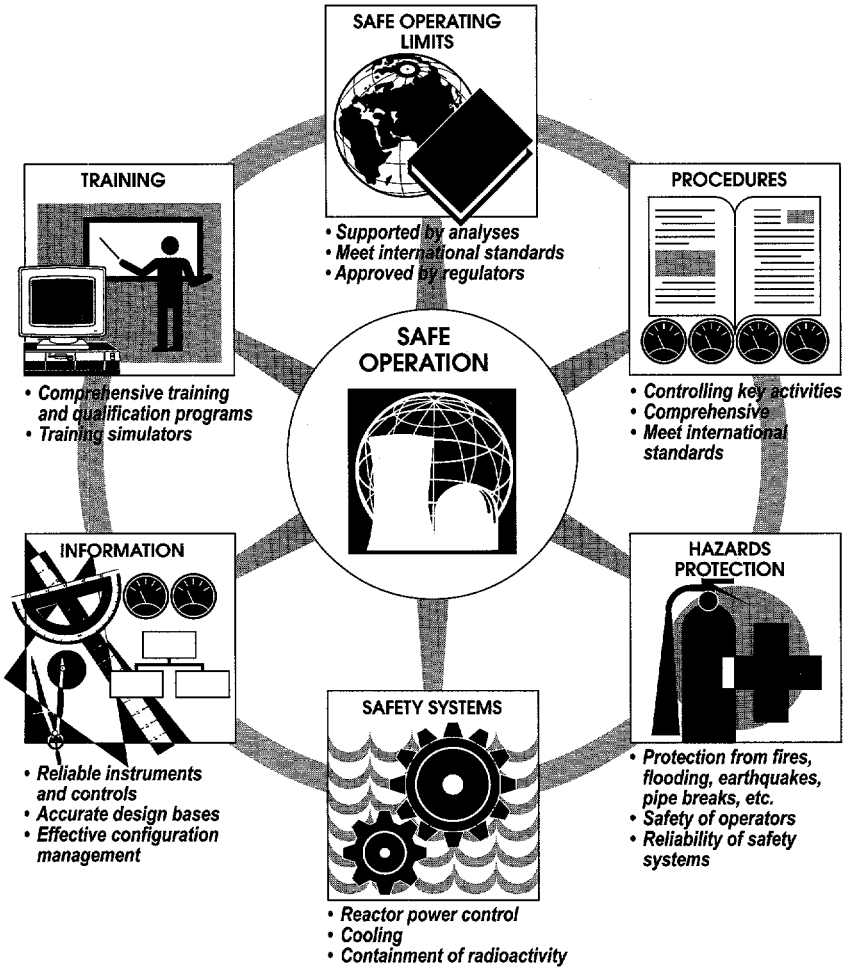
For the future, the Laboratory plans to continue to provide the policy-relevant analyses required by the Policy Office. Future issues for the office will most certainly be global issues, as global climate change issues will likely remain in the forefront for the long term. Such issues as large-scale regional issues, sustainable development, and global environmental equity are also likely to remain important issues for the foreseeable future. The Laboratory expects to support the Policy Office in contributing to U.S. actions conducted as part of the U.S. Joint Implementation Plan. Joint Implementation efforts are undertaken by more than an individual country to reduce climate change emissions.

Additional work is under way for the Policy Office's Office of Energy Efficiency and Alternative Fuels in the area of industrial energy efficiency and its potential contribution to achieving U.S. energy and environmental goals. The Laboratory is investigating strategies for reconciling compliance with environmental requirements with improvements in productivity and energy efficiency, focusing specifically on the paper and steel industries. We are also evaluating the effects of various policy mechanisms on greenhouse gas emissions from U.S. manufacturing. This analysis will be used in support of U.S. Climate Change Treaty negotiations. Other work addresses how computer models can best be used to evaluate potential energy policies that affect the U.S. industrial sector.

Office of Nuclear Energy, Science and Technology

Pacific Northwest increased its participation in the DOE Office of Nuclear Energy, Science and Technology (NE) programs. Current and projected funding for the DOE-NE programs are shown in the Resource Projections.

Over the planning period, the Laboratory plans to expand its role in DOE-NE's research and development programs in the areas of the storage, use, and disposal of surplus plutonium from arms reduction; actinide burning; radioactive waste minimization; isotope production and distribution; and advanced reactor design review and



Under a DOE program to improve international nuclear safety, Soviet-designed nuclear power plants in eight countries are reducing operating risks, improving personnel training, and upgrading key safety systems.

certification. In addition, the Laboratory expects to take a lead role in supporting DOE-NE's efforts to help Ukraine establish the International Chornobyl Center on Nuclear Safety, Radioactive Waste and Radioecology at the city of Slavutych.

Nuclear energy programs to meet future power needs in the U.S. are not expected to expand until the latter part of the planning period. The Laboratory plans to participate in activities aimed at revitalizing nuclear power as these programs develop.

Nuclear Energy Research and Development (AF)

DOE has assigned the Laboratory the responsibility for providing project management and technical and administrative support for DOE's International Nuclear Safety Program. The objective of this program is to reduce the risks of Soviet-designed reactors by working cooperatively with host countries to strengthen their nuclear safety cultures and supporting infrastructures. The older nuclear power plants designed and constructed by the Soviet Union do not meet international standards for nuclear safety. At the same time, the former Soviet Union states have concluded that continued operation of these plants is required to provide energy to support their struggling economies.

International Nuclear Safety Program

The DOE's International Nuclear Safety and Chornobyl Initiative program is designed to reduce the national security and environmental threats posed by the operation of unsafe and aging nuclear facilities around the world. The goals of this program are to

- improve nuclear safety worldwide, particularly the safety of Soviet-designed nuclear power plants
- secure shutdown of the Chornobyl nuclear power plant, site of the world's worst nuclear disaster
- develop and maintain core competencies in nuclear safety through the establishment of international nuclear safety centers in the U.S. and elsewhere, and through cooperative research and development with other countries and international organizations.

DOE has devoted substantial resources to this work, which offers significant benefits to the United States and other countries by

- helping prevent a nuclear accident that could destabilize the newly independent countries of Russia, Ukraine, and Central and Eastern Europe. Such an accident also could threaten the viability of nuclear power worldwide.
- supporting a stable business climate for U.S. and international investments in the former Soviet Union
- providing protection for the public, economic, and environmental health of all European countries.

DOE has assigned the Laboratory the responsibility for providing project management and lead technical and administrative support for the program, with assistance from other DOE national laboratories, U.S. commercial organizations, and governmental and scientific organizations in the host countries. Laboratory staff in the International Nuclear Safety Program Office bring a strong set of qualifications to this role. Many of the program's key technical staff at the Laboratory previously held lead positions at the Hanford Site's N-Reactor, which has certain similar design features to many Soviet-designed reactors. Other staff held lead positions in management,

operations, reactor personnel training, licensing, and other key areas in both government and commercial U.S. reactors. Laboratory program staff include a former Chornobyl reactor operator and regulator, native Russian experts in nuclear operations, and Russian-speaking nuclear-energy experts who facilitate program activities in residence in Russia and Ukraine, respectively. As the lead contracting organization for the program, the Laboratory contracts for safety-related services and equipment from more than two dozen U.S. firms, all the nuclear power plants, and key technical and scientific institutions in the host countries.

Program activities are selected to reduce the most significant risks identified by the host countries, the International Atomic Energy Agency, and the G-24 nations. As opposed to merely providing assistance, activities support the transfer of technology and establishment of a strong safety culture that enables the host countries to sustain the safety improvements over time.

The Laboratory supports DOE in achieving the following measures of program success:

- development of and agreement on program goals, objectives, and strategic plans between the United States and the host countries
- involvement of plant operators, plant technical support, and regulators in program planning and execution
- agreement among the Untied States and host countries on safety problems and priorities
- evidence of the host country making independent decisions regarding safety upgrades, operations, and shutdown in light of safety concerns
- measurable improvements in plant operational and operator performance
- successful operation of international nuclear safety centers in Russia and Ukraine
- development of comprehensive decommissioning and decontamination plans for the Chornobyl nuclear power plant in anticipation of shutdown.

Under the International Nuclear Safety and Chornobyl Initiative program, the Laboratory supports DOE in four major efforts, which are described in the following sections:

- Soviet-Designed Reactor Safety Program, which focuses on improving the safety of Soviet-designed reactors in Russia, Ukraine, and five Eastern European countries
- International Chornobyl Center on Nuclear Safety, Radioactive Waste and Radioecology, in Ukraine
- core conversion initiative, which involves modifying three Russian reactors to stop production of weapons-grade plutonium while maintaining critically needed energy supply for the surrounding regimes in Siberia
- implementation of U.S. commitments to support closure of the Chornobyl nuclear power plant.

Soviet-Designed Reactor Safety Program This program originated from U.S. commitments made at the 1992 G-7 conference to provide assistance to Russia, Ukraine, Bulgaria, Czech Republic, Hungary, Lithuania, and Slovakia in reducing risks associated with the older Soviet-designed reactor types. Since 1992, the program's scope has expanded to include a broader range of safety-related activities and four Soviet reactor designs: RBMK, VVER-440/230, VVER-440/213, and VVER-1000. As of FY 1996, 18 nuclear power plants with 60 reactor units in the seven countries identified above participate in the program.

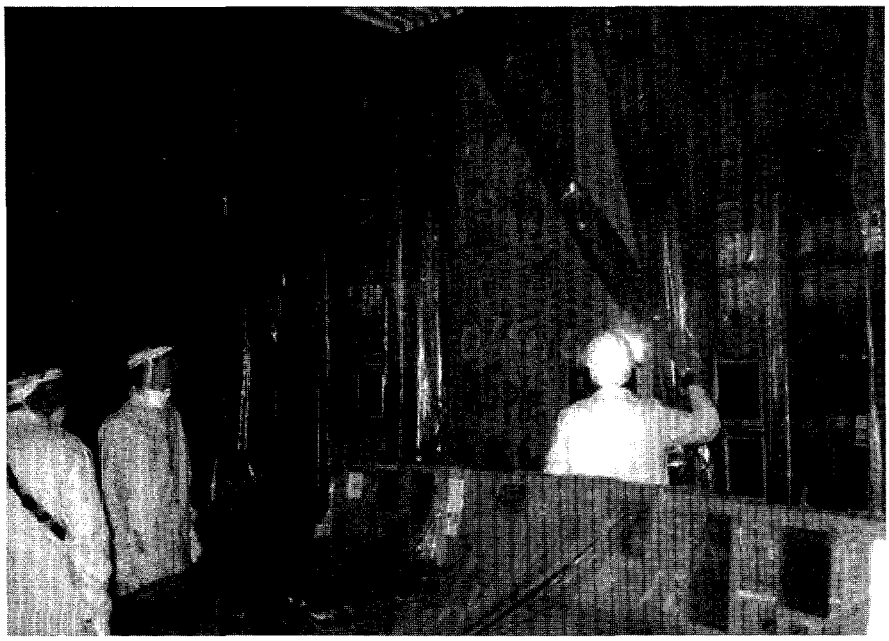
The Soviet-Designed Reactor Safety Program has five elements that are critical to achieving lasting improvements in nuclear safety culture and infrastructure development. All of them involve working cooperatively with the host countries to

- improve the capabilities of nuclear power plant operators to establish sound operational procedures and to develop methods for responding to operational abnormalities
- improve the physical condition of the plants, particularly their safety systems
- provide professionals involved in the design, operation, and regulation of nuclear power plants with the techniques and expertise required to conduct safety analyses that are consistent with Western practices
- develop domestic liability legislation to enable a broader involvement of U.S. private industry and establish a strong, independent regulatory authority.

Through FY 1996, funds allocated to the Laboratory for the Soviet-Designed Reactor Safety Program totaled $180 million. Fiscal year 1997 funds for the Laboratory for this program are expected to be about $100 million, with continuing funding expected at about $50 million per year throughout the planning period covered in this report.

International Chornobyl Center on Nuclear Safety, Radioactive Waste and Radioecology One way DOE maintains core competencies in nuclear safety is through supporting international nuclear safety centers, which undertake cooperative research and development programs, information exchanges, computer modeling, and other activities. DOE is working with Ukraine to establish one such center, called the International Chornobyl Center on Nuclear Safety, Radioactive Waste and Radioecology. In FY 1996, Ukraine's President Kuchma officially established the Center and appointed a Ukrainian director. The Center is located at the city of Slavutych, near the Chornobyl nuclear power plant, at which two reactors continue to provide heat and electricity for surrounding communities. The Center's objectives are to

- develop expertise for providing operational safety support to Ukrainian nuclear power plants
- address environmental issues at Chornobyl—such as radioisotope transport, remediation technologies, and cleanup methods
- help diversify Chornobyl's economic base and maintain necessary nuclear expertise after the remaining two reactors shut down in the year 2000.



In the plastic-shrouded control room of the damaged Chornobyl reactor Unit 4, U.S. and Ukrainian specialists view the radiation levels marked on the wall after the 1986 accident. Pacific Northwest scientists are providing technical support to specialists from Ukraine and other countries to repair the deteriorating concrete and steel structure that encloses the ruined reactor.

DOE has given Laboratory staff a key role in facilitating Center development and implementation. To support Center startup, including identifying and prioritizing opportunities for new projects, the Laboratory has assigned several technical staff as well as establishing a full-time position in Slavutych. As with the Soviet-Designed Reactor Safety Program, the Laboratory is responsible for purchasing applicable services and equipment from U.S. commercial companies to benefit the Center. A U.S. telecommunications company is installing satellite equipment at Slavutych that will enable interaction and data exchange by voice, fax, and electronic mail between Center experts and their counterparts worldwide.

Over the planning period, the Laboratory will continue transferring and developing nuclear safety and environmental management technology and applying that technology to address the needs at Chornobyl and throughout Ukraine.

Funding through FY 1996 for the Laboratory's involvement in this Center and related projects is $31 million. Fiscal year 1997 funding is expected to be about $12 million. The funding profile for subsequent years will be determined after the Center's business plan is developed.

Conversion of Russia's Plutonium-Production Reactors The mission of DOE's Nuclear Security/Russian Production Reactor Shutdown program is to reduce the threats posed by continued operation of reactors that produce weapons materials, and to promote management practices that minimize the risks of proliferation of weapons-usable nuclear materials. The Laboratory supports DOE in a key goal of this program—implementation of the U.S.-Russian agreement to cease the production of weapons-grade plutonium.

A key objective for this goal is to work with Russia to convert their production reactors to a mode that eliminates production of weapons-grade plutonium while still providing heat and electricity required by local communities, and identify long-term replacement power sources. In 1995, as part of a U.S./Russian technical team, Laboratory engineers completed a study of options for stopping Russian plutonium production while maintaining energy generation. The study demonstrated that one of the options, reactor conversion, would be technically possible within 3 years, would eliminate the production of weapons-grade plutonium, and would improve the safety of the reactors. A bilateral commission in 1995 selected that option. Over the next several years, the Laboratory anticipates continuing its participation on the joint U.S./Russia team to

- develop and test a design for the converted reactor cores
- support Russia in modifying the plant designs and obtaining operating licenses from the Russian regulatory organization
- upgrade reactors systems and equipment to accommodate new fuel.

Funding for the Laboratory's involvement in this work through FY 1996 is $5 million. The project is scheduled for completion within the planning period covered in this report, with additional funding expected at about $80 million for completion.

Chornobyl Closure Initiatives The DOE mission in this area is to implement the United States commitments under the G-7 Memorandum of Understanding with Ukraine on the closure of the Chornobyl nuclear power plant. The Laboratory has been assigned project management and lead technical and administrative support to DOE with assistance from other DOE laboratories and industrial contractors. This program, which is in its early stages, includes equipment for monitoring the sarchopagus and protecting the surveillance and maintenance teams, participating in the European Union study of short-term and long-term sarcophagus stabilization and remediation measures plus decontamination, decommissioning and waste management projects. An allocation of $33 million from several FY 1996 sources is in the congressional notification process. Fiscal year 1997 funding is expected to be about $22 million. The funding profile for subsequent years will be determined following ongoing G-7 negotiations.

Radioisotope Production and Use

Pacific Northwest replaced Westinghouse Hanford Company in 1996 as the Hanford contractor organization responsible for the production and sales of yttrium-90, cesium-137, and other selected isotopes under sponsorship of the DOE Office of Nuclear Energy. The Laboratory is developing new radiochemical separation technology for retrieving various isotopes from nuclear waste materials for applications in medical diagnostic and therapeutic procedures. A new area of emphasis in this program is the isolation and purification of several alpha-emitting radionuclides for use in cancer therapy. These short-lived alpha emitters include bismuth-213 and radium-223, which are being tested in preclinical laboratory research for their ability to selectively destroy cancer cells when attached to targeting molecules such as monoclonal antibodies.

Office of Fossil Energy

Pacific Northwest's involvement in the DOE's Fossil Energy programs is expected to be sustained at current levels as the Office of Fossil Energy faces level to decreasing funding. The Laboratory's research will continue to be focused on natural gas and oil industry needs, environmental regulation, energy conversion, gas and coal chemistry, advanced materials development, and environmental effects of coal use.

The Laboratory will continue to support Fossil Energy in their efforts to ensure the nation's energy security and to respond to needs expected to emerge from business deregulation of the natural gas and electric power industries. Challenges emerging from the new competitive environment will include

- sustaining the excellent track record for the safe, reliable delivery of natural gas while significantly reducing the operation and maintenance costs of the natural gas delivery system and effectively addressing industry environmental issues
- developing a set of distributed energy systems employing fuel cell and gas turbine technologies to move the supply of electric energy closer to the end user.

The integrity and reliability of the energy delivery infrastructure will become increasingly important over the next few years as energy delivery (natural gas and electric) companies seek to profitably respond to deregulation by implementing a number of initiatives aimed at reducing their infrastructure investments. Responses, such as this, to the new competitive environment caused by deregulation may likely increase the frequency of service interruptions and cost of operation and maintenance. Distributed energy sources will also cause increased cost and operating pressures on the delivery system as will the need to respond to business oriented issues such as energy trading, the newly emerging futures market, and the desire and need to provide tailored service to end users. Providing the base technologies necessary to respond to these drives and ensure the continued safe, reliable, and efficient operation of the nation's energy delivery systems will emerge as a high priority federal role over the next 5 years. In addition, significant efforts will be applied to effectively utilize the extensive environmental remediation and waste management experience and capabilities (such as risk assessment, contaminant transport, environmental characterization, and monitoring) to address the important environmental issues associated with energy exploration, production, and delivery.

Regulatory compliance has become the central area of research that can assist the competitiveness of the industry. The $37 billion estimated to be required between 1991 and 2000 for plant upgrades to produce reformulated fuels required under the Clean Air Act Amendments is only $6 billion less than the current book value of all U.S. refineries. The U.S. refining industry faces environmental compliance costs totaling at least $150 billion through 2010. The purpose of the Refinery of the Future Initiative and the Natural Gas and Oil Technology Partnership is to develop research solutions to problems that DOE and the petroleum industry have in common. These partnerships are designed with industry participation and collaboration and incorporate a wide variety of cooperative mechanisms.

The Natural Gas and Oil Technology Partnership was formed in 1988 as an alliance among DOE, Sandia National Laboratories, Los Alamos National Laboratory, and the petroleum industry. With the implementation of the Computational Technology initiative in FY 1995, the partnership was expanded to include the other DOE national laboratories. The Computational Technology program focuses on exploration and production computing technology. Pacific Northwest is committed to actively participating in the four major technology areas: Computational Technology, borehole seismic, drilling and completion, and oil recovery. We have technical capabilities in molecular computation and design, data fusion, multiphase fluid flow, and several other areas that could be applied to achieve the goals of the initiative.

The Solid State Electrolyte Materials Project is developing electrically conductive ceramic materials for use in solid-oxide fuel cells (SOFCs) and in gas separation membrane applications, focusing on ceramic materials synthesis, forming technology, materials stability at high temperature, and electrical and catalytic properties. Solid-state electrolyte materials, fully dense ceramics that conduct some combination of electrons, oxygen ions, or protons, offer significant promise in enhancing the utilization of fossil fuels in energy production. Solid-oxide fuel cells are composed largely of electrically conductive ceramics and provide direct conversion of fossil fuels to electrical energy in a highly efficient and environmentally attractive manner. Among the strategic goals of the Fossil Energy Advanced Research and Technology Program is to develop SOFCs to enable their use in commercial power generation. Mixed oxygen ion and electron-conducting ceramic membranes are also being developed by this project to provide a low-cost means to separate oxygen from air, which is needed for a wide range of

fossil energy applications including SOFCs. The mixed conductors may additionally be used in membrane reactors to upgrade natural gas feedstocks through the oxidative coupling of methane and to produce syngas (hydrogen and carbon monoxide).

Another program, Advanced Materials for Solid-Oxide Fuel Cells, emphasizes the major generic issues of SOFCs performance and manufacturing. The research and development emphasizes critical issues of materials processing, fabrication, and performance. It is anticipated that the Laboratory will expand its involvement with U.S. industry to provide development support for more efficient manufacturing of advanced SOFCs in areas of CRADAs and technology transfer. It is anticipated that the Laboratory will expand research and development on SOFCs through involvement with U.S. companies in developing the fuel cells. Programs also are being directed to provide support for more efficient manufacturing of SOFCs.

This research is associated with the Laboratory's molecular sciences research activities and utilizes interdisciplinary research to gain an understanding of the processes related to catalytic, high-temperature membrane, inorganic, and electrochemical technologies.

The Laboratory's research and development for SOFCs continued in FY 1995 and will continue beyond. These efforts will continue to expand and include CRADAs and private support with industry in areas of material synthesis, processing, fabrication, and performance for application to solid-oxide fuel cells.

Methods employing nuclear magnetic resonance and gel permeation chromatography are being developed for determining the structural analysis and molecular weight of coals that have been degraded to forms of lower molecular weight by microbial treatment. Although analysis of biodegraded coals will remain an important research function at the Laboratory, projects are planned that will increase our involvement in coal liquefaction technology development. The Laboratory has begun research to synthesize ultrafine catalyst particles for coal liquefaction. Ultrafine catalyst particles less than 10 nanometers in diameter have high surface areas and the ability to penetrate into coal pores. These properties can decrease the quantity of catalyst used for liquefaction and increase liquefaction rates and selectivity. The catalyst particles are prepared using novel refinements in the emerging technology of reverse micelle inorganic chemistry and for thermal expansion/decomposition methods.

A 3-year CRADA has been established between Pacific Northwest and Phillips Petroleum Company to develop a novel laboratory process for treating spent catalysts from petroleum refineries. This process uses electrochemistry to remove contaminants that accumulate during processing that result in decreased efficiency. The technology is more environmentally friendly than conventional methods of dealing with spent catalysts and provides opportunities to improve conversion of crude oil to transportation fuels.

National Security

Pacific Northwest's national security activities are derived from and support the DOE's national security core business area. The Laboratory's current national security mission is based on the historical role of the Laboratory in defense materials production, the early tasking by the Atomic Energy Commission to develop sensitive radionuclide collection and analysis capabilities to monitor worldwide radioactive fallout and Hanford Site sources, and its continuing support to each of the DOE's mission areas.

Our national security objective is to integrate the full spectrum of technical knowledge at the Laboratory to anticipate and rapidly respond with creative and innovative solutions that enhance national and international security. Our goal is to provide an objective and independent national technical resource to national and international agencies and industries to

- support policy development and implementation planning
- develop and apply technology to implement national security policy
- provide technologies to meet national security requirements generated by the disparate threats across the broad spectrum of mission requirements.

The Laboratory has a growing, technologically rich, and well-recognized role in five national security focus areas: arms control and nonproliferation, intelligence, safeguards and security, defense systems technologies, and defense production and logistics.

The Laboratory's national security work is principally conducted for DOE's Office of Nonproliferation and National Security, Office of Defense Programs, and other federal agencies through the Work for Others Program.

Our national security work is performed throughout the Laboratory, thereby ensuring that the full resources of the Laboratory are applied to meet programmatic needs. There are real and recognized interfaces and overlaps with the other areas of the Laboratory. These interfaces are strengths in meeting national and international challenges not only in national security but the other business areas as well.

National Security led a LDRD initiative in Intelligence Information Technologies. This initiative started in FY 1995 and will conclude in FY 1997. The Intelligence Information Technologies initiative is aimed at developing the Laboratory's resource base in advanced information analysis and management to a major capability level that is nationally recognized. Our strategic approach is to focus on the specific needs of the Intelligence Community where information technologies and systems to generate tools and create infrastructure changes will result in the optimum distribution of analysts' time and improvements in production efficiency. This demand has been generated because of

- shrinking budgets, hence fewer analysts
- an increase in analytic tasking
- a greater number and diversity of targets for analysts

- rapidly growing volumes of available information
- diverse types and sources of information (classified and open source).

We are pursuing technical research in specific areas of information technologies. The approach is to build on existing capabilities and project experiences along with current activities that link the Laboratory directly to DOE and other members of the Intelligence Community.

The research emphasis in this initiative is to develop enabling technologies that will support a variety of applications. Through the connectivity of the Laboratory to the Intelligence Community via DOE (an active member of the Intelligence Community), we have identified and addressed three of the most pressing technology development areas. These are

- heterogeneous information sources with emphasis on automated methods for the creation of dynamic metadata, multimedia, distributed information systems, and automated active agents for browsing, analysis, and maintenance capabilities
- document and text understanding with emphasis on information discovery and transformation from retrieved text to analytical structures
- intuitive user interface with emphasis on the analysts' work environment and the use of multiple sensory perceptions (e.g., sonification and animation) to achieve a more natural interaction with the information space.

As a planned 3-year effort, the research activities for the Intelligence Information Technologies initiative will be completed in FY 1997. Significant progress has been made in the three task areas, even with the reduction of investment funding, which has resulted in a research emphasis in the first two areas identified above. The research has kept abreast of the Intelligence Community's direction in information technology and has benefited from the guidance of a Technical Advisory Panel composed of key scientists and executives from the DOE, Central Intelligence Agency, Federal Bureau of Investigation, and DoD. The achievement of new intellectual property is very promising, particularly in the development of a unique text processing engine. It is estimated that potential business to be derived from the development and advancement of information technologies through this initiative will exceed $20 million per annum within the next 5 years.

The laboratory-level Medical Technologies and Systems LDRD initiative also has its origin in National Security.

Office of Defense Programs

Pacific Northwest National Laboratory's work for the Assistant Secretary for Defense Programs includes safeguards and security activities in direct support of defense programs, participation in the production of special isotopes, and technical support to the nuclear weapons complex.

The Laboratory also assists Defense Programs in interpreting safeguards and security policies and identifying cost-effective implementation procedures for the Defense Programs complex.

The production of special isotopes (Materials Support [GE]) often requires the capabilities of several sites and contractors because of size, space, or other limitations. The Laboratory has unique capabilities for handling long reactor fuel and reactor components. We continue to support the Mark-42 target program. The Mark-42 targets are used for the production of plutonium-242, americium-243, and curium-244.

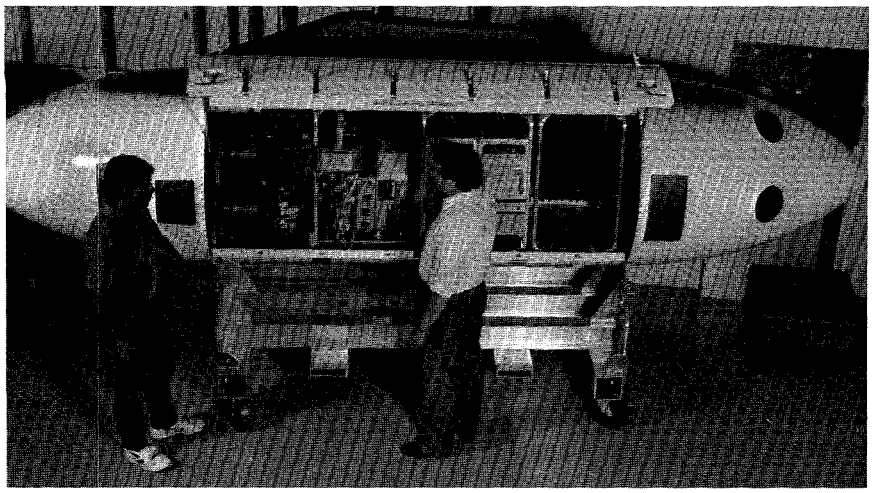
We also continue to provide technical support to the Defense Programs complex in specific materials support activities. The Laboratory is working closely with the Office of Military Application and Stockpile Support (DP-20) to define a light water reactor tritium target qualification program—a program designed to qualify the target system design first demonstrated in a previous Tritium Target Development Program initiated under the DOE New Production Reactor Office between FY 1989 and FY 1992. The qualification program would provide a tritium target system that could be used with confidence in the DOE's contingency option for tritium production for nuclear weapons applications.

Office of Nonproliferation and National Security

Pacific Northwest's support to the Office of Nonproliferation and National Security is provided to the Office of Research and Development, Office of Energy Intelligence, Office of Arms Control and Nonproliferation, the Office of Security Affairs, and Office of Emergency Management. The Laboratory participates in the Executive Council of the Office of Nonproliferation and National Security and provides direct support as requested.

For example, the Laboratory has supported the DOE's Office of the Deputy Secretary and the Office of Nonproliferation and National Security in the fulfillment of Congressionally mandated interagency coordination of counter proliferation programs since the inception of the Counter Proliferation Program Review Committee in 1993. We have provided continuity over the tenure of three different DOE-NN Office directors in reporting to Congress on proliferation prevention and emergency response conducted by the Department, and the interface and coordination of these activities with the Department of Defense and the Intelligence Community. Staff have been instrumental in the formulation of a Memorandum of Understanding between the Energy and Defense Departments for counter proliferation technology development. We are assisting the DOE as it strives to bring the full capabilities of its national laboratories in the areas of biotechnology and the chemical sciences to bear on the growing threat from biological and chemical weapons proliferation.

The Laboratory is also a participant in the Industrial Partnering Program with the Newly Independent States (NIS/IPP) of the former Soviet Union. The goals of this U.S. government program executed jointly by the Departments of State and Energy are to stabilize supporting technology equipment and



Pacific Northwest has developed sensors that can be flown on aircraft for use in detecting proliferation of nuclear and chemical weapons. Shown here are the Real-Time Airborne Radionuclide Detector/ Analyzer and the Ion-Trap Mass Spectrometer as installed in an Airborne Multisensor Pod. These sensors can produce laboratory-quality data from the air at selected altitudes over remote locations.

facilities to enhance global nonproliferation; develop advanced technology commercial opportunities and markets; enhance U.S. science and engineering capabilities; and engage weapons scientists, engineers, and technicians in nonweapon activities. This program is cooperatively managed by a 10-member Interlaboratory Board that is responsible for establishing guidelines for projects. Projects supported by NIS/IPP are classified in two thrusts. Thrust One projects are cooperative research projects between U.S. national laboratories and NIS institutes. Thrust Two projects are intended to provide market opportunities for technology jointly developed and/or manufactured and are carried out in a three-way partnership that includes a U.S. industry representative. The U.S. industry representative is required to be a member of the United States Industry Coalition and is expected to provide matching funds in order to participate in whatever market opportunities arise from the collaborative work.

Office of Research and Development

Pacific Northwest is a major contributor to the Office of Research and Development programs in worldwide nuclear materials production detection, nuclear weapons test detection and monitoring, and nuclear materials diversion/smuggling detection. The Laboratory draws from its core capabilities in nuclear materials production, sensor systems, environmental monitoring, and nuclear intelligence to provide DOE and its customers with innovative solutions to pressing national security problems.

A critical area of concern is proliferation of nuclear, chemical, and biological weapons and their associated delivery vehicles. The DOE has an objective to detect and assess nuclear proliferation and to ensure that the U.S. government has the ability to enter into and evaluate compliance with existing and future bilateral and multilateral agreements controlling nuclear weapons and their proliferation. The Laboratory is focusing its national security technology capabilities to identify needs and develop technologies to monitor, detect, and analyze for indications of such proliferation.

Pacific Northwest is the lead laboratory for the Airborne Multisensor Pod System mission to Kazakastan in 1996. The objective of this mission is nuclear nonproliferation and confidence building with simultaneous support for international commercial enterprise in this former Soviet communist republic. U.S. industry is a major partner in this activity. The mission will deploy advanced remote sensing equipment to demonstrate its utility for nonproliferation as well as mineral and hydrocarbon exploration, and geological data acquisition for other purposes. It is hoped that it will serve as a model for similar missions to other Newly Independent States of the former Soviet Union. The Laboratory's ability to deploy scientific and arms control missions such as these is based in part on the indigenous airborne atmospheric sensor capability which has existed at the Laboratory for over 30 years.

The Laboratory, through the sponsorship of the Office of Research and Development, has developed remote monitoring instrumentation as candidates for use by the U.S. government and other governments worldwide for the monitoring of the Comprehensive Test Ban Treaty (CTBT). One device, the Automated Particulate Sampler System, is based on long-standing particulate radionuclide sampling and analysis techniques for atmospheric and vented underground test monitoring. It employs advanced methods and computer control to provide the necessary high sensitivity in real time in an easily operated, stand-alone configuration for deployment throughout the world. Another system, the Automated Radioxenon Analyzer is similarly configured, but is based on the novel detection and measurement of xenon-133 and other xenon gas-phase isotopes as unique indicators of recent (illegal) testing. These systems are strong candidates as components of the International Monitoring System for CTBT verification.

The Laboratory has also played a key leadership role in formulating an integrated diversion detection, "nuclear smuggling" program through the support of not only the Research and Development Office, but other Nonproliferation and National Security components as well. Laboratory activity is primarily related to attribution assessment through advanced nuclear forensic analysis, and is part of a multilaboratory capability that is being integrated to provide direct support to U.S. government agencies.

We support the DOE's treaty involvement through technology development, expert knowledge, and onsite support

in Washington, D.C.; the Conference on Disarmament in Geneva, Switzerland; the United Nations Special Commission (UNSCOM); and the International Atomic Energy Agency. A Laboratory staff member is also assigned as DOE's representative on the U.S. delegation negotiating modifications to the Anti-Ballistic Missile Treaty.

Office of Energy Intelligence

Pacific Northwest directly supports the DOE Office of Energy Intelligence in areas of nuclear nonproliferation, energy assessment, and intelligence support. We perform intelligence data processing and analyses that address national issues in weapons materials production, nonproliferation, energy resources, and other tasks as appropriate. The Laboratory further supports studies and application of technologies in special programs. Products and services provided to the DOE Office of Energy Intelligence contribute to the support of policymakers and the intelligence community. Additionally, in coordination with DOE's Office of Energy Intelligence, the Laboratory applies its capabilities and technologies to perform intelligence-related work for other government organizations.

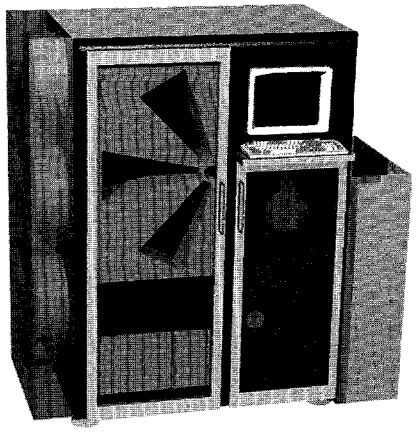
Office of Arms Control and Nonproliferation

Pacific Northwest directly supports the DOE Office of Arms Control and Nonproliferation in the specific functional areas of former Soviet Union materials, protection, control, and accounting; negotiations and treaty implementation; export control; and international safeguards. Laboratory staff serve in several key leadership positions related to nuclear threat reduction. Laboratory projects supporting the objectives of DOE's Office of Arms Control and Nonproliferation draw upon the Laboratory's substantial expertise in nuclear materials production, environmental monitoring, and nuclear intelligence.

The Laboratory participates as a member of the Materials Protection, Control and Accounting (MPC&A) Steering Committee coordinating DOE efforts to improve safeguards on nuclear weapons materials in the former Soviet Union, particularly the Russian Federation. Several staff serve on offsite assignments within DOE Headquarters leading the "government-to-government" component of the MPC&A Program under the direction of the Office of Arms Control and Nonproliferation. Laboratory staff are involved in many of the tasks associated with this highly visible and growing U.S. government activity.

The Laboratory also supports Office of Arms Control and Nonproliferation activities focused on strengthening the Nuclear Nonproliferation Treaty Regime. The Laboratory has played an important role in the effort to place excess weapons plutonium at the Hanford Site under international safeguards, according to the President's Voluntary Offer. Similarly, three Laboratory staff are the major part of the DOE technical team overseeing U.S. government assistance to the Democratic Peoples Republic of Korea (DPRK) in safely containing and disposing of DPRK reactor fuel under the Framework Agreement. Staff members were among the first foreign visitors to the Nyongbyon nuclear reactor complex, and are serving on a rotational basis onsite there until containment operations are completed in 1997. In looking for new ways to safeguard nuclear material, the International Atomic Energy Agency has been investigating environmental monitoring techniques. Monitoring the environment adjacent to suspected nuclear facilities has high probability of detecting effluents from nuclear processes. The Laboratory has been supporting this initiative through DOE.

The Laboratory provides scientific, engineering, and operations expertise from the DOE weapons material production complex for the negotiation and implementation of arms control treaties and agreements. The Laboratory has facilitated the use of the Hanford Site, a past weapons material production site, to provide "real world" familiarization and insight for the Conference on Disarmament's U.S. and foreign ambassadors and principals negotiating the Fissile Material Cutoff Treaty. The Laboratory staff support



Air Particulate Sampler for Comprehensive Test Ban Treaty verification.

DOE in the preparation, review, and analysis of U.S. government policy positions/options for the cessation of Russian plutonium production. The Laboratory also provides technical support for verification under the U.S.-Russian highly enriched uranium purchase agreement that the materials delivered to the U.S. Uranium Enrichment Corporation have been derived from Russian weapons-grade uranium. These examples illustrate the breadth of Laboratory arms control involvement, extending from the beginnings of policy formulation, through treaty negotiation, to follow-on treaty implementation.

The Laboratory supports DOE efforts with the 31-country Nuclear Suppliers Group that develops and institutes multilateral export controls to non-Nuclear Suppliers Group countries. Laboratory staff provide assistance to DOE under the Nuclear Suppliers Group by providing the technical justification for changes and modifications to the former International Atomic Energy Agency list and the U.S. recommendations for nuclear dual-use export control. In addition, other classified services to DOE in the technology export arena are provided. A Laboratory staff member also chairs a multiagency technical review group that addresses sensitive nuclear issues. The Laboratory acts as a technical reviewer for DOE on specific authorization requests by U.S. companies who wish to assist foreign

The portable Advanced Imaging System (AIMS) can be used by physicians, physician assistants, and medics to quickly assess life-threatening injuries at the battlefield and other emergency sites. AIMS provides on-the-spot visualization of fluid collections, injuries to solid organs, and penetrating injuries. It also may be used as a telemedicine tool to relay images to radiologists or surgeons geographically separated from the injured person.

atomic energy activities. Laboratory capabilities are applied in support of the DOE role in developing the nuclear-related technology sections of the Military Critical Technologies List. Laboratory staff are also members of a U.S. delegation headed by the U.S. Customs Service to assess and train Newly Independent States non-weapons states on export controls of strategic and dual-use materials. As part of this activity, Laboratory staff are called upon to provide training and technical support to U.S. Customs staff on various nuclear nonproliferation issues and technical matters.

Office of Security Affairs

Pacific Northwest activities for the Office of Security Affairs cover four major areas that provide strong linkages across the Nuclear Safeguards and Security Program. Each of the major activities addresses significant portions of the overall protection program and focuses on integrating these portions to enhance the effectiveness and efficiency of the operation. The primary areas addressed by the Laboratory include 1) Information Security planning, policy, practices, and procedures; 2) Material Control and Accountability technology transfer, performance-based policy implementation, technology and procedural alternatives; 3) management assessment techniques and resource review support; and 4) national level initiatives of Arms Control and Nonproliferation impacting domestic safeguards and security.

Major assumptions used in the formulation of these activities are 1) DOE's assets requiring protection have increased but changing missions require consolidation and more efficient use of technologies to reduce operational costs and facilitate accessibility to the complex; 2) national level policy on security is undergoing dramatic changes; 3) significant changes are required at DOE facilities to prepare for the implementation of arms control and nonproliferation treaties that will permit intrusive inspections by international agencies and foreign individuals; 4) DOE's openness initiatives and economic competitiveness must be addressed, and sensitive technology and some level of the nuclear weapons program must be protected in this environment; and 5) DOE Headquarters' organizations and field components must work in concert to solve issues that cross traditional management structures (i.e., safety, health physics, safeguards, etc.).

The development of performance-based implementation guidance that recognizes the need for flexibility across the DOE complex and the ability to provide assistance to field elements to implement this guidance will strengthen DOE Headquarters' support to field elements and facilitate the implementation of cost-saving safeguards and security measures while meeting customer and stakeholder needs.

The preparation of DOE facilities for inspections under the auspices of international treaties will provide visibility for DOE as a leader in the formulation of national security-related policies and procedures and will further the success of the associated national level initiatives.

The identification, dissemination, and transfer of technology, practices, and procedures across the DOE complex will ensure that a state-of-the-art safeguards and security program is in place and capable of providing effective and efficient protection for DOE assets, including accountability and control of special nuclear material.

This program is directed toward supporting DOE's overall mission, and the success of these activities will lead to DOE's ability to open many facilities for decontamination, decommissioning, and alternative uses.

Laboratory support to Security Affairs is expected to remain stable but the

technical challenges should grow in complexity as the operational goals of DOE continue to change.

Office of Emergency Management

Pacific Northwest supports the Office of Emergency Management in the determination of technical requirements and the development and deployment of technical systems in support of mission needs. The Laboratory participates in the coordination with other government agencies led by this office. The Laboratory also supports the Office of Emergency Management through a direct high-speed communication link between DOE Headquarters and the Laboratory. Using the Emergency Operations system, Laboratory scientists can provide real-time analysis and support during emergency situations where expertise is needed to manage and solve real-world problems. This computer system is available on a 24-hour basis.

Science and Technology Partnerships

Pacific Northwest's long history of working with industry to "Put Technology to Work" provides us with a unique perspective on how to leverage federal investments in mission-oriented research to solve industry problems.

In this context, the Laboratory's objectives for improving U.S. economic productivity are to

- develop and implement science and technology partnerships with industry segments, other DOE laboratories, and academia
- balance market pull with technology push in Laboratory programmatic activities
- shorten the technology life cycle from research to commercial deployment through cross-functional parallel activities
- assist government and industry in moving from cleanup to waste minimization and pollution prevention (i.e., toward sustainability)
- leverage federal investments and the combined talents of the DOE laboratory system and Battelle to diversify the local Tri-Cities and Northwest regional economies, strengthen their export potential, and create new high-wage jobs.

Key elements of the Laboratory's science and technology partnerships strategy are the Office of Research and Technology Applications, Industry-Laboratory Cooperative Projects, Designated User Facilities, Patents and Software Licensing, and Recognition and Awards.

Under the Laboratory's new business model, five mission areas are accountable for the entire cycle of research, development, and commercialization of technologies within their approved business lines. We use a number of approaches to market including conventional (1830) contract research and development, proprietary research through our Use Permit (1831 contract), Cooperative Research and Development Agreements, technical service agreements, joint ventures, limited liability partnerships, and licensing. These approaches are tailored to the customer's needs in a truly market-driven, user-friendly business relationship.

In addition, we facilitate partnerships between local/regional stakeholders and the Laboratory's mission-aligned divisions through the Economic Development Office, which promotes technology development and commercialization for local/regional job creation. The four primary Economic Development Office markets are agribusiness, environmental products and systems, medical products, and energy systems, which capitalize on the Laboratory's capabilities and the area's strengths. The Economic Development Office primarily targets newly created businesses and small, growing businesses in contrast to the larger business emphasis of the divisions. But the goals are the same—to contribute to the growth of a diversified technology-based economy that provides high-value jobs for a well-educated U.S. work force.

Within the Economic Development Office are four broad program areas: Entrepreneurial Programs, Small Business Technology Programs, Technology Partnerships, and Designated User Facilities, which include our management of the Tri-Cities Science and Technology Park, the Advanced Process Engineering Laboratory project, and the Agribusiness Commercialization and Development Center.

Office of Research and Technology Applications

The Office of Research and Technology Applications (ORTA) was established by the Stevenson-Wydler Technology Innovation Act of 1980 to promote technology transfer activities at federal research and development laboratories. At Pacific Northwest, ORTA (in the Economic Development Office) provides a single point of contact into the laboratory from outside. ORTA also provides an interface with DOE Headquarters and a link to the DOE laboratories. This role has been and continues to be especially important during this time of transition for both the Laboratory and DOE technology transfer programs. The Laboratory ORTA is responsible for four major areas mandated by Stevenson-Wydler; these are outlined below.

ORTA is responsible for developing and managing innovative technology commercialization mechanisms and initiatives (such as the Entrepreneurial Leave of Absence program, a major focus). To meet this responsibility, ORTA leverages federal funding and local seed capital and provides financial assistance to facilitate entrepreneurial activities. The Entrepreneurial Leave of Absence (see "Entrepreneurial Programs" below) is a young, innovative program designed to create technology-based local firms and high-value jobs outside the Hanford Site. With help from other divisions of the Laboratory, ORTA continues to develop policies, budgets, and encouragement for Laboratory staff to help move our technologies into the local and regional marketplace quickly and effectively. One strategy has been the recent addition of an 800 number

for ORTA. Signs encouraging potential partners to use the number have been posted in the Tri-Cities and Seattle-Tacoma airports.

ORTA is also responsible for cooperating with and assisting local, regional, and national organizations that link research and development resources of the Laboratory and the federal government to potential users (a major strength). ORTA works with technology transfer organizations on all levels from the Tri-City Industrial Development Council (TRIDEC) to the 600-plus laboratory members of the Federal Laboratory Consortium. The Consortium, moreover, provides a system for working directly with industry. The result of these links is federal support for technology commercialization initiatives and related activities as well as strengthening the Laboratory's image as the regional technology resource of choice.

In compliance with Stevenson-Wydler, ORTA also reports information about Laboratory partnerships (licenses, CRADAs, new companies, etc.) by preparing and transmitting success stories via electronic and print media as well as presentations and personal contacts, including travel, telephone, and video conferences. Now that the responsibility for commercializing technology has been delegated to the Laboratory divisions, ORTA depends on the Laboratory network of technology commercialization stewards to provide the information necessary for effective reporting to DOE and others in the local and federal sectors.

Finally, Stevenson-Wydler requires ORTA to maintain current knowledge of relevant technology-transfer-related laws, regulations, and orders to ensure Laboratory compliance. Because knowledge of relevant federal legislation, infrastructure, and philosophy is critical to strategic planning for technology development and commercialization, this responsibility is especially important during this time of transition with DOE and within the Laboratory. ORTA's familiarity with federal technology transfer legislation, initiatives, and other activities regarding technology partnerships and commercialization is expected to strengthen the Laboratory's position in federal and private sectors as the most relevant and productive supplier of science and technology in those areas where we concentrate our efforts.

Industry-Laboratory Cooperative Projects

Industrial partnerships play an important role in 1) enhancing the Laboratory's core competencies, 2) meeting the goals of DOE's core missions, and 3) reindustrializing the local and regional economy in the post-Hanford era. As a multiprogram laboratory, Pacific Northwest believes that working cooperatively with industry enhances research results and leverages both private and public funding, while promoting economic growth and creating high-wage jobs.

Our collaborative projects with industry range from creating new businesses with entrepreneurs to working with large industrial consortia and are described below.

Entrepreneurial Programs

Entrepreneurial programs within the Economic Development Office provide a broad range of assistance to entrepreneurs wishing to start up new technology-based business in the area. This includes access to intellectual property, market assessment and business plan assistance, equipment and facilities, and very early-stage financing. Linkage to the Tri-City area's Entrepreneurial Support Network broadens our support to include training, incubator space, business services, and small loans.

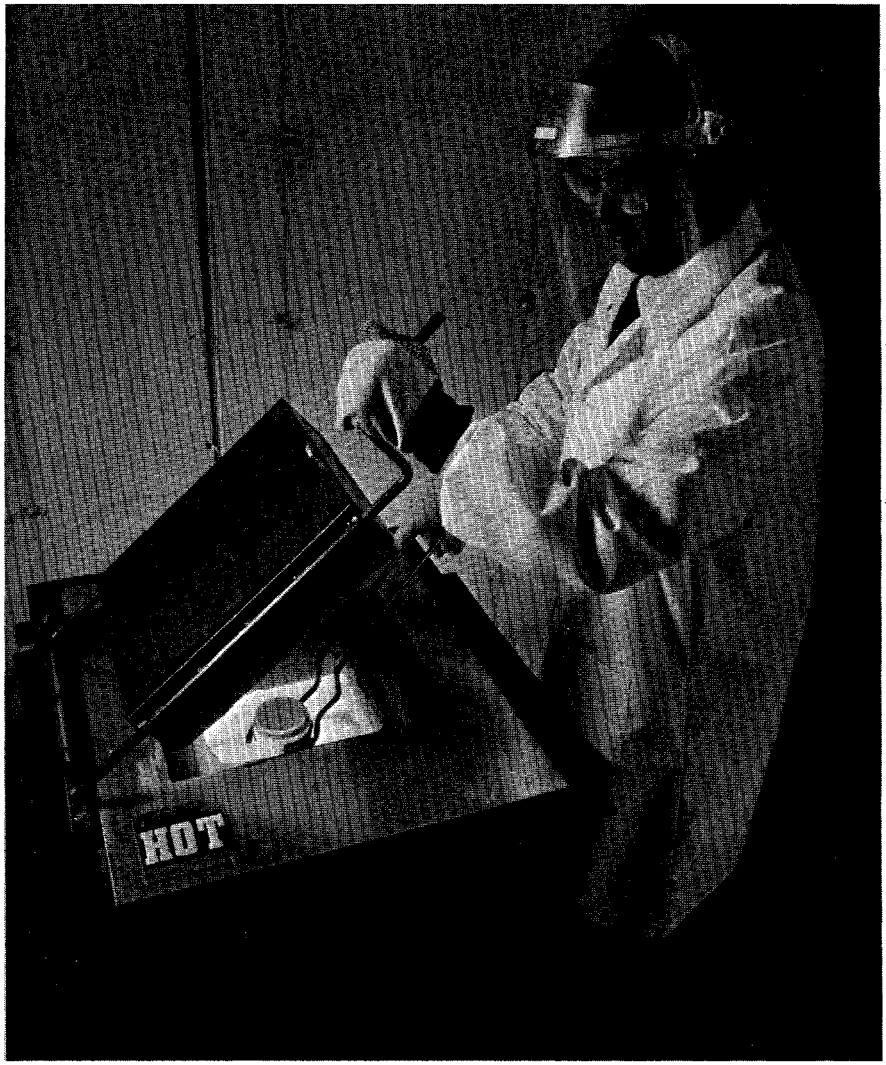
As noted earlier, late in FY 1995 we initiated an Entrepreneurial Leave of Absence program for Laboratory staff. Under this program, approved staff are able to take up to a 3-year leave of absence with benefits to commercialize Laboratory technologies. Since program inception, we have started eight new local businesses ranging from medical products to agricultural services.

1. **Credit Card Solutions, Inc.**, will design, sell, and install software products for the business credit card industry. The company was started by three Laboratory staff members, the first to take advantage of the Laboratory's Entrepreneurial Leave of Absence program. The software is based on software developed at the Laboratory to implement and operate an ongoing Laboratory program.
2. **KLM Analytical** uses x-ray fluorescence to provide economical, rapid analysis of a wide variety of samples including water, paint, and glass. Equipment was transferred from the Laboratory, and our Richland and Sequim laboratories have provided samples for analysis, thus serving as the first customers.
3. **Alligator Corporation** serves the environmental industry by commercializing selected Pacific Northwest technologies through partnerships with dominant firms in waste minimization and pollution prevention. Battelle licensed its technology for conversion of wet biomass to methane to Alligator Corp. The Laboratory is also providing technical assistance.
4. **Infometrics, Inc.**, commercializes software for public education and to assist small businesses in understanding and fulfilling their regulatory reporting requirements. The company will develop information-based software and provide software development services to other companies.
5. **Integrated Environmental Technologies** uses its award-winning technology for plasma electroconversion to convert a variety of waste streams into a nonhazardous, usable, glass product and a useful combustible gas. The technology was licensed from Battelle.
6. **BetaScint, Incorporated** provides fiber-optic-based radiation sensors for sale or hire in support of environmental restoration, treaty verification, and routine monitoring activities throughout the world. The company is a joint venture with The Belhaven Group. BetaScint has obtained a license from Battelle, and the Laboratory is helping identify markets and locate potential local partners and financial resources.

7. **XL Sci-Tech, Incorporated** is developing for commercialization a new bone-like structural material made of calcium phosphate glass. The new material is absorbed by the human body and thus could eliminate the need to remove metal plates and pins inserted previously to repair broken bones. The company was started through the Laboratory's Entrepreneurial Program, although the technology was developed before the inventor was employed by the Laboratory. The Small Business Innovation Research program has awarded the firm a research grant, and a CRADA with the Laboratory is being sought. The Laboratory is also providing technical assistance and pursuing the loan of equipment to the new firm.

8. **Valley Vine Machinery Company** is a new firm created through the Laboratory's Entrepreneurial Program. The company will be manufacturing a new tool, a tractor-mounted mechanical grape pruner for the grape juice and wine industries. Valley Vine Machinery Company will eventually provide pruning services to regional growers as well as fabricate and sell pruners to growers who wish to prune their own vineyards. The Laboratory is providing technical assistance, market assessments, and space for the new business.

We have also created two new businesses combining Laboratory resources with outside entrepreneurs. One is a medical products firm, the other a recreational sports product business. Based on the "deal flow" currently in process and the broad regional interest, we project five to ten new businesses being created annually. However, the limiting factors are neither technology nor the availability of entrepreneurs, but the limitations on resources, particularly seed capital and suitable incubator space. Hence, the emphasis in these programs for the foreseeable future will be to network with venture capital groups and work with our area's industrial parks to create the necessary work space.



XL Sci-Tech is developing new materials—glass-reinforced composites made by reinforcing standard resorbable phosphate fibers or particulates.

Small Business Technology Programs

Small business technology programs support the goals of 1) expanding existing businesses, attracting outside industry, and growing new businesses by initiating long-term relationships with select small businesses to accelerate their growth and create new jobs in the community; 2) conducting small business outreach; and 3) managing the DOE-funded Technical Assistance Program, which provides technical assistance at no charge to firms that request it. Technical assistance is defined as short-term efforts focused on assisting companies, local governments, or trade organizations with specific technical problems and to improve efficiency and production. The Laboratory continues to expand its technical assistance with U.S. firms, especially those in the Northwest.

The Office of Small Business Programs within the Economic Development Office provides access to staff expertise and specialized facilities of the Laboratory and other federal laboratories. It is managed by a full-time Laboratory staff member with research and industrial experience, who serves as a window to the Laboratory and federal

laboratory system capabilities. The office works with the region's small- and medium-sized businesses with emphasis on women-owned and minority-owned businesses to help them launch new commercial products, expand their production, address key technical problems, and be more competitive in the commercial world. In February 1996, the office manager was awarded the 1995 Technology Partnerships Customer Service Award for Individual Achievement by the Secretary of Energy.

In FY 1995 we assisted 60 small businesses in this manner, and in FY 1996, 70 more. The majority of these businesses are within 60 miles of the Laboratory and all but a few are in the Northwest region. Interest is outstripping our small Energy Research-Laboratory Technology Research (ER-LTR) budget. A grant was received from DOE's 3161 Economic Transition program to provide technical assistance to local firms.

We also assist small businesses in applying for research grants under the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. Assistance for these programs consists of notifying firms of relevant topics that are available, providing samples of winning proposals from the past to use as models, and locating researchers at the Laboratory with whom small businesses can collaborate.

In addition, we will assist small firms by making available unique equipment at the Laboratory, special analytical services, literature searches, and, in some cases, may loan equipment. Traditional technology commercialization mechanisms, such as CRADAs, staff exchanges, and licenses, are also used.

Some examples of the program's more recent accomplishments are

- consulting help to a Tacoma inventor on a new snowboard design that is the basis for a new recreational sports firm
- consulting help and prototypes to a local physician on a device for drug delivery, which has led to an SBIR proposal, a CRADA, and pre-clinical trials of the device
- a cooperative effort between Laboratory staff and a southwestern Washington engineering firm, which has led to novel microtechnology that could improve the efficiency of commercial HVAC systems
- collaboration on an SBIR project with a Spokane software firm to improve wide-area computer networking technology
- a recent winning STTR proposal, which has teamed the Laboratory with a small local firm to develop a Stirling cycle engine.

This office coordinates closely with the Small Business Development Centers located at Washington State University and the University of Oregon, which have offices in every community college in the states of Washington and Oregon. Through these links, we have participated in three technology exhibitions so far in FY 1996 in Portland, Yakima, and Spokane and had articles published in five regional commerce publications.

The Office of Small Business Programs also coordinates with the Business Assistance Center at the Washington Department of Community, Trade, and Economic Development; the Washington Technology Center; Spokane Intercollegiate Research and Technology Institute (SIRTI); TRIDEC; the Oregon Economic Development Department; and the Advanced Science and Technology Institute in Oregon. This coordination allows all of the organizations to leverage their respective resources and provide a more complete service to the region's businesses. For example, through the Washington Technology Center and SIRTI relationships, we were able to help three local businesses propose projects this fiscal year in response to the calls for proposals.

Future plans will depend on funding available from ER-LTR and/or 3161 grants. But, we have the network in place in Washington, and started in Oregon and Idaho, so that technical assistance to as many as 100 businesses annually is attainable.

Technology Partnerships

We create technology partnerships with universities, other DOE laboratories, and industry in all our mission areas to ensure that the best technical resources are brought to bear on challenging technical issues. Today's challenges require complex products to be developed, and a team approach is essential. We use a variety of mechanisms depending on the customer's needs. It may simply require a personnel exchange or it may demand a large industry/academic consortia.

Personnel Exchanges Under personnel exchanges, Laboratory staff may be assigned to work onsite with companies for up to 1 year to assist in technology development and application. In other cases, personnel may come to work at the Laboratory where they will have direct access to the expertise and facilities for a given task. Personnel exchanges are an excellent mechanism for the DOE laboratories and private-sector organizations to become familiar with each other's interests and capabilities to provide a basis for more extensive future interactions through other means (for example, cooperative research and development projects).

Nearly all of the Laboratory's formal personnel exchanges are conducted with support from the ER-LTR program. The Laboratory has participated in personnel exchanges with industry and universities since the program was initiated in 1985. Exchanges are proposed whenever interests, objectives, and schedules coincide. These exchanges have brought representatives to the Laboratory from approximately eight different companies and one university. In addition, we have sent 15 of our staff members to industry. Further details on these exchanges are provided in the program plan for the ER-LTR program presented in the Science and Technology section of this plan. Because of FY 1996 funding reductions in this program, only two formal personnel exchanges are planned for FY 1996. This number is anticipated to increase slightly in FY 1997 if the program is funded at the proposed level. Personnel exchanges may also increase as a result of the future

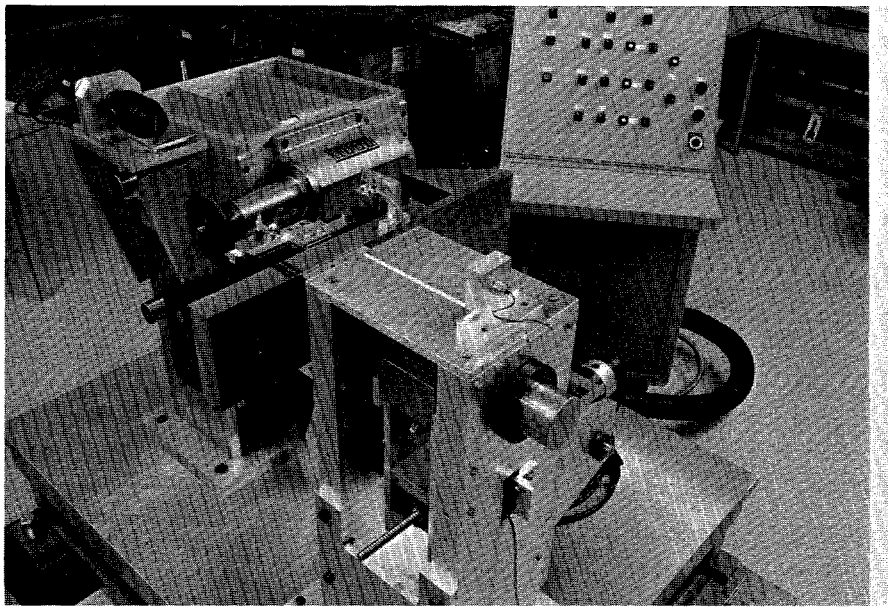
operation of the EMSL, although a specific source of funding for such exchanges has not yet been identified.

Cooperative Research and Development Agreements Some of the Laboratory's partnerships are achieved through CRADAs. Under these contractual agreements, partners agree to collaborate, share costs, and pool the results of a particular research and development program. CRADAs provide an important mechanism for the Laboratory and other DOE laboratories to enhance their capabilities, leverage resources, and assist U.S. industry. At the Laboratory, the creation of CRADAs is energized by a supportive DOE Richland Operations Office that reviews and approves the Laboratory's proposed CRADAs in a few days to a few weeks.

In the past, the Laboratory has made numerous verbal and written announcements inviting partners to enter into CRADAs. Funding was available to specifically support CRADAs, and the number and value of CRADAs grew substantially. In FY 1995, we signed and initiated 25 CRADAs, giving a total of 85 signed CRADAs with a combined total value of $68.8 million since the authority to enter into CRADAs was received in 1990. Approximately one-third of these 85 CRADAs have now been completed, providing beneficial results to both the industry partners and the Laboratory. In FY 1995, we had a record number of amendments to existing CRADAs signed (18).

The Laboratory anticipates that FY 1995 will represent the record year for CRADA initiation for the foreseeable future. Funding for the ER-LTR program, which has historically funded the majority of the Laboratory's CRADAs, was reduced substantially in FY 1996. In addition, with the exception of DOE-EE, other DOE programs have not indicated significant interest in supporting cooperative research and development activities through CRADAs. As a result of these factors, the rate of initiation of new CRADAs at the Laboratory has fallen substantially in FY 1996, and is not expected to increase significantly in the foreseeable future.

1996 FLC Award Winner



Pacific Northwest researchers developed and transferred an automated tool profile grinding machine. They used their expertise in automated control systems to assist Freeborn Tool, a small company in Spokane, in replacing its conventional manual, pattern-based process for manufacturing wood shaper tools with an automated tool profile grinding machine. The new machine can produce tools with easily replaceable tips, thus opening the door to an entirely new product line for Freeborn Tool. When Freeborn Tool first expressed interest in the Laboratory's expertise but could not afford a major development contract, the team provided access to the Lab's research and development capabilities through a staff exchange and then a Cooperative Research and Development Agreement.

Most of the new CRADAs that are being initiated involve multiple DOE laboratories, multiple industry partners, and/or involvement with small business. A few of our most recently signed CRADAs are listed below, along with the relevant DOE supporting office:

- SciBus Analytica, Inc.—A multilaboratory CRADA involving Los Alamos National Laboratory, Sandia National Laboratories, Oak Ridge National Laboratory, Idaho National Engineering Laboratory, Pacific Northwest National Laboratory, and SciBus to develop improved methods of automated contaminant analysis (funded by the DOE-EM program).
- American Society of Mechanical Engineers (ASME)—A multilaboratory CRADA involving Oak Ridge National Laboratory, Idaho National Engineering Laboratory, Pacific Northwest National Laboratory, and ASME to develop improved aluminum alloys that require less heat treatment in processing and fabrication (funded by the DOE-EE program).
- Soph-ware Associates—A CRADA funded directly by the industry partner (Soph-ware Associates) through a SBIR grant to develop improved distributed multimedia computer software architecture.
- Earth Search Sciences Inc.—A CRADA to assess mineral deposits and provide other important geophysical measurements through an Airborne Multisensor Pod Systems (AMPS) Mission to Kazakastan

(funded by the Office of Nuclear Nonproliferation, DOE-NN).

- Department of Defense, Sterling Reflector and Daniel Karpen—A CRADA to evaluate full-spectrum polarized lighting technology in applications at a Department of Defense installation and to broadly communicate the results of this evaluation (funded by the DOE-EE program).
- Department of Defense and Polarized Lighting Incorporated—A CRADA to evaluate light-polarized panels in applications at a Department of Defense installation and to broadly communicate the results of this evaluation (funded by the DOE-EE program).

Industry Consortia Pacific Northwest has been a key participant in the development of several major industry partnerships that are currently ongoing between DOE, its laboratories, and major U.S. industries. Several specific research projects have already been initiated within the context of these partnerships. We plan to continue to pursue these partnerships. Examples of ongoing projects in which the Laboratory is participating include

- AMTEX—Demand Activated Manufacturing Architecture (DAMA)—To define, develop, integrate, and deliver the architecture and tools of an electronic marketplace that will enable all sectors of the U.S. textile industry to reduce costs and increase responsiveness.
- AMTEX—Textile Resource Conservation Project (TReC)—To assist the U.S. textile industry in developing and implementing technology to conserve natural resources and reduce environmental impacts of their manufacturing operations.
- AMTEX—On-line Process Control for Flexible Fiber Manufacturing (OPCon)—To develop on-line measurement systems of key fiber properties that will enable industry to increase their flexibility and responsiveness while saving energy and reducing waste.
- USCAR—Low Emissions R&D Partnership—Cylinder Design for Reduced Emission Origins—To bring the latest diagnostic technology to bear on the characterization of dynamic temperatures and processes occurring within an engine cylinder.
- USCAR—Low Emissions R&D Partnership—Metal Matrix Composite Gears—To develop metal matrix composite gears with reinforcing materials only in the teeth so that the center can be machined and attached. These aluminum gears replace steel gears that weigh twice as much.
- USCAR—Low Emissions R&D Partnership—Ultra High Durability, High Temperature Spark Delivery System—To develop an ignition system for lean burn engines.
- USCAR—Environmental Research Consortium—Instrumentation for High-Speed Analysis of Vehicle Emissions—To develop new technology for rapid and accurate measurement of low levels of specific compounds contained in vehicle exhaust. Funding for this project is being supplied by the ER-LTR program.

The Laboratory's efforts in the AMTEX projects have been supported by the ER-LTR program. Funding support for FY 1997 is slated to come from DOE-EE Office of Industrial Technologies. Funding for the USCAR projects is being supplied by the DOE-EE and -ER offices.

The Laboratory believes that the establishment of successful partnerships with U.S. industry and other external organizations is an important element of its future. The Laboratory has been a leader in establishing major industry-led partnerships, such as those mentioned above. Our interest in such partnerships is a reflection of the Laboratory's long-standing commitment to serving industry and putting technology to work.

However, the present political climate and budget situation for major industry partnerships indicates that few such partnerships will be established in the foreseeable future. In fact, retaining support for partnerships that have already been established will be difficult. For the foreseeable future, the Laboratory plans to focus its efforts on participating in the existing AMTEX and USCAR partnerships. Involvement in other partnership efforts will be minimized until political and budgetary support for such efforts evolve.

Another approach to joint technology development with industrial consortia is via membership in key technology trade associations throughout the Northwest, including the Washington Software Association, American Electronics Association, and the Washington Biotechnology and Biomedical Association. Active support and participation in these organizations provides the Laboratory with a strong presence in the Northwest region which fosters more effective transfer of technology into the industrial sector.

Activities in the Washington Software Association include membership on the board of directors, participation in the Education Committee, and formation and leadership in the Washington Software Association-sponsored Digital Media Alliance. A Laboratory staff member provides oversight and direction for the newly formed Digital Media Design Laboratory at the University of Washington. Other activities include leadership in the Washington Software Association scholarship program and coordination of grant application and awards to Eastern Washington educational institutions.

Laboratory staff also participate in regional conference and business development activities of the American Electronics Association and plan to become more active by assuming a position on the board of directors in the Washington Biotechnology and Biomedical Association.

Use Permit As an alternative mechanism to CRADAs, industry can enter into a technology partnership with the Laboratory via the Use Permit. This permit allows Battelle to contract directly with private industry for conduct of research and development activities by Laboratory staff that can remain proprietary indefinitely.

The Use Permit has proved to be a valuable mechanism for facilitating

the use of the Laboratory's technical resources to assist U.S. industry and for tailoring available technology for application by industry. At the beginning of FY 1995, we had 118 active contracts with industry under the Use Permit with a value of $32.1 million.

Local/Regional Economic Development A key part of our Economic Development Office function is to use Laboratory technology to partner with firms outside the region and cause or influence their relocation to the area. Alternatively, we use our technology in partnership with larger firms with divisions in the area that will result in their expansion. In most cases, Hanford cleanup needs provide the initial market for the technology or service. Some examples of Economic Development Office success stories in this area include

- a deal involving a Laboratory license for waste stabilization technology (Terra-vit™) and a site in the Tri-Cities Science and Technology Park will result in a new venture for an out-of-state firm
- a CRADA with the Laboratory and loan of key staff is the basis for a new environmental division of a large international firm
- a Memorandum of Understanding with a local Fortune 1000 firm for technology commercialization from the Laboratory should lead to growth of business unrelated to Hanford
- joint proposals between the Laboratory and a large consulting engineering firm to other funding agencies, if successful, will result in new jobs for both organizations.

Designated User Facilities

When commercializing technologies, a company's needs can sometimes be met best through the use of specialized equipment or facilities that are available at the Laboratory. Our strategy to meet these needs is built around the leadership and management of the Tri-Cities Science and Technology Park, which is intended to be the area's center for rapid deployment of technologies and local designated user facilities. Occupants of the 2,600-acre park include the Washington State University branch campus, the Laboratory, and about 60 business and technical organizations involved in life sciences, energy, advanced materials, and environmental cleanup development. Demonstration zones, user facilities, and product centers within the Park are intended to support the rapid deployment of both Hanford and Laboratory technologies for commercialization. Scientific and environmental problems are being solved by combining talents, resources, and organizations with state-of-the-art technologies. For example,

- As described earlier, Pacific Northwest's $230 million EMSL will serve as a national collaborative research and technology laboratory, providing educational and training opportunities for future scientists. Scheduled to open in FY 1998, the new laboratory will make a number of unique research resources (for example, 900+ megahertz nuclear magnetic resonance equipment) available to the external scientific community.
- The $6.5 million Advanced Process Engineering Laboratory (APEL), a joint project with DOE, the City of Richland, Port of Benton, and Washington Public Power Supply System, will refurbish an existing facility to create a permitted, high-bay incubator that will spin off new technology-based enterprises focused on environmental remediation and pollution prevention. Several new businesses have already requested space in the APEL to pilot their technologies and transition to manufacturing. However, a decision to move forward on this project is predicated on receipt of 3161 funds from DOE.
- The Agribusiness Commercialization and Development (ABCD) Center was established to stimulate local economic development and diversification by providing an atmosphere and infrastructure that encourage the seeding of new businesses into the commercial/private sector. The ABCD Center serves as a technical resource and liaison between prospective companies and other sources of information and technology, and helps rapidly deploy Hanford/Laboratory technologies to support agribusiness from field to production. It assists local agribusiness firms and entrepreneurs in commercializing technologies by finding investors, recruiting manufacturers to relocate in the area, promoting new technologies, and creating new businesses. Current ventures include a new food irradiation business, a joint effort to develop a smart irrigation system, a project to apply a biotech invention to denitrify local well water, and a joint venture to build a local canola oil plant.
- The Hanford Demonstration Zone is a joint effort between DOE-Richland Operations Office, the state and local regulators, the Laboratory, and site contractors to provide an approved infrastructure for testing and demonstrating new and mature technologies applicable for site cleanup needs. The members of this partnership will, through the implementation of the Hanford Demonstration Zone, enhance the effectiveness of site cleanup efforts by ensuring that best-in-class technologies are identified in response to needs; that new environmental treatment technologies are rapidly tested, demonstrated, certified, and deployed through innovative licensing, procurement, regulatory, and technology partnership mechanisms; and that the technologies advance rapidly from demonstrated prototypes to commercialized products whose owners will add to the cluster of environmental technology companies in the mid-Columbia region surrounding Hanford.
- Two product development centers working in conjunction with the community and private sector for initiation in late FY 1996 are the 1) Advanced Recycle and Reuse Center (ARRC), which will apply advanced technology to recover useful products from municipal waste and 2) Tri-Cities Medical Enterprise Center, which is modeled after the ABCD center and will facilitate the deployment of Laboratory technologies into medical products and health service businesses in the region.

Intellectual Property and Licensing Activities FY 1995

Invention disclosures received	143
U.S. Patent Applications Filed	49
U.S. Patents Issued	17
Foreign Patent Applications Filed	25
Foreign Patent Applications Issued	3
Patent Licenses Executed	10
Copyright Licenses Executed	7
Other License Agreements	10
Royalties Received	$242K

Patents and Software Licensing

As discussed earlier, under the new business model the responsibility for intellectual property development and deployment is vested in the research divisions. Each division has one or more intellectual property stewards who are associated with the business and product lines and have expertise in technology commercialization. This approach enables the alignment and use of intellectual property in the most effective way relative to the research markets of the division and improved decision making for technology deployment through a variety of mechanisms. Alternative uses of intellectual property include increasing the uniqueness of our product offerings, licensing, the basis for the formation of new (spin-off) business ventures, use in contract research for both government and industrial clients, technical publications, and various forms of release to public domain.

Intellectual property is both internally developed and externally acquired to meet customer needs. As part of that process, each organization has selected those pieces of intellectual property that are most closely aligned with the strategic intents of their product lines and will deploy them as their core intellectual property. The rest of the intellectual property portfolio in their care, the non-core part, is to be made available for deployment and commercialization through any prudent and reasonable means with preference given to benefiting the local and regional economy. The Economic Development Office plays a key role in the deployment and commercialization of non-core Laboratory intellectual property through their outreach programs and the newly created Entrepreneurial Leave of Absence Program.

We seek the involvement of industry as early as possible to gain an accurate perspective of the marketplace demand for Laboratory products and technology. This also enables us to obtain their guidance in technology development so that the resultant products not only meet the objectives of the government-sponsored research but are ready for commercialization by our partners. We also rely upon independent outside market analysis firms to evaluate our technologies in order to place discretionary investments in areas having the greatest potential return on investment.

Our intellectual property protection strategy for the future will focus more attention on key inventions and collections of inventions related to key mission areas and the most attractive commercialization opportunities. In seeking industrial partners earlier, we will also seek their sponsorship for patent protection and maintenance costs. We will file for foreign patents only when the technology has a clear worldwide market potential. Because these decisions are now made within the research division product lines, it is expected that market-driven actions will be taken in a more timely fashion.

The table summarizes the Laboratory's FY 1995 intellectual property and licensing activities.

During FY 1995, several key licenses were signed with U.S. industry. For instance an electronic dendrometer that measures stress on plants (the same as a heart monitor provides physicians with feedback on the human heart) was licensed to Dynamax, Inc. Unlike the heart monitor, however, the dendrometer also gives botanists readings on environmental factors such as air temperature, wind speed, solar radiation, precipitation, soil temperature and soil moisture, all by measuring the minute change in plant stem thickness. These instruments have value throughout the world to increase crop production by monitoring the effects on plant life of air pollution and providing bioassays for environmental studies and predicting forest fire potential.

Several of the Laboratory's previously licensed technologies are now achieving commercial success. For example, two Laboratory scientists developed the Ion Chamber Check Source, an inexpensive instrument used to verify the accuracy of radiation survey equipment in the field. Its principle of operation involves checking all operating ranges of the survey meter without changing the position of the source or chamber. It uses a strontium-90 beta source with a rotating filter wheel to change radiation levels. Its spring-loaded shutter greatly improves safety for the operator. Over 30 units were fabricated at the Laboratory for Hanford Site research. Battelle licensed the technology to Isotope Products of Burbank, California, who has refined, manufactured, and marketed the instrument. They have made commercial sales to industrial customers as well as government agencies or contractors.

Through a partnership between Pacific Northwest and a small industrial firm, high-quality ceramic powders used in the manufacture of several high-technology products can now be produced rapidly and efficiently. In this project, a materials synthesis process, known as the glycine-nitrate process, was developed by the Laboratory

in its science programs and was transferred for application by an industry partner, Seattle Specialty Ceramics, Inc. The process is now providing benefits back to the Laboratory and DOE programs through the availability of high-quality powders for research and development programs. Through a license and multiyear CRADA with the Laboratory, Seattle Specialty Ceramics was able to refine the technology for commercial use and begin sales less than 2 years after the CRADA was initiated. The customer base in August 1995 included seven universities, four national laboratories, nine U.S. corporations, and six foreign corporations. The glycine-nitrate process was recognized with an R&D 100 Award in 1992, and the developers received a Federal Laboratory Consortium Award for Excellence in Technology Transfer in 1993. The ceramic powders are used in multicomponent solid-oxide fuel cells, ceramic engine parts, complex ceramic oxide films for protective coatings, improved gaseous separation, and other products.

Environmental technologies developed at the Laboratory are also being commercialized. These include, NitRem, a dual-use hydrothermal technology with wide applications to both military and commercial aqueous wastes, and the Dual-Shell Reactor, which enables economical, large-scale, high-pressure processing of corrosive substances. The Dual-Shell Reactor is uniquely suited to high-pressure aqueous oxidation reactions. An exclusive license for the NitRem and Dual-Shell Reactor technologies was consummated with Innotek Corporation of Little Rock, Arkansas. Innotek has entered into a global marketing agreement with Foster Wheeler Corporation and won a contract to build a NitRem demonstration plant at Radford Army Ammunition Plant. Other team members include Pacific Northwest National Laboratory, the National Defense Center for Environmental Excellence, Glitsch Process Systems Inc., and the Texas Regional Institute for Environmental Studies.

Laboratory staff also developed the Catalyzed Electrochemical Oxidation technology that safely and inexpensively turns hazardous wastes into harmless compounds like CO_2 and water. Under a licensing agreement, EOSystems of San Jose, California, has obtained exclusive rights to market waste-handling systems using catalyzed electrochemical oxidation technology. EOSystems and its partners will provide various levels of service, ranging from simple service contracts on capital equipment to complete onsite waste management services.

The following tables summarize and project the Laboratory's technology transfer effort as well as its licensing income and use.

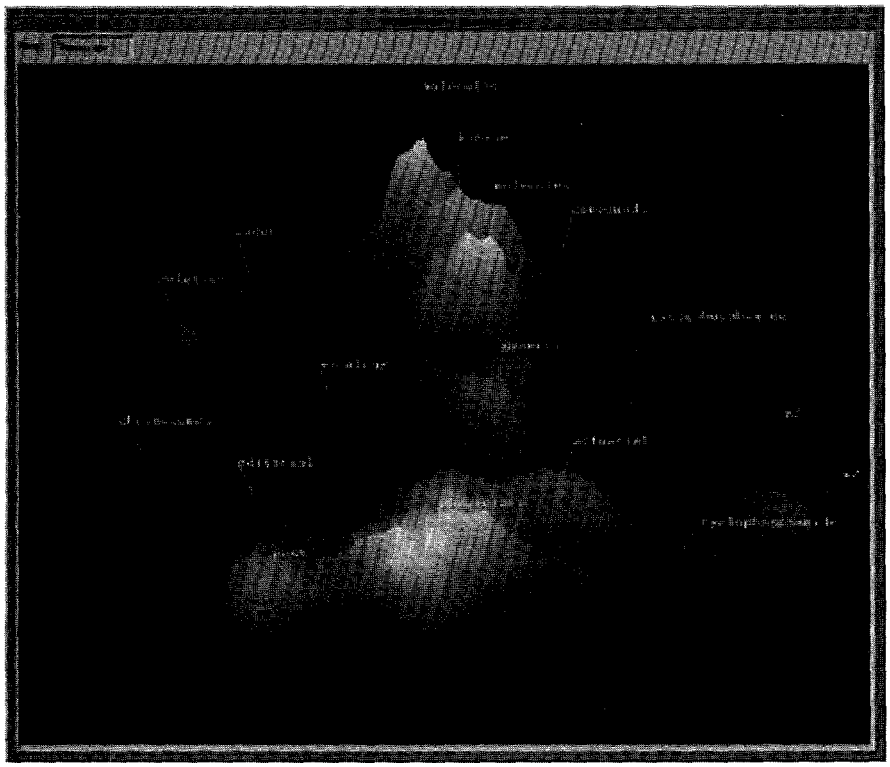
Recognition and Awards

Pacific Northwest National Laboratory has a comprehensive Recognition and Reward Program for the commercialization of intellectual property that includes royalty-sharing and equity-sharing (modeled after the "best of the best" from similar federal and industrial programs). An annual Technology Transfer Day at the Laboratory also recognizes contributors to the technology commercialization process (e.g., those receiving patents, software and book copyrights, R&D 100, Federal Laboratory Consortium, or Entrepreneurial awards during the past year).

The R&D 100 awards are conducted by *Research & Development Magazine*. The national competition identifies the 100 most significant technological advances. Since 1969, the Laboratory has received 35 of these prestigious awards. The technologies for which the Laboratory won five R&D 100 awards in 1996 are

- Plasma Source Quistor (PSQ) Mass Spectrometer - is a unique mass spectrometer for elemental and isotopic analysis. The PSQ offers an attractive alternative to conventional atomic mass spectrometry at a lower cost, smaller size, and with unmatched analytical features and performance. Its innovative technology enables scientists to select, capture, and chemically manipulate atomic ions for superior detection and analysis. Finnigan Corporation is a joint winner with Pacific Northwest.
- Liquid Multilayer/Polymer Multilayer Processes for Vacuum Deposition of Polymer Films - enables vacuum deposition of smooth, continuous polymer layers on flexible surfaces. The layers can be as thin as 100 Angstroms or as thick as a few hundred microns. Commercialization of the LML/PML processes means easier manufacture and higher quality for many products, including high-energy-density, lightweight, rechargeable lithium polymer batteries used in electronic devices such as cellular phones and laptop computers. Moltech Corporation, manufacturer of the batteries, is a joint winner with Pacific Northwest.
- SPIRE: Spatial Paradigm for Information Retrieval and Exploration Software - fundamentally transforms the tasks and processes of information retrieval and analysis. In an era of rapidly expanding access to information, SPIRE provides a suite of information access, analysis, and visualization tools that enable the user to visually analyze the information needed to make decisions and solve problems. SPIRE accepts large volumes of text in almost any format, determines the relationships within the text, and presents these relationships in a visual format. This approach allows users to rapidly discover known and hidden information relationships, and then read only the pertinent documents rather than wading through large volumes of text.
- Catalyzed Electrochemical Oxidation (CEO) - is a low-temperature, ambient-pressure process that can replace incineration as a hazardous waste treatment. It is 25 to 50 percent cheaper than incineration and safer, because aqueous components are not vaporized. Using the oxidation power of cerium, CEO can destroy hazardous pesticides, chemical weapons, solvents, laboratory, mixed organic and biological wastes. With its flow-through ultrasonic mixer, it can dispose of immiscible liquids like petroleum wastes. The CEO process is easily scalable, and the equipment is highly portable, making it a good choice for universities

1996 R&D 100 Award Winner



SPIRE is a new and exciting software application that allows users to explore complex themes and relationships found in written documents. A collection of visual and interactive tools, SPIRE graphically displays images based on word similarities and themes in text. No prior knowledge of the information or selection of themes or topics is required. SPIRE creates its visualizations by processing these similarities into the key topic and themes and organizing the data into visual representations that promotes exploration and discovery.

and small private labs, shipboard wastes, as well as large manufacturing facilities. The CEO process is a joint entry with EOSystems, Inc.

- Autonomous Environmental Sentinel (AES) - is a multi-sensor probe that collects data in aquatic environments at depths up to 300 meters. The system takes water samples on a time-series or event-triggered mode, and is controlled by an on-board microprocessor. The AES is the only multi-parameter probe that measures gamma radiation. It can monitor water systems near sewage treatment plants, hazardous waste sites, as well as characterize coastal environments before military operations and gather research data. If it detects undesired chemicals or radioactivity, it broadcasts a warning. After surfacing, information can be downloaded by satellite telemetry, spread-spectrum radio-frequency transmission, or manual recovery and download. This probe is a joint entry with Battelle Memorial Institute and Ocean Sensors.

The Laboratory continues to lead the competition in the Federal Laboratory Consortium's Award for Excellence in Technology Transfer. The Federal Laboratory Consortium Award recognizes "uncommon creativity" and initiative in transferring technology that provides significant benefits to private industry and to state and local governments. The competition is open to all of the federal laboratories—approximately 600—representing 16 federal agencies. Since 1984, the first year of the competition, Pacific Northwest National Laboratory has won 32 awards, more than any other federal laboratory and almost twice as many as any other DOE laboratory. In 1996, the Laboratory received three awards, for the following:

- User friendly software for energy-efficient building design—Researchers overcame the skepticism of industry and energy software traditionalists and spearheaded an effort that resulted in commercial release of the unique product - Softdesk Energy. To achieve their goals, the researchers recruited an industry partner, and together they linked with the University of Oregon to provide the expertise needed in software development and energy-efficient design. Softdesk Energy is expected to reach tens of thousands of building engineers and architects.
- Automated tool profile grinding machine—Researchers used their expertise in automated control systems to assist Freeborn Tool, a small company in Spokane, in replacing its conventional manual, pattern-based process for manufacturing wood shaper tools with an automated tool profile grinding machine. The new machine can produce tools with easily replaceable tips, thus opening the door to an entirely new product line for Freeborn Tool. When Freeborn Tool first expressed interest in the Laboratory's expertise but could not afford a major development contract, the team provided access to the Laboratory's research and development capabilities through a staff exchange and then a Cooperative Research and Development Agreement.
- Vacuum process for depositing and bonding thin, multi-layered polymer films for application in the production of lithium polymer batteries used in flashlights, computers, and countless other items—The technology was transferred to Moltech Corporation through an innovative package of technology transfer

Technology Transfer Effort

(Budget Authorization $ in Thousands)

	1995	1996	1997	1998	1999	2000	2001	2002
Outreach & Economic Development Activity[a]	1500	1500	1500	1500	1500	1500	1500	1500
Patent/Licensing Activity[a]	2500	1700	1700	1700	1800	1800	1800	1800
CRADA Funding—Federal:								
Office of Energy Research[b]	7800	3200	2500	2500	2600	2700	2700	2700
Other Federal	800	1000	1200	1300	1300	1300	1300	1300
CRADA Funding—Private Industry	400	300	400	500	500	500	500	500
Total CRADA Funding[c]	**9000**	**4500**	**4100**	**4300**	**4400**	**4500**	**4500**	**4500**
Staffing (Full-Time Equivalents)								
Outreach & Economic Development	6	12	12	12	12	12	12	12
Patent/Licensing Activity	18	12	12	12	12	12	12	12
CRADA Activity[d]	6	3	3	3	3	3	3	3
Total Staffing[e]	30	27	27	27	27	27	27	27

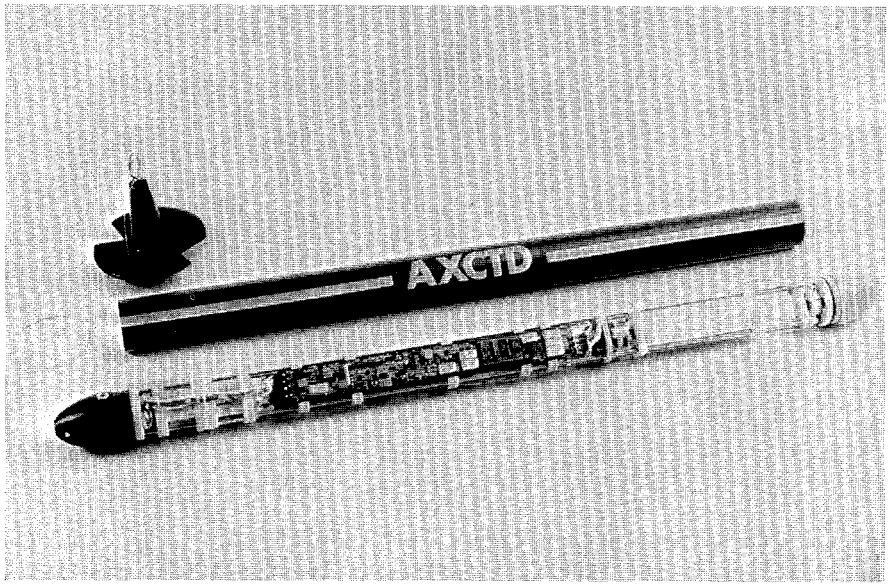
(a) Represents internal and external funds budgeted for crosscutting technology transfer activities, including labor and other costs.
(b) Includes CRADAs performed with institutional support funds, spinoff CRADAs, and The AMTEX Partnership. A significant part of The AMTEX Partnership CRADA funding in FY 1994 was used by other DOE-ER laboratories. In FY 1996, AMTEX Partnership funding was sent directly to the laboratories involved and we expect this trend to continue.
(c) Represents external funds in support of CRADAs from federal and private organizations, excluding in-kind contributions.
(d) Represents staff developing and negotiating CRADAs, most of which are supported by external funds.
(e) Represents all Pacific Northwest National Laboratory staff conducting crosscutting technology transfer activities.

Licensing Income and Use

(Budget Authorization $ in Thousands)

	1995	1996	1997	1998	1999
Number of New Licenses	27	27	30	30	30
License Income	242	300	450	700	900
Use of Income					
Invention Administration	202	250	285	335	385
Scientific or Applied R&D	0	0	100	275	405
Awards	40	50	65	90	110
Education/Training	0	0	0	0	0
Total	242	300	450	700	900

1996 R&D 100 Award Winner



The Autonomous Environmental Sentinel is a multi-sensor probe that collects physical and chemical data in aquatic environments. Missile-like and about the size of a baseball bat, the probe is equipped with various sensors and can be deployed from ships, small boats, submersibles, or aircraft.

mechanisms including a CRADA, a private development contract, a nonexclusive license, and an option for an exclusive license for lithium polymer battery production.

During FY 1997, the Laboratory will place increased emphasis on gaining recognition for staff and the Laboratory for outstanding technology development and deployment. Nominations for Federal Laboratory Consortium awards were submitted in September for 1997 awards for new products from the research areas of information technology, analytical instrumentation, energy, and waste treatment.

Laboratory Directed Research and Development Program

The relevance and value of a DOE multiprogram laboratory lie in its ability to apply science and technology to national needs that fall within the mission areas of the DOE. The increasing complexity of these needs and the inadequacy of conventional approaches demand that creativity and innovation underlie scientific and technological efforts. In addition, new ideas and opportunities frequently occur at a faster pace than can be anticipated or adopted in the federal budget process.

A national laboratory must establish and maintain an environment in which creativity and innovation are encouraged and supported if it is to fulfill its objectives and remain viable in the long term. For these reasons, external reviews of the DOE multiprogram laboratories have consistently recommended that laboratory directors be allowed to allocate a percentage of their operating budget to support discretionary research and development projects.

DOE Order 5000.4A establishes DOE's policy regarding Laboratory Directed Research and Development (LDRD) at its multiprogram laboratories and authorizes them to allocate up to 6 percent of their operating budgets to LDRD. LDRD is "...research and development work of a creative and innovative nature which is selected by the director of a laboratory, or his/her designee, for the purpose of maintaining the scientific and technological vitality of the laboratory and to respond to scientific and technological opportunities."

Program Administration and Management

Laboratory Directed Research and Development at Pacific Northwest is funded through an overhead account that is part of the General and Administrative overhead which is applied to funds received under the 1830 Contract. Formal proposals in an authorized format are required for each LDRD project.

Decisions regarding funding levels for the LDRD account are made by the Laboratory Director. Primary responsibility for allocations to individual LDRD projects within these accounts rests with the Laboratory Strategy Council (composed of senior line managers), who assist the Director in determining these allocations. The Laboratory Technical Council (composed of senior technical staff and line managers) also assists the process by ensuring the scientific and technical merit of the projects through formal internal and external peer review.

All projects are reviewed for technical merit by line managers and/or scientific staff. Written guidance pertaining to the criteria and guidelines for LDRD projects provided in DOE Order 5000.4A are widely distributed to Laboratory staff and managers through a formal LDRD Guide and other correspondence. Adherence to the criteria of 5000.4A is further ensured through reviews by the LDRD Office. Individual projects are usually limited to $1 million in total funding and $500,000 in a single fiscal year. The Director of Finance is responsible for financial oversight of the LDRD Program. Accountability for individual LDRD projects rests with the principal investigators conducting the projects.

Laboratory Directed Research and Development

(Budget Authorization $ in Millions)

Current Program	1993	1994	1995	1996[a]
Total LDRD Funding	11.8	13.8	15	15.5

(a) The estimated amount for FY 1996 is a forecast maximum which DOE has approved.

Scientific and Technical Investment Areas

In recognition that the Laboratory must focus on a defined set of research that reflects our missions and unique assets, LDRD investments are focused on developing new and innovative approaches in research which support our "core technical capabilities." Currently, the Laboratory's core technical capabilities are identified as

- Atmospheric Sciences
- Biotechnology
- Marine Sciences
- Computer and Information Science
- Design and Manufacturing Engineering
- Ecological Science
- Electronics and Sensors
- Health Protection and Dosimetry
- Human Systems Performance
- Hydrologic and Geologic Sciences
- Integrated Technology Policy and Regulatory Analysis
- Chemical Instrumentation and Analysis
- Materials Science and Engineering
- Molecular Science
- Nuclear Science and Engineering
- Process Science and Engineering
- Risk and Safety Analysis
- Statistics and Applied Mathematics
- Thermal and Energy Systems
- Toxicology

Currently, the largest proportion of Laboratory-level LDRD funds is allocated to our capability in molecular science and the second largest allocation is process science and engineering. A significant proportion (approximately 25 percent in FY 1996) of the Laboratory's LDRD funds are allocated to projects proposed by individual researchers or small research teams within the various technical research organizations. The funding allocated to each of these projects is typically $35K or less. Funding is also allocated to a group of the Laboratory's most senior scientists (i.e., Level V scientists) to support the exploration of innovative new scientific ideas from throughout the Laboratory.

The Laboratory plans to continue to focus the majority of its LDRD investments in the capability areas of molecular science, process science and engineering, biotechnology (with an emphasis on microbial biotechnology), computer and information science, materials science and engineering, risk and safety analysis, electronics and sensors, and health protection and dosimetry.

Selected Highlights of LDRD Projects

In FY 1995, 181 LDRD projects were selected for support through the Laboratory's LDRD project selection process. Selected highlights of the results of these projects follow:

- A project entitled "Identification, Purification and Characterization of the Reductive Dehalogenase of *Desulfomonile tiedjei* DCB-1" resulted in the identification and purification of a dehalogenase that converted 3-chlorobenzoate to benzoate. The dehalogenase was purified from the cytoplasmic membrane of DCB-1. This is the first time that a reductive dehalogenase has been purified from an anaerobic bacterium.
- A project entitled "Mesophorous Materials" resulted in the development of an acid synthesis method for three-dimensional mesophorous zirconia. The new material was studied using x-ray diffraction and found to be weakly crystalline. Additional work on the project resulted in the development of a treatment to improve the thermal stability of mesophorous materials. Experiments were also conducted that demonstrated good catalytic activity of the materials in hydrogenation reactions and high magnetic permeability when the materials are infiltrated with nickel.
- A project entitled "Characterization of Structure and Dynamics of Surface Adsorbates and Their Surfaces" utilized nuclear magnetic resonance to identify the nature of the molecular level interactions that cause cesium salts to act as a promotor in ethylene oxide catalyst systems based on supported silver on alumina. The project also demonstrated proof-of-concept for using the silver alumina catalyst as a dechlorination catalyst for carbon tetrachloride using N_2 as a carrier.
- Studies of "Automated Document and Text Processing" resulted in the development of a prototype information retrieval system with a number of superior characteristics compared to other similar systems. These

characteristics include an improved method for statistically identifying topics from within natural-language-based documents, a unique method for text compression, and a novel method for representing topics based on their relationships to other topics.

- A project entitled "Ionizing Radiation Assisted Processing of Hazardous Wastes" has identified promising approaches to using common photochemical oxidation catalysts, such as TiO_2, as a gamma radiation catalysts for the oxidation of organics, or reduction of metal species present in the Hanford tanks. Destruction of EDTA, a major component of tank wastes, was accomplished with TiO_2 catalysts using gamma radiation. Engineering bounding studies demonstrating proof-of-feasibility for the process were completed, and standardized methods for EDTA quantification were developed.
- A project entitled "PBPK-Based Breath Analysis Instrumentation" resulted in the development of pharmacokinetic models to describe the uptake, tissue distribution, metabolism, and elimination of carbon tetrachloride and benzene. These models will eventually aid the development of occupational exposure assessments using real-time breath analysis instrumentation.

More extensive information on the technical highlights of Pacific Northwest National Laboratory's LDRD Program is reported in the 1995 Annual Report on Laboratory Directed Research and Development. Although LDRD expenditures at the Laboratory over the past 2 to 3 years have steadily increased, funding over the next 2 or 3 years is planned to be relatively constant, reflecting an expectation of a relatively flat overall Laboratory budget and the need to be as cost-competitive as possible. Despite these constraints, LDRD will remain one of the highest priority activities at the Laboratory. A reporting of past and anticipated 1996 LDRD expenditures is provided in the table.

Work for Other DOE Sites

Pacific Northwest will continue to provide expertise for solving varied problems at a number of DOE sites. Technical services will continue to focus on waste management and site cleanup. The Laboratory provides support to institutional areas such as safety, dosimetry, and security. Management support efforts include information management systems, environmental impact statement support, and risk assessment and management. The Laboratory is also working with other laboratories to set up electronic mechanisms for distributed collaborative experimental environments for joint research projects.

The Laboratory has supported the environmental restoration of the DOE Laboratory for Energy Related Health Research near Davis, California. The project consists of supporting decommissioning of five buildings and remediation of soils and groundwater. Major accomplishments include decontamination and decommissioning of all five buildings and characterization of the sites. This activity has been a model for other decontamination and decommissioning activities and has saved DOE several million dollars by streamlining the activities. The Laboratory's involvement at this site will reduce in the coming years. We are also identifying mature cleanup technologies from foreign sources and delivering them to DOE sites in a project supported out of Argonne National Laboratory. To date, over 100 technologies have been identified from the private sector and the support was extended to the programs at the Idaho National Engineering Laboratory.

As the primary developer of waste vitrification technology, we continue to transfer the technology for treatment of nuclear and other hazardous wastes at DOE sites. The Laboratory is providing direct support to other sites in areas such as high-level waste vitrification processes, waste form qualification, and innovative waste treatment technologies. Since project inception in the early 1980s, we have been a technology partner providing major support to the West Valley Demonstration Project in New York State. In support of the Oak Ridge National Laboratory, tests have been conducted and are continuing to support decisions on whether to vitrify in situ buried low-level and transuranic waste in the onsite trenches. Multi-hundred-tons treatability tests were conducted in a waste pit during FY 1996 in support of the Record of Decision process for closure of sites at Oak Ridge. The Laboratory will continue to support Oak Ridge National Laboratory in this effort if the decision is to move forward with this approach. In addition, the Laboratory is providing high-waste-loading glasses for multiple programs managed at Idaho National Engineering Laboratory and other sites. The work includes developing glasses that are processable over a wide range of compositions to allow treatment of wastes previously thought not suitable for vitrification.

In addition to transferring technologies to other sites, the Laboratory in conjunction with its operating company, Battelle, is teaming with several environmental service companies to provide waste management and other services to other sites. One joint venture, Greenhill Technologies, LLC, is between Battelle and Waste Control Specialists. This venture is pursuing several options for management of wastes at DOE sites. This venture provides a much more direct vehicle to deploy the technologies coming from the Laboratory's DOE programs into actual operations.

Pacific Northwest is providing support to the Waste Isolation Pilot Plant (WIPP) by determining the corrosion and gas generation characteristics of low-carbon steel in the WIPP environment. Another related project is determining the solubility of actinide compounds in complex brines. As part of the DOE-DoD Strategic Environmental Research and Development

Program at Sandia National Laboratories, we are providing data system development and experimental design for the unmanned aircraft component of the Atmospheric Radiation Measurement Program. This work has led to the first applications of unmanned aircraft for atmospheric research.

The Laboratory will continue supporting other DOE sites over the next several years as we transfer some of the new technologies being developed for the Hanford Site. In the long term, the level of support is expected to be relatively flat.

Work for Others

In addition to contributing to the implementation of the DOE Strategic Plan, Pacific Northwest performs work for other federal agencies in selected scientific and technical areas in accordance with DOE polices. Work undertaken for other federal agencies was $59 million FY 1995. It is expected to increase slightly in 1996. The largest segments of the Laboratory's work for others program are work for the Department of Defense and the Nuclear Regulatory Commission.

A number of other federal agencies fund work at the Laboratory. They include the Environmental Protection Agency, Health and Human Services, the National Aeronautic and Space Administration, and the Federal Emergency Management Agency. The work for these agencies is briefly described below.

Department of Defense

Pacific Northwest National Laboratory's work for the DoD primarily utilizes the Laboratory's capabilities in electronics and sensors, statistics and applied mathematics, computer and information sciences, materials science, chemical and instrumentation analyses, process technology, risk management, and integrated technology policy and regulatory analysis. The level of activity for DoD was $37 million for FY 1996 and is expected to increase slightly beyond. The Laboratory is currently working in the following technical areas:

- treaty verification and technology assessment
- information sciences and architectures
- advanced materials and process development
- sensors, electronic, and automated systems and their applications
- systems analysis and technology evaluation
- environmental science and waste technology
- pollution prevention, technology development, demonstration, and deployment
- environmental toxicology
- analytical chemistry and radionuclide applications
- process technology.

The Laboratory has a significant role in the area of treaty verification and technology assessment based on our unique technical skills. This work, in close coordination with DOE, is performed for a number of DoD clients in support of national security needs.

The Laboratory supports Navy, Marine, Army, and Air Force research and development needs for systems integration using our capabilities in information sciences, networking architectures, and software development. Programs with the Air Force and Army use advanced graphic technologies, automated training systems, expert systems, and advanced workstation technology to simplify and automate operations. Network architectures and distributed computing techniques are developed to meet the unique needs in systems integration projects for the munitions and depot commands of the Army.

The Laboratory, in collaboration with U.S. Army I Corps at Fort Lewis, has developed a low-cost, personal computer-based battlefield visualization system intended to support the visualization requirements of forces operating on 21st century digital battlefields. The system, called Smart Terrain, takes advantage of emerging high-performance personal computer-based three-dimensional graphics acceleration hardware technology and an advanced software architecture to provide a terrain visualization capability comparable to that previously available only on expensive, dedicated graphics computers.

We expect to continue providing support to the U.S. Army in advanced materials such as thick section composites. The Kinetic Energy Projectile Project supports design, analysis, testing, and development of advanced munitions and manufacturing techniques for the Armament Research Development and Engineering Center. Studies of composite materials and other unique materials are performed for many other DoD clients.

The Laboratory has developed unique capabilities in very thin film and high-quality optical coatings. This leading edge capability has historically met needs for missile guidance filters for the Army and large-scale laser mirrors for strategic defense needs. The Laboratory is now applying this technology base to high-power density battery and unique identification and paint filters for both military anti-fratricide and industrial applications.

Sensors, electronics, and automated systems development work is also expected to continue. We are developing sensors for chemical, environmental, and biological measurement and imaging technology for DoD. Millimeter wave, radio frequency, electrooptical, and fiber-optic technologies have been developed for test range instrumentation systems for the Army and missile test systems for the Navy. Ultrasonic and electromagnetic imaging systems to evaluate airframe, munitions, and undersea components are being fielded. A variety of unique robotics for safety testing

and specialized repair tasks, such as reverse engineering systems and printed circuit board repair, have been developed for the Army. Large and small mobile robots equipped with various sensors have been developed for the DoD and DOE communities. We developed a telerobotic system for disposal of explosive ordnance for the Navy. A serpentine robotic arm is currently under development for the Navy Explosive Ordnance Disposal Technical Center.

The Laboratory supports DoD environmental program needs for the Army, Navy, and Air Force using our capabilities in process technology, pollution prevention, water and land resources, risk management, and environmental and regulatory compliance. A wide range of integrated products and services are provided to our DoD customers. They include system engineering, decision analysis, life-cycle analysis, strategic planning, technology management, site assessments/characterization/remedial investigations, feasibility studies, NEPA support, environmental toxicology, remediation and pollution prevention, and technology development, adaptation, demonstration, and deployment. The emphasis is on demonstration and deployment of improved and innovative approaches and technologies to assess and clean up complex sites and reduce waste (pollution prevention) from existing and new systems.

Pacific Northwest provides expert assistance to the DoD in systems analysis, technology evaluation, and statistics. This work includes the technical support for modernization of major weapons production and logistics elements for the Army; evaluation of organization systems, procedures and methods, safety systems, and functioning of joint programs; and the assessments of human factors impacts and training requirements. Industrial base modernization programs evaluate and apply computer-integrated manufacturing in Army production plants, and provide efficient automation technology options to meet specialized maintenance technology requirements of the Army, Navy, and Air Force.

The Laboratory has a program with the Defense Advanced Research Projects Agency (DARPA) for developing medical systems and technologies that improve health care and battlefield treatment of the injured. We are working with both DoD and DOE to expand this effort into a broad and integrated partnership that would include all the national laboratories and Army medical centers.

The Laboratory is continuing development of significant microsystems technology capabilities in areas of microthermal and microchemical systems that are of particular interest to DoD clients. For the DARPA, we are developing compact, microchannel chemical reactors. Our current efforts consist of the development of an integrated combustor/evaporator, which is designed to serve as a low-NOx heat source to drive man-portable soldier systems such as a compact personal cooling unit, and a liquid-hydrocarbon fuel processor that is designed to support man-portable power generation in a light-weight fuel cell. These projects are benefiting as leveraged investments, by DARPA, against companion efforts to develop compact, microsystem-based heat pumps and hydrocarbon conversion units for the DOE.

Pacific Northwest is the lead laboratory for energy management for DOE's Federal Energy Management Program (FEMP). Under FEMP, the Laboratory has developed and is deploying a model program for installation-wide energy-system modernization. Software tools and methodological approaches are being developed for rapid assessment of the energy resource potential at each installation. The Laboratory then works with the installation energy manager and local utilities to create demand-side management programs. This approach modernizes federal energy systems with funds from the utility's capacity savings through conservation. The program also is developing a knowledge-based decision guide for operating and maintaining heating plants and assisting facilities planning using geographic information technology.

The Laboratory continues to provide a variety of DoD clients with analytical chemistry support and radionuclide applications development. Very sensitive and high-precision analytical techniques are available at the Laboratory to meet measurement and testing requirements. Historical and unique skills in analyzing radionuclides support specialized DoD needs.

Laboratory staff are assisting the U.S. Army and Navy in developing unique and innovative technologies to effect the disposal and remediation of highly toxic defense systems material. We are currently assisting the Army Program Manager for Non Stockpile Chemical Weapons (PMNSCW) examine and characterize the inhalation toxicity of aerosolized blister agents. Additionally, our technical staff have proposed to support PMNSCW in the examination and qualification of the Laboratory's chemical weapons destruction technologies.

In addition, the Laboratory is currently supporting the U.S. Navy in the disposal of a unique weapons/fuel mixture. The first effort involves the removal of over a million pounds of obsolete and leaking containers of napalm (a mixture of gasoline, benzene, and polystyrene). This is a 5-year effort led by our technical staff who will design, validate, and implement the disposal strategy. This effort is in its second year.

Furthermore, our technical staff are assisting the U.S. Navy Surface Warfare Center-Indian Head to design and validate a torpedo fuel disposal facility for deployment at Keyport Undersea Warfare Center using our patented Catalyzed Electrochemical Oxidation technology. Following successful validation of the Catalyzed Electrochemical Oxidation technology, a follow-on program is planned to construct the full-scale treatment facility.

Federal Emergency Management Agency

The Laboratory will continue to support the Federal Emergency Management Agency (FEMA) through the development of automated decision support tools in the areas of emergency planning and crisis management. FEMA's primary focus is in the area of the

long-term, multiple-hazard application of the Federal Emergency Management Information System (FEMIS).

The U.S. Army now has the leadership role in directing the development of a computing system that will support state and local emergency management agencies in dealing with emergencies under the Chemical Stockpile Emergency Preparedness Program (CSEPP). The main development activity in the emergency management area is the FEMIS.

FEMIS/CSEPP is being developed to open system standards, and it is designed to support any UNIX-based open system hardware set. It is also architected to be the foundation of a multiple-hazard emergency management system. The initial product release took place in December 1994, followed by releases and installations in Utah in July and October of 1996. FEMIS v1.2 was delivered to the test contractor in April 1996. Follow-on development has been approved and is being funded. FEMA has funded an extension of the FEMIS/CSEPP development effort designed to port v1.1.5 and v1.2 of the FEMIS to their primary platform (IBM RS6000). The opportunity exists for FEMA to use the FEMIS product to establish a national test bed for emergency management modeling and planning.

Follow-on support for FEMA may involve development/integration of individual hazard modules for the system, enhancements to its basic functionality, and configuration management of the in-place system during its lifetime. This effort would extend approximately 10 years into the future.

Nuclear Regulatory Commission

Pacific Northwest National Laboratory's research and technical work supports all of the U.S. Nuclear Regulatory Commission program offices, regional offices, and several administrative offices. The work covers all aspects of nuclear safety regulation. In FY 1996, the Nuclear Regulatory Commission's total budget decreased approximately $50 million from FY 1995. The Nuclear Regulatory Commission's budget is expected to remain stable in FY 1997 although the areas of emphasis may shift. This budget decrease has had an impact on the work done at the national laboratories. Estimated level of activity for Pacific Northwest during FY 1996 is about $8 to $10 million with this level expected to hold during the following years.

Significant activities for the Nuclear Regulatory Commission that will be completed during FY 1996 include the following:

The Standard Review Plan Update and Development Program (SRP-UDP), to update the Standard Review Plan (NUREG-0800) for the Office of Nuclear Reactor Regulation (NRR), was completed in FY 1996. The Standard Review Plan will be used by Nuclear Regulatory Commission staff to review applications for license and/or design certification concerning nuclear power plants or modifications thereto. The Laboratory assisted the Nuclear Regulatory Commission with updating NUREG-0800 to reflect the existing agency requirements and guidance and to incorporate review guidance and acceptance criteria for unique technology and the unique application of existing technology in future designs. A maintenance effort of approximately $250K per year will begin in FY 1996 and continue for the next few years.

Development of a construction inspection database for the NRR was completed in FY 1996. This database was developed to manage the Nuclear Regulatory Commission's construction inspection programs for future plants. The database, including data input, retrieval, and report generation, is based on off-the-shelf software, making it widely applicable to other projects that need similar schedule managing, tracking, and report generation capabilities.

The Laboratory's role in the Nuclear Plant Aging Research (NPAR) Program for the Office of Nuclear Regulatory Research (RES) will be completed in FY 1996. NPAR addressed issues associated with the reliability of safety-related equipment, plant life extension, and license renewal. However, the Laboratory anticipates providing related assistance to the Nuclear Regulatory Commission in 1996 and beyond with future license renewal activities including the review and assessment of license renewal applications.

Laboratory support to NRR in evaluating past reactor operator crew examinations to identify trends and patterns in operators and crew ability on the job was completed in FY 1996. The Laboratory evaluated variables such as operator education and experience in an attempt to infer from these variables the effects on operator ability on the job and to compare results to human reliability analysis methods used in current probabilistic risk assessments.

Following is a discussion of the areas of support to the Nuclear Regulatory Commission that will continue or develop over the planning period.

Office of Nuclear Reactor Regulation

The Laboratory will continue to provide support during FY 1996 to NRR's Operator Licensing Branch in licensing commercial power plant nuclear reactor operators and senior reactor operators and in evaluating facility operator requalification programs. The Laboratory has provided this support annually to approximately 300 to 400 candidates at 50 sites nationwide, supporting all five regions and headquarters. The Laboratory has 18 fully certified examiners qualified to administer exams in all pressurized-water reactors, boiling-water reactors, and nonpower/research reactors. Workload may decline significantly during the next 5 years due to proposed, but not yet adopted, regulatory changes for administration of Nuclear Regulatory Commission requalification examinations. The Nuclear Regulatory Commission implemented during the first half of FY 1996 a pilot program where utilities prepared their own operator examinations; the Nuclear Regulatory Commission will be reviewing the results during the second half of FY 1996. The broad background of the operator licensing examiners and their specialized training provides a pool of staff able to support a wide variety of other activities for both the Nuclear Regulatory

Commission and DOE. The experience of the examiners continues to be beneficial in performing the following types of activities: maintenance and training inspections, risk analysis, risk management, simulator evaluations, emergency preparedness assessments, and individual plant examinations.

Pacific Northwest will continue to support NRR's Division of Reactor Project Management by providing technical assistance in improving work processes, supporting staff reviews of decommissioning-related activities, and assisting the staff in improving the process to review potentially generic safety-related information. This support includes information technology and applicable training of Nuclear Regulatory Commission staff.

The Laboratory will continue to support the NRR's Division of System, Safety and Analysis in the area of commercial in-reactor fuel performance. This work includes performing technical review of vendor and utility submittals on fuel designs, fuel performance codes, and control rod assemblies. Laboratory staff will continue to prepare an annual summary of in-reactor fuel performance based on information from the vendors and open literature publications. This summary includes discussions of design trends, failure trends, and other topics of relevance to fuel performance. An increasing role will be to assist the Nuclear Regulatory Commission in onsite audits and inspection of fuel vendors and utilities.

Laboratory staff will provide assistance to the NRR in regulatory and licensing activities in the siting and environmental protection areas, including the Environmental Standard Review Plan update and development effort. We will provide multidisciplinary managerial and technical expertise to assist the Nuclear Regulatory Commission in its licensing reviews for early site permits and operating reactors, and in updating regulatory guidance.

Office of Nuclear Regulatory Research

Laboratory staff will continue to provide technical assistance to the RES in support of decommissioning analysis and regulation. Technical analysis and cost estimates are provided for decommissioning licensed nuclear reactor power plants and for licensed fuel-cycle and nonfuel-cycle nuclear facilities. The support the Laboratory has provided to the Nuclear Regulatory Commission on short-turnaround analyses and addenda to previous decommissioning analysis reports should continue on a task basis. Current and future work for the Nuclear Regulatory Commission includes completing the reevaluation of the original pressurized-water reactor and boiling-water reactor power station decommissioning analyses (NUREG/CR-0130 and NUREG/CR-0672) and a computer program developed for estimating decommissioning costs; periodic updates of NUREG-1307 to reflect changes in the low-level waste burial site charge schedules; an analysis of the decommissioning of a large sealed-source user facility; and the reevaluation of the earlier fuel-cycle and nonfuel-cycle facility reports to reflect current financial and regulatory conditions.

Nondestructive evaluation projects conducted at the Laboratory for RES have provided the engineering databases to support the Nuclear Regulatory Commission's position and policy on regulatory guides, position statements, codes, and regulations. The elements of these projects include 1) studying nondestructive evaluation reliability to determine the effectiveness of in-service inspections; 2) optimizing in-service inspection programs using nondestructive evaluation reliability data, probabilistic risk assessment methods, and fracture mechanics analysis to control risks; 3) assessing new nondestructive evaluation techniques and transferring technology to the Nuclear Regulatory Commission regional offices and to the utility industry; 4) developing a technical database for fabrication flaws in U.S. reactor pressure vessels for use in remaining life predictions; 5) designing and fabricating a steam generator mockup for regional Nuclear Regulatory Commission staff to assess inspection performance at reactor sites; and 6) developing information on computer-based ultrasonic systems to enable Nuclear Regulatory Commission staff to understand and audit inspection results. The nondestructive evaluation technologies under study at the Laboratory include ultrasonics, eddy currents, and acoustic emission. It is anticipated that when the advanced light-water reactor designs proceed, the Laboratory will be involved in similar work for the new designs.

The Laboratory will continue to provide technical assistance to the NRR in support of low-level radioactive waste storage. Such support includes classification, characterization, and assessment of waste streams and activated metals; source terms for performance assessments; and characterization of chelating agents.

The Laboratory will become the primary technical resource for RES on commercial nuclear fuel. Issues related to high-burnup fuel in nuclear power plants are gaining in importance for the Nuclear Regulatory Commission. Continued development and revision of two fuel performance computer codes will be performed by the Laboratory. This work closely connects with the fuel-related work being done for NRR.

Office of Nuclear Material Safety and Safeguards

Pacific Northwest will continue to provide technical assistance to the Office of Nuclear Material Safety and Safeguards (NMSS) in the area of regulation of the Gaseous Diffusion Plants at Portsmouth, Ohio, and Paducah, Tennessee, which are being operated by U.S. Enrichment Corporation (USEC) through a lease arrangement by DOE. The Laboratory will assist NMSS in at least three areas: 1) engineering, systems, management controls, and human factors; 2) radiation and chemical safety; and 3) safeguards. The key activities for the short term will be to assist the Nuclear Regulatory Commission in developing the specific technical and inspection criteria and guidance and assisting with the reviews and inspections. Because the Gaseous Diffusion Plants must be

certified annually, this activity is expected to continue during the planning period. This assistance may also take the form of help provided to region staff, Office for Analysis and Evaluation of Operational Data, or other Nuclear Regulatory Commission offices, and the Gaseous Diffusion Plants resident inspectors.

USEC is also pursuing development of the Advanced Vapor Laser Isotope Separation (AVLIS) technology to supplement/replace the Gaseous Diffusion Plants for commercial enrichment services. The Nuclear Regulatory Commission is expected to ask the Laboratory for assistance in reviewing such a license application in the future.

The Laboratory continues to provide support to NMSS in FY 1996 in the area of chemical safety, security and safeguards, fuel-cycle regulatory guides, and international physical protection. This work is expected to continue. Should DOE decide to turn over additional facilities to Nuclear Regulatory Commission regulation, opportunities will exist to assist the Nuclear Regulatory Commission in reviewing those facilities.

Other Nuclear Regulatory Commission Offices

The Laboratory continues to support the Office for Analysis and Evaluation of Operational Data by refining analytical tools used by the Nuclear Regulatory Commission's Emergency Response Organization. New and/or improved models that address cloud shine, modify wind fields, process meteorological forecasts, present results graphically, calculate dose rates, etc., will be added to the RATCHET and RASCAL codes. After the codes are revised, tested, and installed, the Laboratory will train Nuclear Regulatory Commission staff in the use of the models.

Environmental Protection Agency

Pacific Northwest conducts research to assist the Environmental Protection Agency in its central role of environmental regulation in the United States. The level of activity for the Environmental Protection Agency was $2.7 million in FY 1995 and decreased slightly in FY 1996. The Laboratory will continue to conduct a variety of research and development activities to improve the state of knowledge about exposure, impacts, and risk from pollutants on human health and ecological systems. The Laboratory is conducting research to investigate the causes and effects of global climate change, and we expect that the Environmental Protection Agency will continue its support for such research in its Global Climate Research Program. The Laboratory is also involved in measuring and assessing the impacts of pollutants on ecosystems including the Arctic, Great Lakes, the Everglades, and Northwest watersheds. Laboratory researchers provide technical support to the Environmental Monitoring and Assessment Program by assisting in the design of studies to estimate the current status, extent, changes, and trends in indicators of the condition of the nation's ecological resources on a regional basis. We also provide technical support to the Environmental Protection Agency's Ocean Disposal Program by conducting bioassays related to disposal area siting projects. In addition, the Laboratory is developing and demonstrating methodologies and technologies to understand and mitigate risks associated with hazardous materials.

The primary areas of research that we will conduct for the Environmental Protection Agency include the following:

- modeling and assessment of the environmental impacts of increasing concentrations of trace contaminants in the atmosphere and potential resultant global climate change
- assessing the technologies and economic impacts of selected international strategies to reduce greenhouse gas emissions
- analysis and modeling of hazardous waste transport and fate in soil, water (both fresh and marine), air, and biota
- measurements and mass balance determinations to assess sources and sinks of polychlorinated biphenyls in Lake Michigan
- research, evaluation, testing, development, and demonstrations of alternative or innovative hazardous waste treatment and radon mitigation technologies
- measurement and analysis of the effects of toxic and hazardous chemicals on terrestrial and aquatic ecological systems, including the marine environment
- modeling the formation, transport, and impacts of acid rain and evaluation of strategies to control it.

Department of Transportation

Pacific Northwest recently established the Transportation Technology product line to focus and coordinate our business in the transportation sector. Our objective is to apply technology to promote a cost-effective and sustainable internodal transportation system that effectively ties the United States together and links it to the rest of the world. The U.S. Department of Transportation is expected to become a major customer as this portion of our business grows. We expect to continue work we have been performing for the Federal Aviation Administration to develop and deploy technologies to improve passenger security screening and to develop effective programs to deter alcohol and substance abuse in the aviation industry. We plan to expand our business with the Department of Transportation by applying our capabilities to assist with developing and deploying the Intelligent Transportation System, to improve the cost-effectiveness of the highway infrastructure, and to improve the safety and efficiency of the nation's railroads.

Health and Human Services

Pacific Northwest's major Health and Human Services program is conducted for the National Toxicology Program. The National Toxicology Program is a program of NIEHS (National Institute of Environmental Health Services), a component of the National Institutes of Health, which is part of the Department of Health and

Human Services. The Laboratory has established a center of excellence in inhalation technology and toxicology for the National Toxicology Program that is consistent with, and complementary to, our long-standing research efforts conducted for DOE. This program has strengthened our knowledge and capabilities in these areas, which are being applied to research on hazardous wastes.

The National Toxicology Program was established 13 years ago to coordinate and strengthen government activities in characterization of the toxicity of chemicals. The National Toxicology Program is charged with

- broadening the spectrum of toxicologic information on selected chemicals
- increasing the number of chemicals studied, within funding limits
- developing and validating assays and protocols responsive to regulatory needs
- communicating program plans and results to government agencies, the medical and scientific communities, and the public.

The National Toxicology Program has recently initiated toxicology and carcinogenesis studies related to electromagnetic field exposures.

Toxicology-related research is central to the three major agencies of the National Toxicology Program: the Food and Drug Administration, NIEHS, and the Centers for Disease Control's National Institute for Occupational Safety and Health. The total government-sponsored inhalation toxicology program at the Laboratory is currently funded at $8 to $11 million per year, of which less than 2 percent has been funded through Work for Others agreements under our operating contract (1830).

During the past decade, the National Toxicology Program has established an integrated program for studying chemicals. The program investigates multiple toxicologic endpoints using assay protocols tailored to each chemical. The "traditional" 2-year carcinogenesis bioassay has been strengthened into a comprehensive toxicologic evaluation that provides information not only on a chemical's carcinogenic potential in laboratory animals but also on genetic toxicity; chemical absorption, distribution, metabolism, and excretion; target-organ toxicity; and reproductive effects. Among the endpoints examined in specific cases are neurobehavioral, immunologic, hematopoietic, respiratory, physiologic, and endocrine effects. During the past several years, increased numbers of chemicals have been tested by the inhalation route of exposure because inhalation is a common route by which workers and the general populace are exposed to potentially toxic chemicals. Data acquired from exposures of laboratory animals under controlled conditions are used to assess potential health effects in humans and may be used to set standards for worker protection or to indicate new areas for basic research.

The Laboratory has the following primary goals and areas of research for the National Toxicology Program:

- continue to be a dominant inhalation toxicology laboratory by maintaining and improving the technical quality of the research conducted
- broaden the scope of work performed to include greater in-depth evaluation of target-organ toxicities, such as pulmonary function, cardiovascular physiology, cell and tissue kinetics, tissue distribution of native and biotransformed chemicals, ultrastructural analyses, and pharmacokinetics studies
- demonstrate to the National Toxicology Program our capabilities in molecular biology
- conduct additional studies with laboratory animals on the developmental toxicity of chemicals following inhalation exposure
- conduct a major National Toxicology Program study examining the effect of electromagnetic fields on breast cancer development
- complete construction of the regional electromagnetic fields exposure facility at the Laboratory to provide enhanced capability for increased NIEHS-funded electromagnetic fields grants.

Other Federal Agencies and Nonfederal

Several other federal agencies fund work at the Laboratory. They include the Departments of Agriculture, Commerce, Housing and Urban Development, Interior, Justice, State, the Treasury Department, and the National Science Foundation.

The Laboratory's work for nonfederal organizations (i.e., local governmental and commercial entities) under the 1830 operating contract was $1 million in FY 1996 and is expected to be about $1 million in FY 1997.

6 Critical Success Factors

Battelle's traditional values serve as a guidepost on the quality journey at the Pacific Northwest National Laboratory. They include the following:

Benefit of humanity—Our operations always must be oriented toward solving significant problems and advancing the quality of life.

Innovation—We aspire to be a world leader in scientific discovery, technical inventiveness, and technological innovation aimed at putting technology to work.

Integrity—We expect ethical behavior on the part of all staff members.

Quality—The hallmark of our activities must be services and products of the highest quality commensurate with the needs and resources of our customers.

Teamwork—We strive to transform creativity and inventiveness into high-quality services and products through the teamwork of diversely talented staff members dedicated to achieving a common objective, with strong linkages to the broader community at large.

Corporate citizenship—We must honor our obligations to society by making Pacific Northwest an economic, intellectual, and social asset to each community in which we operate. And we must aggressively strive to meet all environment, safety, and health goals.

Growth—A world of increasing population, complexity, and interdependence needs a Laboratory that also is growing and advancing in capabilities for serving societal needs.

Earnings—In order to continue and advance, it is necessary that we generate the retained earnings to achieve our objectives, and thus serve our public purposes.

These values come alive through the actions of talented people working together on solving significant problems to maintain the Laboratory's relevance and increase productivity. Management provides the tools and information needed by staff to deliver creative and innovative results to the customer and an environment that is safe, healthy, and personally rewarding. Thus, human resources; information resources; environment, safety, and health compliance; and communication and trust are critical elements for the Laboratory to successfully carry out its mission. These elements are discussed in this section of the plan.

Human Resources

The Human Resources vision is to be an agent of change in building Pacific Northwest's work environment to become a learning organization focused on achieving the Laboratory's critical outcomes. This working environment must support and allow the needed innovation networks to flourish. To build effective innovation networks, the Laboratory must attract, retain, and develop a diverse staff, with a broad base of skills and knowledge to support our clients' needs. Major elements of Human Resources include general Laboratory personnel programs and affirmative action/equal opportunity employment.

Laboratory Personnel

Areas receiving special attention are staff development, recruiting high-quality staff, and developing a total compensation reward system that supports the Laboratory's strategic goals.

Staff Development

A critical outcome for the Laboratory is developing effective leadership. Laboratory management is moving forward with a formal leadership development effort to enhance leadership performance at all levels of the organization. The effort builds upon those core leadership development concepts already in place in the organization. Key to this effort is training designed to enhance leadership skills for the purpose of developing our staff capabilities, as well as addressing work-related problems and situations. The training delivery system for this skill development has been modified to provide just-in-time training for intact work groups and ad hoc teams. Open enrollment opportunities are available to support individual needs. The overall development effort addresses assessed needs. Among these are team leadership, feedback and recognition, communication, and change management. This effort is designed to positively influence personal and organizational behavior and to create a supportive work environment.

As a part of the management system, we link the Laboratory vision/mission and organizational goals to individual performance objectives through the staff development review process. A major outcome of this linkage is the enabling and empowerment of staff and management to maximize personal and professional growth while maintaining strategic alignment with the purposes of the Laboratory.

The Laboratory has fully automated the Training Information System to streamline training processes including the identification of training requirements, course scheduling and registration, and training documentation. Integral parts of this system are the training catalog and the training requirements questionnaire. The Laboratory's system is linked with the Hanford Site, Washington State University, and Columbia Basin College. This linkage allows direct registration in training activities across organizational lines. This expansion enriches the course offerings available to staff by encompassing the

Laboratory Staff Composition[a]

(Full- and Part-Time Employees)

Occupational Codes	Total # (%)	PhD	MS/MA	BS/BA	Other
Managers	447 (12.6)	111	146	129	61
Technical Staff	1615 (45.4)	446	450	526	193
Administrative Specialists	402 (11.3)	10	74	213	105
Technician	167 (4.7)	0	1	13	153
All Other	926 (26.0)	0	2	60	864
Totals	**3557**	**567**	**673**	**941**	**1376**

(a) Data as of September 10, 1996.

breadth of technical and developmental learning activities offered by each organization.

As part of the staff development process, staff members are encouraged to participate in education programs to enhance their job skills and advance their learning. While many staff members are enrolled in local schools while working full-time, leaves of absence are available for staff electing to attend a university located out of the community. Tuition reimbursements, continuation of benefits, and graduate stipends are available for staff on educational leaves of absence.

Additional staff development efforts include career development workshops, personal and organizational assessments, expansion of the training and development curriculum, and a training and development approach that promotes "applied learning" by focusing on real-time business requirements and issues. A pilot mentoring program has been launched and will be evaluated to determine the possibility of expansion into the full Laboratory.

Staffing

Restructuring of the Laboratory's largest client, the Department of Energy, along with reduction in DOE budgets has had a direct impact on the Laboratory's staffing requirements. Our focus has shifted from lessening the impact of work force reductions to maintaining and building on those human resources talents necessary to meet our changing business requirements. The Laboratory is assessing our skill mix, and identifying those areas where staff resources should be focused and where additional staff should be acquired. There is a growing demand for the recruiting of highly skilled, unique senior staff who are also in high demand in the national labor market. Therefore, we must establish new and innovative methods of identifying these highly qualified candidates. The Laboratory's senior managers are working to stabilize our existing programs, seek new programs, and accelerate new business development. Thus, future staffing requirements will focus on creating succession plans and targeting the selection of candidates whose qualifications support the technical development, relationship management, and expert delivery systems of the Laboratory. Although the need for entry level bachelors, masters, and Ph.D. graduates has been adversely impacted by budget and staff reductions, it remains our intent to continue our ongoing relationships with colleges and universities in order to retain our competitive position for hiring top technical graduates. While on-campus recruiting will lessen during this period, we will continue to use the services of Associated Western Universities, Inc. (AWU) to bring minority and female science and engineering students into the Laboratory for summer and other internship positions.

Compensation and Benefits

Pacific Northwest is committed to the design and administration of a total compensation program that encourages and rewards excellence and that attracts, retains, and motivates a highly qualified and competent staff. The Laboratory maintains multiple job evaluation systems and salary structures that are reviewed annually and modified to ensure that all Laboratory positions are defined and valued in a manner that is internally equitable and externally competitive. We plan to undertake an overall review of our all compensation and benefits programs (total remuneration) to assess all compensation components (salaries, benefits, other compensation elements), compared to national averages and other research organizations, so that we can set appropriate levels for all compensation/benefits programs. An annual performance review process, part of the staff development review program, appraises each staff member and helps to ensure that individual goals and contributions are recognized and rewarded.

In the benefits area, a Human Resources goal is to provide cost-effective programs that support the Laboratory's recruitment and retention efforts. A key initiative is to provide staff the opportunity of making choices in their benefits program. This program recognizes the diversity of today's work force in offering benefits options and coverage choices. In addition to

responding to a competitive labor market, our program must be responsive to the need to control our overall costs and charge-out rates. We have recently made adjustments to our benefits programs to bring them more in line with national norms and will continue to make such adjustments as warranted by survey comparisons.

Affirmative Action and Equal Employment Opportunity

The Equal Employment Opportunity/ Affirmative Action (EEO/AA) Office at the Laboratory is focused on a results-oriented, active program orientation rather than mere compliance-related activities. Emphasis goes beyond legal and regulatory requirements of the function and aims at instilling the value of diversity into the fabric of the organization. The importance of differing points of view is critical to the creative spirit of the Laboratory. Our activities center around four major areas: special programs, training, compliance, and community outreach. We also want to enhance the Laboratory's ability to attract and retain qualified women and minority staff.

Although the focus of the EEO/AA programs is not mere compliance, compliance-related activities can be used to enhance our ability to measure and manage diversity. The following two Equal Opportunity tables provide a breakdown of staff by race and gender.

By monitoring turnover rates, hire rates, promotion rates, and setting stretch affirmative action goals, we can make changes in our programs to fit the needs of the organization. Our affirmative action goals are set on an annual basis according to an eight-factor availability analysis computed individually for each of our 26 job groups. Since our hiring activity in the future is expected to be limited to critical placements, we expect the majority of our affirmative action efforts to be focused on internal promotions or preparation for future promotion.

Our downsizing efforts were closely monitored to ensure that no adverse impact exists to those in protected classes. We achieved our goal of maintaining the positive strides that we had made in diversifying our work force over the last few years in the midst of downsizing. Our retention of minorities and women to date has been encouraging.

Some of our current activities are as follows: 1) continued active involvement in the Region X Industry Liaison Group, as a partnership effort with the Office of Federal Contract Compliance Programs (OFCCP). The Industry Liaison Group was recently nominated by the Region X OFCCP Director for an Exemplary Voluntary Efforts (EVE) Award as a result of a successful "Native American Student Career Day" hosted by the Industry Liaison Group at the University of Washington. Over 100 at-risk Native American high school students attended the one-day event; 2) the Laboratory recently initiated the development of the Hanford Community Diversity Council in order to collaborate, facilitate, and initiate championing the value/contribution of all employees across the Hanford Site.

Strategic Planning and Evaluation

After review of our internal assessments, we have updated our strategic direction and believe it is appropriate to jointly address diversity and quality-of-work-life issues by focusing on creating a supportive work environment because of the following discoveries:

- a supportive work environment is common to both diversity and quality of work life and is a critical factor influencing a person's work experience
- other common issues were identified through these assessments.

This customer feedback indicates a desire for a tailored approach to addressing diversity and quality-of-work-life needs within the divisions and directorates as well as a Laboratory-wide mechanism to identify and address issues.

As a result, we are implementing a three-pronged approach to managing diversity and quality-of-work-life issues:

- creation of a tailored diversity/ quality-of-work-life approach for each division/directorate
- modification of the current Staff Diversity Enhancement Program (SDEP) to become an inclusive Supportive Work Environment User Group
- integration of diversity/quality of work life into our Leadership Program.

Work Force Diversity/Supportive Work Environment

An important aspect of our competitive advantage and future viability lies in our ability to create a supportive work environment in which all staff may fully contribute their skills, talents, and experiences to achieving personal and organizational goals. The existence of a supportive work environment is a critical outcome which is supported by the following key principles:

- all staff demonstrate the ability and willingness to value and/or manage differences
- productivity, creativity, and problem solving are optimized through diverse thinking and perspectives
- staff treat each other with mutual respect and dignity
- true equal opportunity exists for all staff
- the work environment is free from harassment
- the work environment allows flexibility
- staff have a clear sense of purpose.

Staff Diversity Enhancement Program

The purpose of this program is to enhance the Laboratory's ability to attract and retain quality staff members who are minorities and women. The

Equal Employment Opportunity[a]

(1996 Full- and Part-Time Permanent Employees)

Occupational Codes	Total		Minority Total		White		Black		Hispanic		Native American		Asian/ Pacific Islanders		Staff with Disabilities
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Managers	374	73	18	3	356	70	4	2	5	1	5	0	4	0	13
Technical Staff	1288	327	91	28	1197	299	7	5	21	4	7	2	56	17	40
Administrative Specialists	157	245	14	17	143	228	5	3	7	8	0	2	2	4	7
Technicians	106	61	10	6	96	55	1	0	7	5	2	0	0	1	0
All Others	297	629	33	70	264	559	8	16	23	41	2	6	0	7	20
Totals	**2222**	**1335**	**166**	**124**	**2056**	**1211**	**25**	**26**	**63**	**59**	**16**	**10**	**62**	**29**	**80**

Occupational Codes	Total%		Minority Total%		% White		% Black		% Hispanic		% Native American		% Asian/Pacific Islanders	
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Managers	83.7	16.3	4.0	0.7	79.6	15.7	0.9	0.4	1.1	0.2	1.1	0.0	0.9	0.0
Technical Staff	79.8	20.2	5.6	1.7	74.1	18.5	0.4	0.3	1.3	0.2	0.4	0.1	3.5	1.1
Administrative Specialists	39.1	60.9	3.5	4.2	35.6	56.7	1.2	0.7	1.7	2.0	0.0	0.5	0.5	1.0
Technicians	63.5	36.5	6.0	3.6	57.5	32.9	0.6	0.0	4.2	3.0	1.2	0.0	0.0	0.6
All Others	32.1	67.9	3.6	7.6	28.5	60.4	0.9	1.7	2.5	4.4	0.2	0.6	0.0	0.8

(a) Data as of September 10, 1996.

Equal Employment Opportunity[a]

(1991 Full- and Part-Time Permanent Employees)

Occupational Codes	Total		Minority Total		White		Black		Hispanic		Native American		Asian/ Pacific Islanders		Staff with Disabilities
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
Managers	343	44	20	0	323	44	5	0	3	0	8	0	4	0	12
Technical Staff	1301	268	56	16	1245	252	5	3	11	2	10	2	30	9	47
Administrative Specialists	189	221	22	16	167	205	9	3	8	6	1	2	4	5	11
Technicians	155	88	6	3	149	85	0	1	4	2	2	0	0	0	4
All Others	371	902	40	87	331	815	12	27	22	41	2	7	4	12	22
Totals	**2359**	**1523**	**144**	**122**	**2215**	**1401**	**31**	**34**	**48**	**51**	**23**	**11**	**42**	**26**	**96**

Occupational Codes	Total%		Minority Total%		% White		% Black		% Hispanic		% Native American		% Asian/Pacific Islanders	
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Managers	88.6	11.4	5.2	0.0	83.5	11.4	1.3	0.0	0.8	0.0	2.1	0.0	1.0	0.0
Technical Staff	82.9	17.1	3.6	1.0	79.3	16.1	0.3	0.2	0.7	0.1	0.6	0.1	1.9	0.6
Administrative Specialists	46.1	53.9	5.4	3.9	40.7	50.0	2.2	0.7	2.0	1.5	0.2	0.5	1.0	1.2
Technicians	63.8	36.2	2.5	1.2	61.3	35.0	0.0	0.4	1.6	0.8	0.8	0.0	0.0	0.0
All Others	29.1	70.9	3.1	6.8	26.0	64.0	0.9	2.1	1.7	3.2	0.2	0.5	0.3	0.9

(a) Data as of December 31, 1991.

program serves several purposes. It is used as a network for job referrals, professional associations, and community contacts. It also serves as the beginning of a retention program aimed at providing valuable staff members with quality career placement and growth. Seven committees have been focusing on specific needs and issues for each of the seven protected classes (African American, Asian, Hispanic, Native American, Women, Veterans, and Disabled).

An evaluation of the effectiveness of the SDEP in FY 1995 identified the need to restructure. We have expanded the membership of the current SDEP to become more representative of the organization. This group will identify supportive work environment issues with emphasis on managing diversity and quality of work life. Recommendations and action plans will be developed to address needs within the fourth quarter of FY 1996.

Awareness Training

To meet the changing needs of the Laboratory, several training programs focus on EEO/AA and diversity. Quarterly, we offer management classes in equal employment opportunity and harassment awareness in the workplace. A shorter version of the course on sexual harassment awareness in the workplace is being given to staff.

Concepts and tools for managing diversity are currently being integrated into the Laboratory's Leadership Development Program efforts. The focus will be to increase managers' effectiveness in creating a supportive work environment where all staff may contribute their skills, talents, and experiences to achieve Laboratory goals. Integration is currently under way.

The Diversity Advisors Program (DAP) was piloted from January to June 1995. This program represented a reversal in standard mentoring roles. In this program, the Leadership Team member was considered the less-experienced member regarding diversity. Seven members of the Leadership Team were paired with advisors who helped them gain insight/knowledge/awareness into specific diversity issues that they identified. Issues dealt with included race/gender/support versus research/exempt versus nonexempt. The program received extremely positive feedback from all participants. A common kudos cited by participants was the development of a personal relationship between the pair and the Leadership Team member's exposure to differences. Ten Diversity Advisor pairs will be established during FY 1996.

Other Activities

In addition to training, special programs, and compliance activities, the Laboratory actively funded and participated in three special initiatives focusing on affirmative action recruiting. These included sponsorship of the American Indians in Sciences and Engineers Society Regional Conference, the Society for Professional Hispanic Engineers, and the Black Engineer of the Year Conference. In FY 1995, the Laboratory also sponsored a workshop at the event, "The Evolution of Diversity: Lessons Learned."

Career Fairs/Job Placement Activities

Laboratory staff participate in numerous career fair and job placement activities throughout the year. The level of participation is directly related to the recruitment needs of the Laboratory. Traditional sources for attracting qualified minority and women candidates include

- SER (Hispanic) National Employment Advisory Council
- Hispanic National Achievement Awards Conference
- Society of Women Engineers (SWE) Annual Conference/Job Fair
- GEM Selection Meeting
- National Society for Black Engineers (NSBE) Conference and Career Fair
- Society of Hispanic Professional Engineers (SHPE) Annual Conference
- American Indian Science and Engineering Society (AISES) National Conference
- Black Engineers Awards Conference
- National Organization of Black Chemical Engineers (NOBChE).

We expect our active involvement in NSBE, AISES, SHPE, and SWE to be focused more on a local rather than a national level throughout FY 1996.

Laboratory staff also participate in cooperative work study programs with local high schools and area colleges to help provide women and minority students with requisite skills for employment in industry. The Cooperative Office Education (COE) Program and Inquiry into Science (IIS) Program provide part-time employment to high school seniors. These jobs may be in any area at the Laboratory and may include entry-level work in the technician and clerical areas.

As shown in the Core Business Areas section of this Institutional Plan, the Laboratory is actively involved in the educational process from elementary school through postdoctoral studies. Several of these educational programs specifically target women and minorities: Science Alive, Student Research Apprenticeship Program; OPTIONS; HBCU programs; Environment Career Opportunities for Minorities; Life Gets Better; Washington State Mathematics, Engineering and Science Achievement (MESA) Program; and National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM). Other activities/programs focusing on women and minorities include: Take Our Daughters to Work Day, Washington Science Teachers Association Equal Opportunities in Science Committee, and the Expanding Your Horizons Conferences for Young Women.

Environment, Safety, and Health Management

The Pacific Northwest National Laboratory aspires to be the premier environmental science and technology laboratory in the world. The Laboratory cannot achieve this aspiration without achieving excellence in Environment, Safety, and Health (ES&H) protection. Our ES&H organization and management systems must provide the highest quality, most cost-effective products

and services to the Laboratory's mission and the satisfaction of our customers.

We will achieve this level of ES&H performance through a common management philosophy used for achieving excellence and efficiency in every aspect of our mission.

Goals and Objectives

The Laboratory has established six Critical Outcomes for the Laboratory. One of these Critical Outcomes is ES&H/Conduct of Operations (ConOps), which states:

> "We will conduct our work in a manner that fully protects the environment and health and safety of our staff and the public."

This Critical Outcome is supported by objectives and underlying performance indicators:

- "Establish the organizational and system-related infrastructure for ES&H and conduct of operation." Performance indicators assigned to this objective include performance against an Operations Improvement Program (OIP) master schedule and results of internal and external customer feedback surveys.
- "Achieve operational excellence in worker safety and health, environmental protection, and operational work control." Performance indicators assigned to this objective are specific to worker safety and health, environmental protection, and operational work control.

These objectives and their corresponding performance indicators were negotiated with and agreed to by the Department of Energy, Richland Operations Office, prior to inclusion in the Appraisal Plan, the operating contract, and the incentive fee. They also provide the vehicle for the Laboratory to communicate its strategic ES&H goals to all staff and incorporate appropriate performance indicators into work plans and individual staff goals.

Current Conditions

The Laboratory made significant improvements in the areas of ES&H and ConOps in FY 1995. The need for such improvements resulted from a joint conclusion by the DOE-Richland Operations Office and the Laboratory Director that the Laboratory's operational performance in these areas was far below that experienced in all other aspects of the Laboratory's mission and well below the expectations of both parties. The Richland Operations Office and the Laboratory jointly resolved to remedy its fundamental problems, including cultural, behavioral, attitudinal, leadership, and organizational problems, in a 12-to-18-month period and achieve a highly efficient, "best-in-class" status for the Laboratory among its national and international peers in 3 to 4 years.

The improvements made within the past 18 months are considered outstanding, including changes to the Laboratory's management systems. The Laboratory has initiated a complete paradigm shift in management strategy and philosophy that, when fully implemented, will provide an effective and efficient management system for meeting contemporary expectations. New organizational structures and functional assignments were initiated in FY 1995 and implementation issues are being resolved in FY 1996 as the Laboratory continues to refine and communicate the roles, responsibilities, authorities, and accountabilities of its new management systems to all staff and to propagate the commitment of senior management through the working level.

Reaching the Laboratory's goal to be the environmental science and technology provider of choice requires full use of facilities in a safe, reliable, and cost-effective manner. The Laboratory is achieving this goal by closing nonstrategic, uneconomical, and underutilized facilities. Research activities are being consolidated to the North Richland Campus and the southern portion of the 300 Area. Since March 1996, 49 facilities have been vacated; by the end of FY 1997, 43 (30 of the currently vacated facilities plus 13 vacated during FY 1997) facilities are expected to be transferred for alternative use or placed into the Hanford Site deactivation program. More than 80 facilities are expected to be closed over a 5-year period with an ultimate annual savings of $7.5 million. In addition, at the beginning of FY 1997 the Laboratory plans to transfer operation of two of its three Category 2 Nuclear Facilities (324 and 327 Building) to the Project Hanford Management Contractors.

Both the ES&H organization and the Laboratory have undergone significant downsizing in the past year. This occurred while substantial improvements were being made to the ES&H program and new value-added services were being delivered to the internal customer. This required the ES&H organization to become increasingly efficient and focused on the most important aspects of its operation. However, it has also resulted in a lack of resources (e.g., staff) to support a multitude of external assessments at the traditional pace. To mitigate this, the Richland Operations Office and the Laboratory have attempted to coordinate their assessments to eliminate redundancy, enhance productivity, and focus on areas of highest risk.

Significant issues facing the Laboratory currently include the following:

- Environmental compliance continues to be an area where focused efforts are necessary to improve the Laboratory's performance. Two specific issues in this area are disposal of existing legacy waste and the implementation of waste management practices in the daily work that deals both with the routine generation of waste and with avoiding creation of future legacy waste problems.
- Completion of a set of appropriate and relevant ES&H requirements, procedures, and guidelines for the work (and associated hazards) of the Laboratory. The replacement of the old manual system with new, more accessible and useful ES&H requirements and procedures will be a continuing emphasis during FY 1997.
- Development and implementation of an integrated ES&H management system that will result in ES&H becoming a integral part of the planning and execution of the work conducted by the Laboratory.

- Anticipation that DOE will issue 10 CFR 834, *Radiation Protection of the Public and the Environment*, in late 1996. Several issues exist relative to the development of the Environmental Radiological Protection Plan (ERPP) and implementation of the Rule at Pacific Northwest. These issues include receiving formal direction from the Richland Operations Office to lead the preparation of a Hanford Site ERPP and obtaining external funding to cover both the development of the Hanford Site ERPP and Pacific Northwest's input to that Plan.
- Completion of work in the Training and Qualification Initiative to establish a comprehensive, full-service, Laboratory-level management system.

The ES&H organization continues to receive unfunded mandates from DOE that deviate from planned work and are variant from agreed-upon initiatives. These mandates often require the diversion of scare resources from primary ES&H objectives and detract from the Laboratory's ability to implement its ES&H improvement plans and, thereby, achieve an effective and efficient ES&H program. To minimize these impacts, the Laboratory is actively working with the Richland Operations Office Assistant Manager of Technology as these mandates emerge to ensure that only those that support our objectives and the Critical Outcomes are implemented.

Policies, Organization, and Management

ES&H management philosophy and approach at the Laboratory consist of seven basic elements

- Commitment - Commitment to ES&H excellence is an obvious outgrowth of the Laboratory's mission. Excellence in environmental technology demands excellence in ES&H.
- Competence - Commitment without competence is "wishful thinking." Over the past 12 months, the Laboratory has undertaken a major upgrade of its ES&H and facilities organizations, in many cases reassigning scientific and technical staff who were providing ES&H services to external organizations. Today, the Laboratory is selling to itself the same level of ES&H quality we have been selling to our customers for years.
- Requirements - Commitment and competence without linkage to appropriate requirements can be "operation by tribal knowledge." That linkage requires the formality of a standardized process, but tailored to the specific types of activities being conducted and the facilities being operated. It also requires strong worker involvement. ES&H expertise has been infused into the workplace where ES&H management systems have been developed. Staff are specifically being involved in the development of ES&H Standards.
- Customization - Each organization's facilities and activities are different, and each laboratory must establish its own optimized method for implementing its authorization basis. The method will depend on the relative hazards, administrative systems, regional demands, and mission-driven organizational construct.
- Change Control - A system must be created that is dynamic enough to accept and address changes in mission, work scope, available funds, and business practices. However, stability and predictability must be brought to the workers and management processes. These goals can only be achieved through a businesslike, work-scope-based change control process.
- Confirmation - To avoid repeating our mistakes, an aggressive but integrated assessment program must be maintained. At the Laboratory, ES&H staff have effectively worked with the DOE-Richland Operations Office to eliminate unnecessary layering.
- Contract - The entire package, our mission, our philosophy, and our performance expectations were incorporated into the Laboratory contract. The Laboratory's FY 1996 performance contract with the Richland Operations Office includes detailed measures in six Critical Outcomes. The ES&H/ConOps critical outcome area and related self-assessment program performance compose 40 percent of the Laboratory's annual evaluation.

In FY 1995 major progress was made in establishing an effective and efficient ES&H organization. The new ES&H organization features customer-focused, field-deployed ES&H experts as integral parts of the facility-owner/user teams; a major shift from an "audit" role to a "problem solver" role; and about 40 percent overhead cost reduction without loss of quality service or increased risk to worker and public health and safety or to the environment. Key leadership staff were added in the areas of environmental compliance, radiological control, occupational safety and health, and independent oversight. These leaders came from the Laboratory's research and development organizations that provide ES&H/ConOps support to a multiplicity of clients.

In addition, a new Facilities and Operations Directorate was implemented that clarified roles, responsibilities, accountabilities, and authorities relative to conduct of operations throughout the 186 facilities of the Laboratory. A new facility management model was developed and approved by senior management to formalize facilities operations and establish a landlord/occupant relationship between facilities owners and facility users. Facility operational boundary criteria that define the critical elements which create adequate control levels to perform a broad spectrum of research and development activities safely and in compliance are a key element of this model. A Facility Use Agreement serves as a contract between the landlord (Facility Management) and occupant (research and development), providing standards, operational boundaries for the facility, and responsibilities and accountabilities of the landlord and occupant.

Plans and Initiatives

The Laboratory Director initiated the Operations Improvement Program in November 1994. The Operations Improvement Program specifically identified ES&H, ConOps, Training

ES&H Plan Funding Request

($ in Millions)

	Fiscal Year				
	1996	1997	1998	1999	2000
Expense	0.5	1.3	0.7	4.3	4.0
Capital Equipment	0.0	0.0	0.3	0.3	0.3
Capital Construction	1.5	3.25	3.25	0.0	0.0

and Qualifications, and several related support systems as key initiatives for improvement. The objective of the Operations Improvement Program is to implement organizational structures with clear roles, responsibilities, accountabilities, and authorities that are supported by efficient management systems and excellent technical support service personnel, resulting in sustainable operational excellence. From its inception, the Operations Improvement Program has been a joint effort by the Laboratory and DOE to proactively and systematically implement the infrastructure tools to make the Laboratory safer and more efficient.

The Operations Improvement Program will continue for at least two more years to meet the following success indicators:

- Laboratory standards and appropriate subject matter experts are readily available to assist management and staff
- Laboratory is able to readily demonstrate effective ConOps
- ES&H organization performance is judged effective and efficient
- field verification demonstrates effective implementation of 10 CFR 835
- roles, responsibilities, accountabilities, and authorities are understood, accepted, and verified through execution
- Training Management organization has been effectively implemented and appropriate Training Management Standards are in place
- Laboratory Self-Assessment Program is judged effective and efficient
- Facility Use Agreements are operating effectively.

Achievement of these indicators will foster DOE's continued confidence in our ability to operate the Laboratory safely, efficiently, and effectively. Part of that success will be economic, where we will deliver quality work at a lower price through cost-effective compliance and smoother work processes while encountering fewer problems. Improvements in the quality of the environment in which we operate will be as important as our external reputation and cost savings. Ensuring that staff are satisfied with the systems they use to deliver research and development products is one of the Operations Improvement Program's top priorities.

Key achievements

- development, implementation, and verification of an Radiation Protection Program Plan for 10 CFR 835
- completion and receipt of the DOE-Richland Operations Office approval for a revised 324 Building safety analysis report and submittal of the revised 325 Building safety analysis report
- assignment of a nationally recognized Safety and Health training expert as manager of a newly created, centralized organization for the Laboratory-wide training and qualifications program.

Key initiatives include

- resolution of significant legacy waste and operational waste management program/system weaknesses via a strategic, change-controlled special project in place under the ES&H Directorate
- development and implementation of a new Laboratory-wide Integrated Assessment Program in FY 1996. This includes the Laboratory-level and key Division/Directorate-level Self-Assessment Programs and a new Independent Oversight Program recently assigned to the ES&H Directorate.
- development of an integrated infrastructure and process framework for the Laboratory's requirements system, including an integrated systems approach to safety management. This system will provide traceability between Laboratory policies and procedures and external regulations and requirements. Coupled with a Standards Development Initiative within the Operations Improvement Program, this system will improve the accessibility and usability of all Laboratory-wide policies and procedures.
- Major objectives of the Training and Qualification Initiative are to upgrade training and qualification policies and standards and to establish, implement, and maintain a new Laboratory-wide management system for training and qualifications
- The Laboratory has begun implementing an Integrated ES&H Management System that will fully deploy systematic, integrated ES&H activities into management and work practices at all levels to enable missions to be efficiently and effectively accomplished while protecting the workers, the public, and the environment. This will ensure that ES&H is integrated into the work conducted by the Laboratory thus achieving "defense in depth" through careful application of controls tailored to the work being performed.

Energy Research-Funded ES&H Improvement Items

In FY 1995, Energy Research began to provide operating funds for some ES&H initiatives. The funding is available for one-time costs or start-up costs associated with ongoing activities, but is not available to support continuing ES&H program elements.

The following initiatives were funded during FY 1996:

- Enhancements to an Ergonomics Program that will lead to a reduction of repetitive trauma injuries and a more proactive approach to problem identification and correction including development of managers' training and training of additional ES&H staff to conduct evaluations.
- Piloting the Environmental Compliance Representative process for Energy Research facilities. The Environmental Compliance Representatives will provide direct technical support to line managers in meeting their environmental compliance responsibilities. This will ensure early identification and resolution of environmental compliance issues and integration of environmental protection into the design and conduct of work.
- Enhancing the Pollution Prevention Program to minimize generation of waste through an improved recycling program, an enhanced chemical exchange program, and improvements to the affirmative procurement program.
- Continued development of the Safety and Health Information Management System (SHIMS). Revised the accident/injury reporting module and designed the next module to incorporate industrial hygiene data and hazards inventory information into the system.

The following short-term initiatives are proposed candidates for Energy Research funding in FY 1997:

- Development of the ERPP and Procedures for 10 CFR 834: Develop the ERPP, the procedures necessary to support implementation of 10 CFR 834, and conduct final verification of implementation. The regulation is expected to be issued in FY 1997 with full implementation required 18 months later.
- Environmental Compliance Representative Implementation: This effort would continue the pilot by expanding it to the Facilities and Operations Directorate and the facilities transition program which are not currently covered. This will provide direct technical support to facility and program managers to assist them in meeting their responsibilities for environmental compliance.
- Surveillance and Maintenance of Energy Research Facilities: The Laboratory is in the process of closing underutilized and uneconomic facilities for which Energy Research is the landlord. Surveillance and minimum maintenance activities must begin in FY 1997 to prevent deterioration of these facilities and to ensure control of safety hazards such as roof or floor failures, animal or insect infestation, and weather damage. This would include radiological surveillance of radiologically contaminated facilities as required by 10 CFR 835, and appropriate controls for other hazardous materials such as asbestos and polychlorinated biphenyls.
- Continued development of the Safety and Health Information Management System: Development and implementation of Phase II will begin. This will include capabilities for exposure monitoring data, workplace exposure assessment results, medical surveillance and qualification, monitoring and clearance data, access to safety training information, etc., in addition to the currently available accident and injury reporting capability.
- Further enhancement of the Pollution Prevention Program: This will include expansion of the recycling program to include small batteries, oil, metals, laboratory glassware, and unopened chemicals; expansion of the affirmative procurement program; improved tracking and prioritization methods to provide increased focus; and facilitating participation in an eco-industrial park for the Tri-Cities.

Energy Research also provides funding for construction, capital equipment, and facility upgrades and improvements. Following is the list of current activities which the Laboratory is undertaking with this funding:

- General Plant Projects (GPP): Composed primarily of discrete corrective activities required to bring Energy Research facilities into compliance with ES&H regulatory requirements.
- General Purpose Facilities (GPF): FY 1995 Line Item, Electrical Safety Rehabilitation will provide replacement of deteriorated wiring and outmoded equipment in multiprogram buildings.

The Laboratory will continue to give a high priority to funding environmental, safety, and health activities; however, additional requirements have generally resulted in higher costs. The Laboratory must receive direct funding for implementation of these additional requirements.

Environmental Restoration and Waste Management Activities

The DOE and the Laboratory are committed to providing a safe and compliant work environment. Resources are being focused to 1) assess and clean up inactive waste sites and facilities, 2) continue safe and effective waste management operations while emphasizing the systematic minimization of waste materials generated, and 3) coordinate and integrate a focused research and technology development program for application to waste management and environmental protection.

A systematic approach is being used to manage and operate the Laboratory's environmental compliance and waste management systems. Numerous activities of vital importance to all phases of environmental compliance and waste management are currently being funded by DOE-Environmental Management. The following funding highlights are included in the Environmental Restoration and Waste Management Plan:

- Environmental Compliance Projects: The Environmental Compliance Projects provides a comprehensive management system to efficiently resolve large or complex environmental compliance problems facing the Laboratory. These projects are being specifically targeted at those environmental compliance issues that are beyond the time and resource capabilities of individual Laboratory

Waste Minimization Plan Funding

($ in Millions)

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Capital Requirements								
DOE-ER (Office of Energy Research)	0.0	0.0	0.0	0.13	0.14	0.15	0.16	0.17
DOE-EM	0.05	0.03	0.0	0.0	0.0	0.0	0.0	0.0
Operating Requirements								
DOE-ER (Office of Energy Research)	0.05	0.11	0.15	0.15	0.16	0.16	0.16	0.17
DOE-EM	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total for Laboratory	**0.45**	**0.31**	**0.35**	**0.48**	**0.5**	**0.51**	**0.52**	**0.54**

facilities or divisions. They include a compliance assessment process and resources to identify potential compliance problems at the facility level and will develop corrective actions working in conjunction with responsible line management. Activities for FY 1996 are focused on completion of compliance activities and regulatory commitments initiated in FY 1995. This includes

- finalizing and submitting the closure plan for the unpermitted mixed waste management units located in 324 Building Radiochemical Engineering Cell Complex
- submitting the draft RCRA Part B Application for 325 Building Hazardous Waste Treatment Unit/ Shielded Analytical Laboratory
- preparing administrative closure documents and certification for RCRA Part A applications related to former research programs in selected Laboratory facilities
- finalizing project planning for regulatory approval of High Level Vault Tank interim stabilization
- establishing a network of environmental compliance representatives for Environmental Management facilities at the Laboratory to work with research and development divisions on environmental issues and problems.

- Waste Minimization and Pollution Prevention: Comprehensive efforts are being pursued to provide technology and systems assessments that will result in the minimization, recycling, or prevention of waste production at the generating source, thereby decreasing or eliminating the amount of waste that requires disposal. During this planning cycle, a specific investment surcharge will be assessed to each waste generator which will provide focused funds for technology implementations and result in dramatic reductions in total waste volumes generated in the out years.
- Environmental Compliance Activities: Technical support services and management systems are provided to assist line management implementation of requirements in areas such as RCRA, Toxic Substance Control Act, NEPA, CERCLA, and air and water. The environmental compliance function includes support for permitting and completion of required environmental reporting.
- Waste Operations: Funding is provided by DOE to manage and operate the activities and facilities necessary to effectively manage the wastes and effluents generated by the Laboratory. Effluent Management programs within the Laboratory ensure that human health and the environment are protected by managing air and water effluents safely and in full compliance with the applicable laws and regulations. The Waste Management System provides the facilities and services necessary to accumulate, characterize, package, transport, store, and dispose of all wastes generated within the Laboratory.
- Waste Cleanup: Over the past several decades, facilities within the Laboratory have accumulated a legacy of waste materials from previous research and development programs. Focused efforts are now being funded to clean up and dispose of these waste materials to allow facility reuse or safe and compliant transition of these facilities to shutdown status and/or deactivation and demolition. One specific effort of waste cleanup activities includes the cleanup of the large legacy of waste materials from within the 324 Nuclear Facility by as early as December 1998. B Cell will be reused for any identified future programmatic needs. If no needs are identified, then the facility will be deactivated and prepared for future demolition.
- Safety: Specific portions of the Environmental Management funding are focused on the activities necessary to provide surveillance and maintenance support of the Laboratory's Nuclear Facilities. To ensure these facilities are operated safely and in compliance while protecting the public health and safety.
- Technology: Each of the funded areas listed above contains efforts that are

DOE-EM ES&H Funding Requests

($ in Millions)

	Authorization				Planning Case				
	1994	1995	1996	1997	1998	1999	2000	2001	2002
EM-30 Expense Totals	34.7	43.4	32.7	15.3	14.7	19.7	11.8	23.5	14.7
EM-30 Capital Totals	3.5	1.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0

DOE-EM Landlord ES&H Funding Requests

($ in Millions)

	Authorization			Planning Case				
	1995	1996	1997	1998	1999	2000	2001	2002
EM-60 Capital Totals	3.7	2.8	0.0	1.3	2.0	2.0	2.0	2.0
EM-60 Expense Totals	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.2

ES&H Management Plan

($ in Millions)

	Authorization			Planning Case				
	1995	1996	1997	1998	1999	2000	2001	2002
Core Program	21.6	23.7	26.2	26.8	27.4	28.1	28.8	29.2
Compliance Program	4.4	2.7	5.5	7.1	3.1	2.8	2.0	1.7
Improvement Items	0.1	0.1	0.05	1.7	0.8	0.1	0.1	0.1
Total for Laboratory	**26.1**	**26.5**	**31.8**	**35.6**	**31.3**	**31.0**	**30.9**	**31.1**

focused on integration with ongoing technology development activities within the Laboratory and across the DOE complex. These efforts ensure the maximum use of improved technologies in all phases of the waste management cycle. Specific introduction of new technologies are made whenever reduction of life-cycle cost and/or appropriate improvements to worker and public health and safety are warranted.

Detailed funding of the described programs and activities are shown in the table.

Hanford Site-Wide Funded ES&H

The Hanford Site Landlord Program (EM-60) enhances the Hanford Site general purpose infrastructure in support of Hanford Site cleanup. The general purpose infrastructure consists of buildings, systems, and equipment that, by design or use, are not essentially dedicated to a single program mission. The Landlord Program primarily consists of capital funding (see the Landlord Funded ES&H table) for ongoing replacements and enhancements to general purpose facilities; water services; electrical distribution; roads; steam; building additions or replacements (if not used by a single program); and other general environment, safety, and health equipment. General purpose facilities on-going projects are 324 and 325 Buildings Facility Compliance and Building and Utility Replacement.

General plant projects activities consist of the 325 Radioactive Liquid Waste System (RLWS) load-out station. The DOE Site Infrastructure Division is working toward closing the railroad system that transfers RLWS waste from

the 300 Area to the 200 Area. The 325 RLWS load-out station is required in FY 1998 to service the 325 nuclear facility as well as the entire Laboratory complex in the 300 Area. The Laboratory can either utilize an EM-funded LR56 cask system (essentially a lead-lined and trailer-mounted tank) or our bowling ball casks. Both comply with all DOE requirements regulating the transport of highly radioactive liquids.

Operating-expense funded activities include National Electrical Code compliance activities, installation of backflow prevention devices, stairway replacements, and ventilation system upgrades.

Information Resources Management

Goals and Objectives

Information Resources Management (IRM) is focused on the delivery of effective and efficient computing and network infrastructure, business and science applications, and a full range of Information Sciences supporting services. In 1995, the Laboratory's Information Science enterprise was restructured to enhance mission focus, improve productivity, and reduce management costs in response to the Achieving the Competitive Edge program aimed at streamlining the organization and drastically reducing operating costs. At the same time, we initiated infrastructure changes that significantly improve the Laboratory's computational capability and introduced a number of applications which increased the productivity of the scientific and administrative staff. We also reduced Information Science staff, especially in overhead-funded areas, and initiated projects to reduce or eliminate low-value work and to acquire resources more effectively and efficiently.

Pacific Northwest National Laboratory's Information Science vision is to be a Laboratory without walls—where staff work interactively with each other and in collaboration with universities, government, industry, and the international community to solve significant national problems. Our greatest challenge is to deliver the infrastructure, applications, and services required to support the environmental quality and scientific research missions of the Laboratory while reducing the Laboratory's management costs by implementing productivity enhancing systems, processes, and applications.

We envision four key Information Science strategies that support our vision: 1) empowering the user with technically effective and cost-efficient systems, tools, and applications; 2) carefully defining and meeting the information technology needs across the Laboratory; 3) making the most effective use of information technology within constrained budgets; and 4) ensuring stable, reliable, and efficient implementation and operation of the computing and network resources.

Current Situation

The Laboratory's Integrated Computing Environment provides the computing, network, information, and service infrastructure supporting scientific and engineering research, development, and technology deployment; management of the business; and access to scientific and technical information. The Integrated Computing Environment consists of a single local and wide-area network infrastructure, the attached computing resources from office workstations to supercomputers, software tools, utilities and applications, and services to support the user community. The Integrated Computing Environment supports a full range of network services including Internet access and a robust Intranet for the distribution of internal Laboratory information.

More than 7,000 IBM PCs and compatibles, Macintosh, and/or UNIX workstations are used to support research, management, and administrative functions. About half of the systems are located on the desktop with the others supporting the infrastructure (e.g., servers) or are dedicated to other activities (e.g., data acquisition, control, training, etc.).

Voice communication and voice mail are provided by an InteCom IBX S/80 digital voice/data telephone system serving the 45 percent of Laboratory staff located in private facilities. The Hanford Site Integrated Voice and Data Telephone System serves the remaining staff located in DOE facilities.

Dedicated video conferencing is supported by two-switched 56k services located in conference rooms. Similar systems are located at Battelle's corporate and the Laboratory's Washington, D.C., offices providing an alternative to travel for meetings and collaboration. Low-cost portable video conferencing was piloted for general purpose use in wired conference rooms and three systems are being deployed. Mbone functionality is supported by the Laboratory network and is primarily used in support of conferences or collaborative activity, but is not yet a universal service to all desktops.

The Laboratory network is based on multiple FDDI backbones with more than 120 hub-wired Ethernet segments. There are about 6,000 workstation connections, 500 network printers, 125 servers, and 30 routers. Fifty servers provide generalized services while an additional 75 servers support application-specific services. The network serves 116 buildings with more than 20 miles of fiber in the primary FDDI ring and another 50 miles of fiber interconnecting Laboratory buildings. User-level security is implemented on the network with forced expiration of passwords. Dial-up access is mediated using smartcard technology. A firewall provides unrestricted outbound access to the Internet while restricting inbound access. Anonymous FTP services are available to the Internet community via a server located outside the firewall. The Laboratory is connected to the Energy Sciences network (ESnet) by an FTS-2000 T1 circuit to Livermore. The network also supports Domain Name Services, X.500 Directory Services, time services, automatic software distribution and install, unattended backup and restore for user workstations files, as well as mail, calendaring, file storage, and system access.

T1 service is also available between the Laboratory's Richland facilities, its Washington, D.C. Offices, Marine Sciences Laboratory, and Seattle,

Washington, campus. Another T1 link provides access to the regional research and education network, NorthWestNet. This provides Internet access backup for the ESnet link and direct access to the Laboratory from the regional and national universities, as well as industry and the international community via Internet.

High-performance graphics workstations (e.g., Silicon Graphics, Intergraph, and others) give access to advanced tools for still-frame and full-motion three-dimension color visualization. A multimedia laboratory provides facilities for high-quality multimedia productions and supports graphics laser printing, audio and video recording, as well as CD-ROM and videotape production.

Midrange systems have been almost completely replaced with individual and/or clustered high-performance workstations for both scientific and administrative computing. Four clusters are operating (DEC, HP, IBM, and Sun). A limited VAX capability serves as the Internet mail gateway and supports a declining number of legacy applications requiring VAX compatibility.

Supercomputing requirements are satisfied by a combination of in-house systems and remote access to other DOE sites (Los Alamos, Argonne, and National Energy Research Supercomputing Center [NERSC]). In-house resources include a Kendall Square Research KSR2 system with 80 processors, 2.56 gigabytes of main memory, and 40 gigabytes of disk storage installed in the interim EMSL, and the several clusters mentioned earlier. Following a competitive acquisition, an order has been placed for a 472-processor IBM SP with a capacity of more than 200 peak gigaflops. The system is being delivered in two phases beginning in June 1996 with a 192-processor, with 27 gigabytes of memory, and 566 gigabytes of secondary storage. The 472-processor full-scale system with 62 gigabytes of memory and 1,238 gigabytes of secondary storage will be delivered in March 1997 to support research in the EMSL.

The Business Information Systems infrastructure is distributed across three environments. A large-scale, IBM-compatible system operated by the Hanford Management and Operations Contractor is used for off-prime-shift batch processing. A Sun multiprocessor running Oracle under UNIX and operated by Pacific Northwest is used as a data repository for on-line management and project reporting. Network servers are used for transaction processing and user access to information distributed from the Sun repository using Sybase and Oracle client-server relational database technology and graphical front end tools (e.g., Business Objects, OMNIS 7.0).

Strategies

Information Science plays a significant role in support of the Laboratory's missions. The Information Science organization delivers the baseline infrastructure for the conduct of programmatic scientific research and technology development, develops and operates automated management and administrative systems, and performs research and development in computer science and technology. In 1995 we combined the separate research and administrative computing organizations into a single unit to integrate our technical effectiveness, reduce management cost, and limit redundant capabilities. The focus for computing and information technology resource investments includes

- continued expansion and upgrade of the capacity and functionality of our local and wide-area network infrastructure
- significant expansion of scientific and engineering computing capability and capacity with emphasis on high-performance computing, modeling, and simulation
- administrative and management information systems focused on eliminating the few remaining mainframe applications and implementing high-payoff productivity applications
- multiprogram, multilaboratory collaboration and leadership as well as outreach to the academic and industrial communities.

Scientific and Engineering Computing

Scientific and engineering computing is an essential component supporting our core competencies. Competency is maintained in

- computational modeling and simulation
- environmental management systems
- advanced computing and network infrastructures
- scientific and engineering applications.

Following are descriptions of selected efforts in these areas. Resource projections are contained in program-specific requests covered elsewhere in this document.

Computational Modeling and Simulation Our core competencies in the major disciplines supporting Laboratory missions are linked and extended by modeling and simulation. By enabling research staff to study phenomena that are inaccessible to direct experiment, too costly or socially unacceptable for experiment, or too complex for analytical theory, modeling, and simulation provide insights into environmental and scientific phenomena otherwise unavailable.

Key modeling and simulation activities include computational chemistry modeling and simulation; environmental contaminant characterization, transport, and remediation modeling (atmospheric, oceanic, surface water, and subsurface); global climate and coupled atmospheric/ocean modeling; analysis of the structure and function of enzymes that act as biological catalysts and of biomolecules that control critical biogeochemical processes in the environment; and thermal hydraulics fluid-flow modeling and simulation.

We have released version 1.2 of the NWChem suite of molecular modeling software which provides 10 to 100 times more computing capability than has been available before on even the most powerful supercomputers. NWChem is broadly functional across

multiple computational chemistry methods, scales efficiently in both problem and computer size, is portable, extensible, and adheres to open systems standards. Its capabilities include energies and analytic gradients; geometry optimization; and second derivatives by numerical difference of gradients, classic molecular dynamics, and mixed classical-quantum molecular dynamics.

To support modeling and simulation, an advanced capability in graphics and visualization is maintained. We are developing both input and output-oriented tools for the research community. For example, an Extensible Computational Chemistry Environment (ECCE) is being developed that integrates NWChem and other codes so scientists can perform complex modeling and simulation tasks efficiently from their desktop workstations using data-centered, object-oriented, graphical user interfaces for input, analysis, and visualization. Two visualization laboratories have been established. One is a general purpose facility while the other is specialized for the Environmental Molecular Sciences Laboratory.

Our core competencies support the development of atmospheric models for contaminant transport and dispersion, chemical and physical transformation, and deposition to determine the continental and oceanic fate of air pollutants. We are responsible for the ongoing development of a second-generation energy generation/economic model as well as the Global Change Assessment Model. In addition, experimental data systems and measurement technologies are used to validate, diagnose, and improve the performance of atmospheric General Circulation Models.

The Laboratory's capabilities in thermal-hydraulic safety code development are used by the nuclear industry and most recently for the Hanford Tank Safety Mitigation and Flammable Gas Projects.

Modeling is also being used to support the design of next-generation instruments. One example is modeling next generation Fourier transform ion cyclotron resonance mass spectrometry instruments to guide designs that are an order of magnitude more precise than previous instruments.

Advanced Computing and Network Infrastructures We develop pilot and prototype versions of the next generation of scientific computing systems, tools and infrastructure, instrument acquisition, and control systems. Efforts are aimed at moving the technology forward by introducing advances in controlled environments. Key strategies include

- bringing the EMSL high-performance computing and network infrastructure on-line and integrating it with PNLnet
- restructure network access controls to accommodate required open access while protecting information from inappropriate disclosure and systems from misuse
- ensuring that the stability and reliability of the Integrated Computing Environment infrastructure are uncompromised; that network performance is acceptable
- continuously evaluating emerging technology and adding local area, Internet, and Intranet functionality that makes the infrastructure transparent, easy to use, adequately protected, and supports emerging applications (e.g., multimedia).

For the EMSL we are acquiring and implementing an advanced network based on Asynchronous Transfer Mode and switched Ethernet technology. Technology components are being acquired and installed in FY 1996. As part of this effort an Automatic Network Test suite was developed extending the public domain work of the U.S. Army and the National Center for Supercomputer Applications. The suite is used to benchmark a wide variety of network products from a single master station.

The Laboratory supports the International Nuclear Safety Program. We have established a contract for satellite-derived telecommunications between the Laboratory and the International Center in Slavutych, Ukraine. The system provides network, voice, and facsimile services over an ISDN link. In the future, we expect the link to support video conferencing as well.

We have also taken steps to enhance the security of the internal Intranet by extending user level security to internal web pages in the same way we restrict access to certain information systems and/or applications. This provides us with the ability to more effectively provide access to visitors, guests, and other persons with access to PNLnet (e.g., other Hanford contractors), appropriate web pages, and/or applications while blocking access to others.

An Internet web authoring tool has been developed and placed in the public domain. Named Marmot™, this tool is a cross-platform client (Windows, Macintosh)/server system for publishing materials in http and Gopher+ compatible format. Marmot supports document conversions, local style guides, and group authoring; enforces publication business rules; and automates the generation of html pages.

We are continuing to improve the reliability and performance of the network and expanding its functionality. The oldest segments of the cable plant have been replaced and we are replacing older network devices with systems that can be remotely monitored and controlled. Uninterruptible Power Supplies for primary routers and hubs are in place. We have added personal computer and Macintosh servers to improve performance, completed the transition from OS/2 to NT Advanced Server, and will add a redundant X.500 directory server. An additional FDDI ring, dedicated to application server file transfer, graphics, and replication services for distributed applications will be added to improve performance.

Energy and Environmental Management Systems The Laboratory develops environmental database and management systems both for Hanford and the wider DOE community. We developed the Tank Waste Information Network System (TWINS), a multimedia-capable departmental system that links waste tank information from Rocky Flats, Oak Ridge, Savannah River, Idaho, and Hanford into a common systems

hub located at the Laboratory with access provided to a wide range of external customers across the DOE complex; and the Hanford Environmental Information System (HEIS) which stores, manages, and aids in the analysis of Hanford's environmental sampling data that are crucial to Hanford's environmental cleanup and restoration mission.

The National Radiobiology Archives has been established to contain dose-effects data, a repository of documents and research records, and a tissue archive for life span studies on animals conducted across DOE over the past five decades. The archive is now in the process of being transferred to Washington State University for long-term operation and maintenance.

Development is continuing on the Remedial Action Assessment System (RAAS), an advisory tool that identifies, screens, links, and evaluates technologies and unit processes for the remediation of operable units and waste management units in compliance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

With funding support from the U.S. Army, the Laboratory is developing the Federal Energy Decision System (FEDS) which provides planners with a comprehensive approach to fuel-neutral energy resource planning and acquisition. The model FEDS, Version 3, was released in 1995 and further development to extend its functionality is ongoing. In addition, we have developed the Federal Emergency Management Information System (FEMIS) with joint support from the Army and the Federal Emergency Management Administration. This support is expected to continue for individual modules which expand or differentiate the emergencies FEMIS will support.

Scientific and Engineering Applications Other systems development includes real time data acquisition and process control, artificial intelligence, neural networks, power systems dynamics, medical informatics, and satellite image processing.

Pacific Northwest is developing measurement-based analysis techniques for understanding power systems dynamics, the evaluation of distributed utility system options, and artificial intelligence-based tools for load forecasting and systems diagnosis.

Medical informatics is focused on the development of cost-effective tools for medical image visualization, diagnostic assistance, training, information processing, and telemedicine. The Laboratory has entered into an agreement with an industrial firm to commercialize a holographic imaging system for medical applications.

The Laboratory is involved extensively in research and development on technology that fundamentally transforms the tasks of text-based information retrieval and analysis. Through the creation of spatial representation for complex, symbolic information, this technology dramatically reduces the time required to mine and analyze large, text-based document collections.

Business and Management Information Systems

Development of information systems is based on an annual budgeting process consistent with the enterprise-level strategies developed originally as a part of the WISDM whole systems enterprise model. That model was developed in FY 1990. Systems development is based on the principle that information is an organizational asset and is collected, organized, protected, and made conveniently available to authorized staff. Applications interfaces are designed to have a common look and feel based on generic user interfaces and operating procedures. Requirements are developed up front by a group representing all stakeholders. Data is entered only once at its point of origin and made electronically available for reuse in multiple applications.

At the start of FY 1996, we initiated an effort to revisit the WISDM model in view of changing technical, economic, and business events. We will complete the revised plan for the development and/or redevelopment of the Laboratory's management and administrative systems in FY 1996 and it will be used to guide our efforts in FY 1997 and beyond.

Key strategies for management and administrative computing are to

- utilize electronic creation, routing, and approval for internal transactions eliminating paper flow and its attendant cost and delays to the maximum extent practical
- implement all new systems using network-based client-server technology based on commercial software; and transition legacy systems to this environment and implement all transaction input systems for real-time processing, modularize the core business functions, and eliminate the use of the Hanford mainframe
- maximize the electronic distribution of management, administrative, and technical information to staff
- implement systems in web compatible and/or accessible technology and increase the use of the internal web for information delivery.

We completed the development of a portable, encrypted, electronic signature system kernel designed to be used with multiple applications for creating electronic documents, attaching electronic signatures, routing the documents for further signatures, and storing the results in an auditable format to meet records retention requirements. The kernel system was subject to an external peer review and approved for use by DOE in FY 1995. At the start of FY 1996, we introduced a fully automated, client/server-based electronic time reporting system with employee and manager electronic signatures which significantly improves staff productivity, increases accuracy, and reduces process delays. The kernel is also being used for the submission and approval of electronic purchase requisitions. All records material is stored on an optical jukebox. We anticipate implementing additional applications using the kernel.

Replatforming the Laboratory's business systems continues to be strategically important. Applications running on a midrange Sequent database were rehosted to a Sun Sparc multiprocessor platform in FY 1995 and a data warehouse, or repository, was established

on the Sun to store and maintain enterprise data. Input to the repository is from a set of transaction processing databases located on distributed file servers. The repository supports long-term storage and access, replication services for the transaction processing environment, and contains the enterprise data dictionary and applications inventory. This enhances centralized control mechanisms while supporting the distribution of operational applications, and establishes the basis for moving to a near-real-time administrative applications environment.

The next major step is to replatform IBM mainframe applications to the Sun and other servers. At the same time, our custom cost-accounting system will be re-implemented using commercial software. Also critical to this is to design transaction input systems such that all transactions are completed when the transaction is created. Thus, there is no further processing, and the results of the transaction are available immediately. This is a key step in moving toward a real-time financial system.

Standard Query Language is the preferred technology for database access, and compatible front-end tools provide the user interface and access to the Laboratory repository and transaction databases. Application and utility software are acquired or developed to support all three mainstream Laboratory platforms: PC and compatibles, Macintosh, and UNIX.

Streamlining the procurement process is a strategic priority. In addition to implementing electronic purchase requisition, routing, and approvals, a Purchase-Card system is in full operation using reconciliation software developed by the Laboratory which is now being commercialized by a spin-off company started by Laboratory staff members. We are also implementing revised basic ordering agreements for the acquisition of PC-compatible and Macintosh workstations which will be delivered, fully configured with all standard Laboratory software.

We are putting significant emphasis on the development of the internal web for distribution and access to Laboratory information. Our strategies include moving forms distribution to the Intranet and using the web to deliver training. Following an FY 1995 pilot, we have launched a program that will put our policy and procedures manuals on-line as we are revising the management policies and procedures. Our strategic intent is to eliminate all paper-based manuals.

We also continue to increase our presence on the Internet through the development and revision of our home pages. Along with this we have revised our publishing procedures.

We have implemented a fully automated Training Information System which identifies training requirements, course scheduling and registration, and work completed. In addition, the system is Internet linked to the Hanford Site and local colleges to provide on-line registration. Local and remote web-based training has been initiated on a pilot basis for several mandatory courses (e.g., Radiation Worker training) and will be extended in future years.

Other applications commercially acquired and/or developed in FY 1995 included a capabilities database and employee skills coding system, electronic staff advances and reimbursement, Laboratory core competencies database with Intranet access, employee work location, and a Safety & Health Information Management System.

We are redeveloping the purchasing/subcontracts system, proposal pricing, and financial system using commercial software.

Collaboration and Outreach

Within the DOE's Energy Research program, Pacific Northwest staff continue to provide interlaboratory coordination, program direction, and leadership for the Atmospheric Studies in Complex Terrain (ASCOT), Atmospheric Radiation Measurement (ARM), and Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) programs. While the ASCOT program is winding down, we expect to continue participating in the ARM and CHAMMP programs.

Laboratory staff participation on standards committees include ANSI X3T5, Open Systems Interconnections; IEEE P1074.1, Software Lifecycle Processes working group; IEEE Mass Storage group; IEEE P1059, working group on the Standard of Software Verification and Validation; and IEEE 802.10, working group on Computer Communications, Security, and Privacy.

Laboratory staff continue to be active on DOE committees and with the regional universities including participation in EXERSUG, ESnet steering and site coordinator's committees; the Scientific Computing Information Exchange (SCIE) group of multiprogram laboratories; supporting the DOE-Headquarters Procurement Consolidation task group, Distributed Computing Coordinating Committee for Energy Research; and serving on the executive board and technical committee of NorthWestNet.

Educational outreach includes a computational chemistry pilot program to provide Kennewick High School students with access to the EMSL to perform molecular modeling; providing ESnet access to local high schools in support of the National Educational Supercomputer program at NERSC; selected student Internet access under the Disabilities, Opportunities, Internetworking and Technology (DO-IT) program; and general access for teachers and students of the Kennewick, Washington, school district. The Internet access program with the Kennewick School District has been expanded through a Washington State grant to provide remote access and control of the Battelle telescope on Rattlesnake Mountain. Internet access is supported by an excess personal computer installed outside the Laboratory firewall with dial access to local schools. The Laboratory continues, in cooperation with DOE-Richland Operations Office, to provide IBM computers, color monitors, and laser printers for a computer laboratory at Park Middle School in Kennewick under the Science Education Equipment Loan program.

The level of collaboration with and outreach to external organizations increased significantly in FY 1994 and was relatively stable in FY 1995. We expect to continue to sustain collaborations already in place and to initiate

Major Items of Equipment
(Budget Authorization $ in Millions)

	Fiscal Year							
	1996	1997	1998	1999	2000	2001	2002	2003
Construction Capital Equipment[a]	6.08	9.23	0.0	0.0	0.0	0.0	0.0	0.0
Programmatic Capital Equipment (KP)	0.0	0.0	1.5	1.2	0.6	0.0	25.0	3.2
Total Funding	**6.08**	**9.23**	**1.5**	**1.2**	**0.6**	**0.0**	**25.0**	**3.2**

(a) Construction Project EM-91-100.

new ones depending on developing new requirements and seizing opportunities that materialize. Increased opportunities are expected to occur in the K-12 educational outreach program which remains a high priority activity and for Internet collaboratories.

Technology Transfer and Sharing

Software commercialized includes Softdesk, an energy design tool with computer-aided design; NUCLIDES, a nuclear instrumentation code; ReOPt, a remedial operations code which provides information on nearly 700 environmental contaminants and 88 remediation technologies; Multi-Media Environmental Database Editor (MMED); and SYNTH, a gamma ray spectroscopy code.

The Laboratory's Declassified Document Tracking System (DDTS) was recently transferred to Rocky Flats. The system 1) tracks, coordinates, and catalogs declassification efforts; 2) directly feeds Opennet, the Office of Scientific and Technical Information (OSTI) web-based repository at Oak Ridge; and 3) provides an accessible database of declassified material. The database is now the Hanford standard for OSTI reporting and has been used at Hanford and Rocky Flats to respond to litigation requests.

We plan to continue to commercialize software of broad interest to the industry. When that is not possible, we will make it available in the public domain. We are seeking partners for commercialization of Marmot and are readying the release of the automated network benchmarking software to the public domain.

Resources and Initiatives

Resource requirements for direct programmatic research programs are included in program-specific sections of this document. Business information systems and most infrastructure investments are funded from general purpose and overhead accounts. Discussions of resource requirements for Major Items of Equipment follows.

Major Items of Equipment (MIEs) have been requested through the Unified Budget call (UNICALL) for the Hanford Site. Through FY 1997 the Laboratory's proposed major items of equipment will be funded as part of Construction Project EM-91-100, EMSL. After FY 1997, funding requests for MIEs will be directed to the responsible program offices.

Based on the goal of fielding a fully functional, equipped, and staffed research facility in FY 1997, we have completed the acquisition of a massively parallel production system to provide the high-performance production environment to support the research program and the production database and archive system. Both systems were acquired through fully open competition.

An order has been placed for a 472-processor IBM SP with a capacity of over 200 peak gigaflops. The system is being delivered in two phases beginning in June 1996 with a 192-processor, with 27 gigabytes of memory, and 566 gigabytes of secondary storage. The 472-processor full-scale system with 62 gigabytes of memory and 1238 gigabytes of secondary storage will be delivered in March 1997 to support research in the EMSL.

An order has been placed for an Emass database and archive running FileServ hierarchical storage management software. The system is hosted on three Silicon Graphics Challenge series systems with 2.5 gigabytes of memory, over 500 gigabytes of secondary storage, and a robotic tapes archive.

Acquisitions for modest upgrades of the EMSL high-performance computers (i.e., the production and experimental machines) are requested in FY 1998, FY 1999, and FY 2000. Acquisition of a replacement for the original high-performance, massively parallel, production computer and the database archive 5 years after their original acquisition will be required if the EMSL is to maintain its state-of-the-art capabilities. These are proposed for FY 2002 with additions in FY 2003. Capital resource requirements for these acquisitions are shown in the table.

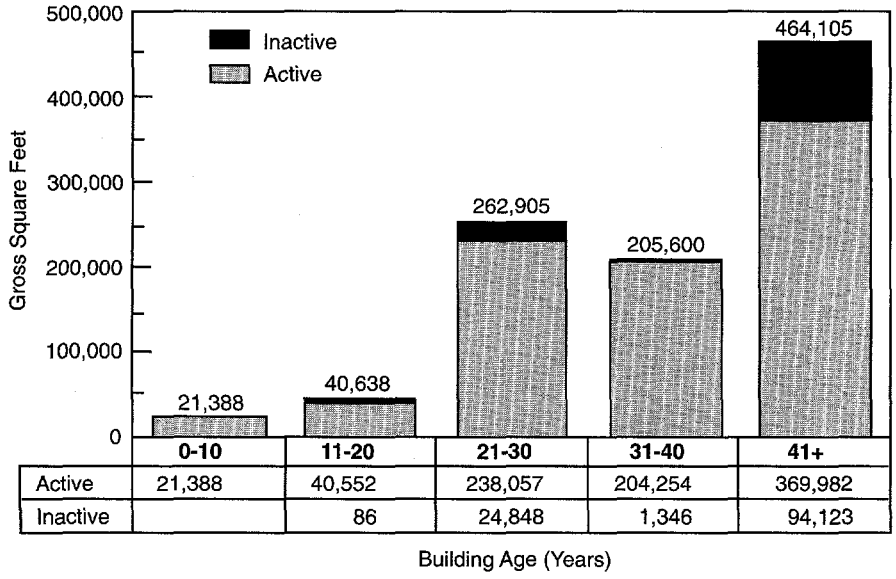
Site and Facilities

Laboratory Description

The Pacific Northwest National Laboratory serves 1) as one of five Department of Energy multiprogram energy research laboratories, and 2) as the research and development center for

FY 1996 Laboratory Space Distribution

Location	Area square feet (million)	Area square meters (million)
Main Site (300 Area)	0.94	0.087
Leased	0.11	0.010
All Other	0.06	0.006
Total	1.11	0.103



Laboratory area and age distribution (years).

the Hanford Site. Because of this dual role, the Hanford Site Landlord Program, under the purview of the Office of Environmental Management, is responsible for general purpose facilities and equipment primarily supporting Hanford Site mission activities. The Multiprogram Energy Laboratories-Facilities Support (MEL-FS) program, under the purview of the Office of Energy Research, is responsible for multiprogram facilities and equipment.

The Laboratory consists of a collection of buildings containing approximately 195,000 square meters (2.07 million square feet) with assigned responsibility as follows:

- DOE-owned facilities 93,000 square meters (1.0 million square feet)
- Battelle-owned facilities 46,000 square meters (0.5 million square feet)
- DOE-leased facilities 10,000 square meters (0.11 million square feet)
- Battelle-leased facilities 43,000 square meters (0.46 million square feet).

Through formal arrangement with the DOE, these facilities compose the Consolidated Laboratory and are used by over 3,500 Battelle employees to perform work for the DOE, other federal agencies, and private industry. The Consolidated Laboratory is the combined DOE owned/leased and Battelle owned/leased facilities that are by mutual agreement between DOE and Battelle available to conduct contract 1830 work as well as Battelle private work. This concept avails the total set of DOE and Battelle facilities capabilities in seeking best fit to complete research work.

The Laboratory Space Distribution table illustrates that the Laboratory's Richland DOE facilities are located primarily in two areas. Most DOE-owned facilities are located in the Hanford Site's 300 Area. The 300 Area occupies approximately 4 square kilometers (1.5 square miles or 960 acres) in the southeastern portion of the Hanford Site, along the west bank of the Columbia River. The DOE-leased space is located south of the 300 Area and adjacent to the Battelle private facilities in the Richland North Research Complex. The other DOE-owned facilities are located in different operating areas on the Hanford Site.

The remaining graphics and text focus on the 99 DOE-owned buildings. The figure showing the age of the Laboratory's buildings illustrates that 93 percent of the 67 active DOE-owned facilities are over 20 years old, and 66 percent are over 30 years old. Only 2,000 square meters (21,388 square feet) are less than 10 years old. The average age of the 67 active DOE-owned buildings is 29 years. The EMSL is on the Hanford Site on recently acquired government land adjacent to Battelle private facilities.

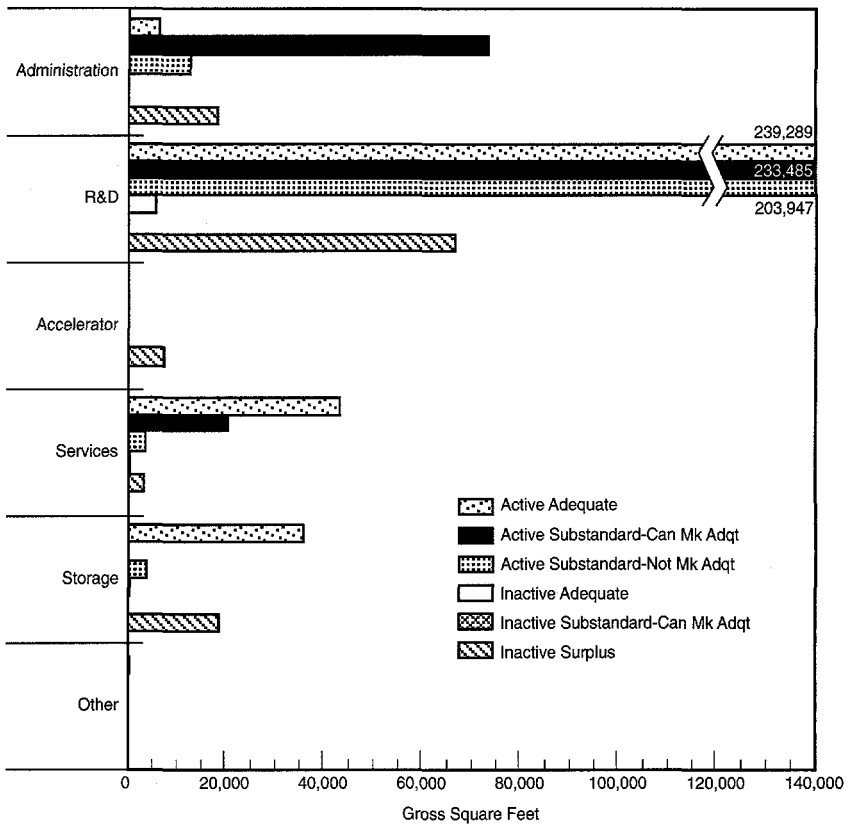
The figure showing the condition of laboratory space by functional unit illustrates that by far, research and development space is the predominant type of space. Included in this category are laboratories (both nuclear and non-nuclear) for chemistry, materials, environmental and biological research, computation, electrical/electronics, applied physics, and general purpose research. The remaining functional types of space include administrative, service, storage, and other.

The Laboratory has made substantial progress in achieving its long-term facility strategy. This strategy is focused on vacating old, contaminated facilities in the north 300 Area and consolidating research activities in the south 300 Area.

This consolidation required relocating existing research equipment and reconfiguration of buildings and building systems. Consolidation efforts continue through FY 1998 by relocating from nonviable, contaminated facilities in the 300 Area North to renovated laboratories. Building life cycle plans capture needed rehabilitations, replacements, and reconfigurations required to provide safe, reliable and economical facilities to meet the changing needs of research. Funding is requested from the cognizant Secretarial Offices to maintain the viability of strategic facilities.

The Laboratory's DOE-owned office space is concentrated in one permanent facility and 12 trailers, as well as limited office space within laboratory buildings. The only DOE-owned office building is 23 years old and will require renovation in the near future. Staff were relocated out of approximately 17,000 square feet of substandard trailer space and 60,000 square feet of DOE-leased office space in FY 1995 and FY 1996.

The remaining space is a mixture of shops, storage buildings, miscellaneous unique facilities (such as a technical library), service buildings, and environmental monitoring stations. The condition of the majority of the space is considered adequate. The Laboratory's facilities inventory also includes a collection of other structures such as meteorological towers. In general, the condition of these structures is considered adequate. The replacement value of the Laboratory's facilities inventory is summarized in the table, "Facilities Replacement Value." The FY 1996 data comes from the Richland Property System, a site-wide computerized inventory of DOE's property holdings. The replacement value of $410 million for buildings is due to the extensive array of research, engineering, and computational laboratories operated by the Laboratory. Replacement values have been calculated based on a replacement factor provided by DOE for the year the facility was constructed. This replacement factor is multiplied by the original construction cost of a building, plus any capital improvements made to the building.



	Active Adequate	Active Substandard Can Mk Adqt	Active Substandard Not Mk Adqt	Inactive Adequate	Inactive Substandard Can Mk Adqt	Inactive Surplus
Administration	7,392	70,424	10,590			18,899
R&D	239,289	233,485	203,947	5,185		65,297
Accelerator						8,021
Service	44,130	21,700	3,776	100		3,286
Storage	35,006		4,142	800		18,815
Other	352					
Total	326,169	325,609	222,455	6,085		114,318

Condition of Laboratory space by functional unit.

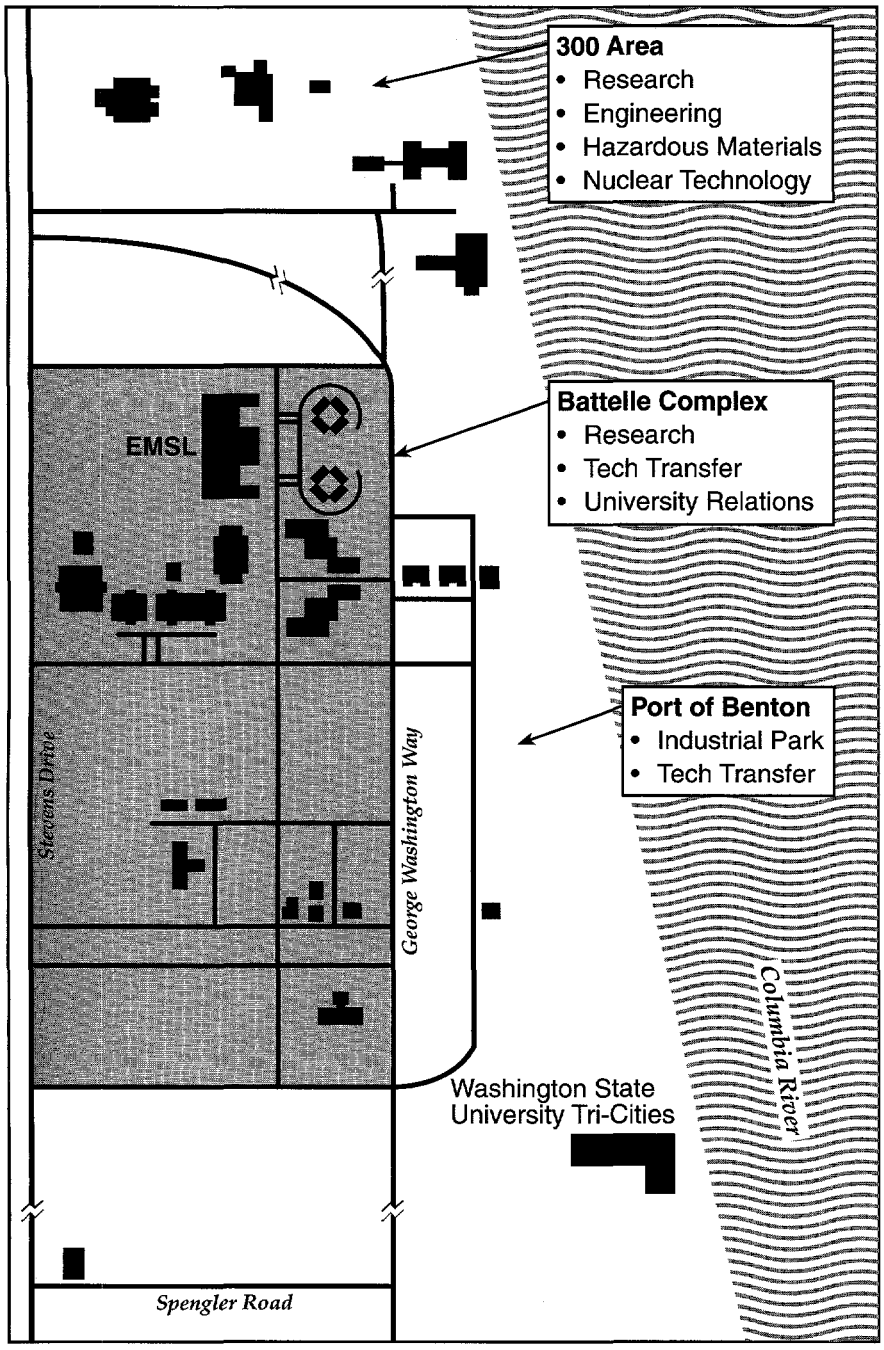
The site utilities and infrastructure services are operated by the Hanford Site 300 Area Management and Operations Contractor. Pacific Northwest, as well as other 300 Area occupants, interface with the Management and Operations Contractor to provide utility and site infrastructure requirements.

Facilities Plans and Options

A national center for science and technology in the Northwest area is developing around the Laboratory. This center, the Tri-Cities Science and Technology Park, integrates capabilities for

Facilities Replacement Value

Facilities Type	Replacement in FY 1996 $ (millions)
Buildings	410
All Other	6
Total	**416**



The Tri-Cities Science and Technology Park encompasses the 300 Area to the north and WSU-TC facilities to the south.

basic science, applied research and development, and technology applications. The Park (see the figure) encompasses the DOE facilities in the southern portion of the 300 Area, to include EMSL; the research and development laboratories owned by Battelle in the south, as well as Port of Benton and Washington State University Tri-Cities facilities; a total of 50 companies and organizations employing 8,000 people.

The interests of both government and industry are actively represented. Federally developed technologies are effectively transferred to the public and private sectors. The activities of the Park encourage the local economy to diversify, thereby reducing the historical dependence on DOE operations at Hanford. Regional business leaders, small local businesses, state officials, and federal agencies are working together to ensure that industry and government are aware of the unique technical, economic, managerial, and geographic assets that are available at Hanford. The focus remains on the diverse development of the 2,600 acres of land within the Park boundaries.

The 300 Area is within the northern boundary of the Park. This area is composed of DOE-owned facilities. The 300 Area Site Development Plan calls for locating new laboratory facilities in the southern portion of the area, demolishing the older facilities in the north and restoring their sites. Declining budgets and a need to retain its competitive position led the Laboratory in FY 1996 to begin consolidating research activities into a set of laboratory facilities collocated in 300 Area South. Many remote and older facilities have been vacated and placed in a "cheap to keep" mode. Two nuclear facilities with no long-term research mission will be transferred to the Project Hanford Management Contractor (PHMC) in FY 1997 to be transitioned to decommission and demolition. The Laboratory will ensure that vacated facilities do not pose a hazard to staff and the environment until operating responsibility is transferred. During consolidation, the Laboratory is seeking ways of collocating its radiological work into a smaller number of buildings to improve conduct of operations and lower operating costs. Pacific Northwest facility maintenance, along with capital investments in rehabilitation and reconfiguration, will be focused in existing 300 Area South strategic laboratories to provide a safe, reliable, responsible, and cost-effective facility platform for research.

The Laboratory is developing Facility Use Agreements (FUAs) for its facilities. Facility Use Agreements are written contracts between facility operations and building occupant groups wherein the operating envelope and the

physical as-built character/attributes of a building are identified. Facility Use Agreements are the vehicle to define with building occupants the current and future use of the facilities. Such communication enhances building-specific life cycle plans and project development. Pilot agreements have been written for each facility for six categories: 1) occupant/facility scope and mission, 2) physical attributes of facility that satisfy scope and mission, 3) operational boundaries that limit facility use, 4) definition of responsibilities for ensuring that physical boundary limiting conditions are met (by both occupant and facility management), 5) verification (self-assessment) of the execution of responsibilities, 6) administration of the "contract" - change control, document control, space charge back, services delivered with roles, responsibilities, accountabilities, and authorities. All Pacific Northwest facilities will be operating under Facility Use Agreements by October 1996.

General Purpose Facilities Plans

Two programs provide major construction project line item support for the rehabilitation and replacement of the general purpose DOE-owned facilities operated by the Laboratory. The programs are the Hanford Site Landlord Program under the purview of the Office of Environmental Management and the Multiprogram Energy Laboratories-Facilities Support program under the purview of the Office of Energy Research. The construction projects include general use areas such as administrative and laboratory space. The Major Construction Projects table in a later portion of this section lists the General Purpose Facilities projects.

With the exception of a permitted waste facility, all Pacific Northwest facilities are considered general purpose. This means the facilities and equipment are used by two or more DOE programs. The Laboratory's future development plans and options are inseparably linked with national DOE strategies and guided by strategic initiatives being pursued at Hanford. By focusing on health and safety of the public and workers, and the other vital elements of these plans as well (energy, environment, education, economy, and national security), the Laboratory will achieve its vision of becoming a national center for science and technology. The Laboratory's planning emphasis is to

- ensure Laboratory facilities are operated and maintained in full compliance with all applicable laws and regulations
- plan for and provide safe and operable facilities to accommodate and support ongoing and new research activities
- operate and maintain facilities economically to provide for the safety and health of plant personnel, protect the public and environs, protect property, and support research needs
- concentrate scarce financial resources on strategically important facilities that support overall Laboratory core competencies
- link, integrate, and unify the Laboratory's strategic and program plans with facility and site development plans and with specific design and construction projects
- improve the use of existing space and continue to thoroughly examine appropriate adaptations of existing space to new business areas
- consolidate similar technical functions wherever appropriate.

Facility upgrades have been focused on solving four general problem areas: compliance with environmental, safety, and health regulations; infrastructure deterioration; changing purpose of some Pacific Northwest facilities; and shrinking DOE budgets.

Through internal and external audits, reviews, inspections, and surveillances, the Laboratory and others have assessed the level of compliance with environment, safety, and health requirements. These include requirements derived from Washington State environmental laws, Environmental Protection Agency regulations, the DOE Occupational Safety and Health Administration standards, and actions set forth in the Hanford Federal Facility Agreements (Tri-Party Agreement). The reviews focused on overall operations, documentation, agreements, planning, and the facility's performance. Facility-related deficiencies and proposed corrective actions have been included in several funding plans, and are described in this section under Facilities Resource Requirements.

Consistent with the strategic objectives of the Laboratory, a modernization plan is being developed in conjunction with asset-based life cycle planning to anticipate facilities and infrastructure requirements for the next 20 years. An FY 1995 third party inspection of Laboratory facilities was completed by recognized professionals. Their analysis confirmed the Laboratory's own assessments of building conditions and priority of corrective actions. Proposed facility infrastructure upgrades include piping system replacements, exhaust system upgrades, HVAC control upgrades, fire protection compliance, and fire alarm upgrades.

Enhanced facilities are required to support science, technology, and educational initiatives that will help DOE achieve its goals. In keeping with the Laboratory's strategy to concentrate scarce financial resources on strategically important facilities that support overall Laboratory initiatives, facility improvements are focused on these major facilities. Shrinking DOE budgets and a desire to increase its competitiveness drove line organizations to implement a facility consolidation plan. At the same time, the Laboratory put in place a space charge back system. Occupiable space is divided into six types with a rate applied to each designed usage type. Organizations are charged for the type and amount of space they occupy. Facility utilization has increased. Planned and proposed facility investments are directed at modernizing and reconfiguring strategic laboratory facilities to allow further consolidation.

General Plant Projects Ongoing corrective activities are required to keep facilities supporting the energy research and environmental management business areas in compliance with external air, surface water, and solid waste regulatory requirements,

and internal DOE requirements. Representative projects include correcting Life Safety Code deficiencies, including upgrading stairwells, ADA requirements, and improving exit corridors to current standards; compressed air system replacement; HVAC controls replacement; and air-conditioning upgrades. General plant project requirements are not duplicated in the construction line items. Pacific Northwest requests $3.5 million per year from Energy Research for FY 1997-2002 multiprogram general plant project requirements. From Environmental Management, the Laboratory requests $2 million per year.

General Purpose Equipment The Laboratory's multiprogram general purpose equipment requirements fall into two broad capital support categories: general purpose equipment for support services and nonprogrammatic equipment for functions such as safety, information systems networks and communications, security, and crafts. General purpose equipment is required for a basic, multipurpose laboratory capability to support research activities.

The multiprogram general purpose equipment funding, provided at a fairly constant level in recent history, is being applied to meet priority requirements. Because funding was limited to $1 million in FY 1996, not enough is available for state-of-the-art technological improvements beyond that needed to support priority items.

The Laboratory's Hanford Support general purpose equipment requirements are included in the Environmental Restoration and Waste Management Five-Year Plan. In general, environmental restoration and waste management general purpose equipment funding needs are not projected to be met in the near future.

Inactive Surplus Facilities Plan

In FY 1996, a Facility Transition Project Team was established to manage consolidation of research activities including the reconfiguration of space, relocation of staff and equipment, and disposition of surplus vacant facilities. As a result of a concerted Laboratory-wide effort, by the end of FY 1996, 53 DOE-owned facilities were vacated. Of the vacated facilities, 31 Energy Research and 3 Environmental Management facilities were placed in a standby "cheap to keep" condition, and 19 trailers/pole buildings (20,000 square feet) were physically removed from the site.

Pacific Northwest has identified an additional 14 Energy Research and 9 Environmental Management facilities that are surplus to its mission. Ten Energy Research buildings will be vacated and placed into standby and 4 Energy Research trailers will be removed. Nine Environmental Management facilities will be transferred to the PHMC in FY 1997. There are 13 Energy Research/Environmental Management facilities that are radiologically contaminated.

In FY 1997, proposed activities include continuing the facility transition effort, with a projected total of 44 DOE-owned facilities to be transferred for alternate use or entered into the Hanford Site deactivation effort. Surveillance and maintenance activities will be required to begin in FY 1997 to prevent deterioration of the facilities in standby and to control hazards resulting from roof and floor failures, animal and insect infestation, weather damage, etc. The Laboratory estimates it will need $220K in FY 1997 to perform surveillance and maintenance activities.

Facilities Resource Requirements

The Laboratory's capital asset management process systematically identifies facility requirements, develops life cycle management plans for individual facilities, evaluates priorities of facility requirements, and initiates development of capital projects. The Life Cycle Asset Management (LCAM) order places accountability and authority for the management of site and facilities on the DOE Site Operations Office and the contractor(s). The Laboratory's capital facility requirements, as currently authorized and projected, are summarized in the Major Construction Projects table. The overall multiyear program plan

- is consistent with the DOE constrained budgetary guidance
- assumes a long-term effort will be necessary to fund and implement full requirements of the Laboratory
- emphasizes a commitment to compliance with operational, environmental, safety, health, and security standards, and a significant role for the Laboratory research and development efforts for the DOE and the nation.

The following program and funding profiles were developed to establish a balance between high-priority work and the realities of the current federal budget climate. The Laboratory's project priority setting process uses a DOE-developed prioritization methodology, the Capital Asset Management Process (CAMP). The deficiencies, purpose, and needs of each project are evaluated using guidance criteria given in one or more of four basic categories: Health & Safety, Environment & Waste Management, Safeguards & Security, and Mission & Investment. A numerical rating is assigned to each activity. This rating allows a relative ranking to be established between the various competing activities. This prioritization methodology is the basic tool used to objectively aid the decision-making processes in weighing the relative importance of our facility improvement projects.

Developing and implementing the Laboratory's coordinated multiyear integrated facilities plan is significant because the funding of DOE programs at the Laboratory is relatively diverse and the program relationships at the Hanford Site are complex. The Laboratory needs the institutional support of both Energy Research and Environmental Management to provide an adequate basis for the Laboratory to best serve DOE's needs. The following discussion summarizes our specific program plans and requirements. National Environmental Policy Act documentation has been approved unless otherwise noted.

Programmatic Line Item Construction Funding Pacific Northwest National Laboratory has one programmatic line item construction project, the Environmental Molecular Sciences Laboratory.

Environmental Molecular Sciences Laboratory (91-EM-100) The Environmental Molecular Sciences Laboratory will be a 19,000-square-meter (200,000-square-foot), state-of-the-art research facility. It will support basic and applied research in the environmental molecular sciences. A wide range of research will be performed in the EMSL to develop new knowledge and technologies that, when implemented, will reduce the cost and increase the effectiveness of environmental restoration and waste management efforts undertaken at Hanford and other DOE sites. The facility will house approximately 200 permanent building occupants and 70 visiting scientists and includes a seminar area that will accommodate 100 people.

Multiprogram Energy Laboratories-Facilities Support Program The Multiprogram Energy Laboratories-Facilities Support program is designed to maintain infrastructure integrity at DOE's multiprogram energy laboratory facilities. The program provides construction support for the rehabilitation and replacement of general purpose facilities, and operating funds to support Laboratory planning and management activities. The strategy of the MEL-FS program is to maintain operations in a safe, cost-effective, and productive manner; reduce the backlog of facilities deficiencies; address environment, safety, and health remediation needs; and provide resources to manage surplus facilities related to Energy Research activities. A brief description of the four ongoing and two proposed major construction MEL-FS program projects are listed below.

Safety Compliance Modifications, 326 Building (92-E-601) This ES&H-driven FY 1992 line item has a total estimated construction cost of $8.5 million. The purpose of this project is to ensure continuity of operations in a vital laboratory facility supporting Energy Research programs. The 326 Building figures prominently in research in structural materials, microstructural analyses, chemical methods and separations, component analysis, supercritical fluids, superconducting materials, and in various other basic research programs. This project will bring the 326 Building, which is an aged but strategically important laboratory, into compliance with DOE Order 6430.1A, General Design Criteria, NFPA requirements, National Electric Code requirements, and Washington State requirements.

Life Safety Code Compliance (93-E-317) This ES&H-driven FY 1993 line item has a total estimated construction cost of $2 million and corrects immediate Life Safety Code compliance problems in several aged multiprogram laboratories. Affected buildings requiring near-term safety improvements include 306W, 331, 337, and 3720. Actions include protecting vertical openings, stairwell enclosures, and exit corridors to address OSHA issues.

The Life Safety Code specifies how buildings must be arranged and constructed to protect occupants in the event of an emergency evacuation. The code is mandated by DOE Order 5480.4 (Environmental Protection, Safety and Health Protection Standards) and DOE Order 6430.1A (General Design Criteria). Changes in the construction of Laboratory facilities are needed to comply with the requirements of the Life Safety Code. Failure to comply with the Life Safety Code impacts the potential safety of staff members and visitors if emergency evacuation of a facility is needed. This project corrects OSHA deficiencies.

Electrical Safety Rehabilitation (95-E-303) This ES&H-driven FY 1995 line item has a total estimated construction cost of $3.2 million for replacing deteriorated wiring and outmoded equipment and eliminating unsafe operating conditions in several key multiprogram laboratories. Actions include rehabilitation of emergency power building distribution systems, motor control centers, correcting wire/raceway sizes, protecting equipment by installing additional circuit breakers, and grounding and bonding of electrical for safety purposes.

Affected buildings range from 20 to 40 years old and have electrical systems that are worn out and present a safety hazard. These improvements are required to provide building electrical systems that are safe, efficient, reliable, and maintainable as required by the DOE Order 5480.4 (Environmental Protection, Safety and Health Protection Standards) and DOE Order 6430.1A (General Design Criteria). The existing electrical systems do not meet the National Electric Code for safe working clearances, separation of cables, and shock prevention.

Multiprogram Laboratory Rehabilitation (95-E-310) This Building Rehabilitation and Upgrade FY 1995 line item has a total estimated construction cost of $6.1 million. The 331 Building, Life Sciences Laboratory, was designed to accommodate the care and use of large and small animals. Originally, the facility was dedicated to life span animal research. Experiments included exposure to chemical carcinogens and radiation. Current and planned laboratory needs call for cell biology, tissue, and general chemistry type laboratories to support new programs related to areas of molecular biology. This type of research is already being performed on the third floor of the 331 Building in existing laboratory space that has been remodeled. It is advantageous to provide new laboratories adjacent or close to these. This project will replace the third floor small animal area with cell biology, tissue, and general chemistry type laboratories and consolidate animal care facilities on the first floor of the 331 Building. The 331A Building, adjacent to the main 331 Building, is currently vacant and in relatively poor condition. The building cannot be effectively remodeled to suit any current or future research need and therefore will be demolished.

Multiprogram Energy Laboratories Infrastructure Piping Replacement (99-E-XXX) This FY 1999 line item has a total estimated construction cost of $4.1 million. This project will replace the water piping for three Energy Research sponsored facilities. The existing systems in the buildings (331 Building, 26 years; 326 Building, 43 years; 337 Building, 23 years) have exceeded their life cycle, or approached the nominal range requiring replacement based on life cycle standards. The facilities are strategic assets of the Laboratory and require continued stewardship to

maintain their value. Failed components and pipe sections are common occurrences which have disrupted operations and resulted in property loss. Inspections and analysis have confirmed deficient piping infrastructure.

320 Building Rehabilitation and Reconfiguration (99-E-XXX) This FY 1999 line item has a total estimated construction cost of $8.7 million. The 320 Building is one of the core facilities of Pacific Northwest. The Laboratory's business strategy is to consolidate mass spectrometric capabilities into the 320 Building. The mission of the building remains basic research. The focus is on analytical research of low-level, ultra-trace radionuclear and chemical materials using optical and mass spectrometric equipment and procedures. The building's current condition cannot meet mission requirements because of aged systems. The condition has been confirmed by inspections and overviews of life cycle analysis based on the nominal life expectancy of the building components. This project will replace building piping systems and major HVAC components. Interior modifications will address noncompliant life safety code issues, inefficient HVAC capacities and controls, and make the building compliant with ADA access and use codes. Technology updates will include the replacement of an inefficient and dated clean room capability and installation of components which will make the building system more energy efficient. The 320 Building is the last Pacific Northwest core facility to receive major rehabilitation. The project will extend the building's life expectancy an additional 20 years.

Environmental Management Funding
The facilities that are not assigned as multiprogram facilities to Energy Research are primarily supporting the Hanford mission. The DOE Environmental Management Office is also the Hanford Site Landlord, and as such, is assigned funding responsibility for the Laboratory's general purpose Hanford Support facilities (318, 324, 325, 327, 3730, 3760, 622R, and 747A). An assortment of trailers, small storage buildings, and meteorological facilities round out the Environmental Management Landlord inventory of 26 facilities.

These facilities support the Hanford Site environmental restoration and waste management mission and the Laboratory's site service responsibilities including environmental surveillance, monitoring, and oversight programs; preparation of major environmental documents; occupational dosimetry; radiological calibrations; operation of the whole-body counter; emergency preparedness; occupational radiation exposure records; and operation of the Hanford Technical Library. DOE Environmental Management line item construction candidates are briefly described below.

329 Building Compliance (91-E-322) The total estimated construction cost for this FY 1991 project is $9.9 million. The project renovates major building systems in an aged, but strategically important laboratory. Improvements include better ventilation, air filtration, and waste water piping to control radionuclides and ensure safe liquid effluent. These renovations are necessary to comply with the Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, and other requirements.

The project includes the following modifications to the 329 Building:

- upgrade the HVAC system to meet the requirements of 40 CFR 61 (National Emission Standard for Hazardous Air Pollutants); and to comply with the Best Available Radionuclide Control Technology requirement, and the State of Washington Administrative Code Chapter 402-80 (Monitoring and Enforcement of Air Quality and Emission Standards for Radionuclides)
- replace corroded service piping
- replace deteriorated waste piping systems to comply with DOE Order 5400.1 (General Environmental Protection Program) and with 40 CFR 116 (Federal Water Pollution Control Act), which require that hazardous materials cannot be released in a liquid effluent (extensive corroded piping holds the potential for releasing radioactive constituents)
- upgrade the fire protection system to meet NFPA 13
- replace a portion of the building electrical system to meet NFPA 70 (the National Electric Code)
- establish laboratory and corridor fire separation to comply with NFPA 101, which is a mandatory requirement of DOE Order 6430.1
- provide access for the physically disabled to comply with 41 CFR 101.19.6 (Uniform Federal Accessibility)
- modify laboratories to relieve crowding and reduce safety risks.

The purpose of the project is to ensure continuity of operations in a vital laboratory supporting DOE business areas in environmental restoration. Significant analytical chemistry associated with Tri-Party Agreement Milestone M-10, and RCRA and CERCLA is performed in the facility. The laboratory houses part of the Chemical Measurement Section. This section includes the only Hanford Site laboratory staff qualified to meet Environmental Protection Agency Contract Laboratory Program environmental measurements, an important part of the Tri-Party Agreement. The 329 Building also houses critical chemical laboratories and staff associated with method development research for DOE's waste management effort.

325 Facility Compliance/Renovation (93-D-184) This FY 1993 line item has a total estimated construction cost of $6 million. The 325 facility is a vital laboratory. This project is necessary to support the continuance of radiochemical research and development, and the consolidation of 300 Area radiological work and closure of inadequate facilities. The project consists of the following actions: 1) provide fire separations for electrical switchgear; 2) replace electrical panels, power conditioners, and switchgear circuit trips; 3) replace 17 Plexiglas glove boxes; 4) remove the B-Unit stack sampler; 5) upgrade the fire sprinkler system; and 6) install a P-10 gas system.

Major Construction Projects - FY 1997-2002 Planning Period

(Budget Authorization $ in Millions)

	Total Est. Const. Costs	Fiscal Year 1995	1996	1997	1998	1999	2000	2001	2002
FUNDED CONSTRUCTION									
General Plant Projects									
General Plant Projects (KP)[a]		2.0	2.0						
General Plant Projects EM 60 (EW)[a]		1.2	0.3						
Environmental Management Projects (EW)									
329 Building Compliance	9.9								
325 Facility Compliance/Renovation	6.0	1.0							
324 Facility Compliance/Renovation	4.0	1.5	2.5						
Multiprogram Energy Laboratories-Facilities Support Program Projects (KG)									
Safety Compliance Modifications, 326 Building	8.5	1.9							
Life Safety Code Compliance	2.0	0.5							
Multiprogram Laboratory Rehabilitation	6.1	0.4	2.7	3.0					
Electrical Safety Rehabilitation	3.2	0.2	1.5	1.5					
Program Related Projects									
Environmental Molecular Sciences Laboratory ER (KP)	207.9	40.0	50.0	35.1					
Total Funded Construction		**48.7**	**59.0**	**39.6**					
BUDGETED CONSTRUCTION									
General Plant Projects									
General Plant Projects (KP)				2.0					
Total Budgeted Construction				**2.0**					
PROPOSED CONSTRUCTION									
General Plant Projects									
General Plant Projects (KP)					3.5	3.5	3.5	3.5	3.5
General Plant Projects EM 60 (EW)					2.5	2.0	2.0	2.0	2.0
Multiprogram Energy Laboratories-Facilities Support Program Project (KG)									
Multiprogram Energy Laboratories Infrastructure Piping Replacement	4.1					2.0	1.0	1.1	
320 Building Rehabilitation and Reconfiguration	8.7					3.0	4.5	1.2	
Total Proposed Construction					**6.0**	**10.5**	**11.0**	**7.8**	**5.5**
Total Construction		**48.7**	**59.0**	**41.6**	**6.0**	**10.5**	**11.0**	**7.8**	**5.5**

(a) Budget codes are identified in parentheses.

324 Facility Compliance/Renovation (95-D-454) This FY 1995 line item has a total estimated construction cost of $4 million. This activity focuses on renovation of major building systems in an aged, but strategically important, Hanford Support laboratory. Much of the work in the building is associated with the DOE-EM business area including development and testing of new engineered systems and equipment for DOE's environmental and restoration programs and cleanup efforts at multiple DOE, DoD, and industrial solvent, heavy metal, and mixed waste sites. Facility capabilities include hot cells, nonradioactive laboratories, and high-bay space for bench- to full-scale prototype work. The project includes the following actions: 1) upgrade/replace HVAC systems; 2) replace contaminated piping systems; 3) upgrade the sprinkler system; 4) remove and replace large areas of asbestos; and 5) replace deteriorated interior building facilities such as electrical panels, electrical equipment, and other building equipment.

Assets Management

Pacific Northwest has taken steps to accelerate the schedule of its long-term

Consolidated Information Center
(Budget Authorization $ in Millions)

	Fiscal Year					
Current Programs	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Operating	2.5	2.5	2.5	2.6	2.6	2.6
Move and Relocation	0.0	0.4	0.0	0.0	0.0	0.0
Capital Equipment	0.1	0.1	0.1	0.0	0.1	0.0
Total	**2.6**	**3.0**	**2.6**	**2.6**	**2.7**	**2.6**

facility strategy which vacates old, contaminated facilities in the 300 Area North and offsite leased facilities to consolidate research activities on two campuses, Richland North and the 300 Area South. A review of facility holdings was completed in FY 1995. This review identified that of the 119 DOE-owned facilities that the Pacific Northwest occupies on the Hanford Site, 76 facilities were no longer required.

A Facility Transition Project Team was established at the Laboratory to manage the reconfiguration of space, relocation of staff and equipment, and disposition of vacant facilities. As a result of a concerted Laboratory-wide effort, 53 DOE-owned facilities were vacated by the end of FY 1996. Of the vacated facilities, 31 Energy Research and 3 Environmental Management facilities were placed in a standby "cheap to keep" condition, and 19 trailers/pole buildings (20,000 square feet) were physically removed from the site.

Pacific Northwest worked with the Hanford Site Management and Operations Contractor to excess the 331J Building and Incinerator, 331F Storage Facility, 331E Greenhouse Facility, and 16 office trailers in place. The three buildings and the incinerator were auctioned with the proceeds going to DOE. Declaration of Excess forms were filled out for the trailers and entered into a screening cycle controlled by the Site Management and Operations Contractor. This allowed other government, federal, and state agencies to obtain ownership providing they would fund the removal and transportation of the trailers. An abandoned monitoring station constructed with asbestos siding was transferred to the owner of the land on which it resides.

Portions of the 306W, Material Development Laboratory, have been shut down and placed in a "cheap to keep" mode. Complete shutdown of the entire facility has been delayed to accommodate ongoing research programs; however, considerable cost saving measures have been completed. The steam heat to the facility has been replaced with electrical heaters and the former once-through ventilation has been replaced with a recirculating system. These changes will drastically reduce the energy requirements and maintenance costs.

Consolidated Information Center

The Hanford Technical Library, managed by Pacific Northwest National Laboratory as a Hanford Site service for the DOE, represents a unique information resource. Its staff provide integrated scientific and technical information resources and services. They will continue to be major contributors to effective information management. The main library is located within the 300 Area on the Hanford Site.

More accessible, but much smaller, is the library at the Washington State University Tri-Cities campus, adjacent to the Laboratory. Pacific Northwest has proposed consolidating the two libraries, thereby minimizing duplication and overlap through the use of shared facilities and collections. This will benefit Hanford staff, visiting scientists, WSU faculty and students, and the general public. The consolidation will also allow the joint library to provide evening and weekend services.

The consolidated library will be located in leased space in a new building on the WSU-TC campus called the Consolidated Information Center. The new building will also include WSU's University Center for Professional Education and an Environmental and Technology Resource Center managed by WSU. The library facility will be operated by the Laboratory, in conjunction with WSU-TC. The DOE Public Reading Room, which is currently managed by the Laboratory and located on the WSU-TC campus, will also be located in the new library.

The Washington State Legislature has appropriated $1.4 million for the architectural design and $14 million for construction of the facility. The DOE and General Services Administration have agreed in principal on a 20-year lease for part of the facility, essentially providing half of the $14 million construction costs. The project is expected to be completed in May 1997.

The Consolidated Information Center will be tied into the Hanford Local Area Network. Staff and users will have full access to the electronic library services that are currently provided, as well as to additional services that may be added.

The consolidation of the holdings of the Hanford Technical Library and the WSU-TC library, and the increased accessibility of electronic information will create a unique and very valuable set of resources. This consolidation will also make the resources available from one location to a much larger community, and will make the Laboratory's research results more easily available to WSU students and faculty and to the public. The consolidation is an important local ingredient for building and supporting an infrastructure that contributes to and is part of the DOE's science education and technical information foundation.

The primary incremental budgetary impacts will be the building lease cost for the library space (similar to current costs) and the one-time costs associated with the move to the new facility in FY 1997.

Communication and Trust

Pacific Northwest National Laboratory is supporting DOE in its continuing transformation to a new culture of openness. For the Laboratory to maintain credibility as a DOE national multiprogram laboratory, it must be viewed internally and externally as an organization where trust and respect are pervasive and good communication is second nature.

Effectively communicating information and building trust with staff, customers, and stakeholders is essential in the Laboratory's pursuit to become a world-class laboratory.

Successful managers at the Laboratory listen to customers, staff, and stakeholders, and work with them in teams characterized by openness and trust, risk-taking, and readiness to explore new ideas.

Effective management of scientific and technical information is recognized by successful project and line managers as an important component of every research project and program, both as an input and as an output. The Laboratory intends to continue managing the use of such information effectively within its distributed environment. The Laboratory emphasizes the rapid transfer of knowledge to the scientific and public communities, using a variety of formats and channels, in support of DOE's mission. Planning for information management activities will continue to be integrated into the Laboratory's planning and budget processes by program and project managers, in partnership with DOE programmatic staff. The Laboratory will continue to emphasize effective delivery of scientific and technical information as an important outcome of its research.

The Laboratory's efforts to improve communications and build trust include

- accurate communication of information to help staff make informed decisions
- participation across the Laboratory in planning and implementing activities to achieve quality and improve productivity
- communication of the Laboratory's accomplishments internally, locally, regionally, and throughout the United States
- communication of the benefits of science to the public to help them appreciate the value of the science and technology investment to meeting national needs
- commitment to the effective management of scientific and technical information and its key role in promoting the DOE's missions and in creating an informed public.

7 Resource Projections

The resource requirements of research and development for Hanford Site support are included in the resource projections of the various funding programs. Research and development for other DOE sites at other DOE facilities; however, is shown as a separate program. The resource projections for FY 1996 are actual values.

Laboratory Funding Summary
(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
DOE Effort	446.4	384.7	433.5	474.5	401.8	398.5	402.2	392.6
Work for Others	59.4	50.0	61.0	62.8	65.2	66.4	67.6	67.6
Total Operating	**505.8**	**434.7**	**494.5**	**537.3**	**467.0**	**464.9**	**469.8**	**460.2**
Capital Equipment	19.1	12.6	16.6	15.8	17.1	36.8	18.1	18.8
General Purpose Equipment-GPE	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8
General Plant Projects-GPP	1.1	2.2	2.0	6.0	5.5	5.5	5.5	5.5
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Program Line Items	40.9	50.0	35.1	0.0	0.0	0.0	0.0	0.0
MEL-FS[b] Construction	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
Total Laboratory Funding	**572.6**	**507.0**	**553.5**	**559.9**	**495.4**	**513.5**	**496.5**	**485.3**

(a) Budget authorization escalated through FY 2001.
(b) Multiprogram Energy Laboratories-Facilities Support.

Laboratory Personnel Summary
(Personnel in FTE)

	Fiscal Year							
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
DOE Effort	1449	1276	1139	1241	1274	1277	1274	1276
Work for Others	291	202	241	241	242	240	244	244
Total Operating	**1740**	**1478**	**1380**	**1482**	**1516**	**1517**	**1518**	**1520**
Capital Equipment	21	12	21	18	19	21	20	21
General Plant Projects-GPP	2	3	2	7	6	6	6	6
Landlord Line Items	2	3	0	0	0	0	0	0
Program Line Items	53	63	43	0	0	0	0	0
MEL-FS[a] Construction	4	5	6	0	6	6	3	0
Total Direct	**1822**	**1564**	**1452**	**1507**	**1547**	**1550**	**1547**	**1547**
Indirect	1924	1444	1270	1270	1270	1270	1270	1270
Total Laboratory Personnel (FTE)	**3746**	**3008**	**2722**	**2777**	**2817**	**2820**	**2817**	**2817**

(a) Multiprogram Energy Laboratories-Facilities Support.

Funding by Secretarial Officer

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research								
Operating	58.7	58.3	52.1	60.2	64.2	67.4	68.8	70.2
EMSL Operations-Expense	0.0	0.0	5.0	28.0	30.0	32.0	33.5	34.0
Capital Equipment	10.0	10.3	13.1	10.3	10.6	10.8	11.1	11.3
EMSL Operations Capital Equipment	0.0	0.0	0.0	2.0	2.5	22.3	3.5	4.0
General Purpose Equipment-GPE	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8
General Plant Projects-GPP	0.4	2.0	2.0	3.5	3.5	3.5	3.5	3.5
MELS-FS[b] Construction	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
EMSL Construction	40.0	50.0	35.1	0.0	0.0	0.0	0.0	0.0
Total	**112.8**	**125.6**	**112.6**	**104.8**	**116.6**	**142.3**	**123.5**	**123.8**
Office of Environmental Management								
Operating	201.9	150.3	112.0	105.1	104.3	94.0	102.9	91.4
Capital Equipment	7.4	2.2	1.5	1.5	1.5	1.2	1.0	1.0
General Purpose Equipment-GPE	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects-GPP	0.7	0.3	0.0	2.5	2.0	2.0	2.0	2.0
Program Line Items	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Total	**212.9**	**155.3**	**113.5**	**109.1**	**107.8**	**97.2**	**105.9**	**94.4**
Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	26.0	19.6	26.5	26.8	27.8	29.0	30.8	30.8
Capital Equipment	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	**26.5**	**19.8**	**26.7**	**27.0**	**28.0**	**29.2**	**31.0**	**31.0**
Office of Civilian Radioactive Waste Management								
Total Operating	**4.9**	**1.0**	**1.2**	**1.3**	**1.5**	**1.5**	**1.5**	**1.5**
Assistant Secretary for Environment, Safety and Health								
Operating	18.4	18.4	10.3	10.3	10.3	10.3	10.3	10.3
Capital Equipment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total	**18.5**	**18.5**	**10.4**	**10.4**	**10.4**	**10.4**	**10.4**	**10.4**
Assistant Secretary for Defense Programs								
Operating	1.7	9.3	17.0	27.0	27.0	27.0	17.0	17.0
Capital Equipment	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0
Total	**1.7**	**9.8**	**17.5**	**27.5**	**28.0**	**28.0**	**18.0**	**18.0**

Funding by Secretarial Officer (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Office of Science Education & Technical Information								
Total Operating	**1.3**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Office of Nonproliferation and National Security								
Operating	29.5	37.0	31.2	31.2	31.5	31.5	31.5	31.5
Capital Equipment	1.1	3.6	1.2	1.2	1.2	1.2	1.2	1.2
Line Item	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**30.6**	**40.6**	**32.4**	**32.4**	**32.7**	**32.7**	**32.7**	**32.7**
Assistant Secretary for Nuclear Energy								
Total Operating	**74.4**	**57.5**	**150.5**	**155.5**	**75.5**	**75.5**	**75.5**	**75.5**
Assistant Secretary for Fossil Energy								
Total Operating	**1.9**	**2.1**	**3.4**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**
Office of Policy								
Total Operating	**0.7**	**0.6**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Other DOE Organizations								
TA Nat'l Energy Information System	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BPA	1.0	2.0	2.1	2.2	2.3	2.4	2.5	2.5
Total Operating	**1.2**	**2.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.5**
Other DOE Sites								
Total Operating	**25.8**	**13.4**	**20.5**	**21.0**	**21.5**	**22.0**	**22.0**	**22.0**
Total DOE Programs								
Operating	446.4	384.7	433.5	474.5	401.8	398.5	402.2	392.6
Capital Equipment	19.1	12.6	16.6	15.8	17.1	36.8	18.1	18.8
General Purpose Equipment-GPE	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8
General Plant Projects-GPP	1.1	2.2	2.0	6.0	5.5	5.5	5.5	5.5
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Program Line Items	40.9	50.0	35.1	0.0	0.0	0.0	0.0	0.0
MEL-FS[b] Construction	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
Total	**513.2**	**457.0**	**492.5**	**497.1**	**430.2**	**447.1**	**428.9**	**417.7**

Funding by Secretarial Officer (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Work for Others								
Nuclear Regulatory Commission	10.9	6.0	7.0	7.0	7.0	7.0	7.0	7.0
Department of Defense	32.7	37.0	40.0	42.8	45.2	46.4	47.6	47.6
Environmental Protection Agency	2.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0
DOT and Other Federal Agencies	12.8	4.0	11.0	11.0	11.0	11.0	11.0	11.0
Other - Nonfederal Agencies	0.3	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Total	**59.4**	**50.0**	**61.0**	**62.8**	**65.2**	**66.4**	**67.6**	**67.6**
Total Laboratory Funding								
Operating	505.8	434.7	494.5	537.3	467.0	464.9	469.8	460.2
Capital Equipment	19.1	12.6	16.6	15.8	17.1	36.8	18.1	18.8
General Purpose Equipment-GPE	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8
General Plant Projects-GPP	1.1	2.2	2.0	6.0	5.5	5.5	5.5	5.5
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Program Line Items	40.9	50.0	35.1	0.0	0.0	0.0	0.0	0.0
MEL-FS[b] Construction	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
Total	**572.6**	**507.0**	**553.5**	**559.9**	**495.4**	**513.5**	**496.5**	**485.3**

(a) Budget authorization escalated through FY 2001.
(b) Multiprogram Energy Laboratories-Facilities Support.

Direct Personnel by Secretarial Officer

(Personnel in FTE)

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research								
Operating	219	206	216	326	353	310	382	400
Office of Environmental Management								
Operating	762	620	411	372	371	278	370	340
Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	98	69	102	100	106	92	117	120
Office of Civilian Radioactive Waste Management								
Operating	19	4	5	5	6	5	6	6
Assistant Secretary for Environment, Safety and Health								
Operating	69	68	40	39	39	33	39	40
Assistant Secretary for Defense Programs								
Operating	7	34	66	101	103	300	64	66
Office of Science Education & Technical Information								
Operating	5	2	2	2	2	2	2	2
Office of Nonproliferation and National Security								
Operating	111	136	120	117	120	100	119	123
Assistant Secretary for Nuclear Energy								
Operating	48	75	72	72	62	62	62	62
Assistant Secretary for Fossil Energy								
Operating	7	6	13	16	16	13	16	16
Office of Policy								
Operating	3	3	5	4	5	4	5	5

Direct Personnel by Secretarial Officer (contd)

(Personnel in FTE)

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Other DOE Organizations								
Operating	4	4	8	8	9	8	9	10
Other DOE Sites								
Operating	97	49	79	79	82	70	83	86
Total DOE Program	**1449**	**1276**	**1139**	**1241**	**1274**	**1277**	**1274**	**1276**
Work for Others								
Nuclear Regulatory Commission	46	24	28	27	26	25	25	25
Department of Defense	179	150	158	164	168	168	172	172
Environmental Protection Agency	11	8	8	8	7	7	7	7
DOT and Other Federal Agencies	54	16	43	42	41	40	40	40
Other - Nonfederal Agencies	1	4	4	0	0	0	0	0
Total	**291**	**202**	**241**	**241**	**242**	**240**	**244**	**244**
Laboratory Direct								
Operating	1740	1478	1380	1482	1516	1517	1518	1520
Capital Equipment	21	12	21	18	19	21	20	21
General Plant Projects-GPP	2	3	2	7	6	6	6	6
Landlord Line Items	2	3	0	0	0	0	0	0
Program Line Items	53	63	43	0	0	0	0	0
MEL-FS[a] Construction	4	5	6	0	6	6	3	0
Total Laboratory Direct	**1822**	**1564**	**1452**	**1507**	**1547**	**1550**	**1547**	**1547**
Total Laboratory Indirect	1924	1444	1270	1270	1270	1270	1270	1270
Total Laboratory Personnel (FTE)	**3746**	**3008**	**2722**	**2777**	**2817**	**2820**	**2817**	**2817**

(a) Multiprogram Energy Laboratories-Facilities Support.

Resources by Major DOE Areas

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Office of Energy Research								
Magnetic Fusion (AT)	3.5	1.5	2.2	2.5	2.5	2.5	2.5	2.5
High Energy Physics (KA)	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nuclear Physics (KB)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Basic Energy Sciences (KC)	11.4	11.5	14.0	17.6	20.6	23.5	24.4	25.2
Biological/Environ Research Prog Dir (KR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Advisory & Oversight Program Dir (KF)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
ER Laboratory Technology Transfer (KU)	7.9	3.4	3.6	4.1	4.8	4.8	4.8	4.8
Multiprogram Energy Laboratories (KG)	0.7	0.5	1.2	1.3	1.5	1.4	1.4	1.4
Energy Research Analysis (KD)	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.5
Biological & Environmental Research (KP)	34.7	38.8	30.6	34.1	34.2	34.6	35.1	35.7
EMSL Operations-Expense (KP - BER)	0.0	0.0	5.0	28.0	30.0	32.0	33.5	34.0
Operating	**58.7**	**56.6**	**57.1**	**88.2**	**94.2**	**99.4**	**102.3**	**104.2**
Capital Equipment (AT)	**0.2**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
Capital Equipment (KC)	1.0	1.2	2.0	2.2	2.5	2.7	3.0	3.2
Capital Equipment (KP)	8.8	5.4	11.0	8.0	8.0	8.0	8.0	8.0
EMSL Operations Capital (KP - BER)	0.0	0.0	0.0	2.0	2.5	22.3	3.5	4.0
Capital Equipment	**10.0**	**6.6**	**13.1**	**12.3**	**13.1**	**33.1**	**14.6**	**15.3**
General Purpose Equipment-GPE (KP)	**0.7**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
General Plant Projects-GPP (KP)	0.4	2.0	2.0	3.5	3.5	3.5	3.5	3.5
Multiprogram Energy Laboratories (KG)	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
Program Line Item (EMSL)	40.0	50.0	35.1	0.0	0.0	0.0	0.0	0.0
Total Funding	**112.8**	**120.2**	**112.6**	**104.8**	**116.6**	**142.3**	**123.5**	**123.8**
Direct Personnel								
Operating	219	206	216	326	353	310	382	400
Capital	13	8	17	15	16	19	18	19
General Plant Projects-GPP	1	3	2	4	4	4	4	4
Multiprogram Energy Laboratories (KG)	4	5	6	0	6	6	3	0
Program Line Items	52	63	43	0	0	0	0	0
Total Direct Personnel	**289**	**285**	**284**	**345**	**379**	**339**	**407**	**423**

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Office of Environmental Management								
Technical Development (EW)	24.8	23.0	25.5	24.0	24.0	21.0	18.0	15.0
Waste Management (EW)	142.9	125.0	75.5	72.2	72.2	66.9	78.8	70.3
Waste Management (EX)	19.0	12.0	2.9	0.8	0.8	0.3	0.3	0.3
Environmental Restoration (EW)	15.2	9.0	8.1	8.1	7.3	5.8	5.8	5.8
Environmental Restoration (EX)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Operating	**201.9**	**169.0**	**112.0**	**105.1**	**104.3**	**94.0**	**102.9**	**91.4**
Capital Equipment (EW/EX)	7.4	1.6	1.5	1.5	1.5	1.2	1.0	1.0
General Purpose Equipment-GPE	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects-GPP	0.7	0.2	0.0	2.5	2.0	2.0	2.0	2.0
Program Line Items	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	**212.9**	**173.3**	**113.5**	**109.1**	**107.8**	**97.2**	**105.9**	**94.4**
Direct Personnel								
Operating	762	620	411	372	371	278	370	340
Capital Equipment	7	2	2	2	2	1	1	1
General Plant Projects-GPP	1	0	0	3	2	2	2	2
Program Line Items	1	0	0	0	0	0	0	0
Landlord Line Items	2	3	0	0	0	0	0	0
Total Direct Personnel	**773**	**625**	**413**	**377**	**375**	**281**	**373**	**343**

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Assistant Secretary for Energy Efficiency and Renewable Energy								
Electric Energy Systems (AK)	1.6	0.9	1.0	1.2	1.4	1.4	1.4	1.4
Energy Storage Systems (AL)	0.1	0.0	0.8	0.8	0.8	0.8	0.8	0.8
Geothermal Systems (AM)	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
Hydrogen Research (AR)	0.1	0.0	0.3	0.3	0.3	0.3	0.3	0.3
Solar Energy (EB)	0.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Buildings Sector-(includes FEMP) (EC)	15.7	11.0	13.2	12.6	12.6	13.1	13.6	13.6
Industrial Energy Conservation (ED)	4.2	2.6	4.8	5.0	5.2	5.4	5.6	5.6
Transportation Sector (EE)	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.0
Tech & Financial Assistance (EF)	1.0	1.2	1.1	1.1	1.2	1.2	1.2	1.2
Utility Sector (EK)	0.3	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Policy And Management (EH)	0.4	0.1	1.0	1.0	1.0	1.0	1.0	1.0
Policy And Management (KK04)	0.3	0.1	1.0	1.0	1.0	1.0	1.0	1.0
Operating	**26.0**	**18.6**	**26.5**	**26.8**	**27.8**	**29.0**	**30.8**	**30.8**
Capital Equipment	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total Funding	**26.5**	**18.8**	**26.7**	**27.0**	**28.0**	**29.2**	**31.0**	**31.0**
Direct Operating Personnel	98	69	102	100	106	92	117	120
Office of Civilian Radioactive Waste Management								
Nuclear Waste Fund (DB)	0.3	0.5	0.7	0.8	1.0	1.0	1.0	1.0
Civilian Radioactive Waste R&D (DC)	4.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total Funding	**4.9**	**1.0**	**1.2**	**1.3**	**1.5**	**1.5**	**1.5**	**1.5**
Direct Operating Personnel	19	4	5	5	6	5	6	6
Assistant Secretary for Environment, Safety and Health								
Environmental, Safety and Health (HA-01)	13.1	14.1	6.1	6.1	6.1	6.1	6.1	6.1
Program Direction (HA-04)	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Nuclear Safety Policy (HP)	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Office of Security Evaluation (HS)	1.6	2.3	2.0	2.0	2.0	2.0	2.0	2.0
Nuclear Safety Oversight (NS)	2.0	1.2	1.5	1.5	1.5	1.5	1.5	1.5
Radiological Oversight (NR)	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operating	**18.4**	**18.4**	**10.3**	**10.3**	**10.3**	**10.3**	**10.3**	**10.3**
Capital Equipment (HA-01)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment (HS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	**18.5**	**18.5**	**10.4**	**10.4**	**10.4**	**10.4**	**10.4**	**10.4**
Direct Operating Personnel	69	68	40	39	39	33	39	40

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Assistant Secretary for Defense Programs								
Materials Production (GE/DP)	1.7	9.3	17.0	27.0	27.0	27.0	17.0	17.0
Operating	**1.7**	**9.3**	**17.0**	**27.0**	**27.0**	**27.0**	**17.0**	**17.0**
Capital Equipment	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.0
Total Funding	**1.7**	**9.8**	**17.5**	**27.5**	**28.0**	**28.0**	**18.0**	**18.0**
Direct Operating Personnel	7	34	66	101	103	300	64	66
Office of Science Education & Technical Information								
University & Science Education (KT)	1.3	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Univ. & Science Education - Defense (KV)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	**1.3**	**0.4**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**	**0.5**
Direct Operating Personnel	5	2	2	2	2	2	2	2
Office of Nonproliferation and National Security								
Emergency Management Division (GB0506)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Verification & Control Technology (GC)	15.2	15.3	14.5	14.5	14.8	14.8	14.8	14.8
Nuclear Safeguards & Security (GD)	2.6	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Expt Control, Nonprolif & Safeguards (GJ)	6.2	14.1	9.0	9.0	9.0	9.0	9.0	9.0
Intelligence (NT)	5.3	4.5	4.6	4.6	4.6	4.6	4.6	4.6
Operating	**29.5**	**37.0**	**31.2**	**31.2**	**31.5**	**31.5**	**31.5**	**31.5**
Capital Equipment (GC)	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment (GD)	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment (NT)	0.0	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	**30.6**	**40.6**	**32.4**	**32.4**	**32.7**	**32.7**	**32.7**	**32.7**
Direct Personnel								
Operating	111	136	120	117	120	100	119	123
Capital Equipment	1	2	2	1	1	1	1	1
Total Direct Personnel	**112**	**138**	**122**	**118**	**121**	**101**	**120**	**124**

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Assistant Secretary for Nuclear Energy								
Nuclear Energy R&D (AF)	71.2	55.0	150.0	155.0	75.0	75.0	75.0	75.0
Uranium Enrichment (CD)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy & Management (KK)	2.3	1.0	0.5	0.5	0.5	0.5	0.5	0.5
Isotope Production (ST)	0.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	**74.4**	**57.5**	**150.5**	**155.5**	**75.5**	**75.5**	**75.5**	**75.5**
Direct Operating Personnel	48	75	72	72	62	62	62	62
Assistant Secretary for Fossil Energy								
Coal (AA)	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0
Gas (AB)	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Petroleum (AC)	0.5	0.3	1.4	2.2	2.2	2.2	2.2	2.2
Total Funding	**1.9**	**1.7**	**3.4**	**4.2**	**4.2**	**4.2**	**4.2**	**4.2**
Direct Operating Personnel	7	6	13	16	16	13	16	16
Office of Policy								
Policy, Planning & Analysis (PE)	0.7	0.8	1.2	1.2	1.2	1.2	1.2	1.2
Total Funding	**0.7**	**0.8**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Direct Operating Personnel	3	3	5	4	5	4	5	5
Other DOE Organizations								
Nat'l Energy Information System (TA)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bonneville Power Administration	1.0	1.0	2.1	2.2	2.3	2.4	2.5	2.5
Total Funding	**1.2**	**1.0**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.5**
Direct Personnel	4	4	8	8	9	8	9	10
Other DOE Sites								
Total Funding	**25.8**	**13.4**	**20.5**	**21.0**	**21.5**	**22.0**	**22.0**	**22.0**
Direct Personnel	97	49	79	79	82	70	83	86
Total DOE Programs								
Operating	446.4	384.7	433.5	474.5	401.8	398.5	402.2	392.6
Capital Equipment	19.1	12.6	16.6	15.8	17.1	36.8	18.1	18.8
General Purpose Equipment-GPE	1.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8
General Plant Projects-GPP	1.1	2.2	2.0	6.0	5.5	5.5	5.5	5.5
Landlord Line Items	1.5	2.5	0.0	0.0	0.0	0.0	0.0	0.0
Program Line Items	40.9	50.0	35.1	0.0	0.0	0.0	0.0	0.0
MEL-FS[b] Construction	3.0	4.2	4.5	0.0	5.0	5.5	2.3	0.0
Total Funding	**513.2**	**457.0**	**492.5**	**497.1**	**430.2**	**447.1**	**428.9**	**417.7**

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Total DOE Programs (Contd)								
Direct Personnel								
Operating	1449	1276	1139	1241	1274	1277	1274	1276
Capital	21	12	21	18	19	21	23	21
General Plant Projects (GPP)	2	3	2	7	6	6	6	6
Landlord Line Items	2	3	0	0	0	0	0	0
Program Line Items	53	63	43	0	0	0	0	0
MEL-FS[b] Construction	4	5	6	0	6	6	3	0
Total Direct Personnel	1531	1362	1211	1266	1305	1310	1303	1303
Work for Others								
Nuclear Regulatory Commission								
Operating	10.9	6.0	7.0	7.0	7.0	7.0	7.0	7.0
Direct Personnel	46	24	28	27	26	25	25	25
Department of Defense								
Operating	32.7	37.0	40.0	42.8	45.2	46.4	47.6	47.6
Direct Personnel	179	150	158	164	168	168	172	172
Environmental Protection Agency								
Operating	2.7	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Direct Personnel	11	8	8	8	7	7	7	7
DOT and Other Federal Agencies								
Operating	12.8	4.0	11.0	11.0	11.0	11.0	11.0	11.0
Direct Personnel	54	16	43	42	41	40	40	40
Other - Nonfederal Agencies								
Operating	0.3	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1	4	4	0	0	0	0	0
Total Work for Others								
Operating	**59.4**	**50.0**	**61.0**	**62.8**	**65.2**	**66.4**	**67.6**	**67.6**
Direct Personnel	291	202	241	241	242	240	244	244

Resources by Major DOE Areas (contd)

(Budget Authorization $ in Millions)[a]

	Fiscal Year							
	1995	1996	1997	1998	1999	2000	2001	2002
Total Laboratory Funding								
Operating	**505.8**	**434.7**	**494.5**	**537.3**	**467.0**	**464.9**	**469.8**	**460.2**
Direct Personnel	1740	1478	1380	1482	1516	1517	1518	1520
Capital	**19.1**	**12.6**	**16.6**	**15.8**	**17.1**	**36.8**	**18.1**	**18.8**
Direct Personnel	21	12	21	18	19	21	20	21
General Purpose Equipment-GPE	**1.2**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
General Plant Projects-GPP	**1.1**	**2.2**	**2.0**	**6.0**	**5.5**	**5.5**	**5.5**	**5.5**
Direct Personnel	2	3	2	7	6	6	6	6
Landlord Line Items	**1.5**	**2.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct Personnel	2	3	0	0	0	0	0	0
Program Line Items	**40.9**	**50.0**	**35.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Direct Personnel	53	63	43	0	0	0	0	0
MEL-FS[b] Construction	**3.0**	**4.2**	**4.5**	**0.0**	**5.0**	**5.5**	**2.3**	**0.0**
Direct Personnel	4	5	6	0	6	6	3	0
Indirect Personnel	**1924**	**1444**	**1270**	**1270**	**1270**	**1270**	**1270**	**1270**
Total Funding	**572.6**	**507.0**	**553.5**	**559.9**	**495.4**	**513.5**	**496.5**	**485.3**
Total Personnel	**3746**	**3008**	**2722**	**2777**	**2817**	**2820**	**2817**	**2817**

(a) Budget authorization escalated through FY 2001.
(b) Multiprogram Energy Laboratories-Facilities Support.

Subcontracting and Procurement

The Laboratory is dependent upon external resources (universities and industry) for support in achieving timely and successful completion of assigned programs and projects. This is accomplished by staff in the Contracts organization who use the procurement acquisition process in acquiring needed equipment, materials, supplies, and services. The table below reflects actual subcontracted amounts for FY 1996 and projections for FY 1997 through FY 1999.

Small and Disadvantaged Business Procurement

The Laboratory is committed to support the socioeconomic objectives of DOE and has established procedures and programs that support meeting those objectives.

Subcontracting and Procurement Table

(Dollar Amounts in Millions)

	Fiscal Year 1996	1997	1998	1999
Obligated	205.0	200.4	216.8	242.4
Subcontracting and Procurement from:				
Universities	13.3	13.0	14.1	15.7
All Others	154.0	150.6	162.8	182.1
Other DOE	37.7	36.8	39.9	44.6
Total External Subcontracts and Procurements	**205.0**	**200.4**	**216.8**	**242.4**

Small and Disadvantaged Business Procurement Table

(Dollar Amounts in Millions)

	Fiscal Year 1996		1997		1998	
Procurement from Small Business	69.1	33.7%	67.4	33.6%	73.1	33.7%
Procurement from Disadvantaged Businesses	6.3	3.0%	6.1	3.0%	6.7	3.1%

Pacific Northwest National Laboratory

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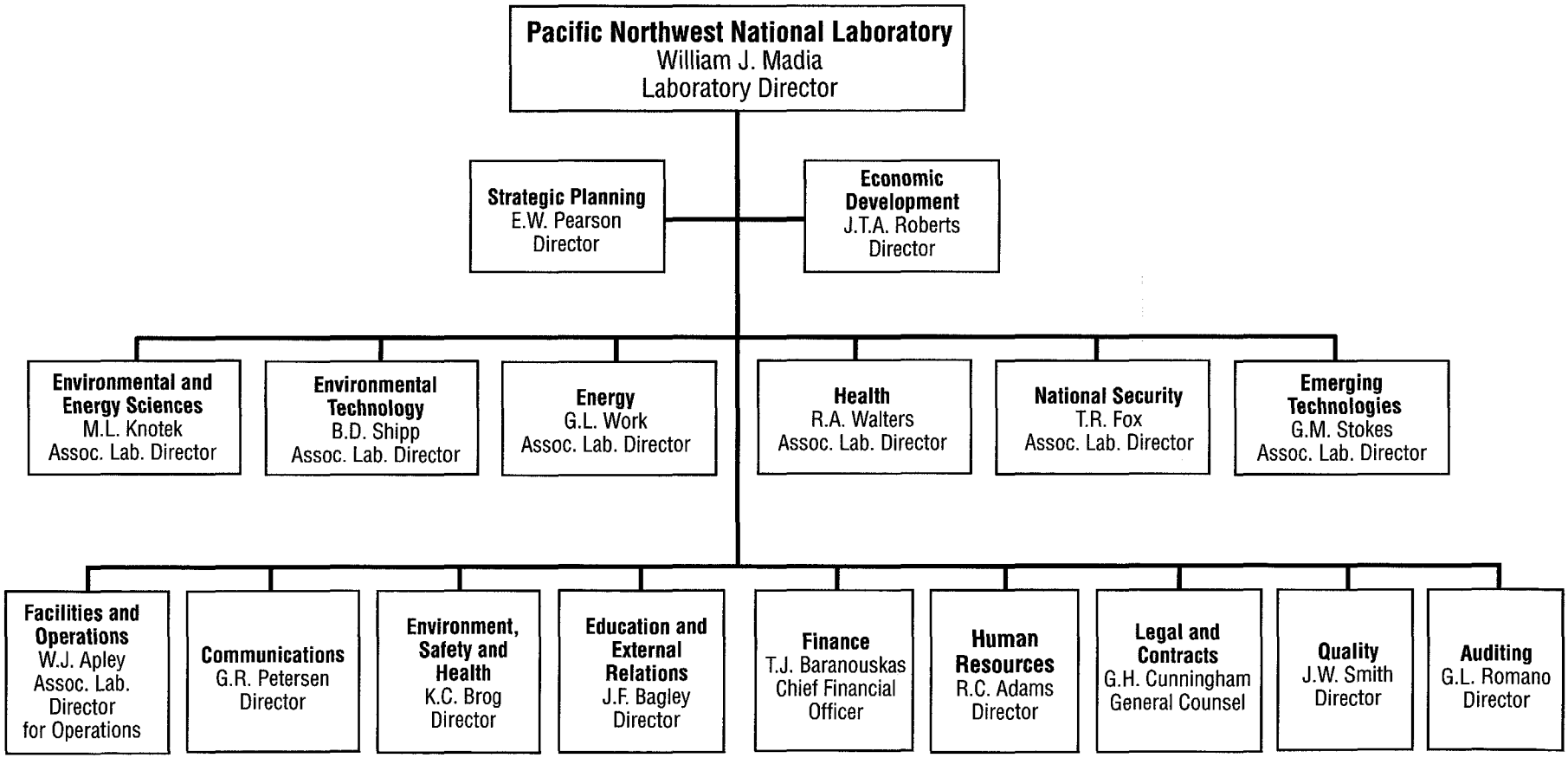

8 Acronyms and Abbreviations

ACTI	Advanced Computational Technology Initiative
AEDOT	Advanced Energy Design and Operation Technologies
AISES	American Indian Science and Engineering Society
ALARA	as low as reasonably achievable
AMTEX	American Textile Industry
APEL	Advanced Process Engineering Laboratory
ARM	Atmospheric Radiation Measurement
ASCOT	Atmospheric Studies in Complex Terrain
ASME	American Society of Mechanical Engineers
AVLIS	Advanced Vapor Laser Isotope Separation
AWU	Associated Western Universities Inc.
BES	Office of Basic Energy Sciences
BSGP	Building Standards and Guidelines Program
CART	Cloud and Radiation Testbed
CEDR	Comprehensive Epidemiologic Data Resource
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CHAMMP	Computer Hardware, Advanced Mathematics and Model Physics
CHCs	chlorinated hydrocarbons
Con Ops	Conduct of Operations
CORE	Collaborative Research Environment
CRADA	Cooperative Research and Development Agreement
CSEPP	Chemical Stockpile Emergency Preparedness Program
CTBT	Comprehensive Test Ban Treaty
DARPA	Defense Advanced Research Projects Agency
DNA	deoxyribonucleic acid
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EEO/AA	Equal Employment Opportunity/Affirmative Action
EM	Office of Environmental Management
EMSL	Environmental Molecular Sciences Laboratory
EPAct	Energy Policy Act
EPRI	Electric Power Research Institute
ER	Office of Energy Research
ER-LTR	Office of Energy Research Laboratory Technology Research
ERPP	Environmental Radiological Protection Plan
ES&H	Environment, Safety, and Health
ESEECAP	Environmental Science and Engineering Education Coordination and Assistance Project
ESI-MS	electrospray ionization mass spectrometry
ESNET	Energy Sciences NETwork
FDDI	fiber digital data interface
FE	Office of Fossil Energy
FEDS	Federal Energy Decision System
FEMA	Federal Emergency Management Agency
FEMIS	Federal Emergency Management Information System
FEMP	Federal Energy Management Program
FI	flow injection

FLC	Federal Laboratory Consortium
FTEPR	Fourier transform electron paramagnetic resonance
FTICR	Fourier transform ion cyclotron resonance
FUAs	facility use agreements
FY	fiscal year
GCAM	Global Change Assessment Model
GCMs	general circulation models
GEM	Graduate Degrees for Minorities in Engineering and Science
GPE	General Purpose Equipment
GPF	General Purpose Facilities
GPP	General Plant Projects
HBCU	Historically Black Colleges and Universities
HEPA	high-efficiency particulate air
HERS	Home Energy Rating Systems
HVAC	heating, ventilation, and air-conditioning
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IGEX	International Germanium Experiment
IGBP	International Geosphere Biosphere Program
IPCC	Intergovernmental Panel on Climate Change
ISFET	ion sensitive field-effect transistor
ITER	International Thermonuclear Experimental Reactor
Lab Coop	DOE Laboratory Cooperative program
LCAD	Life-Cycle Computer Aided Data
LDRD	Laboratory Directed Research and Development
MAP	Manufactured Housing Acquisition Program
MCSCF	multiconfiguration self-consistent field
MEL-FS	Multiprogram Energy Laboratories-Facilities Support
MESA	Mathematics, Engineering and Science Achievement
MPPs	massively parallel processors
MRI	magnetic resonance imaging
MRS	magnetic resonance spectroscopy
MSCF	Molecular Science Computing Facility
NABIR	National and Accelerated Bioremediation Research
NE	Office of Nuclear Energy
NEPA	National Environmental Policy Act
NERSC	National Energy Research Supercomputing Center
NFPA	National Fire Protection Association
NICE3	National Industrial Competitiveness through Energy, Environment and Economics
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIS/IPP	New Independent States Industrial Partnering Program
NMSS	Office of Nuclear Material Safety and Safeguards
NOBChE	National Organization of Black Chemical Engineers
NPAR	Nuclear Plant Aging Research
NRC	Nuclear Regulatory Commission
NRR	Nuclear Reactor Regulation
NSBE	National Society for Black Engineers
NUMA	nonuniform memory access
OBPCS	Office of Budget, Planning and Customer Service
OFCCP	Office of Federal Contract Compliance Programs
OGCMs	ocean general circulation models

OHER	Office of Health and Environmental Research
ORTA	Office of Research and Technology Applications
OSHA	Occupational Safety and Health Administration
OSPI	Office of the Superintendent of Public Instruction
PASS	Pacific Northwest National Laboratory Affiliate Staff Scientist
PC	personal computer
PHMC	Project Hanford Management Contractor
PO	Policy Office
RAAS	Remedial Action Assessment System
Radcon	radiological control
RAISE	Research Internships for Students with Disabilities
RCRA	Resource Conservation and Recovery Act
RES	Office of Nuclear Regulatory Research
RLWS	Radioactive Liquid Waste System
RW	Office of Civilian Radioactive Waste Management
SBIR	Small Business Innovation Research
SDEP	Staff Diversity Enhancement Program
SERS	Science and Engineering Research Semester
SHPE	Society of Hispanic Professional Engineers
SI	sequential injection
SISR	Surface/Interface Structure and Reactions
SMES	superconducting magnetic energy storage
SOFCs	solid-oxide fuel cells
STCG	Site Technology Coordination Group
STTR	Small Business Technology Transfer
SWE	Society of Women Engineers
TEES®	Thermochemical Environment Energy System
TOF	time of flight
TRAC	Teacher Research Associates
TReC	Textile Resource Conservation Project
TRIDEC	Tri-City Industrial Development Council
TWINS	Tank Waste Information Network System
TWRS	Tank Waste Remediation System
USCAR	U.S. Council for Automotive Research
USEC	U.S. Enrichment Corporation
USGCRP	U.S. Global Change Research Program
WAMS	Wide Area Measurement Systems
WIPP	Waste Isolation Pilot Plant
WSU-TC	Washington State University at Tri-Cities
XAFS	x-ray absorption fine structure

* U.S. GPO 1996: 590-379