

Front Cover

Pacific Northwest Laboratory's 750-megahertz nuclear magnetic resonance spectrometer superimposed over a schematic of the ultrahigh field nuclear magnetic resonance spectrometer currently in design for the Environmental Molecular Sciences Laboratory (EMSL). The 750-megahertz spectrometer, the world's first instrument of that power in commercial use, is installed in interim EMSL facilities at PNL and is being used in research related to the Department of Energy's environmental cleanup efforts at the Hanford Site. The ultrahigh field (900 to 1000 megahertz) nuclear magnetic resonance spectrometer will be one of the key advanced research capabilities in the new EMSL when it begins operations in early FY 1998.

Inside Cover

The 750-megahertz and ultrahigh field nuclear magnetic resonance spectrometers in the EMSL will provide unparalleled sensitivity and resolution principally for investigations in the area of biomolecular structure and dynamics for molecules of biological and/or environmental relevance. The crystal structure of the *cro* repressor protein complexed with its DNA operator sequence is shown above. This gene regulatory protein offers a convenient model for studying damaged-DNA/protein interactions. PNL researchers are currently studying the *cro* protein using the 750-megahertz spectrometer. The inset of a region of the two-dimensional NOESY spectrum shows the excellent spectral resolution produced at 750 megahertz. Studies at higher fields will provide more accurate structural information, shorter data acquisition periods, application to larger proteins, and enable studies of low solubility DNA-protein complexes.

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Pacific Northwest Laboratory Institutional Plan FY 1995 - 2000

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Pacific Northwest Laboratory

Operated for the U.S. Department of Energy by Battelle Memorial Institute

Contents

Situation Analysis Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology. Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Possil Energy National Security Office of Defense Programs Office of Defense Programs Office of Defense Programs Office of Onoppetitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	1	Director's Statement	1
Mission Core Competencies 3 Laboratory Strategic Plan Situation Analysis Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Possil Energy National Security Office of Defense Programs Office of Defense Programs Office of Possil Energy National Security Office of Honoproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	2	Laboratory Mission and Core Competencies	3
3 Laboratory Strategic Plan Situation Analysis Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Nuclear Energy Office of Possil Energy National Security Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Mission	
Situation Ánalysis Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Nuclear Energy Office of Nuclear Energy Office of Nospil Energy National Security Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Core Competencies	3
Situation Ánalysis Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Nuclear Energy Office of Nuclear Energy Office of Nospil Energy National Security Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	3	Laboratory Strategic Plan	5
Primary Planning Assumptions Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Nuclear Energy Office of Nuclear Energy Office of Possil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Strategic Objectives: PNL Support to the Department of Energy Strategic Plan Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Possil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		·	
Fundamental Strategies 4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Civilian Radioactive Waste Management Office of Policy Office of Policy Office of Fossil Energy National Security Office of Defense Programs Office of Defense Programs Office of Polopuliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
4 Laboratory Initiatives Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Policy Office of Nuclear Energy Office of Possil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Molecular Sciences Research Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environmental Management Office of Environmental Management Office of Environmental Management Office of Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Possil Energy National Security National Security Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	4	-	
Microbial Biotechnology Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	7		
Global Environmental Change Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Modeling of Complex Physical Systems Advanced Processing Technology Energy Technology Development Medical Technologies and Systems 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Possil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Advanced Processing Technology Energy Technology Development Medical Technologies and Systems. 5 Core Business Areas Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy. Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Energy Technology Development Medical Technologies and Systems			
Medical Technologies and Systems Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Nuclear Energy Office of Nuclear Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		0 0,	
Science and Technology Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Medical Technologies and Systems	32
Environmental Molecular Sciences Laboratory Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL	5	Core Business Areas	37
Office of Energy Research Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Science and Technology	37
Science, Mathematics, Engineering, and Technology Education Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Environmental Molecular Sciences Laboratory	37
Environmental Quality Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Office of Energy Research	45
Office of Environmental Management Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Science, Mathematics, Engineering, and Technology Education	66
Office of Environment, Safety and Health Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Environmental Quality	
Hanford Site Support Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		· · · · · · · · · · · · · · · · · · ·	
Energy Resources Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		Office of Environment, Safety and Health	
Office of Energy Efficiency and Renewable Energy Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		• •	
Bonneville Power Administration Office of Civilian Radioactive Waste Management Office of Policy Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
Office of Civilian Radioactive Waste Management Office of Policy		· · · · · · · · · · · · · · · · · · ·	
Office of Policy			
Office of Nuclear Energy Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		J	
Office of Fossil Energy National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL			
National Security Office of Defense Programs Office of Nonproliferation and National Security Industrial Competitiveness Full Integration of the Industrial Competitiveness Mission Throughout PNL		•	
Office of Defense Programs		··	
Office of Nonproliferation and National Security			
Industrial CompetitivenessFull Integration of the Industrial Competitiveness Mission Throughout PNL			
Full Integration of the Industrial Competitiveness Mission Throughout PNL		· · · · · · · · · · · · · · · · · · ·	
· · · · · · · · · · · · · · · · · · ·			
CHUADGEO HIGDSHALAWATEDESS OF CIVI		Enhanced Industrial Awareness of PNL	

	Providing Technical Assistance and Collaborating with U.S. Industry	
	Protection and Commercialization of Intellectual Property	
	Laboratory Directed Research and Development Program	
	Program Administration and Management	
	Scientific and Technical Investment Areas	
	Selected Highlights of FY 1993 and FY 1994 LDRD Projects	
	Work for Other DOE Sites	
	Work for Others	
	Department of Defense	
	Nuclear Regulatory Commission	
	Environmental Protection Agency	
	Health and Human Services	
	National Aeronautics and Space Administration	
	Federal Emergency Management Agency	
	Other Federal Agencies and Nonfederal	123
6	Critical Success Factors	124
	Human Resources	124
	Laboratory Personnel	124
	Affirmative Action and Equal Employment Opportunity	126
	Environment, Safety, and Health Management	
	ES&H Goals and Objectives	130
	Current Conditions	130
	ES&H Policies, Organization, and Management	130
	ES&H Plans and Initiatives	132
	Performance Indicators	136
	Environmental Restoration and Waste Management Activities	136
	Hanford Site-Wide Funded ES&H	137
	Information Resource Management	138
	Empowering the User	
	Defining and Meeting Information Management Needs	
	Effective Use of Information Technology	138
	Cost Effectiveness	
	Environment and Accomplishments	
	Infrastructure	
	Scientific and Engineering Computing	
	Site and Facilities	
	Laboratory Description	
	Consolidated Information Center	
	Summary	
	Communication and Trust	153
7	Resource Projections	154
8	Acronyms and Abbreviations	170



Director's Statement

As I complete my first 100 days as director of the Pacific Northwest Laboratory, I'm confident that I'm part of a team that is well-positioned to make significant contributions to the missions stated in the U.S. Department of Energy's Strategic Plan, Fueling a Competitive Economy.

I believe that our future depends on our response to the two fundamental challenges of relevance and productivity. At PNL relevance means more than ensuring that our projects and programs are aligned with the DOE mission and national needs, and productivity means more than cutting costs. If we are truly relevant, our customers must see that our products and services add substantial value and make real contributions to their ability to achieve their goals. If we are truly productive, we will excel in the timeliness, cost, and quality of our work and the stewardship of the resources entrusted to our care. To meet these standards, we must provide an environment characterized by uniform traditions of trust and mutual respect in which we all have the opportunity to learn and develop our talents and skills.

To ensure *relevance*, we have developed, maintained, and invested in a set of core competencies critical to DOE's missions. Rather than trying to be all things to all people, in each DOE mission area we work only on those challenges that match our core competencies of Integrated Environmental Research, Process Science and Engineering, and Energy Systems Development.

Basic research is the fundamental source of new knowledge and new solutions to today's most challenging or even intractable problems. Therefore, we must continually strive to maintain an outstanding



Dr. William J. Madia, Director of Pacific Northwest Laboratory, with a model of the EMSL in the foreground and the EMSL construction site in the background.

fundamental science base, closely linked to DOE's missions and underlying our core competencies. The Environmental Molecular Sciences Laboratory (EMSL), the centerpiece of PNL's basic science and technology strategy, is directed to providing solutions to critical national needs. To ensure the greatest return on new knowledge, we also seek to

fully integrate basic and applied research with development and application activities thereby accelerating technology deployment.

To solve complex, interdisciplinary problems, we actively seek partners from other national laboratories, universities, or industries that possess complementary areas of technical or scientific excellence. At Hanford, for example, we have joined with the site contractors and other DOE laboratories to bring the very best technical capabilities to bear on major cleanup problems. The linkage between the Laboratory's science and technology programs and applications here at Hanford is real and substantial.

In line with our commitment to relevance and productivity, we have established a set of high-level goals that we believe represent our most critical commitment to DOE and the nation. In cooperation with DOE and our academic and industrial partners, we will:

- Support DOE's Science and Technology mission by delivering the
 Environmental Molecular Sciences
 Laboratory as a preeminent collaborative research facility, and in
 so doing, bring the nation's best
 scientific talent to bear on the
 Department's critical challenges.
- Support the environmental mission by delivering knowledge DOE requires to make scientifically sound risk-based decisions and producing technology that significantly reduces the cost and improves the timeliness and effectiveness of environmental remediation at Hanford and across the entire DOE complex.
- Develop and deploy technologies and strategies that improve the reliability, increase efficiency, and minimize the adverse health and environmental impacts of energy systems.
- Develop arms control, nonproliferation, and intelligence technologies that enhance national security.

- Develop solutions that measurably help modernize America's manufacturing and process industries, thus creating new high-wage jobs and increasing U.S. export potential. We will make major contributions to the regional economy and to the transition of the local economy to the post-Hanford era.
- Help develop the next generation of scientists, engineers, and scientifically literate citizens. For today's young men and women, we will help ensure that science, engineering, and mathematics will be a route to a rewarding and satisfying career as well as preparation for living in an increasingly technological world.

With respect to *productivity*, we are undertaking a major program to improve the quality of PNL's products, the timeliness with which those products are delivered, the stewardship of our physical and human resources, and our cost-effectiveness. To this end we are implementing a major change program, ACE (Achieving the Competitive Edge) at the Laboratory. The ACE program has three primary objectives

- ensure that our products and services deliver the highest possible value as defined by our clients
- identify ways to accomplish overall performance improvements and sustain long-term productivity gains
- analyze and streamline our cost structure.

Through the ACE program we are committed to making PNL the benchmark for productivity within the laboratory system, improving our timeliness, enhancing the quality

of our products, reducing our costs, and maintaining our stewardship of the assets we manage.

We must also strengthen our Laboratory in other critical ways. Over the next 5 years, we are committed to building a tradition of interactive personal and institutional leadership, encompassing the entire staff of the Laboratory. We are committed to having PNL meet or exceed private-sector standards for Environment, Safety, and Health performance and cost-effectiveness, fully meeting the intent of DOE Orders and requirements.

Those who have served as laboratory director before me have created a solid foundation upon which we will continue to build. In particular, the outstanding opportunity we have for new achievements is my inheritance from Bill Wiley, Laboratory Director from 1984 to 1994. Thanks to Bill's foresight, we successfully made the transition to an Energy Research laboratory with a solid foundation in basic research that is directed at solving environmental, energy, and national security problems. Thanks to his vision, EMSL construction is well under way. And thanks to his commitment, the Laboratory has grown in size, facilities, and impact on DOE programs.

Let me close by saying that the caliber of the people that make up our staff gives me great confidence for our future. I am truly excited by the opportunity to work with our staff as we work together to contribute even more to the solution of our nation's most critical needs. For our time of both great uncertainty and great opportunity we could have no better team.

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Laboratory Mission and Core Competencies

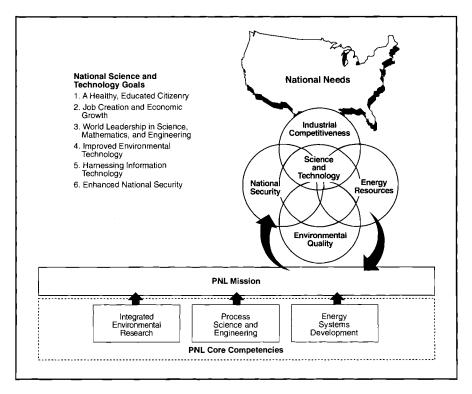
The Pacific Northwest Laboratory's mission and core competencies (see figure) are derived to be relevant to the U.S. Department of Energy's core businesses and to increase the Laboratory's productivity in contributing to selected goals established in each of DOE's five core businesses. The National Science and Technology Council established six goals focused on meeting national needs. DOE is one of the federal agencies accountable for delivering results to achieve these goals. DOE's Strategic Plan identifies five core businesses (in circles) that most effectively utilize its assets for meeting these national goals.

To achieve a quality path, PNL is focused on maintaining relevance with DOE's mission and strategic goals; using teamwork, diversity, and employee empowerment to increase productivity; celebrating accomplishment; ensuring that operations are conducted in compliance with environmental, safety, and health standards; and promoting a learning organization.

Mission

PNL's mission is to conduct research and development to provide science and technology results that improve environmental quality, increase energy efficiency, maintain national security, and promote industrial competitiveness. Partnerships with universities, industry, agencies of state and local governments, and other federal laboratories are fundamental to meeting PNL's programmatic responsibilities, accelerating the technology cycle from concept to application, and promoting economic growth locally, regionally, and nationally.

Included in the scope of these partnerships is the development and operation of major collaborative user facilities; thus, the development and sharing



The connectivity of PNL's mission and core competencies to DOE core businesses is focused on national science and technology goals.

of new knowledge and innovative technology truly become a twoway process.

Using the consolidated resources of Battelle and PNL, the Laboratory has created integrated, cross-disciplinary research programs to develop and transfer technologies that support each DOE core business and carry them beyond Laboratory walls to useful application.

Core Competencies

PNL has developed and maintains three core competencies

- Integrated Environmental Research
- Process Science and Engineering
- Energy Systems Development.

These competencies evolved from the approach PNL used in solving characteristic problems for a DOE client.

PNL's core competencies are characterized as a set of technologies and capabilities, integrated by a dynamic work force to provide a comprehensive solution to a problem that a client wants solved. The individual technologies and capabilities, which are the basis of core competencies, may not be unique to any one institution, but the manner in which they are integrated at PNL to solve a problem is distinguishing.

The core competency of Integrated Environmental Research is directed toward

- Improved sensing and measurement techniques to detect and characterize contaminants.
- Global environment studies that include theoretical and experimental research on ecologic, hydrologic, atmospheric, economic, and energy-related processes affecting regional and global climates.
- Subsurface science, including developing advanced sampling and modeling procedures and research on the microbial basis for in situ bioremediation of contaminated soils and aquifers.
- Biological systems, including epidemiologic surveillance, research on radon and other alpha-emitting nuclides, molecular studies on genetic alterations produced by the interaction of radiation and toxic chemicals with living cells, and research on dosimetry and radioimmunotherapy.
- Environmental transport and fate of pollutants in atmospheric, marine, and terrestrial systems.
- Technical, economic, and regulatory analysis of policy and program alternatives.
- Risk analyses and health physics assessments for the development

- of environmental, health, and safety policies and procedures.
- Independent environmental surveillance and oversight of Hanford Site operations.

Process Science and Engineering areas are directed toward

- Environmental restoration at Hanford and other DOE sites, including novel concepts for remediation of wastes using physical, chemical, or biological processes; and intermediate and field-scale research to evaluate remediation methods.
- Advanced chemical separations and understanding of the behavior of fluids in complex, dynamic environments such as the waste tanks at Hanford.
- Characterization, treatment, and immobilization of radioactive and hazardous wastes in liquids and solids.
- Materials research emphasizing coatings, new processing techniques, and an understanding of the reaction of materials with their environment.
- Development and scale-up of advanced industrial manufacturing processes that recover recyclable materials and minimize or eliminate wastes.

Areas within Energy Systems Development are directed toward

- Energy-efficiency research and technology development that enhance overall energy-system performance in buildings, industry, manufacturing, transportation, and delivery of services by utilities.
- Diagnostics and controls for advanced energy and transportation systems.
- Lightweight materials and fabrication of components for advanced transportation vehicles.
- Advanced technology development, such as microtechnologies and fuel cells, to provide distributed energy services.

PNL's core competencies embody roughly 80 percent of the Laboratory's programmatic activities. The remaining activities such as nuclear reactor and supporting fuel cycle systems and national security technology reflect specialized scientific and technical areas that support DOE core businesses or emerging opportunities.

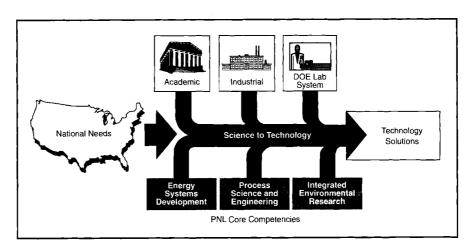


Laboratory Strategic Plan

Situation Analysis

To note that we are living through a time of rapid technological and social change has become a cliché. Yet, for our national science and technology enterprise, the national laboratory system, and most particularly for Pacific Northwest Laboratory, we believe the times are truly extraordinary. The continuous revolution in computing and communications technologies, advances in instrumentation that allow observation and even manipulation at the molecular level, and the frenetic pace at which industrial technologies are born, deployed, and, in turn, supplanted provide any research institution with more than adequate challenges. Yet the nation's technical community must also adjust to a world in which our resources are becoming ever more constrained, even as the demands our society places on science and technology become ever more acute. In particular, the national laboratory system must respond to the change from a world dominated by Cold War pressures to a world in which we are measured by our ability to provide relevant and cost-effective research, development, and application services in support of a diverse array of national needs.

At Pacific Northwest Laboratory this is a particularly appropriate time to reexamine our future. With construction of the Environmental Molecular Sciences Laboratory well under way, we are nearing the culmination of a 10-year effort to revitalize our basic science foundation. We have experienced a period of dramatic growth that has seen PNL nearly double in size over the last 7 years and greatly strengthen its capabilities and technical impact. The Northwest region faces a complex and escalating set of issues, reflective of the challenges facing the nation as a whole, that



PNL's approach to meeting complex national needs is based on maintenance of a vital set of core competencies; broad partnerships with academia, industry, and the full DOE laboratory system; and a strong connection between fundamental research and application.

explicitly pose the challenge of achieving economic growth without compromising the health of the environment. The large federal investment in environmental remediation at Hanford, to which we are a principal technology supplier, is facing acute pressure to deliver results commensurate with expectations and expenditures. Finally, we are completing a change in leadership as, after 10 outstanding years as Laboratory Director, Bill Wiley moves on to new challenges facing Battelle Memorial Institute. With leadership from our new Director, Bill Madia, we seek to build on the foundation of the last 10 years to best serve the Department and the nation.

At the most fundamental level we, and indeed the nation's entire science and technology community, face the twin challenges of *relevance* and *productivity*. By relevance, we mean that what we do must be responsive to national needs. Our work must be understood, valued, and supported by not only the nation's scientific community and policy makers, but by the

public and its elected representatives. Our view of productivity encompasses the four key elements of quality, timeliness, cost-effectiveness, and stewardship. Our ideal is the *timely* delivery of *high-quality* products critical to meeting national needs at *reasonable* cost while exercising stewardship for our staff, intellectual capital, research equipment and facilities, community, and environment.

Given the accelerating pace of technical, geopolitical, and social transformation, to prepare a strategic plan covering our future for the next 2 decades and beyond may seem like an exercise in futility. We believe, however, that this confluence of transformations provides both compelling reason and unprecedented opportunity to redefine our future. Although flexibility and adaptability must be our watchwords, we believe that there are a number of enduring general strategies that are robust against most likely scenarios. In addition, we know that to implement these strategies we must strengthen our institution in certain fundamental ways.

In this strategic plan, we depart from our past practice of listing a large number of detailed planning assumptions in our separate business areas. Rather, we have chosen to look at the broad trends affecting the national science and technology community and the federal investment in research. We have enumerated a small set of primary planning assumptions that underlie our picture of the future world in which we operate, and presented our primary long-term objectives in the context of the Department of Energy's Strategic Plan. We close by describing the strategies which will guide our response to new challenges.

Primary Planning Assumptions

Although our crystal ball is remarkably cloudy when we try to look even a few years ahead in detail, there is a small set of broad assumptions that underlie our planning. These assumptions, which frame our picture of the future world in which we must operate and in which our strategies will be tested, are as follows:

- Resources of all types will be limited. The total national investment, public and private, in science and technology will grow slowly, if at all, over the next few years. Federal investment will be sharply constrained for the foreseeable future by the ongoing attempt to balance the federal budget. As a result, there will be unprecedented technical and political competition for scarce investment resources. Research funding will be directed toward the most relevant and productive providers of science and technology.
- Federal research, development, and application investments will be strongly and explicitly tied to the most pressing technology and policy needs. 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. Even basic research investments will increasingly have to be justified

- in terms of expected benefits in high priority areas. Budgets will be built around broad research priorities, such as those articulated by the National Science and Technology Council.
- The tension between economic development, or the meeting of human needs, and protection of our environment will be a primary driver for science and technology investments for the foreseeable future. As large segments of humanity emerge from relative poverty or seek to achieve Western standards of living, we will be challenged to avoid the environmental consequences of providing an adequate standard of living to all using current-generation energy technologies and industrial practices. Successful response to energy supply and demand issues will be necessary to manage and reduce these pressures. Technology that allows economic growth while maintaining our environment is critical, both to enhance our and our neighbors' standard of living and to preserve our international competitive position.
- The nation's dependence on federal investments in research and development to provide new knowledge that will underpin long-term commercial success will increase. Although industrial research and development investments should show modest growth, the welldocumented trend in industrial investment toward short-term. product-related research will likely continue. Industry must look primarily to government supported research in the universities and federal laboratories to provide the new knowledge from which breakthrough commercial technologies can arise. Stronger interaction among government, industry, and universities will be driven by a common desire to leverage scarce resources and by pressure to speed the application of new developments to commercial technology.
- Advances in scientific instrumentation, computing and information technology, scientific knowledge,

- and engineering practice 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.
- The Department of Energy and DOE's national laboratories will have increased flexibility to respond cost-effectively to national needs. The "reinvention of government" initiative and DOE's response to the pending report from the Commission on Alternative Futures for the National Laboratories (the Galvin Commission) will provide both greater independence of action and greater accountability for results to laboratory management. The Department of Energy and its laboratories, working in partnership, will have both the opportunity and the obligation to eliminate unnecessary costs and delays and to respond more quickly to the full spectrum of national needs. Meeting expectations for enhanced productivity may in fact, be one of the most significant challenges facing Department and its Laboratories.

Our strategic intent derives from consideration of both the opportunities and the obligations that come from these assumptions, and what actions it will take to maintain our success given these assumptions.

Strategic Objectives: PNL Support to the Department of Energy Strategic Plan

In this section we present PNL's highlevel or strategic objectives in the context of the Department of Energy's Strategic Plan, most recently released in 1994. The Department's Strategic Plan establishes goals in each of five core businesses: Science and Technology, Environmental Quality, Energy Resources, Industrial Competitiveness, and National Security. In addition, the plan discusses a number of critical success factors that define the principles by which DOE conducts its work. Pacific Northwest Laboratory supports each of the core businesses, but only in areas where there exists an overlap between our core competencies, built upon past accomplishment and our accumulated skills, and the DOE's goals. In addition, we have set strategic objectives in several of the areas represented by the Department's critical success factors outlined in the DOE Strategic Plan.

Science and Technology

In Science and Technology, the DOE Strategic Plan establishes five primary goals. In brief, these goals include providing science and technology core competencies that enable DOE's businesses to succeed, providing new insight into the nature of matter and energy, effectively constructing leading-edge user facilities, adding value to the U.S. economy through application of new technology, and enhancing science education. PNL programs support four of these five goals; we play no significant role in DOE's high energy and nuclear physics programs.

Our primary objective in support of DOE's Science and Technology mission is that PNL will 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 intend for operation to begin in early FY 1998, at which point we will have completed construction of the conventional facility on schedule and on budget. We will provide maximum scientific capabilities in the Laboratory consistent with the allowed total project cost. It is our goal that by 2001 the facility will house a full complement of research programs and will be fully subscribed by outside users.

Over the next 5 years we intend to continue our emphasis on bringing new scientific knowledge to bear on DOE's environmental, energy, national security, and industrial competitiveness missions. For example, the programs housed in the EMSL will be

fully successful if 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 national security programs must remain well-connected to our science and technology base in areas such as radiation detection and chemical sensors.

We will continue to emphasize our contributions to systemic reform of scientific and mathematics education in support of DOE's efforts to both provide a technically trained, diverse work force of the future and to ensure a technically literate citizenry. Here 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 steadily increase the fraction of our research that is carried out in partnership with the university community, and to continue expansion of the research participation opportunities we provide to visiting students, teachers, and university faculty.

Environmental Quality

In Environmental Quality, PNL actively supports the Department 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 primary objective over the next 5 years is that PNL and its 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. It is our intent to support DOE in

achieving a scientifically defensible, risk-based remediation strategy and schedule, and to deliver technology that helps DOE to meet the schedule at affordable cost. To fulfill this intent we are adding 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 demonstrated strengths in the engineering 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 longer term, however, a strategy of pollution prevention and environmental protection must replace the strategy of waste management and environmental restoration. It is our goal that PNL, 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. Finally, we are committed to maintaining the excellence of our fundamental research programs in the environmental sciences, and in bringing the results of those programs to application in climate, environmental remediation, and other DOE programs.

Energy Resources

We believe that DOE's Energy Resources business will be of continued, and probably increasing, importance to the nation for the foreseeable future, and we embarked 3 years ago on an ongoing effort to focus and strengthen PNL's contribution to this mission. The DOE Strategic Plan specifies four primary goals in this business area: enhancing energy productivity; ensuring reliable, secure

PNL Strategic Objectives

- PNL will 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.
- PNL and its 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.
- PNL and its partners will develop and deploy technologies and strategies that increase the efficiency, improve the reliability, and reduce

- the adverse health and environmental impacts of energy systems.
- PNL and its partners will develop technologies that measurably help modernize America's manufacturing and process industries, thus creating new high-wage jobs and increasing U.S. export potential. In particular, PNL will make major contributions to the regional economy, and to the transition of the local economy to the post-Hanford era.
- PNL will develop arms control, nonproliferation, and intelligence technologies that enhance national security and reduce the danger from weapons of mass destruction.

- PNL is committed to building a tradition of interactive personal and institutional leadership, encompassing the entire staff of the Laboratory.
- PNL 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.
- PNL will be 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.

energy supply; reducing the environmental impacts of energy production, delivery, and use; and promoting economic and regional equity through enhancing our energy production, delivery, and usage systems. PNL programs are primarily directed in support of the first three of these goals.

Our broad objective in the energy area can be stated in language similar to that used by DOE in the Strategic Plan: PNL and its partners will develop and deploy technologies and strategies that increase the efficiency, improve the reliability, and reduce the adverse health and environmental impacts of energy systems. Our ongoing analysis supports the three areas that emerged from our strategic planning effort of 3 years ago as timely and appropriate to PNL. 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 resourceefficient pollution prevention and waste minimization technologies that enhance the economic, energy-efficiency, and environmental performance of U.S. industry.

In executing these three thrusts, we intend to continue placing special emphasis on the Northwest region, including our long-time partnership with the Bonneville Power Administration and our engagement with regional and state energy policy and technology organizations. 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 believe that helping 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 is particularly important to achieving U.S. environmental and economic goals. Over the last 2 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 PNL will play an increasingly active role. We believe that this outreach will be of increasing importance to DOE.

Industrial Competitiveness

As a derivative of the Department's core missions, the DOE Strategic Plan lays out a broad set of goals in the **Industrial Competitiveness business** area, including helping industry make the transition from waste management to pollution prevention, 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. PNL efforts are focused on the first three of these goals. 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 2 to 3 decades, Accordingly, our high-level objective over

the next 5 years is that PNL and its partners will develop technologies that measurably help modernize America's manufacturing and process industries, thus creating new highwage jobs and increasing U.S. export potential. In particular, PNL will make major contributions to the regional economy, and to the transition of the local economy to the post-Hanford era.

Based on our core competencies and our understanding of DOE strategic intent, we are focusing our partnerships for industrial competitiveness on the automotive, textile, chemical, building, oil and gas, analytical instrumentation, and primary materials industries. Through our contributions and operating practices, we intend to enhance DOE's reputation as a partner with industry. We also intend to exploit existing science and technology capabilities and investments to create new products and businesses in the health care and transportation industries. To enable productive and timely contributions, we are attempting to shorten "time to market" of new technologies by strengthening the linkage between basic science and application work. We are also striving to adopt best industrial practices by integrating our research and development efforts with systems integration, manufacturing, and marketing through industrial partnerships.

With regard to the Northwest region in general and the local economy, we believe that PNL has 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 Richland Operations Office, and must be met to ensure that completion of Hanford cleanup does not result in massive economic dislocation. Our intent is, first, to ensure that a growing and vital Pacific Northwest 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 spinoff from PNL, producing products based on PNL technology, or otherwise catalyzed by PNL actions. Finally, through an expanded portfolio of outreach programs, we intend to be a productive and increasingly soughtafter technology resource to local and regional small business.

National Security

PNL is making and will continue to make significant contributions to selected aspects of DOE's National Security mission. The rationale for our involvement is straightforward. PNL core technical capabilities and key technologies, developed through our fundamental research and our applied programs in support of other DOE missions, have direct application to critical nonproliferation and arms control challenges facing the Department. In addition, and of particular current interest. PNL 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.

The DOE Strategic Plan establishes five primary national security goals. Of these we significantly support two: nonproliferation and arms control, and the deployment of dual use technologies. 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 that PNL will 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 year 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.

Critical Success Factors

In addition to setting objectives in each of its missions or core business areas, the DOE Strategic Plan lays out a clear vision of how the Department will be managed. The 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 represent a commitment by DOE to be "best in class" in meeting the performance expectations of the public.

PNL has established three high-level objectives 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, over the next 5 years PNL is committed to building a tradition of interactive personal and institutional leadership, encompassing the entire staff of the Laboratory. 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.

The Department's Strategic Plan communicates a strong and unambiguous commitment to operating so as to ensure the health and safety of our work force and the public and with respect for the environment. We have set as our objective that PNL 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 have been moved to establish this commitment as one of our top level objectives by the recognition that, although our environment, safety, and health statistics are good as compared to industry standards, our operating practices may not yet fully conform to the standard of excellence expected by the Department and the public. Our strategy for

achieving this goal is to evolve as rapidly as possible to industrial environment, safety, and health standards and measures, with continued review of our operating practices for effectiveness and cost. While meeting this goal we will maintain or exceed our past performance on traditional measures of environment, safety, and health outcomes.

Third, we must meet the Department's and the public's expectation for costeffective 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 establish as our 5-year objective that PNL will be 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. As a first major step toward this goal, in 1995 we are initiating a major, multiyear productivity enhancement initiative, Achieving the Competitive Edge, or ACE. Under this program we will examine 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. Detailed and comprehensive information on the processes and resources used to deliver these products will be collected. We will determine the costs associated with these products and the benefit they provide and identify opportunities to enhance the performance of our research, administrative, and management processes. Over the period covered by this Institutional Plan we expect to achieve a significant increase in the fraction of total staff time devoted to research and development, accelerate the delivery of new technical products, dramatically decrease the cycle time associated with administrative and management functions, and ensure effective stewardship of the Laboratory's people, facilities, and programs.

Because of the fierce cost pressures to which we are all responding, we must place particular emphasis on the stewardship aspect of this objective. Apparent increases in productivity obtained by reducing cost through failure to reinvest in existing or failure to develop new capabilities are counterproductive. Efficiency improvements in needed activities and elimination of unnecessary or lowvalue activities will provide the needed productivity increase. However, in making these improvements we must take great care not to compromise PNL's 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 may be the 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 PNL and between PNL and our customers, partners, and the general 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 both accountable for, and entitled to, this foundation.

Fundamental Strategies

In this section we present a set of strategies—how we will achieve our objectives—that we believe respond to the trends presented above.

It is our responsibility to deliver recognizably high-value science and technology to the nation, at reasonable cost, while maintaining the technical capabilities of the Laboratory against future needs. We thus ask ourselves, given our set of planning assumptions, what strategy will ensure that we

provide high value to the nation and DOE, in both the short and long term? How, in this planning context, can we meet the twin challenges of relevance and productivity?

We believe that there are five broad, closely linked and enduring strategies critical to our future.

- We will demonstrate our value to the nation and DOE by focusing our attention on, and delivering highvalue solutions to, the most complex and highest priority problems and technical challenges. Because the Laboratory has been project funded (as opposed to base funded) since its inception, we have developed a strong entrepreneurial culture that allows us to rapidly apply laboratory capabilities to new problems. Over the last few years we have attempted to more tightly focus the Laboratory's programs around those elements of DOE's missions that best match our core competencies. We intend to continue that process, and to set and achieve highlevel objectives that are of real value in meeting DOE's and the nation's most pressing challenges.
- We will build and maintain an outstanding fundamental science capability, directly and effectively linked to the nation's highest priority technology needs and most urgent policy issues. Roughly 10 years ago, as PNL made the transition to being an Energy Research laboratory, we made the commitment to establish a fundamental science capability fully on a par with our traditional engineering and applied science strengths. Through Laboratory Directed Research and Development and programmatic investments we have developed leading-edge fundamental science programs and capabilities in selected areas of the molecular, environmental, and life sciences, that we believe are particularly relevant to the Department's environmental, energy, and industrial missions. We will continue this investment, with heightened emphasis on the direct linkage of our basic science capability to DOE's missions and

- national needs, with emphasis on DOE's Environmental Quality mission.
- 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's technical capabilities around a set of three integrating or core competencies. which we have labeled Integrated Environmental Research, Process Science and Engineering, and Energy Systems Development. We continually review both the health of these competencies 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 universities, industry, and federal laboratories. The breadth and complexity of DOE's missions make it unlikely that any single institution, including PNL, 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, 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. Over the next several years we will continue to make partnership a way of life at PNL.
- 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 embarked on a thorough, in-depth review of our research, management, and administrative and operation practices, and, in cooperation with the Department, expect to achieve dramatic operational improvements over the next several years.

These fundamental strategies are not new; we have been pursuing all five to some extent for several years. They are reflected in the broad partnerships that are executing the major programs that we have developed in the last few years, in our selection of focus areas for our basic science programs and investments, in our explicit consideration of the health of our core competencies in our management practices, and in the progress we have made in reducing overhead rates and in providing administrative process enhancements that increase the productivity of our research staff. We believe, however, that they remain not only valid but essential to our ongoing and continuous effort to build a great national laboratory.

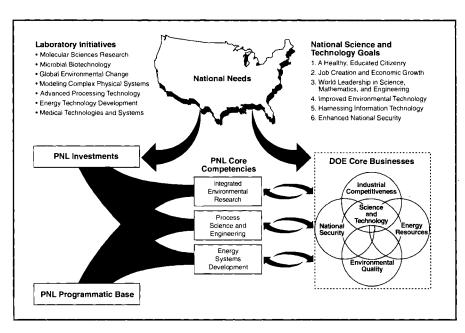
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Laboratory Initiatives

Initiatives open new research and development opportunities to enhance the Pacific Northwest Laboratory's scientific and technical capabilities to support the U.S. Department of Energy in achieving the goals established for its core businesses. As illustrated in the figure, PNL is proposing seven multidisciplinary science and technology initiatives for DOE's consideration. (a) The investment in these initiatives will build new capabilities that, coupled with the capabilities that have evolved from PNL's programmatic base, will enhance the Laboratory's core competencies in order to increase its contribution to the achievement of selected goals established in DOE's core businesses. These initiatives, built on past accomplishment and accumulated skill, indicate where PNL is focusing for the future.

PNL also proposes a number of programmatic initiatives that are described in the scientific and technical programs information under the Core Business Areas section of the Institutional Plan. These include

- Basic Life Sciences/Enzymatic Processing (Science and Technology—Energy Research)
- Integrated Environmental Monitoring (Environmental Quality— Environmental Management)
- Solid Waste Research and Development (Environmental Quality— Environmental Management)
- Health Protection and Standards for Hazardous Chemicals (Environmental Quality—Environmental Management)



Initiatives focused on enhancing PNL's capabilities to support DOE core businesses in contributing to national science and technology goals.

 Technology Research Partnerships (Industrial Competitiveness— Multiple Program Offices).

Molecular Sciences Research

The Pacific Northwest Laboratory proposed the Molecular Sciences Research Initiative in 1986. The objective of the initiative is to advance the molecular sciences and to apply the knowledge gained from these advancements to DOE businesses, especially DOE's environmental quality business. This initiative is the basis for development of the research programs that will be conducted in the Environmental Molecular Sciences Laboratory (EMSL), which is currently under construction at PNL. The Molecular Sciences Research Initiative is a key component of PNL's commitment to strengthen its involvement in fundamental research directed toward DOE's science and technology goals.

Through the Molecular Sciences Research Initiative, we are striving to develop a fundamental understanding of molecular structure, interactions, and dynamics in the complex molecular systems that are important to DOE businesses. A major focus of this research is to help create links between molecular-level understanding of condensed-phase and interfacial chemical interactions and reactions and new solutions to environmental problems at DOE sites, such as contaminated soils and groundwater and the complex waste stored in tanks at Hanford, Major components of the Initiative (e.g., Materials and Interfaces, Environmental Dynamics and Simulation, and Advanced Processing) are specifically directed at linking molecular-level science to field-scale problems. These research activities will provide the fundamental scientific knowledge needed to develop permanent, cost-effective solutions

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

to the nation's environmental problems as well as to develop environmentally acceptable energy options for the future. Research programs are also being developed to address key national initiatives such as High-Performance Computing, Biotechnology, Materials Synthesis and Processing, and Global Change.

Collaborative research involving scientists from other DOE laboratories, universities, and industry are key ingredients in this 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 are partially included in the Resource Projections.

Following are descriptions of the major research programs that are part of PNL's Molecular Sciences Research Initiative.

Chemical Structure and Dynamics

Chemical Structure and Dynamics responds to the need for a fundamental, molecular-level understanding of chemistry at a wide variety of environmentally important interfaces. The research is built around the established relationship between structure, thermodynamics, and kinetics, and involves rigorous studies of fundamental molecular processes in model systems (e.g., well-characterized surfaces, single-component solutions, clusters, and biological molecules), and studies of complex systems found in the environment (e.g., multispecies, multiphase solutions; solid/liquid, liquid/liquid, and gas/surface interfaces; colloidal dispersions; ultrafine aerosols; and functioning biological systems).

Experimental studies of molecular and supramolecular structures and thermodynamics are key to understanding the nature of matter and lead to direct comparison with computational results. Kinetic and mechanistic measurements, combined with real-time dynamics measurements of atomic and molecular motions, provide for a molecular-level description of chemical reactions. The anticipated

results of this work are the achievement of a quantitative understanding of chemical processes at complex interfaces, the 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.

Structural and kinetic studies at model oxide surfaces examine phenomena occurring on metal oxide surfaces to elucidate mechanisms of the complex interfacial chemistry of the subsurface environment. The research is focusing on the development of model systems whose study will enable direct comparison with theory and provide insight into the structures and kinetics of molecules interacting with environmentally important surfaces. Initial work focuses on the interaction of halogenated hydrocarbons with magnesium oxide, silica, and alumina surfaces and applying structural and kinetic data to structure-function relationships. Thin oxide films are grown on single-crystal substrates by molecular-beam epitaxy and/or chemical vapor deposition. Their morphologies (growth modes and structures) are determined by scanning probe microscopies, and interactions of chemical species with these surfaces are studied using variableenergy molecular beam scattering techniques.

Bonding and structure of organic ligands at oxide/water interfaces investigates mechanisms of sorption of organic ligands on mineral surfaces in aqueous environments using sensitive spectroscopic methods and ice models of water chemistry. This research will provide a basis for expanded PNL research on geologically important mineral surfaces and environmentally significant ligand/ complexant interactions. Initial work has concentrated on complexes of organic acids with solid alumina, and extensions to other solid phases common in soils, using fluorescence, infrared, and Raman spectroscopy and near-field optical microscopy to determine the structure and bonding of ligands at surfaces. Such work allows

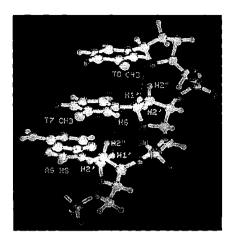
us to develop general principles of organic binding and adsorption/ desorption kinetics, and is expected to provide the basis for funded basic research on the chemistry of aqueousmineral interfaces.

Mechanisms of radiolytic decomposition of complex nuclear waste forms examine the complex mechanisms of radiation (g-ray, x-ray, and electron)induced degradation of glasses and ceramics that are used in the long-term storage of high-level nuclear wastes. The emphasis is on understanding the underlying physical and chemical mechanisms responsible for the loss of integrity of the composite matrix materials. Material removal, surface pitting, and bubble formation are analyzed using atomic-force surface microscopy in conjunction with laser ablation. The production of charge carriers and bulk and surface defects is probed using electron-stimulated desorption and transient conductivity measurements. Radiation-induced chemical effects, such as those due to transmutation of embedded radionuclides, are being studied using appropriately doped glass samples.

Theory, Modeling, and Simulation

Theory, Modeling, and Simulation focuses on combining the elements of theoretical and computational chemistry, materials science, and molecular biology with advanced computing technologies to help provide comprehensive solutions for the environmental, energy, and other missions of the DOE. Research programs have been established in the areas of molecular theory and modeling, solid-state theory and modeling, and biomolecular modeling and simulation. The research effort in molecular theory and modeling is well established (see description under Basic Energy Sciences/ Chemical Sciences). Investments are currently being made to further develop the other two research areas.

One focus of the research in solid-state theory and modeling is on understanding how the molecular properties of clay minerals directly affect mineral-solution equilibria and the



Determination of DNA molecular structure by nuclear magnetic resonance spectroscopy.

transport of contaminants through the subsurface. Current programmatic research is focused on the physics and chemistry of these materials and on the interaction of these materials with selected chemicals. The research initiative in this area includes a project to understand and predict the solidsolution chemistry of oxides, silicates, and carbonates that are important in the environment using first-principles calculations. This study is focused on calculations of the equations of state of oxides, silicates, and carbonate components. A second focus of the research is on understanding how molecular properties of zeolites, metal oxides, and pyrophosphates influence catalytic chemistry. Current programmatic research is focused on the catalytic chemistry of zeolites and pyrophosphates. Investments are being made to understand the influence of surface geometry and electronic structure on the reactivity/selectivity of heterogeneous chemical catalysts. This theoretical study is focused on metal oxides that are being studied experimentally.

Research in biomolecular modeling and simulation empasized the structure and chemical function of complex biomolecules. Investments are being made to extend the research effort in this area to study the dynamics and design of protein-DNA complexes. The primary objective is

to understand the molecular damage to DNA resulting from exposure to chemicals and the mechanisms by which enzymes recognize and repair damaged DNA.

To provide the molecular modeling software required to meet the computing demands of the research programs, Theory, Modeling, and Simulation contains a research and development effort in molecular science software. This effort is focused on the development of software systems that take advantage of emerging computer technologies and advanced computer architectures for modeling the complex molecular systems found in the environment. This includes exploring innovative approaches to describing electron correlation in molecular systems, such as the numerical solution of the Schroëdinger equation.

Materials and Interfaces

Chemical and physical processes that take place in the boundary regions between solids and liquids, two immiscible liquids, gases and solids, and gases and liquids play key roles in solving environmental restoration and 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 are also essential for rational design of chemical sensors that are needed in any environmentally related activities. Sensor research thus logically falls into the area of physical chemistry of complex systems.

Surface chemical bonding differs significantly from bulk material bonding. A current effort measures surface chemical bonding in environmentally relevant materials to understand how this bonding influences the character and rates of surface reactions that involve water and adsorbates of various types (e.g., organics and metal

ion complexes). Research has begun with the simplest, most well-defined, environmentally relevant crystallographic structures (mineral carbonates, metal oxides) where molecular theory and spectroscopy are immediately applicable. Research will then progress to materials with more complex structures, such as iron and titanium oxides with substitutional impurities. Radio-catalysis on titanium dioxide has emerged as a nucleus of much broader interphasial research activity. We are collaborating with other researchers in U.S. industry and universities to advance this concept.

Epitaxial materials synthesis will address problems related to molecular-level understanding of failure mechanisms in protective ceramic coatings. Model metal/ceramic interfaces will be prepared by molecular beam epitaxy and chemical vapor deposition. These systems will be investigated in great detail using both optical and charged-particle probes to understand the details of interface bonding and adhesion and the role in thermoelastic and environmental stress in initiating failure.

Chemical sensor research focuses on development of advanced sensing layers for the design of higher order chemical array systems. When supplemented with chemometrics, such systems are capable of operating with superior performance in demanding environments. Systematic development of new selective polymer layers is based on study of fundamental interactions between polymers and organic vapors. Flow injection analysis has proved to be an efficient approach to analysis of real radioactive samples, specifically, strontium-90 in tank waste.

Macromolecular Structure and Dynamics

The purpose of Macromolecular Structure and Dynamics is to establish a research center that uses leading edge spectroscopic methods to address important contemporary issues in biological and environmental sciences. The long-range research goals of the program focus on health and environmental issues of interest to DOE with a strong emphasis on assessing health risks from environmental pollutants and understanding pathways by which human exposure to these pollutants occurs.

One of the grand challenges of molecular biology is to determine the relationship(s) between structure and dynamics and molecular function (i.e., structural biology). The basic research objective of our structural biology research is to determine the structure and dynamics of native and altered biomolecules that are important for human health. These projects emphasize biological macromolecules, proteins, and nucleic acids involved in regulation and control at the cellular, tissue, or organism level that are not amenable to normal x-ray structure methods or use other spectroscopic techniques which complement those methods. We are concerned with enzymes that produce chemical messengers or that recognize and repair altered molecules. We are interested in how cells recognize and respond to exposure to toxic chemicals and/or radiation. In particular, the interrelationship between the cellular response and the chemical changes introduced in the proteins and nucleic acid will be established. This work relies on state-of-the-art magnetic resonance and mass spectroscopic techniques to study small amounts of natural and modified biomolecules prepared in the laboratory or isolated from biological systems.

Chemistry in the environment is basically chemistry at interfaces. Therefore, an objective of interfacial chemistry research is to determine structural details (selected bond distances, angles, and spatial distributions), and dynamics (rotational and inferences concerning translational diffusion) of small molecules adsorbed to oxide surfaces, metals on supported surfaces, and clays. For clays, we are particularly interested in the mobility of cations within interstitial layers of the clay, possible exchange processes between the interstitial ions and lattice (structural) sites, and how these

dynamics are altered in the presence of pillaring agents and the degree of hydration. Likewise, we are concerned with the structure and dynamics of the surface (e.g., proton motion on aluminas and/or within proton rich domains associated with zeolites) and the mobility of Lewis acid sites on alumina surfaces.

Understanding the interaction between neutral molecules and "isolated" charged particles is an important element of macromolecular structure and dynamics. The principal tool for this research is high resolution Fourier transform ion cyclotron resonance mass spectrometry (FT-ICRMS) coupled with laser-induced thermal desorption techniques. This approach opens the possibility of conducting novel and powerful chemical studies in conjunction with kinetic measurements at "isolated" interfaces. Techniques are currently being developed to trap a single charged particle and to very precisely measure the interactions of this single particle with small molecular species. Thus, the basis exists for the study of particlemolecule interactions, cooperative interactions of a co-adsorbed species, equilibria, and a host of related phenomena at the single molecule limit.

Nuclear magnetic resonance methods can play an important role in waste characterization and risk assessment associated with the environmental cleanup efforts at Hanford and other DOE sites. We are exploring the application of nuclear magnetic resonance techniques to characterize the waste in tanks. Techniques include: 1) ex situ tank waste characterization, analyzing samples from core samples (i.e., the amounts of free moisture, bound moisture, soluble and insoluble organics, metals, nitrites, and nitrates will be determined); 2) in situ tank waste characterization, using special equipment that will be lowered into a hole in the waste to monitor the free moisture concentration; and 3) process control, where nuclear magnetic resonance methods will be used to monitor, regulate, and optimize the processing of the tank waste during cleanup operations. The time differential between ex situ work and in situ

work depends on the outcome of the ex situ experiments.

Characterizing the materials in the waste tanks is the first step in any risk assessment program associated with cleanup. The knowledge acquired in the characterization research will be incorporated in ongoing risk assessment programs.

Instrument development is an essential component of the macromolecular structure and dynamics program. Several developmental projects are under way, including the construction of a 1 gigahertz nuclear magnetic resonance spectrometer and selection of pulsed and continuous wave electron paramagnetic resonance spectrometers ranging in frequency from 2 to 220 gigahertz.

Within the realm of nuclear magnetic resonance spectroscopy, the development of the 23.5 tesla magnet for the 1 gigahertz nuclear magnetic resonance spectrometer presents some significant opportunities for advancing the state of the art in experimental nuclear magnetic resonance spectroscopy. However, to make efficient use of the sensitivity and resolution that such a spectrometer will afford, novel probes (both for liquids and solids) will have to be designed and fabricated. Modern biochemical and solid-state nuclear magnetic resonance probes require the use of double and triply tuned probes, all with variable temperature capabilities. Additional development work is planned around the need for in situ analysis of solid catalysts. Such endeavors require special solid-state cross polarization/magic-angle spinning (CP/MAS) nuclear magnetic resonance probes.

The need to study environmentally relevant samples and materials drives the development of electron paramagnetic resonance instrumentation that will be housed in the EMSL. The operating fields and frequencies are chosen to suit the sample rather than choosing the sample to suit the spectrometer. Consequently, we are developing pulsed and continuous wave electron paramagnetic resonance



Development of the 1 gigahertz nuclear magnetic resonance instrument is a major goal of the nuclear magnetic resonance program at PNL.

spectrometers at different frequencies to study different problems.

The study of toxic very heavy metal ions and radionuclides involves paramagnetic species with very small g-factors or large fine structure splittings. In order to even observe the electron paramagnetic resonance spectra, it is necessary to use low-frequency electron paramagnetic resonance spectrometers for species with very small g-factors and high-frequency spectrometers for species with large fine structure splittings. We are developing a low-frequency 2-gigahertz pulsed and continuous wave electron paramagnetic resonance spectrometer and a high-frequency 220-gigahertz pulsed spectrometer for structural determinations on toxic metals and radionuclides bound to surfaces, proteins, and soil components.

Sensitivity and resolution improvement within the field of mass spectrometry is essential in order to address many of the significant environmental problems. Each order of magnitude improvement in the resolution and sensitivity brings about a quantum advance in the problems that can be solved by mass spectrometry. Our goal is to address important problems that cannot be investigated by today's analytical methods. Therefore, instrumentation and techniques are being developed for the ultrasensitive characterization of extremely small sample sizes with an emphasis on biopolymers. Capillary liquid chromatography (CLC) and capillary electrophoresis (CE) methods are being developed to provide a basis for very high resolution separation of complex chemical, biological, and environmentally relevant mixtures. These methods allow manipulation and sampling of nanoliter to femtoliter volumes, in conjunction with extremely high resolution separations (i.e., millions of theoretical plates). We currently emphasize separations involving bio-polymers (e.g., proteins, oligonucleotides, etc.) relevant to health effects research.

Advanced ultrahigh resolution and ultrasensitive mass spectrometric instruments are being developed, with an emphasis on application to large molecule systems (e.g., biopolymers). New instruments are being developed based on the principles of FT-ICRMS, and currently very high mass spectrometric resolution (>106) and sensitivity (< 1 femtomole detection limits) can be obtained in the characterization of smaller proteins. The underlying

concepts and methods are being developed for obtaining detailed structural information (i.e., biopolymer sequence, sites of modification or adduction, etc.) from extremely small sample sizes. Research includes the development of techniques for extended ion trapping times and step-wise ionmolecule chemistry or other ion manipulation methods to probe ion structure with as few as a single molecule trapped in the FTICR cell. The development of these vastly improved analytical methods also depends upon other research activities related to gaining a detailed understanding of ion motion and interactions in ion traps and the dependence upon the details of the trap design. Another area of study involves the chemistry from which detailed structural information for large molecules can be derived. New methods based upon ion-molecule reactions, laser photodissociation, and dissociation processes induced by collisions will be developed for structural characterization of large molecules.

Computing and Information Sciences

Computing and Information Sciences is focused on developing pilot and prototype implementations of the next generation of scientific computing tools and infrastructure, research information products, and instrument designs and data systems for the EMSL. Efforts are aimed at demonstrating the feasibility of new approaches, technologies, and concepts.

Collaborations are critical to advancement in all scientific fields. A cornerstone of the computing and information sciences research is to take advantage of emerging networking and computer technologies to enhance collaborations. Initial efforts are focused on 1) development of tools and expertise needed to enable and implement computer-facilitated remote collaborations; 2) identification of social, systemic, and technological issues that must be addressed to support the dynamics of scientific

collaborations; and 3) implementation and evaluation of prototype collaborative environments for nuclear magnetic resonance and chemical physics.

New programs are also being developed in several advanced scientific software areas. Research in rapid response sensing applications employs neural network technology to recognize patterns among complex sets of data inputs. Another effort is extending the capabilities of molecular visualization via graphics tools for high-performance parallel computers. Graphics capabilities also provide a foundation for molecular sciences research. Computer modeling of instrument performance also provides significant insights in the optimization of instrument designs. Modeling of next generation FT-ICRMS instruments is contributing to designs capable of making measurements an order of magnitude more precisely than previous instruments.

Environmental Dynamics and Simulation

Environmental Dynamics and Simulation emphasizes developing molecular-scale information on the structure and reactivity of aqueous and gaseous complexes on solid surfaces and in complex fluids, and 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 relates molecular interactions in homogeneous and heterogeneous phases and at interfaces to their phenomenological expression in the environment and brings to bear the capabilities of environmental spectroscopy and advanced computational modeling on the chemical phenomena that affect contaminant fate and transport in various media. The knowledge of the nature of molecular mechanisms resulting from this approach provides information to adjust and expand existing approaches to modeling electrostatic interactions at aqueousmineral interfaces and to improve chemical modeling associated with atmospheric dynamics.

Environmental dynamics and simulation research contributes to DOE's environmental mission by elucidating the individual contributions of molecular species of varying structure and energetics to volume-averaged chemical behavior observed in benchscale experiments of chemical fate and transport in natural systems. Improved models of microscopicscale processes based on the molecular perspective are relevant to a number of research and development programs that address scaling from microscopic to macroscopic dimensions. The majority of the research activities are focused on reactivity of the aqueousmineral interface, with smaller efforts in complex fluids and solutions, bioremediation and enzymatic reactions, advanced characterization, and atmospheric chemistry.

Research is under way to study the interactions between organic ligands and metals. Naturally occurring organic ligands play an important role in soil-pore water equilibria. These ligands influence the weathering of soils and the mobility of metals. The stability of a limited number of metal chelate complexes has been determined experimentally, and semiempirical schemes have been developed to predict the stabilities of certain classes of complexes. These studies have suggested that the steric strain accompanying complexation is an important factor in determining complex stability. The work is aimed at developing a quantitative understanding of the relationship between structure and reactivity of organic ligand/metal complexes. This work is currently being extended to include organic ligands that have potential to selectively extract radionuclides from waste streams.

New capabilities are being developed in both quantum mechanical and molecular dynamics methods to study the molecular interactions that determine surface and bulk properties of important subsurface materials. Amorphous and crystalline ferric oxides and oxide-hydroxides that form ubiquitous mineral coatings in natural environments strongly bind many different metal ions, oxy-anions, and organic

chelates. By using quantum mechanical methods to determine the structures and relative stabilities of different ferric oxide and oxyhydroxide surfaces with no solvent present and examining reactivity of sites to proton adsorption, molecular dynamics methods can then be used to provide solvation corrections to the relative surface energies and relative proton affinities. Such research supports improvement of thermodynamic models of proton adsorption as a result of the enhanced understanding of surface structures, site types, and proton binding energies, and will be extended to more complex systems identified through ongoing characterization of surface interactions in natural environments.

Likewise, the increased importance of diffusion as a transport mechanism for contaminants requires a detailed understanding of diffusive crosscoupling, which results from a flux induced in one component due to a concentration gradient in another component. In many systems, cross coupling is strong enough to induce contaminants to migrate up their concentration gradients. Because crosscoupling coefficients are very difficult to measure in multicomponent systems, one approach is to calculate these coefficients from molecular dynamics simulations and then validate the method against experimental data. Current efforts in this area are focused on calculating binary and ternary diffusion coefficients in alkali chloride solutions.

Another important aspect of environmental dynamics and simulation is the development of expertise in the application of synchrotron radiation to geochemical problems. Synchrotron sources offer very intense, highly collimated, tunable, and essentially monochromatic radiation in the x-ray. ultraviolet, and infrared spectral regions. Our researchers have performed preliminary x-ray absorption spectroscopy (XAS) studies of lead and nickel compounds at the National Synchrotron Light Source at Brookhaven National Laboratory. This research attempts to distinguish among the oxide, hydroxide, carbonate, and hydroxy-carbonate forms of

these elements to help establish which of the forms were responsible for controlling aqueous concentrations in groundwater. Other x-ray absorption spectroscopy research involves measurements of the structural environments of neodymium (an analog of americium) in carbonates, chromium in contaminated soils, and iron at different redox states in clay minerals. PNL staff are also continuing their participation in the Pacific-Northwest Consortium beam-line proposal for the advanced Photon Source at Argonne National Laboratory.

Advanced Processing

Advanced processing is designed to link the molecular science research being performed in the EMSL to the real problems of waste cleanup by providing a pathway for developing scientific ideas and concepts into processes that address DOE's needs, particularly at Hanford.

Advanced processing covers efforts under the Advanced Processing Technology Initiative, Tank Waste Remediation System (TWRS) Advanced Technology Development Program, and the TWRS Tank Waste Treatment Science Program. This effort is to accelerate the technology development cycle by creating interdisciplinary "technology fusion" teams that will deliver timely solutions to problems of national significance.

The nation is faced with the immense task of treating and managing highly toxic byproducts and wastes that have resulted from past commercial and defense-related nuclear material production activities. These byproducts and wastes include complex mixtures of organic and inorganic chemicals and, in some cases, radioactive materials. Carcinogenic chlorinated hydrocarbons are one of the most significant contaminants in soils and groundwater surrounding DOE and U.S. Department of Defense (DOD) facilities. For example, during past operations at the DOE's Hanford Site, an estimated 1000 metric tons of carbon tetrachloride mixed with significant amounts of radioactive materials (plutonium, strontium, technetium,

and other transuranic elements) were disposed of in ways that resulted in widespread contamination of the dry soil zone and a plume of contaminated groundwater that extends over about 12 square kilometers. The current lack of established de minimus standards for such mixed wastes requires that these contaminants be completely isolated and/or destroyed.

Incineration, one of the most commonly proposed methods of handling hazardous waste, can create significant secondary environmental problems. Properly designed, heterogeneous catalytic oxidation or incineration processes combined with catalysis can eliminate such problems.

The development of these new technologies, in turn, requires a sophisticated process science program with the ability to design and test new catalytic materials and facilitate their full implementation into waste processing systems. As the wastes to be dealt with are identified and characterized, catalysts that are compatible with both the waste and the chosen treatment process stream must be identified.

To accomplish this level of compatibility, new catalysts must be created by rational design rather than the currently used trial-and-error process, which is very time intensive. Rational design of an effective catalyst requires research that leads to an understanding of the catalytic reaction mechanism(s) and the design and synthesis of complex, composite materials. This research includes the disciplines of surface and materials chemistry and molecular and materials modeling.

There are major technical uncertainties associated with the current baseline for the remediation of Hanford's 177 waste tanks. These uncertainties are due to the complete heterogeneity of the waste, both between different tanks, and within a single tank. The waste exists in a highly alkaline (pH>12) environment as liquid supernate, slurry, solid salt cake, and sludge, and little is known about the chemical speciation and phases present in the tanks. It is one of the most challenging problems in chemical processing

that has ever existed, and it demands the development of advanced processes for

- separations to remove the relatively small amounts of radionuclides from the bulk of the chemical waste (mostly sodium salts)
- conversions to remove those constituents that interfere with the vitrification of the low-level and high-level waste and remove hazardous processing off-gases from the environment
- retrieval of the waste from storage tanks and transport to the processing plants
- design of chemical and physical sensors to provide in situ, real-time information on the waste stream for process control.

It is also necessary to design materials that can operate in several chemical and radiolytic environments. This must be done in a rational way, based on a solid, scientific understanding of the fundamental chemistry and physics that underlies these processes.

Microbial Biotechnology

The overall goal of the Microbial Biotechnology Initiative is to build a comprehensive capability that significantly contributes to DOE's core businesses. This initiative is initially focused on fundamental investigation of microbial systems linked with microbial applications through directed research. Strategic investments in new staff and selected scientific and engineering capability 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.

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 issues. 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.

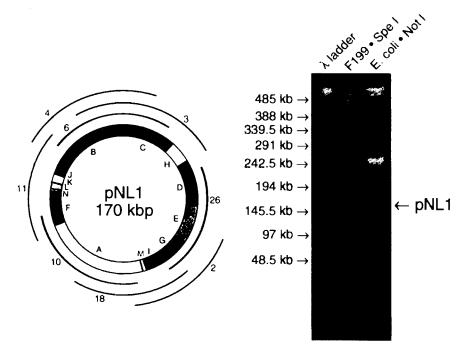
Current DOE biotechnology and biomolecular science programs use the Laboratory's capabilities and facilities in the life sciences (cellular and molecular biology, structural biology, marine pathogenicity), materials and chemical sciences (biomimetics, biomass conversion), earth and environmental sciences (subsurface science, global climate change), and waste technology (bioremediation and pollution prevention). Through the DOE Office of Health and Environmental Research (OHER) Subsurface Science Program, the Laboratory has developed major strengths in multidisciplinary research approaches needed to scale fundamental knowledge to the field and to understand the factors controlling the presence, function, and origins of microorganisms in previously unexplored habitats. This knowledge is critical for resolution of practical DOE waste contamination problems in the field. Through the Environmental Science Research Center (ESRC) at PNL, a part of the Subsurface Science Program, novel uses of microorganisms from the deep subsurface have been identified and potential applications are being explored with other DOE components. For example, knowledge of coupled chemical-microbial processes is being exploited by the DOE Office of Environmental Management to demonstrate manipulation of oxygen levels in the subsurface for in situ remediation. Also, a Cooperative Research and Development Agreement (CRADA) has been established with the pharmaceutical industry to examine deep subsurface microorganisms for their potential as producers of novel bioactive compounds of value in human health.

The Laboratory is focusing initially on 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, economic, and social issues). Basic research in the life sciences (DOE-OHER and DOE Office of Basic Energy Sciences [BES]) is linked with applications (DOE-EM, Office of Energy Efficiency and Renewable Energy [EE], Office of Fossil Energy [FE]) through close coordination between scientists and engineers at the project planning stage and integration with other Laboratory initiatives. In the long term, combining capabilities with those under the Molecular Sciences Research Initiative will position the Laboratory to expand its biotechnology base to include material sciences, biomedical engineering, and human health.

Fundamental research addresses the following issues:

 Isolating and characterizating microorganisms from unexplored and extreme environments to determine their roles in natural 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, 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. PNL investments have recently resulted in derivation of a physical map for a 170 kilobases 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.
- Elucidating the structure and function of important industrial 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. Using purified enzyme from an E. coli gene expression system, nuclear magnetic resonance spectroscopy is being used to determine the structure of tetrachloro p-hydro quinone reductive dehalogenase from a bacterium capable of degrading chlorinated compounds. Molecular modeling tools are being employed to better understand relationships between the structure of thermophilic enzymes (e.g., bacterial subtilisins) and their catalytic activity at high temperature and in nonaqueous solvents.
- Developing interactive, graphically oriented computational tools to link morphological, physiological, and genetic databases to improve the identification and characterization of environmentally and industrially important microorganisms.
- Identifying phylogenetic and functional molecular probes. This will contribute to a more accurate understanding of biological and ecosystem processes and their response to chemical and radiological effects, leading to better ecological and human health risk assessment and risk management tools and methods.
- Identifying and assessing key social and economic issues, including comparative impacts of competing



Sphingomonas, a bacterium isolated from the deep subsurface and capable of degrading a wide range of aromatic compounds has been targeted for initial studies.

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

- 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 costeffective 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 dehalo-

- genation. Initial focus is on uranium bioprecipitation and carbon tetrachloride 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. PNL has recently isolated the first dehalogenase from a bacterium capable of using dehalogenation to derive energy for growth. A process based on this metabolism for degradation of carbon tetrachloride is under way (above).
- Rational protein engineering and automated systems to improve industrial enzyme technology, and identification and selection of novel biocatalysts from nature to enhance efficiency of chemical manufac-

- turing processes. High throughput analyses for novel industrial enzymes combine expertise in automation science, robotics, biomolecular assays, and information systems.
- 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 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 PNL'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 partially included in the Resource Projections section. Programmatic support for this initiative is sought through DOE offices with basic and applied research businesses, including microbial origins, microbial genome, and human

genome programs in OHER; the DOE-EM focus areas, including contaminant plume containment and remediation and mixed waste characterization, treatment, and disposal; 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 PNL's Global Environmental Change (GEC) Initiative is to develop the understanding necessary to support critical national decisions within the context of global change. This goal is being achieved through a Global Studies Program at PNL that focuses on the improvement of scientific understanding of the processes and forces shaping the global environment and the integration of that knowledge on appropriate spatial and temporal scales to guide government policy and the development of technology.

Global change issues develop through interactions between the extremely complex natural biogeophysical system and the rapidly expanding activities of human civilization. In the 20th century the growth of civilization has progressed to the point that human systems have become major geophysical forces. It has become clear that the production and use of energy represents 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 change a central issue in energy policy.

PNL's initiative has four elements:
1) contribute to the base of scientific knowledge on environmental change processes; 2) provide a framework for evaluating technological responses to global change; 3) inform and support the development of policies related to global change; and 4) promote analyses which ensure that the understanding of science, technology, and policy are appropriately integrated with each other. The initiative is based on the

premise that a multidisciplinary laboratory is well positioned to meet these needs and uniquely positioned to effectively perform the vital integration function.

Building the Scientific Base

The PNL scientific research program is well integrated with the entire U.S. Global Change Research Program. This program is developed and 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. The program is a U.S. contribution to the International Geosphere Biosphere Program (IGBP). It is described in the report entitled Our Changing Planet: A U.S. Strategy for Global Change Research. The report describes the role the federal government will play in supporting IGBP research to understand both the continuing change in natural biochemical cycles and the disturbances in those cycles that may be caused by human activities.

As a major player in the national global change research program, DOE has developed programs that are an important part of this major international cooperative effort. Through its support for the Environmental Sciences Division of OHER, PNL has assisted DOE over the past year by active participation in leadership and research in the Atmospheric Radiation Measurement (ARM) and Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) programs. In addition, PNL is a significant contributor to the ocean research element of the Core Carbon Dioxide Research Program; to the understanding of the formation, removal, and climatic consequences of anthropogenic aerosols; and to the development of approaches to detecting impending climate change.

In support of the broad federal objective, as well as the specific DOE business area, PNL is focusing its internal investments on the following key areas: regional climate prediction, climate change and its effects on

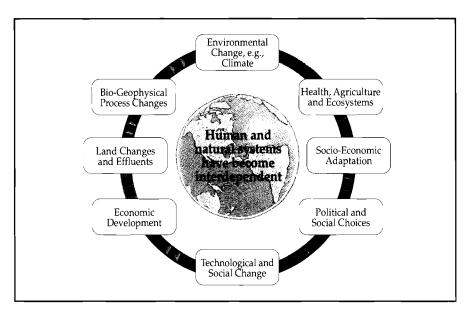
water resources, the effects of climate change on unmanaged ecosystems, and the effect of heterogeneous chemistry on the fate of energy-related pollutants in the atmosphere. Each of these efforts is highly integrated. The goal is to produce a set of linked models that provides a consistent intellectual framework for examining the coupled effects of regional climate change on water resources, unmanaged ecosystems, forests, and agriculture.

Understanding Technology and Global Change

Technology is an important component of the complex considerations involved in understanding global change. PNL 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).

The aim of the Global Studies Program is to integrate the understanding gained from science, technology, and human interactions research, which together define both the global environmental problems and reasonable responses. All of these elements produce understanding that is essential for analyzing the problem and defining effective responses. However, to be useful, the understanding must be integrated in the form of models that can represent the essential interactions within, and between, the various components. Thus, model building and integration serve to link the activities within the Global Studies Program and define the need for establishing supporting relationships with other scientists and institutions.

In addition to developing the secondgeneration emissions model, PNL is attempting to increase the level of understanding about the role of technology in both cause and mitigation of global change. New approaches are required to evaluate technologies



Global change issues develop through interactions between the extremely complex natural biogeophysical system and the rapidly expanding activities of human civilization.

based on environmental factors to prevent global 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. PNL has created and acquired a set of state-ofthe-art analysis tools related to global environmental issues. The Global Studies Program has used these tools to provide integrated policy support to the DOE Environmental Sciences Division (ESD); the Office of Policy: DOE-EE; and the National Energy Strategy development. These support activities include

 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
- analyzing the energy consequences of the Montreal Protocols on chlorofluorocarbons
- evaluating strategies for carbon dioxide emission mitigation.

In anticipation of supporting analysis of future policy concerns, PNL is developing improved economic evaluation tools and methods for evaluating the effect of climate change on human welfare. In particular, we are making 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 PNL's Global Environmental Change Initiative is driven by the need for integrated rather than piecemeal understanding of the global change issue. A particular emphasis in this area has been on promoting understanding on the international level 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 change. PNL activities have led to

- 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 PNL 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, 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.

Funding for PNL's involvement in the Global Environmental Change Initiative is sought from various DOE offices and other organizations as shown in the initiatives table at the end of this section. Most of the multiyear resource requirements are included in the Resource Projections.

Modeling of Complex Physical Systems

PNL's Modeling of Complex Physical Systems Initiative is bringing emerging supercomputing technologies to bear on solving scientific and engineering problems encountered in DOE core businesses. Computational modeling can guide, or even replace, costly experiments or, in some cases, allow investigation of important technical issues that are impossible to address in the laboratory. However, current generation supercomputers do not have the capability to carry out a variety of scientific, engineering, or environmental modeling studies at the necessary resolution or accuracy to achieve these benefits.

Massively parallel computers offer, in principle, the multiple orders-of-magnitude increases in computational capability necessary to attack these problems. However, effective use of these machines on all but very restricted classes of problems is difficult. Our initiative is bringing massively parallel computing to bear on specific computational problems faced in DOE-supported research programs.

By guiding or even replacing difficult and expensive experiments, computational modeling has revolutionized a number of industries important to the nation's economy; the "computational wind tunnel," now widely used in the aerospace industry, is only one of many examples. In essence, the Modeling of Complex Physical Systems Initiative is supporting comparable revolutions in scientific, engineering, and environmental areas important to the DOE. The initiative includes computational chemistry and materials science, environmental chemistry and transport, and engineering fluid mechanics. Extensions to dynamic modeling of the electric power system and climate research are intended.

In each of these technical areas we are following a strategy that includes the following elements:

- implementation of codes on advanced architecture machines as they become available, both for performance evaluation and proof-of-principle calculations
- development of detailed performance models for computational
 algorithms and selected complete
 codes that allow us both to predict performance on potential
 teraFLOPS machines and to help
 guide the development of future
 generation computational hardware and software for scientific
 and engineering applications
- design of numerical algorithms that capture the full benefits of massive parallelism
- investigation of selected forefront computational problems that are clearly beyond the capacity of current generation supercomputers

The initiative is marked by extensive collaboration with other government laboratories, with academic researchers, and with private industry.

The centerpiece of this initiative is the development of software technology required for modeling of molecular processes in the environment. Modeling these complex molecular processes requires highly aggressive use of computational technology. Problems that require computational capabilities beyond the current state of the art include

- modeling solvation and reaction in solution to obtain a detailed understanding of the binding of radionuclides to selected ligating agents
- modeling the interactions of ions and molecules with minerals to obtain a better understanding of the binding of contaminants to soil
- modeling the dynamics of biomolecules in solution in order to redesign enzymes for enhanced detoxification of pollutants.

The Molecular Science Computing Facility planned for the EMSL will provide the hardware and initial molecular science software necessary for this work. In 1994 advanced parallel computing and large-scale data management equipment were acquired to support hardware and software development for this facility.

In 1993 the Modeling of Complex Physical Systems Initiative addressed several forefront problems, including

- modeling the effects of spatial variability on subsurface flow in three dimensions. This requires the solution of equations with millions of computational nodes; current generation supercomputers are effectively limited to much smaller problems.
- modeling the transport and chemical fate of atmospheric contaminants on a global scale
- application of Direct Numerical Simulation techniques to the study of turbulent flow
- full-scale modeling of promising environmental technologies like in situ vitrification and advanced joule-heated furnaces (requiring computing resources far beyond those provided by current generation supercomputers)
- full-scale modeling of waste tank behavior and response to mitigation strategies, such as jet mixing so as to increase the likelihood of success and decrease the chance of catastrophic failures; modeling these time-critical problems



Massively parallel processing computer techniques have been developed to simulate flow and transport through finely detailed geologic structures.

requires the use of the most powerful supercomputers available.

In 1994 we have made significant accomplishments in each of these projects, notably: development of parallel software and completion of a direct numerical simulation study of cell formation and turbulence states in a double-pane window, involving 2.4 million degrees of freedom and 78,000 time steps; development of a massively parallel version of the PNL-Watershed code and use of this code to assess the impact of global warming on the Columbia River watershed; development of a massively parallel code for modeling subsurface flow and transport in aquifers with multiscale material heterogeneities and use of this code to study permeability scaling behavior in geologically complex groundwater systems; development of a parallelized version of the Global Chemistry Model (GChM)

and use of this code to analyze temporal and spatial distribution of global carbon monoxide compared with space shuttle data; development of a domain-decomposed version of the TEMPEST program (used for modeling of waste tank behavior and other fluid dynamics problems); and implementation and evaluation of a variety of parallel numerical methods for fluid dynamics.

Pacific Northwest Laboratory remains an active participant in the Concurrent Supercomputing Consortium. The Consortium, which includes several DOE laboratories, government research agencies, and major research universities, installed the Intel Delta Touchstone supercomputer at California Institute of Technology in May 1991. Significant upgrades in computing capability occurred in 1994. A number of molecular science software packages,

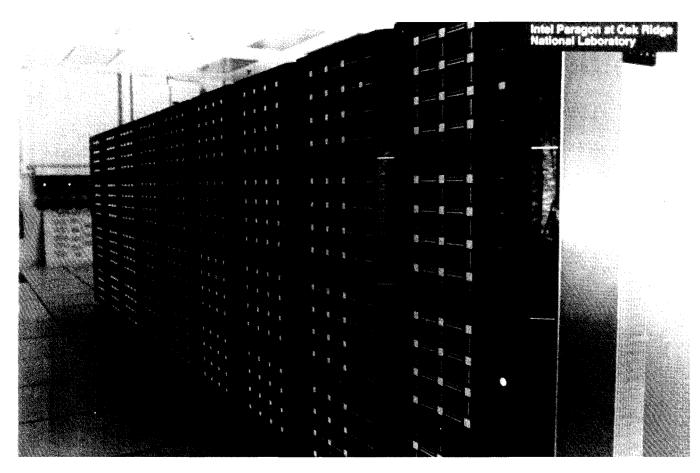
including both electronic structure and molecular dynamics programs, as well as coupled atmospheric chemistry and transport and direct numerical simulation turbulence codes have been implemented on the Intel Delta. The machine is now being used to solve problems beyond the practical limit of conventional supercomputers in both molecular science and atmospheric chemistry and transport.

Our continuing collaboration with Intel Supercomputer Division, supported by the Office of Energy Research Laboratory Technology Transfer Program, remains highly productive. It was recognized in FY 1994 with a Federal Laboratory Consortium award for Excellence in Technology Transfer as a result of Intel's commercialization of parallel computing software resulting from the collaboration.

The Modeling of Complex Physical Systems Initiative offers opportunities for both undergraduate and graduate students to participate in code development work on advanced architecture computers and incorporates postdoctoral fellows on its technical teams. We are seeking to expand the direct industrial participation in and support for this work to stimulate the application of advanced computer architectures to industrial problems.

Funding for specific elements of this initiative will be requested from DOE program offices directly concerned with the technical problems requiring high-performance computing. Baseline funding for development of high-performance computing techniques is sought from the Office of Scientific Computing. Multiyear resource requirements are given in the initiatives table at the end of this section and are not included in the Resource Projections. In FY 1995 we plan to continue efforts in

- Direct Numerical Simulation of Turbulence on a Message Passing
- Parallel TEMPEST
- Computational Modeling of Complex Physical Systems



Intel Corporation has incorporated new computer software from PNL into the Intel Paragon System, shown here at Oak Ridge National Laboratory. The PNL code greatly increases the speed and efficiency of supercomputing operations. PNL's collaboration with Intel resulted in a 1994 Federal Laboratory Consortium award for Excellence in Technology Transfer.

 Massively Parallel Processing Transport Modeling.

Advanced Processing Technology

Advanced processing technologies are required to solve a number of national problems. These include

- characterization, transport, separation, and isolation of radioactive and chemical wastes at DOE sites
- reduction of energy use and minimization of wastes generated by industrial processes
- enhancing U.S. economic competitiveness by providing a means for efficiently processing materials and chemicals vital to the U.S. industrial base.

To solve these problems, new processes and materials must be developed and deployed at an ever increasing rate. At the same time, in today's competitive global economy, energy, environmental consequences, and economic concerns must be concurrently addressed by any new production process. This added complexity requires a paradigm shift in the way process technologies are developed and deployed. Effective integration among basic science, applied research, and engineering development is the key. Fundamental understanding of molecular processes must be integrated with engineering design to rapidly create novel processes, various process elements must be integrated to develop the best final process system, and client needs must be

integrated into the development cycle to ensure that these needs are met.

The Advanced Processing Technology Initiative is

- focusing the Laboratory's process science and technology capability on addressing a problem of national significance
- developing and demonstrating a methodology to rapidly and efficiently develop and deploy technologies to address this problem
- collaborating with industry to identify their needs and build alliances
 that allow PNL and industry to
 work together to address the needs
 of both industry and DOE.

The further goal of the Advanced Processing Technology Initiative is to impove the way advanced processes are developed and deployed. 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.

To date, activities in each of the technology thrust areas are serving as test beds for our coupled technology development approach. For example, the deployment of PNL-developed coating technology funded under DOE-BES is being accelerated by teaming with process engineers to address scale-up issues for industrial application; basic scientists utilizing molecular modeling techniques are teamed with process engineers to understand the structure and enhance the performance of separations media developed at other national laboratories; and basic research to understand the electric field behavior and chemistry of low-temperature plasma technology is broadening and accelerating the use of this technology in existing and new applications.

An Advanced Processing laboratory will be incorporated into the EMSL to bring the science base of the EMSL to bear on process development problems (for further information on the Advanced Processing laboratory, see the description of Advanced Processing in the Molecular Sciences Research Initiative presented at the beginning of this section).

Other research capabilities will be in materials and chemical synthesis, separations, conversion technologies, and engineering development.

The current thrusts of the Advanced Processing Technology Initiative are focused in two areas, advanced processes and advanced materials as discussed below. In addition, industrial interaction is an ingrediant of the initiative.

Advanced Processes

Advanced processes includes efforts in separations, conversion, and fluid dynamics.

Separations Research efforts in the separations area are focused on the processing of aqueous waste streams. 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 American Textile Industry (AMTEX) and Refinery of the Future. The technologies investigated include ion exchange, membrane separations, electroseparations, and supercritical fluid extractions. Development of these technologies requires building on PNL strengths in

- · materials synthesis and processing
- · separation chemistry
- chemical science and processing
- fluid dynamics.

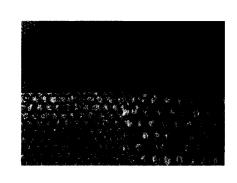
The fundamental research on exchanger design and synthesis for cesium separation was initiated concurrently with process chemistry and engineering to identify and evaluate existing ion exchange materials for radioacative tank waste processing. The materials identified for evaluation included a zeolite developed by PNL, a resorcinol-formaldehyde resin developed by Savannah River Technology Center, the silico-titanates developed by Sandia National Laboratories, and the ferrocyanides studied both at PNL and Oak Ridge National Laboratory. The results of this work have led to important insight into the structure/function relationships of ion exchange materials, allowing for the

future design and application of more efficient and robust separation media.

The membrane and electrochemical research has focused on developing technologies having broader environmental applications. Membrane capabilities are being developed for the separation and recovery of organic compounds such as textile dyes. The electrochemical efforts have been focused on electrokinetics. electrochemical-ion exchange, and electrodialysis. New selective electrodialysis membranes prepared in Russia have been evaluated and compared to conventional U.S.manufactured membranes. Both of these separation technologies have application to waste water treatment.

The supercritical fluid extraction research has focused on the basic investigation of metal chelates in compressible fluid solvents. Research efforts have centered on the development of extraction processes for textile dyes and the extraction of metals from aqueous solutions using ligandimpregnated supercritical carbon dioxide. Both of these efforts are predicated on the fundamental understanding of metal chelate 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. This technology has many applications in waste water treatment and environmental remediation.

Chemical Conversion Conversion, along with separation, is one of the primary steps required in any industrial process. The goal is to integrate PNL's fundamental and applied research, science, and engineering capabilities to develop new processes for chemical conversion. A key objective is to use fundamental knowledge of conversion mechanisms to





New synthesis routes are being evaluated to expand the type of ceramic mesoporous materials that can be made in an effort to broaden their range of applications as ion exchange media.

develop novel processes to reduce energy consumption and waste generation, leading to more efficient and competitive chemical manufacturing processes.

Fundamentally, conversion is the process by which chemical reactions change molecules into other molecules of higher value (or lower toxicity). In many cases, sufficient 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. The emphasis is on developing novel techniques to improve these processes by reducing the temperature, pressure, and residence time operating conditions. This includes two major elements: 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 has centered around highvacuum 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 PNL 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 offgas, unique designs for liquid treatment of organic contaminants which is being incorporated into a patent, and has led to programmatic funding and high industrial interest.

Reaction engineering is focused on developing innovative reactor designs for conversion. Incorporated within reactor design is the concurrent development and deployment of novel materials (e.g., catalysts, membranes) which will make these new reactors possible.

Initial research and development in this area has centered on inorganic membrane reactors. These reactors represent a novel approach to reactor design. Partial oxidation reactions are currently under investigation. Early experimental and theoretical investigations show great promise for obtaining higher product yields. Higher product selectivities are also a result of this design. Source pollution prevention is fostered because the reactor generates fewer byproducts.

New materials are concurrently under investigation. Solid-acid catalysts show promise for producing alkylate gasoline. Strong environmental considerations surround current production routes which require liquid-acid catalysts; these problems will be alleviated by the development of efficient solid-acid catalysts.

New membrane materials are also being investigated. As membranes with greater capabilities are developed, more efficient processes are possible. One area of research is studying high-temperature facilitated transport membranes that will exhibit permselective properties, which enable in situ product separation from reactants. This capability is critical for series and series-parallel reactions.

Fluid Dynamics Fluid Dynamics is intended to improve the ability to understand, predict, and measure the characteristic behavior of complex fluids encountered in advanced processes. These complex fluids include a

variety of solid/liquid mixtures, non-Newtonian fluids, and colloidal suspensions; fluids and mixtures that are often encountered in waste treatment and materials and chemical processing. Currently, the fundamental understanding of how these fluids behave during many processing operations is inadequate, leading to serious inefficiencies and difficulties in process scale-up. The initial focus is on performing experimental and theoretical investigations to improve our understanding of the role of solid particles on the flow structure (turbulence) of solid/liquid mixtures. The impact of rheological changes on the flow structure and behavior in process applications is also a focus of this effort.

Experimental data is being collected to test existing models and where necessary, to develop new models to describe the effects of solid particles and fluid rheology on momentum and energy exchange between the dispersed and continuous phases in multiphase flows. The results of these investigations will provide important data which can be used to validate the multiphase flow models incorporated in computational fluid dynamics (CFD) codes. Such computational fluid dynamics codes have proved to be extremely cost-effective in the design of key processing components in the chemical, oil and gas, and other process industries and are being extensively used by PNL in the design of safety, retrieval, and pretreatment approaches for Hanford waste tanks. The data and the new understanding generated from these efforts will permit extending the range of applicability to situations involving complex fluids and provide important data for code validation.

The new capabilities developed have had significant impact on Hanford's tank waste remediation program. Studies of non-Newtonian jet behavior have shown the impact of fluid rheology on the effectiveness of jet mixing, a critical technology for the mitigation of tank safety problems and for retrieval of tank wastes. Data obtained from the jet mixing studies were used to provide qualitative and quantitative

data for modeling efforts and was critical in driving the development of in situ methods for waste characterization. Investments made in advanced instrumentation technologies (real-time ultrasonic imaging) have begun to produce results for nonintrusive monitoring of particle-laden flows, potentially allowing, for the first time, monitoring of the flow patterns, velocity, and concentration of the flow of radioactive wastes.

The experimental investigations and instrument development efforts will extend basic research funded by the Division of Engineering and Geosciences of DOE-BES. Data describing the effects of particles on turbulence structure complement efforts to improve transport models for particulate and bubbly mixtures. Improved rheological models for complex fluid mixtures will also complement ongoing studies. Finally, applying new measurement techniques, like realtime ultrasonic imaging, to particulate flows will provide essential tools to study the flow of concentrated suspensions.

Advanced Materials

The second thrust area under the Advanced Processing Techology Initiative is in the area of advanced materials. Advanced materials includes efforts in coatings and material synthesis and processing.

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, magnetic shielding, and biomedical. This integration includes state-of-the-art molecular beam epitaxy (MBE) and chemical vapor deposition (CVD) capabilities using ultrahigh vacuum, unique physical vapor deposition (PVD), polymer multilayer (PML) 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 challenges.

In addition to integrating across different coatings processes, we are strengthening the technical and scientific base of the individual coatings components. For example, in the biomimetics (solution phase) coatings effort, we are developing a unique scientific understanding of surfaceinduced thin-film formation. Recent efforts to publicize the biomimetics process have resulted in considerable interest from industry. PNL currently has a CRADA in place (funded by DOE-EE) with General Motors to evaluate the feasibility of biomimetic coatings on fuel delivery components.

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 commercial significance. In addition, expertise is being developed in the fundamental understanding of the factors (supersaturation, chelation, solution speciation) controlling film growth in the deposition solutions. Equipment and expertise are also being developed to measure important mechanical properties of deposited films such as adhesion, thickness. hardness, scratch resistance, and chemical durability.

To strengthen our vapor-phase coatings technology base, we began development of a new type of vacuum coating technology (polymer multilayer, physical vapor deposition), while adding more traditional coating processes to our capabilities. We also cultivated linkages with other researchers to find out where our coating expertise would leverage existing programs, and we canvassed a wide spectrum of potential clients to find out what types of coatings they would be interested in. Almost all of the desired applications did not involve single material depositions exclusively—and often not single process depositions. An in-line, multilayer,

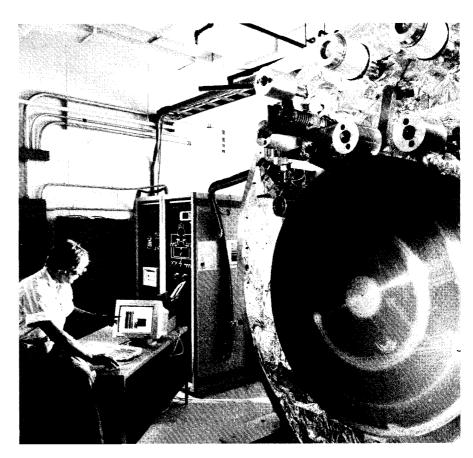
deposition process that lent itself to economic manufacturability was needed. Our new polymer technology generated a great deal of interest because it offered a method of integrating polymer film deposition that opened up a whole new area of product applications. We also undertook the fabrication of a vacuum roll coater. This instrument is capable of multiple, in-line 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 (e-beam and ultraviolet cure).

The development of this unique, single-pass system has resulted in a 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.

Materials Synthesis and Processing

Efforts in this area are driven by the need to synthesize inorganic ion exchangers and convert the materials to an engineered form (e.g., pellets) for use in separations. Techniques that could be used to synthesize metal oxides were examined. Hydrothermal treatment was identified as a key synthesis technique and efforts were initiated to develop capabilities in this area.

A novel continuous process that hydrothermally produces large quantities (kilograms/day) of nanometer size particles has been developed and demonstrated. The process, called Rapid Thermal Decomposition of precursors in Solution (RTDS), produces highly crystalline, high-surface-area powders. The powders are uniformly sized, nanoscale powders of great interest to a wide range of industries. Besides ion exchangers, RTDS produces powders for high-surface-area "super" catalysts, precursors for bulk ceramic parts such as gears and ball bearings, and additives for advanced composite materials. The RTDS process has also been explored as a method of treating



A new technology known as web-coating by vacuum deposition may represent a breakthrough in the rapid and cost-effective fabrication of electrodes and electrolytes—the basic components of batteries.

hazardous liquid waste streams from the textile industry.

The RTDS process was recently demonstrated by producing 200 grams of iron-oxide nanoscale catalyst in support of a DOE-FE-funded project. The production time was only a few hours and the ultrafine powder was specifically synthesized to be used as a catalyst during coal liquefaction. Scale-up of the RTDS system includes developing methods to process the powder into usable forms for specific applications.

Future efforts will focus on developing capabilities in the processing of nanometer size particles. The processing of nanometer size particles into membranes or coatings, for example, that maintain the nanometer size grain structure is of great interest to industry. Capabilities will be developed to understand the fundamentals (i.e., the effect of short-range particle interactions on particle consolidation), as well as the effect of processing on the final grain structure and material properties.

Industrial Interaction

The initiative seeks to develop strategic alliances with selected industries based on industrial needs that crosscut DOE programs. To this end, we are working with the University of Washington and Washington State University to develop an integrated strategy for the chemical processing and petrochemical industries.

Funding requirements for this initiative are given in the table at the end of this section.

Energy Technology Development

Energy resources are critically important to the nation's economic productivity. PNL's Energy Technology
Development Initiative develops and deploys technologies that enable costeffective, energy-efficient production of goods and services, minimize environmental residuals, and stimulate economic competitiveness. In prior years, this initiative included activities to enhance and demonstrate Laboratory capabilities in the energy systems development and process science and engineering core competencies as they relate to industrial process efficiency.

Research activities will be focused in two main areas: 1) improved utilization of existing energy assets, and 2) development of a new generation of distributed energy systems. These two foci were selected after intensive investigation into the most likely future energy scenarios, and are driven by the need for more cost-effective energy supplies (hence the need for better utilization of our existing systems), and by the inexorable trend away from large centralized energy systems toward small modular systems that can be placed close to a customer and tailored specifically to the customer's needs. Three key principles will guide PNL's energy research:

- concentrate on developing technologies that improve the reliability, cost-effectiveness, and efficiency of the energy transmission and distribution infrastructure and increase the productivity and efficiency of energy use in buildings, industry, and transportation
- collaborate with other national laboratories, industry, and universities to ensure the best capabilities are brought to bear on energy technology development
- employ a systems perspective in our energy programs.

PNL is investing in power systems, advanced technologies for operations and maintenance, microtechnologies, energy systems analysis, and lightweight materials development.

Power Systems

PNL is enhancing system analysis and modeling capabilities and applying the enhancements to develop new technologies for improving the operational efficiency and reliability of the nation's energy conversion, transmission and distribution, and utilization infrastructure. We have focused our efforts in two areas: 1) real-time diagnostics and controls for power systems and 2) electric and magnetic field effects.

There is a growing demand for power, an increasing use of the electric transmission and distribution systems for bulk power transfers, a growing demand for access by nonutility generators, and an increase in nontraditional generating technologies (e.g., renewables). Since new transmission capacity is difficult to implement, existing systems must be operated closer to their physical limits, and there is a movement toward small, distributed generation and storage devices at the site of the end user. This places strains on the stability and reliability of the nation's transmission and distribution systems that requires better diagnostic systems and more effective real-time control of system operations.

To meet the need for improved operations, PNL is developing advanced analysis and simulation tools in three main areas:

- measurement-based analysis techniques for modeling and understanding power system dynamics
- new theoretical, mathematical, and computational analysis techniques for model-based power system analysis
- 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.

PNL is conducting related work in monitoring and data management to ensure that our efforts are relevant to industry needs.

The biological effects of low frequency electric and magnetic fields on humans and animals have been studied at PNL for many years. Through the Energy Technology Development Initiative studies are being sponsored to determine the mechanism by which such biological effects occur because additional reliable data about magnetic field exposure are needed to determine whether a magnetic field-biological link exists.

We are developing the test equipment and measurement protocols needed to obtain data on sources of these fields and to characterize the aspect of the fields that produces biological effects. In FY 1993 scientists developed a field source characterization laboratory and used the facility to examine the complex magnetic fields associated with several consumer electrical devices. Currently they are designing and installing an advanced system to allow exposure to complex magnetic fields found in the vicinity of homes and work places. The system will be a unique resource for studying the biological and health effects of electromagnetic fields. They also are interfacing a magnetic field exposure system with flow cytometer equipment. The interface will enable PNL to carry out detailed mechanistic studies of potential electromagnetic fields effects at the cellular level.

PNL has developed processes for shielding electromagnetic fields. We are currently evaluating how our comprehensive capabilities in electromagnetic fields characterization and impact, shielding, and task management can be focused and made available to meet electromagnetic fields needs of industry.

Advanced Technologies for Operations and Management

With the overriding need for American industry to be more competitive in

international markets comes the associated emphasis on cost control and cost-effective operating and maintenance approaches. PNL's focus is the development of technology 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 technology. 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. In FY 1995 PNL will investigate the feasibility of "plug and play" sensor systems and develop a generic sensor validation system 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. The capabilities resulting from investment in this technical area are key to both 1) extending the life and increasing the reliability and capacity of the existing energy infrastructure and 2) effectively operating and managing the large, complex network of distributed energy systems toward which our national energy system is transitioning.

Microtechnologies

New microtechnologies could make small-scale, distributed energy processes economically attractive when compared to centralized processes normally used today. The ability to design and fabricate microsystems out of mechanical and thermal microscale components does not currently exist. The initiative is developing the technology and methodologies required to fabricate complete microscale systems with energy applications.

Initially PNL activities are focused on design, fabrication, and testing of microscale energy conversion systems, such as microscale heat exchangers, heat pumps, and heat engines. For example, we have fabricated and tested the first microscale evaporators and condensers. Results



Microscale heat pump evaporator after several hours of operation with an accumulation of ice on the evaporator surface.

show that performance of these devices far exceeds requirements for space heating and cooling applications and that the microscale evaporators may have important applications in cooling electronic systems. A prototype heat pump using microscale heat exchangers was demonstrated in FY 1993.

The long-term goal of this project is to establish a technical baseline for a new DOE program in designing, developing, and assembling microscale systems for energy applications. We are focusing on developing high-capacity evaporators, system configurations, and microcompressor options. We are also evaluating the need for microscale chemical processing and waste cleanup technologies. In the future, we will design, construct, test, and demonstrate a complete microscale heat pump system.

Energy System Analysis

PNL is enhancing understanding of energy system issues through a variety of research efforts. In FY 1994 PNL continued work with Pacific Gas and Electric, the Electric Power Research Institute, and the National Renewable Energy Laboratory to investigate the feasibility of the distributed utility. The cooperative effort will also characterize the transmission and distribution technologies and develop the necessary planning and analysis tools and information needed to implement the distributed utility infrastructure.

In 1993 PNL developed the capability to examine the economic consequences of technologies to the energy and environmental analysis capabilities of its total energy-cycle analysis model. In FY 1994 PNL demonstrated the benefits of using this capability by

conducting a case study of a microtechnology heat pump. In FY 1995 and beyond, PNL will work with industry to develop a comprehensive tool for characterizing the total energy cycle of industrial technologies.

Transportation Materials Development

This focus area seeks to develop materials and material/component manufacturing methods that will improve the fuel efficiency of, and reduce emissions from, 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.

The superplastic forming technology holds the potential to reduce the weight of new generation vehicles and improve U.S. industrial manufacturing competitiveness. In the next 5 years, PNL plans to expand its role in developing the technology. We will create new superplastic forming materials and processing technology in collaboration with industry and other government agencies. In FY 1994 we initiated a major Basic Energy Sciences program for DOE to examine the deformation mechanisms related to superplastic forming. The program will provide fundamental information that will benefit superplastic forming technology.

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. In FY 1995 PNL will focus on the modeling of exhaust flow and heat transfer in real

exhaust systems, coatings for thermal control and exhaust treatment, and thermal energy storage (TES) concepts for enhanced catalytic converter performance. PNL is also developing new manufacturing approaches that will redesign the engine cylinder to reduce crevice volume, a principal source of emissions generation.

Funding requirements for this initiative are given in the table at the end of this section. Programmatic support is being sought from various DOE offices as well as industry and other federal agencies. Funding requirements are partially given in the Resources Projections section.

Medical Technologies and Systems

The issue of health care costs and health care benefits in the United States is a major national concern.

Advances and refinements in medicine will be shaped and driven by three forces:

- imaging technology and the digitization of data
- information technology
- genetics and microbiology.

PNL and the other DOE national laboratories have requisite capabilities to make significant contributions to the areas of developing new imaging modalities, sensor techniques for noninvasive physiological monitoring, applications of powerful computational methods for networking and analyzing large data sets, biomaterials, robotics, process improvement, and mathematical modeling procedures for optimizing and integrating medical information.

An important part of expanding PNL's capabilities derives from the EMSL. These areas include digital imaging analysis and visualization, novel biosensing and spectroscopy-based imaging technologies, molecular biology techniques for developing specific gene probes as detectors of disease states and invasive pathogens, and extensive facilities for

animal validation tests of new medical technologies.

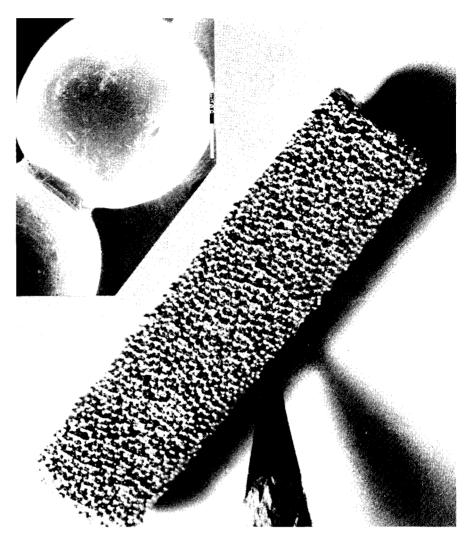
During the first 6 months of the initiative, assessments were performed to identify areas where distinct PNL capabilities could be applied in the medical technology arena. As a result, the Laboratory is focusing on five major technological areas: 1) medical sensors and imaging, 2) computational medicine, 3) medical robotics, 4) medical materials, and 5) medical process improvements. Many of the technologies under consideration in each of these areas were initially developed for non-medical applications, but are currently being adapted for use in biomedical research and clinical procedures. In several cases, these technologies have already been applied in medical practice, while in other areas research and development programs are under way to adapt new imaging, biosensing, and computational technologies for biomedical applications.

The Medical Technologies and Systems Initiative is focused on integrating capabilities in fundamental life sciences with advanced technologies through directed research. The areas being investigated are

Medical Sensors and Imaging-The focus of this area is development of advanced diagnostic instrumentation, high-performance analysis/diagnosis tools, and detection/treatment systems. Medical imaging has been a fundamental driver of advances in medicine and is gaining further sophistication, sensitivity, and applications. Current research at the Laboratory includes the reconstruction of information obtained through nonionizing modalities such as fluorescence, thermography, infrared, ultrasound, holography, and magnetic and electrical currents and fields. These methods have the potential to match or exceed the sensitivity of conventional imaging modalities, improve specificity, and be much less expensive.

The Laboratory is also developing new biological sensing technology to improve clinical diagnostics and treatment. Technologies under development include the use of human growth hormone as both a cancer targeting and treatment agent. Another area of sensor development will allow doctors to diagnose disease based on analysis of a patient's breath. This capability is an extension of existing capabilities in laser and mass spectrometry. Finally, the Laboratory is developing sensor systems for realtime monitoring of radiation exposure during tumor treatment. This new sensor technology will reduce patient risk while improving the overall radiation treatment.

- Computational Medicine-The focus of this area is development of more cost-effective tools for medical image visualization, diagnostic assistance, training, information processing, and tele-medicine. These tools will be used by "digital doctors" to more rapidly access patient history, consult with other physicians, analyze treatment options, perform remote procedures, and improve diagnosis through the use of intelligent diagnostic agents. Work is currently under way to allow the doctor to view three-dimensional images, and provide the tools for accessing distributed patient records. Through the use of artificial neural networks, the Laboratory is developing tools to monitor patients' vital signs and recognize serious abnormalities. Other neural networks have been designed to analyze and diagnose heart disease at an early, more treatable stage. In the area of tele-medicine, the Laboratory is developing tools for physician collaboration and consulting, as well as remote surgical assistance.
- Medical Robotics—The focus of this area is to develop and/or augment robotic, remote, and/or automated systems to enhance surgical, clinical, rehabilitation, and medical laboratory environments. The Laboratory has been actively involved in the development of: tele-robotic systems that advance remote operations through the use of high



This photo shows the calcium phosphate coating produced by a PNL process. The device is an implant which was used in tests. The inset shows a high magnification (50 μ m) of the coating on the implant beads. The process is capable of coating complex and highly porous implant devices with a bioactive calcium phosphate mineral. The pencil point is provided for scale.

bandwidth and high-speed communication, innovative humanmachine interface concepts, and three-dimensional workspace mapping; laboratory automation techniques that automate sample preparation, handling, data logging and interpretation; and low signature vehicles that navigate via high-speed communication. The integration of robotic technologies with sensor physics, microelectromechanical systems and intelligent systems will be used to support defined OHER thrust areas such as: tele-operation surgical platforms and intraoperative guidance during surgical tracking

- and intervention; intelligent assistive devices for the elderly and disabled; and the automation of medical laboratory and hospital functions to increase safety, productivity, and cost effectiveness.
- Medical Materials—The focus
 of this area is development of bio compatible materials which pro vide longer-lasting implants, and
 enhance tissue repair. The Labora tory has been actively involved
 through DOE-BES support in the
 area of biomimetic and advanced
 materials processes which involve
 putting a functionalized bioactive
 surface on the part to be coated.

The functionalized surface is designed to interact with a super-saturated solution and grows a ceramic film. The process is shape independent and grows uniform layers. Applications of this technology include advanced prosthetic and fixation device stabilization, integrated bone grafting for rapid high-strength bone repair, and tissue repair after surgery. These technologies can increase the longevity of surgical implants and enhance the physical well-being of patients.

Medical Process Improvements— Process improvements are fundamental to reducing health care costs and increasing the quality of and access to health care. The Laboratory believes that in order to successfully perform process improvement within medical organizations, an integrated approach is required. Process improvement is more than reengineering. Current work with various organizations integrates strategic and business planning, stakeholder involvement, business and work process analysis, system modeling and simulation,

information systems architecture, human factors analysis and modeling, material planning and inventory management, reengineering and integration, business management, organizational design, and change management. All of these disciplines must be practiced in complimentary fashion. Laboratory strengths focus on each of these disciplines in the context of the organization as a whole. As work is accomplished, primary value chain processes and critical support processes are monitored to ensure that tasks in all processes mesh and provide expected results without loss of quality, data, and customer satisfaction. Finally, changes are institutionalized. That is, they are not just implemented, but are securely sewn into the fabric of the organization and mesh with the continuous improvement process. This approach is applicable to organizations from the small medical clinic to the large HMOs and medical insurance organizations.

Transferring technology is an integral element of this initiative. Current efforts involve transfer to the DOE program offices, other federal agencies, universities, and industry.

Programmatic support for the Medical Technologies and Systems Initiative is sought through DOE offices that emphasize basic and applied research areas. Included are the Advanced Biomedical Technology Initiative, general life sciences research, microbial genome, and human genome programs in OHER, and the Biomimetics Program in Basic Energy Sciences. In addition, several of these potential opportunities are evolving with U.S. Department of Defense/Army Surgeon General's Office, Madigan Army Medical Center, National Institutes of Health, and with industry through CRADAs and other technology transfer mechanisms. Funding requirements for the initiative are given in the table at the end of this section and are not included in the Resource Projections.

Pacific Northwest Laboratory Initiatives

(Budget Authorization \$ in Millions)

Initiative	1994	1995	1996	1997	1998	1999	2000
Advanced Processing Technology							
Operating	2.8	4.9	6.7	8.2	15.7	25.7	26.0
Capital	0.2	0.4	0.9	1.4	1.4	1.6	1.6
Total Advanced Processing Technology	3.0	5.3	7.6	9.6	17.1	27.3	27.6
Energy Technology Development							
Operating							
Energy Efficiency & Renewable Energy	1.8	3.5	5.0	8.0	12.0	15.0	20.0
Energy Research	0.0	0.5	1.5	2.5	3.0	4.0	4.5
Laboratory Technology Transfer	1.2	1.5	2.0	2.5	2.5	2.5	2.5
Private Sector/Other Federal Agencies	0.2	0.5	1.5	3.0	5.0	7.0	10.0
Capital							
Energy Efficiency & Renewable Energy	0.2	0.6	0.9	1.4	1.5	1.7	1.9
Energy Research	0.0	0.0	0.1	0.1	0.1	0.1	0.1
Laboratory Technology Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Private Sector/Other Federal Agencies	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Energy Technology Development	3.4	6.6	11.0	17.5	24.1	30.3	39.0
Global Environmental Change							
DOE Funding	22.4	20.5	21.0	21.0	21.0	21.0	21.0
Biological & Environmental Research(a)	22.4	20.5	21.0	21.0	21.0	21.0	21.0
Policy, Fossil, EE, Sustainable Development	7.2	9.1	10.8	11.5	12.0	12.0	12.0
Other DOE	0.4	0.3	0.3	0.2	0.2	0.2	0.2
Work For Others Environmental Protection Agency	6.0	6.0	5.0	5.0	5.0	5.0	5.0
Environmental Protection Agency	6.0	6.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0	5.0 5.0
Other Federal Agencies Capital Equipment	4.5 6.9	9.6	9.5	7.0	7.0	7.0	7.0
Total Global Environmental Change	47.4	50.5	51.6	49.7	50.2	50.2	50.2
Total Global Environmental Change	**/***	30.3	31.0	47.1	30.2	30.2	30.2
Medical Technologies and Systems DOE							
Office of Health & Environmental Research	0.0	0.0	0.5	2.5	5.5	8.0	10.0
Basic Energy Sciences	0.0	0.5	0.7	1.2	2.0	2.5	3.0
Energy Efficiency & Renewable Energy	0.0	0.0	0.2	0.5	0.8	1.0	1.0
DOD	0.0	1.4	2.0	3.7	4.5	6.0	8.0
DHHS	0.0	0.5	1.2	2.0	3.5	4.2	5.1
Industry	0.0	0.6	1.4	1.5	2.3	3.5	4.5
Total Operating	0.0	3.0	6.0	11.4	18.6	25.2	31.6
Capital Equipment DOE	0.0	0.0	0.4	1.6	2.0	2.5	2.5
Total Medical Technologies and Systems	0.0	3.0	6.4	13.0	20.6	27.7	34.1
Microbial Biotechnology							
Energy Research	1.0	1.3	1.4	1.5	1.8	2.5	4.0
Environmental Management	0.1	0.5	0.7	0.9	1.0	2.5	4.0
Energy Efficiency & Renewable Energy	0.0	0.1	0.5	0.8	1.2	2.0	4.0
Fossil Energy	0.0	0.0	0.1	0.2	0.5	0.8	1.5
Other Federal Agencies	0.1	0.2	0.5	1.0	2.0	2.2	5.0
Industry	0.0	0.4	0.5	1.0	1.5	5.0	7.5
Capital Equipment	0.2	1.9	0.5	0.6	0.6	1.9	3.0
Total Microbial Biotechnology	1.4	4.4	4.2	6.0	8.6	16.9	29.0

Pacific Northwest Laboratory Initiatives (contd)

(Budget Authorization \$ in Millions)

Initiative	1994	1995	1996	1997	1998	1999	2000
Modeling of Complex Physical Systems							
Operating	0.6	1.0	1.5	2.0	2.5	3.0	3.5
Capital	0.0	0.0	0.5	1.0	3.0	3.0	3.0
Total Modeling of Complex Physical Systems	s 0.6	1.0	2.0	3.0	5.5	6.0	6.5
Molecular Sciences Research							
Operating							
Basic Energy Sciences	5.5	6.5	8.0	8.5	9.0	9.5	10.0
Biological & Environmental Research	0.6	1.0	3.0	5.5	9.0	9.5	10.0
Other Energy Research	0.5	1.0	0.5	1.5	3.0	3.1	3.2
Environmental Management and Other	1.0	1.5	2.5	5.5	9.5	9.9	10.4
Capital							
Basic Energy Sciences	1.0	1.0	1.0	1.5	2.0	2.0	2.1
Biological & Environmental Research	0.2	0.5	1.0	1.5	2.0	2.1	2.2
Other Energy Research	0.0	0.0	0.5	0.5	0.5	0.5	0.6
Environmental Management and Other	0.2	0.5	0.5	0.5	0.4	0.4	0.5
Total Molecular Sciences Research	9.0	12.0	17.0	25.0	35.4	37.0	39.0
Total PNL Initiatives	64.8	82.8	99.8	123.8	161.5	195,4	225.4

⁽a) Includes Atmospheric Radiation Measurement program funding, which will have significant subcontracts and is included in the resource projection.



Core Business Areas

As described in Section 3 of this Institutional Plan, Laboratory Strategic Plan, the Pacific Northwest Laboratory is focusing its efforts in order to contribute to selected goals in each of the five core business areas: science and technology, environmental quality, energy resources, national security, and industrial competitiveness. Objectives have been established in each area and PNL's scientific and technical programs are directed toward these objectives which are described below.

Science and Technology

PNL activities provide new scientific knowledge and innovative concepts and technologies that contribute to the U.S. Department of Energy's core businesses of environmental quality, energy resources, national security, and industrial competitiveness. Science and technology activities also include education and training programs to develop and maintain a U.S. work force that is literate in science, mathematics, engineering, and technology.

PNL's objectives in science and technology are to

- advance the frontiers of environmental molecular science research to provide the new knowledge needed to strengthen PNL's research and development and application activities through the establishment of a state-of-the-art research user facility, the Environmental Molecular Sciences Laboratory (EMSL)
- understand the behavior of contaminants in subsurface, marine, and atmospheric environments
- enhance fundamental knowledge related to environmentally and industrially important processes,

- such as chemical separations and the behavior of complex fluids
- bring emerging supercomputing technologies to bear on modeling complex physical systems
- advance understanding of the health effects of chemical and radioactive substances
- improve understanding of environmentally important microbial systems

PNL's scientific and technical activities of each DOE program office contributing to the science and technology core business are described below. The descriptions also explain proposed new programmatic initiatives within these organizations.

Environmental Molecular Sciences Laboratory

The EMSL was first proposed as a major PNL initiative in FY 1989 and was carried forward as an initiative through FY 1992 at which point it received funding from the DOE. This new facility will be an essential part of PNL's ability to provide the fundamental scientific understanding needed for the DOE to successfully achieve its environmental quality and energy resources goals. The new laboratory will be a national collaborative research facility that will 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.

As a collaborative research facility, the EMSL will be a national focal point for molecular science research with an emphasis on the long-term environmental management business area of DOE. As the cornerstone of PNL's fundamental research portfolio, the EMSL will capitalize on today's experi-

mental, 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 the global technological business sector.

To achieve this goal, PNL is building state-of-the-art, fundamental research programs that are responsive to needs identified in an DOE-EM/ER collaboration meeting that was held in Washington, D.C. in May 1994. The representatives of DOE-EM and DOE-ER that attended the meeting sought to identify areas where DOE-ER can fill basic research needs for DOE-EM. Special attention was given to DOE-ER-funded facilities and how they may be used to provide research knowledge needed to help DOE-EM accomplish its environmental cleanup tasks. 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 established in the EMSL to carry out the Molecular Sciences Research Initiative, are vital to efforts to address the complex technical issues associated with DOE's environmental mission.

The EMSL provides a strong linkage among research disciplines critical to environmental remediation and waste management and establishes collaborations with members of the worldwide scientific community in these disciplines. Collaborative efforts undertaken by EMSL staff continue to increase both in number and significance. An EMSL Advisory Committee has been formed to ensure that external users have input into EMSL operations and management. Advisory committees such as the EMSL Advisory Committee will be critical to the success of the EMSL as a user facility.



Construction of the Environmental Molecular Sciences Laboratory began in late FY 1994.

The DOE will spend \$229.9 million to design and develop research instruments, design and construct the building, and acquire and install the advanced instrumentation. A total of \$104 million has been provided to date to manage the project, design the facility, start construction, develop instruments and software, and develop specifications and initiate procurement actions for the advanced equipment that will be vital components of the laboratory. In the FY 1994 DOE budget, \$32 million in line-item funding was authorized for project management, continued equipment development and procurement activities, and construction startup. As required by the National Environmental Policy Act (NEPA), an environmental assessment for EMSL was prepared and a finding of no significant impact was issued. Construction of the facility began in late FY 1994 and is scheduled to be completed in early FY 1998. The EMSL will include the following.

Chemical Structure and Dynamics Research Facilities These facilities support activities aimed at providing a fundamental, molecular-level understanding of chemistry in a wide variety of environmentally important interfaces. The research is built around the well established relationship between structure, thermodynamics, and kinetics as the underpinning of molecular-level understanding of chemical processes. These 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 speciesspecific detection methods required for the wide ranging site and process characterization/analysis needs of the DOE complex.

The Surface/Interface Structure and Reactions (SISR) Facility contains surface/interface instrumentation (including 10 ultrahigh vacuum surface science instruments) to study in detail 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 the ability to grow ices doped with molecules, radicals, and ions to simulate aerosols important in atmospheric chemistry; to model mineral interface chemistry 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 (20K) scanning tunneling microscopes with associated sample-handling and interface capabilities. The SISR Laboratory also contains six multiwavelength laser systems and other energy sources for the initiation of chemical reactions and the state resolved detection of chemical reaction products.

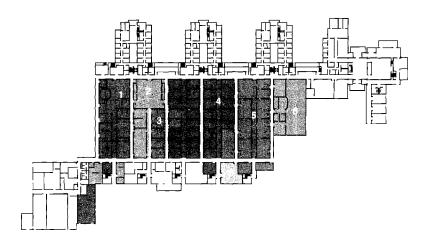
The Time-Resolved and Solution Spectroscopy Facility provides a capability for studying relaxation processes in fluids, ultrafast dynamics in biological systems, and time-resolved processes at surfaces and interfaces. It contains laser systems for generating picosecond and femtosecond pulses, including 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, nearfield optical microscopes will permit 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 forming nine independent research stations that are used in conjunction with neutral and ionic sources that provide high-flux beam currents of cold, massselected 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 provide high-resolution infrared spectroscopic capability using semiconductor diode lasers and a Fouriertransform 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 shortpulsed 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

Modeling molecular processes in the environment requires a fundamental understanding of molecules and their interactions in isolation (gas phase) and in liquids, on surfaces, and at interfaces (condensed phase). This is, however, one of the most challenging problems ever faced by computational molecular science



- Ultrahigh Resolution Mass Spectrometry
- Ultrahigh Field NMR
- Environmental Graphics Facility
 - Environmental Spectroscopy Laboratory
 Environmental Reactions and Processes Facility
- 3 Chemical/Material Characterization Facility
- Reaction and Process Testing Facility
- 4 Integrated Materials Synthesis System• Interphasial Chemistry Facility
 - · Sensor Design, Fabrication, and Testing Facility

- . Cluster Structure and Dynamics Facility
- Time-Resolved Spectroscopy Facility
 Interfacial Structure and Reactions Facility

- Production Computing Center
 Graphics and Visualization Laboratory
 - Experimental Computing Laboratory
 Molecular Science Software
- . Computing Infrastructure
 - High-Performance Computing Software
 - Computer Instrumentation and Electronics

The Environmental Molecular Sciences Laboratory will provide a suite of state-of-the-art, integrated facilities for the performance of focused research related to the environment.

- the molecules of importance range in size from large organic and inorganic species to biomacromolecules (e.g., chelates, dioxins, polychlorinated biphenyls, minerals, zeolites, proteins, enzymes, DNA, etc.)
- 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).

Consideration of the scaling laws for molecular computations shows that this activity will require a level of computing and modeling capability that far exceeds (10 to 1000 times) that available with current supercomputers and molecular modeling applications.

To provide the advanced computing capability needed by the staff and collaborative users of the EMSL, a Molecular Science Computing Facility (MSCF) is being established. The MSCF will provide a robust and highly integrated computing environment,

with high-speed links to external facilities within DOE, collaborating universities, and industry. The facility consists

- The Production Computing Center, which will provide for the production computing needs of the research programs in the EMSL. The center will contain a large-scale, parallel computer system (256 to 512 processors) with a peak performance of 100 to 300 gigaflops (10 to 50 gigaflops sustained), 10 to 50 gigabytes of memory, and 100 to 300 gigabytes of 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 archive system will have an initial capacity of 10+ terabytes.
- 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 advanced computers installed in the Experimental Computing Laboratory, which will provide EMSL software research and development efforts with access to innovative computer systems that show promise for significantly extending the range or reducing the cost of molecular simulations.

Software development is the key if we are to benefit from the advanced computer systems installed in the MSCF. To this end, 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 Molecular Modeling 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 parallel computer systems to be installed in the MSCF, to the emerging teraflops class of massively parallel computers. 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 or large problems, 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



This supercomputer will enable scientists at PNL to collaborate with researchers throughout the United States to develop software applications for complex environmental and molecular research.

fundamental physics will be required. The initial effort is focused on the development of software for modeling the electronic structure of molecules and solids, and for simulating the dynamics of molecules.

 The effort in the Extensible Computational Chemistry Environment 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 managing and analyzing computational experiments. 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 software, and tools for managing the data from molecular computations.

Materials and Interfaces The Materials and Interfaces Research Facility will provide state-of-the-art experimental capability 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 solidliquid, liquid-liquid, solid-solid interfaces include electrochemical, spectroelectrochemical, scanning probe imaging techniques, and optical methods. Also included are capabilities for determination of the structure and composition surfaces and interfaces and capabilities for examination of reactions at atmospheric pressure. The overall objectives of these capabilities are to facilitate 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 will also allow samples to be transferred to off-site users. This aspect is particularly important to sustaining the collaborative mission of the EMSL.

 A Chemical Sensor Laboratory is being established to allow us to develop sensors to meet DOE's sens-

ing 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 stateof-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. Accordingly, the Chemical Sensor Laboratory will include capabilities for the fabrication and modification of sensor devices; the application of thin films of selective materials to sensor devices; electronic equipment to characterize sensors, operate sensors, and measure sensor signals; systems to generate, dilute, and mix analytes for sensor testing, such as gas and vapor streams; and flow injection analysis systems for automated microscale liquid sample handling and analysis. These capabilities are supported with microcomputers and software to automate testing procedures and data collection. In addition, advanced chemometric techniques for signal processing and data analysis are an integral component of sensor and microanalytical system development.

Macromolecular Structure and **Dynamics** The Magnetic Resonance and Mass Spectrometry Facilities are designed to support activities focused on 1) molecular structure of enzymes as they relate to bioremediation processes, to obtain a better understanding of their function and mechanism, especially with regard to the role of ambient inhibitors; 2) human health and environment effects as they impact risk associated with respect to environmental remediation; 3) waste conversion (catalysis) as it relates to the problems associated with environmental contamination; and 4) development of ultrasensitive and specific detection means to provide essential in situ characterization of the contamination site before, during, and after remediation. There are a total of 11 magnetic resonance spectrometers either operational or planned and 8 mass spectrometers

- when the EMSL opens. This represents a substantial asset to the DOE and to the research community at large.
- When the EMSL begins operation in early FY 1998, the Magnetic Resonance Facility will have the following spectrometers in place: an ultrahigh frequency (900 to 1000 megahertz) nuclear magnetic resonance, a 750megahertz nuclear magnetic resonance, and two 500-megahertz nuclear magnetic resonance. These four spectrometers are primarily for liquids use and are completely multinuclear and multichannel devices. Further, a 500-megahertz, a 400-megahertz, and a pair of 300megahertz, wide-bore nuclear magnetic resonance spectrometers will be available for multinuclear solid state experiments; the ultrahigh frequency and 750-megahertz spectrometers can also be used for solid state and microscopic imaging experiments. Finally, the Magnetic Resonance Facility will contain a multifrequency variable field-pulsed Fourier transform electron paramagnetic resonance spectrometer.

The solution phase nuclear magnetic resonance spectrometers (ultrahigh frequency and 750 megahertz) will provide unparalleled sensitivity and resolution principally for investigations in the area of biomolecular structure and dynamics for molecules of biological and/or environmental relevance. One of the 500-megahertz spectrometers will also be utilized for biomolecular structure determinations. The ultrahigh nuclear magnetic resonance spectrometer will represent the highest field nuclear magnetic resonance spectrometer in the world, and the magnet will be the highest persistent field magnet in the world. This high field will also be exploited for selected solid-state experiments where the high field can be utilized to solve important problems, e.g., the study of quadrupolar nuclides, and for imaging experiments with a subcellular resolution. The solid-state spectrometers (500 megahertz, 400 megahertz, and a pair of 300-megahertz wide-bore



The world's first commercial 750-megahertz nuclear magnetic resonance spectrometer was delivered to PNL in late 1993 and is being used to generate high-resolution spectral information on macromolecular structures.

systems) will be used for investigations that require solid-state applications (e.g., materials chemistry and heterogeneous catalysis). The 500megahertz system will also be used for in vivo MRI of small rodents. One of the 500-megahertz liquids instruments and one of the 300megahertz solids spectrometers will also be used to support the advanced processing applications within the EMSL. The FTEPR spectrometer will be used for those systems with unpaired electrons (e.g., metal ions in biological systems, soils, and surfaces). There are development plans to start construction of a DNP-nuclear magnetic resonance and an ultrahigh frequency pulsed electron paramagnetic

- resonnance spectrometer in the same time frame. Finally, the magnetic resonance group will have two large computer and graphics servers for realtime support of the biomolecular structure and dynamics programs.
- The Mass Spectrometry Facility, although specializing in Fourier transform ion cyclotron resonance (FTICR) mass spectrometry, will have a broad array of spectrometers when the EMSL opens for operation (e.g., 12-, 7-, and 4.7-tesla FTICR mass spectrometers and double focusing, triple-quad, and ion trap mass spectrometers. Further, two time-of-flight [TOF] mass spectrometers will be available offering

two different types of ion sources: MALDI- and ORTHO-TOF.)

The mass spectrometry laboratory will provide for a broad mass spectrometry capability. The FT-ICRMS is a one-of-a-kind instrument that will provide high sensitivity, ultrahigh resolution mass spectrometric analysis of complex mixtures and large molecular structures relevant to environmental, waste-related, bioremediation, and health-effects research. The TQMS and ITMS are commercial instruments that can both function as tandem mass spectrometry systems; they have high sample throughput, and are easily operated. The MALDI-TOF is a commercial instrument that offers extraordinary sensitivity in certain applications, in particular for biomacromelecules deposited in certain matrices on surfaces. The ORTHO-TOF is a one-of-a-kind instrument which will also provide extraordinary sensitivity for large molecules by uniquely coupling electrospray ionization capabilities to the timeof-flight mass spectrometer. Finally, the DFMS is a useful instrument offering higher energy studies with high sensitivity, which will be greatly improved by the electrospray ion source development. The DFMS is also the first stage of the planned tandem mass spectrometer.

Computing and Information Sciences

The Computing and Information Sciences program develops, maintains, and operates the advanced computing infrastructure needed for research in the EMSL, creating an integrated computing and instrumentation environment where EMSL staff, visitors, and collaborators can productively utilize computing resources to address DOE's environmental problems at the molecular level. Computing and Information Sciences research and development efforts draw from a wide range of information technologies to advance the EMSL computing environment in areas key to the EMSL computing mission. Many projects embrace collaborations with EMSL scientists, other PNL centers, universities, or industry. The Computing and Information Sciences program also provides leadership in use of emerging information technologies for EMSL collaborative research, for example, by leading the development of an Environmental Molecular Sciences Collaboratory at PNL.

The EMSL Computing and Information Sciences program consists of the following elements:

- The EMSL distributed computing system encompasses all networked desktop, lab, and general use computers within the facility. Advances in technology are being exploited to implement a computing environment where software and computer services are available everywhere, independent of location within the facility. For example, a robust set of software applications can be used from all desktop computers, and common UNIX applications are available for all popular platforms. Software application updates and computer system management are centrally administered, ensuring that EMSL users have access to the latest capabilities. Distributed file storage, printing, authentication, and communications services round out the suite of distributed capabilities. The Distributed Computing System also contains the EMSL electronic information system, providing descriptions of facilities, research program summaries, and technical reports to the World Wide Web.
- A hierarchy of data networks serves the desktop workstations, laboratory computer instrumentation, and highperformance computing systems in EMSL. High speed computer-tocomputer links sustain large volume data transfers between highperformance computers, database and data archive systems, high data rate experiments, and high end graphics displays. Standard desktop and laboratory computers are linked into end-user subscriber networks. An EMSL backbone network joins these high performance networks and end-user subscriber networks with work group servers, and also links EMSL to other laboratory and national networks. Automated network monitoring and management

- tools, and ongoing technology evaluation efforts ensure optimal performance of EMSL networks.
- The Instrument Development Laboratory (IDL) provides resources and expertise for the development and testing of data acquisition and control systems, electronics, interfaces, and software associated with the many instruments of the EMSL. The Instrument Development Laboratory serves as a focus for the evaluation of data acquisition and control hardware and software, as well as providing electronics design, testing, and assembly capabilities for one-ofa-kind and first-of-a-kind instruments. Instrument modeling resources enable optimization of instrument design and operational parameters. The Instrument Development Laboratory also provides a focal point for development of instrument hardware and software standards, and for dissemination of common solutions and acquired expertise.
- · A Collaboratory is a "laboratory without walls" that spans multiple geographical areas with collaborators interacting via electronic means, and the Environmental Molecular Sciences Collaboratory will span the nation as such a resource to the molecular sciences. Research scientists are teamed with computing experts to create a new scientific computing environment for research, that provides for the integration, synthesis, and management of information from many sources and locations, along with resources that support the dynamics of research interactions among geographically dispersed scientists and research facilities.

The effort in Software Capability Development focuses on the computer science, numerical analysis, and engineering aspects of resolving questions of how molecular science applications should be structured. Software research and development efforts are advancing EMSL scientific computing capabilities to:

 fully exploit the present and future massively parallel computer resources in EMSL, through devel-

- opment and integration of numerical libraries and programming tools for high-performance computing
- employ computer graphics to facilitate display and analysis of complex EMSL data sets, including development of user interface and visualization toolkits for simulation or experimental data
- integrate access to scientific information databases with the operation of EMSL research applications through advanced scientific data management system designs, enabling scientists to query very large datasets and to join multiple applications for complex simulations or analyses.

Environmental Dynamics and Simulation The Environmental Dynamics and Simulation Research Facility will consist of a set of integrated laboratories that will link molecular-scale research conducted elsewhere in the EMSL to research on natural environmental systems and materials. These laboratories include the following:

- The Environmental Spectroscopy Laboratory will provide spectroscopic capabilities for examining interfacial chemistry and reactivity of pure-phase and natural materials under ambient environmental conditions in a series of controlledatmosphere environmental chambers. Spectroscopic systems for molecular-scale characterization of reaction mechanisms at natural mineral surfaces and in aqueous media include a fluorescence laser spectroscopy system, laser photoacoustic spectrometer, Fourier transform farinfrared/mid-infrared/Raman spectrometer, and electron 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.
- The Analytical Chemistry, Physical Chemistry, and Radiochemistry 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.

 The Environmental Graphics and Visualization Laboratory will be equipped with state-of-the-art computer workstations linked to the computational infrastructure of the EMSL. Coupled geochemical reactiontransport 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 and integrated computing environment developed for the entire EMSL.

Advanced Processing The EMSL Advanced Processing program is designed to link the molecular science research being performed in the EMSL to the real problems of waste cleanup by providing a pathway for developing scientific ideas and concepts into processes that address the DOE's needs, particularly at Hanford. There are three main research thrusts in the Advanced Processing program:

- Conversion Science—the rational design of catalysts for waste remediation, catalytic incineration, and process chemistry.
- Separations Science—interphasial and colloidal chemistry; the rational design of separation membranes and process design.
- Materials Synthesis—prepare and test materials for advanced separations and conversion processes.

There are two main groupings of research equipment in the Advanced Processing EMSL program. The Spec-

troscopic Characterization Laboratory contains the following capabilities:

- Separations and Detection System— Gas chromatographic separations combined with detection and identification by mass spectrometry and infrared spectroscopy. This system will examine complex mixtures and matrices of inorganic and organic solids, liquids, and gases.
- Ion Analyses System—Combined instruments for the analysis of ionic species in complex mixtures and matrices, including inductively coupled plasma and atomic absorption (with graphite furnace) spectroscopy, along with an ion separation and detection capability. Speciation of anions, cations, and metal complexes will allow for the elucidation of mechanisms and the design of efficient processes.
- Thermal Process Analysis System— Thermal gravimetric analysis capability coupled with a differential scanning calorimeter and mass spectrometer detection to study the mechanistic details of endo- and exothermic process reactions.
- Fourier Transform Infrared Spectrometer—A modular spectrometer that can analyze solid, liquid, and gas samples, this instrument will also have the capability of interfacing with the other systems in the facility to provide spectroscopic analysis of processes.

The Process and Reaction Testing Laboratory contains

- Chemical Reaction Test Stand System—A computer controlled automatic laboratory reactor system for the mechanistic study of chemical processes in solid, liquid, or gas phases. Includes a reaction calorimeter to accurately measure the heat consumed or released during processes.
- Supercritical Fluid Test Stand—A two-vessel, integrated fluid processing system to study supercritical extraction and cleaning. On-line process monitoring is available through a computer interface to benchtop instrumentation, including ultravioletvisible, and infrared spectroscopy.

- Electrochemical Reaction System—A versatile, bench-scale electrochemical system with a variety of electrochemical techniques available for the study of separations: salt-splitting, electrowinning, electrosynthesis, process kinetics and mechanisms, process analysis, and corrosion. The system is capable of batch or flow processing, and capabilities extend from the micro- to bench-scale and beyond.
- Membrane Reaction Development Stand—Custom designed membrane test stand for the study of processes such as reverse osmosis, ultrafiltration, and microfiltration. Includes four test cells that operate independently or in parallel.
- Solvent Extraction Test Stand—Test stand with the capability of examining batch and continuous staged solvent extraction processes for the separation of metals and organics from aqueous and non-aqueous systems. Also has the capability of long-term testing to study the effects of solvent degradation, contamination buildup, and solvent recycling.
- Tubular Reaction System—Custom designed equipment to evaluate high temperature and/or high pressure reactions in gas, liquid, and solid phases using either continuous flow or batch reactors. Includes four continuous flow microreactors and one batch reactor. This system will be used to develop and test catalytic, thermal destruction, and thermal treatment processes.

Staffing and Funding the EMSL

The intellectual resources of the EMSL continue to grow as nationally and internationally known experts are hired to develop and lead the research programs. Research staff continue to contribute to their scientific fields by publishing papers in the technical literature, presenting research results at scientific and technical meetings, and participating in their professional organizations.

Dr. Thom H. Dunning Jr. was appointed Director of the EMSL in February 1994. Dr. Dunning succeeded Dr.

Michael L. Knotek who had served in a dual assignment as acting manager of the EMSL and PNL Senior Director for Science and Technology.

Dr. Raymond A. Bair was appointed EMSL Deputy Manager for Computing and Information Science in June 1994. The research program is responsible for developing, maintaining, and operating the EMSL's advanced computing infrastructure.

Dr. Bruce C. Garrett was appointed acting associate director of the Theory, Modeling, and Simulation research program, replacing Dr. Thom H. Dunning Jr. The search for a permanent associate director for the Theory, Modeling, and Simulation program is in progress.

Dr. Michael A. Kennedy, University of Washington; Dr. Robert A. Wind, Director of Research and Development at Chemagnetics/Otsuka Electronics, Fort Collins, Colorado; Dr. Steve A. Hofstadler, a former postdoctoral fellow at PNL and a graduate of the University of Texas-Austin; and Nancy G. Isern, Syracuse University, joined the Macromolecular Structure and Dynamics group in 1993. Dr. Kennedy was formerly a Hollaender postdoctoral fellow at PNL.

Dr. Lai-Sheng Wang, Rice University, joined the Chemical Structure and Dynamics program in 1993. Eleven new postdoctoral appointees and two graduate students were assigned to the group through the Associated Western Universities (AWU) program.

Dr. J. A. Nichols, IBM, and Dr. M. D. Paulsen, a former postdoctoral appointee at PNL, joined the Theory, Modeling, and Simulation group in 1993. Twenty-two visiting scientists worked with staff from the Theory, Modeling, and Simulation group, and six postdoctoral appointees joined the group through the AWU Program. and Dr. M. F. Guest came from SERC Daresbury Laboratory in England to be the Group Leader of High Performance Molecular Modeling.

Dr. C. J. Bruckner-Lea, University of Utah; Dr. J. W. Grate, Naval Research Laboratory; and Dr. C. H. F. Peden, Sandia National Laboratories joined the Materials and Interfaces program. Two technical specialists, G. C. Dunham from Washington State University and Dr. S. Thevuthasan, University of California-Davis also joined the group. Four postdoctoral appointees and five Science and Engineering Research Semester (SERS) students were assigned to the group through the AWU program.

As a result of our recruiting program, the EMSL staff now totals 95, with 78 additional research and support staff matrixed from other PNL organizations. In addition, 61 postdoctoral appointees are assigned to the EMSL. Key hires anticipated in FY 1995-1996 include new associate directors for the Theory, Modeling, and Simulation and the Environmental Dynamics and Simulation programs. 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.

Office of Energy Research

The PNL strategy for supporting the Office of Energy Research focuses on the development of fundamental knowledge pertinent to the DOE core business areas. The new knowledge resulting from this approach is beneficial to DOE in determining its directions regarding scientific research, technology development, and science and technology policy that support DOE core businesses.

Biological and Environmental Research (KP)^(a)

PNL is a major participant in the DOE's Office of Health and Environmental Research. Current PNL programs include health effects research in biological systems, molecular and cellular research, research on radon and other alpha-emitting nuclides, radiological and chemical physics of biological damage, structural and computational biology, environmental research (subsurface science and terrestrial ecology),

atmospheric physics and chemistry, and climate research. In a major research activity, PNL is providing support to DOE in establishing the Atmospheric Radiation Measurement (ARM) program, a U.S. Global Environmental Change Research Program. The EMSL, which PNL is developing as a major center for collaborative research related to the environment, was also recently placed under the sponsorship and oversight of DOE-OHER.

Biological Research Biological research is addressed through a multilevel approach incorporating studies from the molecular level to the wholeanimal level. Emphasis is placed on gaining a quantitative understanding of fundamental mechanisms that underlie the effects of radiation and chemicals using integrated dosimetric, molecular, cellular, and experimental animal approaches. PNL's program includes basic studies to test hypotheses concerning the interaction of chemical and physical agents with molecules in biological systems and the alteration of these molecules by the transfer of energy. 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 theoretical prediction and experimental verification of doseeffect relationships at low doses. The ultimate objective is to identify the cause of disease states induced by exposure to radiation or toxic chemicals 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.

Specific research activities in the biological research program include 1) studies of molecular mechanisms underlying radiation and chemical damage and progression to cancer, developmental abnormalities, and other health effects; 2) investigation of health effects of alpha-emitting radionuclides (plutonium, radon, and radon progeny) in laboratory animals and in vitro systems, including studies

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

of molecular mechanisms of cell damage and carcinogenesis; and 3) characterization of molecular markers of exposure to toxic agents and susceptibility to health effects that can be applied in epidemiological studies. Characterization of molecular markers is integrated with molecular and cellular research, research on radon and other alpha-emitting nuclides, and research specifically related to potential radiation and chemical exposure during the cleanup of nuclear waste sites

Molecular and Cellular Research Our focus is on understanding the fundamental nature of damage by radiation and chemicals through studies of the molecular alterations produced in the DNA of cells exposed to these agents. These studies include analysis of the damage to DNA in normal and tumor cells obtained from animals exposed to radon, and in mammalian cells exposed to x-rays and radon in vitro. Effects of exposure to x-rays, as a representative low-linear-energy-transfer (LET) radiation, are being compared to those of high-linear-energy-transfer alpha particles from radon progeny. Chemicallyinduced mutations are being studied by exposing chromatin to mutagens and evaluating the sites and nature of the damage and effects on DNA. These studies will provide fundamental understanding of the patterns of genetic alteration induced in DNA by radiation and chemical carcinogens.

A long-term objective is the structural analysis of radiation- and chemicallyinduced DNA damage. EMSL resources enable PNL's health effects research program to apply new theoretical and spectroscopic approaches to understanding mechanisms involved in mutagenesis, carcinogenesis, and developmental abnormalities through modeling three-dimensional structures of macromolecules and providing structural biology information that complements our molecular biology research. Four types of ongoing research are leading in that direction. First, mutations are being characterized in a target gene inserted into the genome of transgenic mice that have been exposed to radon. Second, the role of DNA sequence in the damage resulting from

the binding and migration of hydrated electrons along the DNA backbone is being characterized. Third, the relationship between bulky adducts of carcinogens and chromatin structure is being studied in the 5S RNA gene. Fourth, the Enzymatic Processing of Damaged DNA Initiative is integrating advanced experimental techniques (such as two-dimensional nuclear magnetic resonance and mass spectrometry) and the advanced computational and modeling capabilities in the EMSL with the DOE-OHER Biological Research Program and the Radiological and Chemical Physics Research Program. Integrated experimental and theoretical capabilities for analyzing the interactions of radiation and chemicals with DNA and other macromolecules will be enhanced significantly by the new instrumentation and computing facilities being developed in the EMSL.

The role of radiation-induced chromosome aberrations in gene amplification and carcinogenic progression is being investigated in respiratory tract epithelial cells using in vivo and in vitro models. These studies include the use of in situ hybridization techniques for detecting stable chromosome aberrations and determining the role they play in carcinogenesis. To understand the interactions between radiationinduced chromosome damage and cancer, research is being conducted to evaluate the genotoxic damage produced by exposure to low-dose-rate, internally-deposited radioactive material and exposure to acute external radiation. These studies evaluate the role of linear energy transfer, dose rate, dose fractionation, fraction of cells exposed, and animal species and cell type on radiation-induced changes in cellular response to genotoxic insults.

Numerous studies have shown that the relative biological effectiveness (RBE) of alpha particles (e.g., from radon progeny), neutrons, and other high-linear-energy-transfer radiation increases at low doses and low dose rates, and has a strong variation with the biological endpoint under consideration. In cells grown in vitro, the dose-rate effect appears to result from large changes in radiosensitivity



Chromosome damage can be traced with "paints" using fluorescent in situ hybridization.

through the cell cycle, but this effect in vivo may involve other mechanisms. A research effort is under way to investigate the molecular characteristics of damage produced in chromosomes by spatially and temporally controlled irradiation of mammalian cell nuclei. Analysis of damage to single cells by means of such techniques as the "comet" assay will be combined with single alpha-particle irradiation of cell nuclei using the ion microbeam developed at PNL. These studies will be complemented by flow cytometric cell sorting to prepare cells with wellcharacterized DNA configurations. Such studies will provide detailed information on effects of low doses of high-linear-energy-transfer radiation on mammalian cells. Moreover, the approach will allow investigation of the questions associated with the degenerative and repair interactions that occur between cells when a single cell receives a nonlethal radiation exposure. This approach will also allow investigation of the role of the cell nucleus, organelles, cytoplasmic factors, and the extracellular matrix in these processes and in the response to growth factors and other molecular mediators.

The relative frequencies of the types of mutations caused by different types of radiation are also being analyzed. Mutants in specific target genes in cells exposed in vitro to x-rays and radon and in transgenic mice exposed to radon have been characterized, and results to date suggest that, in many cases, the entire gene is deleted. Other mutants have large deletions, and some have small deletions. In studies on LacI mutations in Big BlueTM transgenic mice, the mutation spectrum in radonirradiated mice is markedly different from that observed in unirradiated mice. Approximately one-fourth of the mutations observed in radon-irradiated mice exhibit multiple events within the LacI gene, which are nearly equally distributed throughout the gene.

Absorption of ionizing radiation by an aqueous medium results in the formation of highly reactive radical and molecular species that can damage DNA. Mechanisms of induction of free radical-induced DNA damage resulting from exposure to ionizing radiations or selected chemical agents are being investigated using combined chromatography-mass spectrometry methods. These methods provide sensitive approaches for simultaneously investigating a number of different types of DNA lesions, including products resulting from radical addition, hydrogen atom abstraction, and crosslinking in exposed DNA samples. Radiation-induced DNA lesions including altered DNA bases (i.e., thymine glycol, 8-oxoguanine) and intra- (i.e., 8,5'-cyclodeoxynucleotide) and inter-(i.e., DNA-protein) molecular crosslinks are being characterized. Development of appropriate sample handling techniques and mass spectrometric methodology will ultimately permit studies that will address the formation, repairability, and repair kinetics of specific molecular lesions in DNA extracted from eukaryotic cells exposed in vivo to free radical-generating agents.

In a second area of intensive investigation 5-bromouracil (5-BrU), incorporated directly into DNA, is being used as a molecular indicator reporting π electron clouds created by the stacked purine and pyrimidine bases. Migration of electrons along this " π -way" in DNA is an important, but not well understood, mechanism underlying the distribution of radiation damage and could help to explain how a nonrandom

distribution of DNA damage occurs following energy deposition by stochastic processes. Our data suggest that radiation damage may be preferentially targeted to certain regions in DNA dependent upon the base sequence, and this observation has important implications regarding the ability of enzymes to repair radiation-induced DNA damage.

Using a combination of biochemical and molecular approaches, we are investigating the early irreversible changes in DNA that are involved in tumor development. Although covalent modification of DNA by chemical carcinogens or their reactive metabolites is believed to constitute the initial event in carcinogenesis, the mechanism whereby these adducts alter gene expression and regulation is poorly understood. A number of mechanisms have been proposed, including incomplete or improper repair of damaged DNA bases that lead to point mutations, deletions, or loss of gene regulation. Our basic approach has been to determine the location and influence of bulky chemical adducts on DNA structure and gene expression in an in vitro model system (i.e., the 5S rRNA gene). After chemical modification of the model gene, the location of the adducts indicated that covalent modification reactions prefer certain base sequences. After reconstitution of the 5S rRNA gene with core histones to form a nucleosome, it was found that histone-DNA interactions partially protect the DNA from modification. We are determining whether modified DNA will reassociate with core histones as it is packaged into nucleosomes and ultimately into chromatin. We are also studying whether a bulky chemical adduct on a defined oligonucleotide alters the probability for radiation damage to occur at nearby bases. If an effect is observed, we will expand these studies to determine whether adjacent lesions are repaired efficiently and accurately by mammalian enzymes.

Currently we are extending these studies to the mouse mammary tumor virus long terminal repeat model, which contains a glucocorticoid receptor binding region that regulates expres-

sion of the thymidine kinase gene. Using a cellular system containing this stably integrated construct, we will determine whether 1) chemicallyinduced damage to the receptor-binding region alters the extent of expression of the thymidine kinase gene, 2) the amount of chemical modification is related to whether the gene is in an inactive state or is transcriptionally active when damaged, and 3) chemical modification is site-specifically repaired. Because of the complexity of these studies, we also plan to incorporate molecular modeling and nuclear magnetic resonance studies to provide refined structural information for critical regions of the DNA. Results from these studies should contribute to fundamental information on early events in carcinogenesis and the underlying mechanisms involved.

Not all damage products are removed from DNA with equal fidelity, and mutations result from persistent lesions which escape DNA repair. Within the Enzymatic Processing of Damaged DNA Initiative, ongoing studies are aimed at understanding the mechanisms by which enzyme systems involved in DNA repair recognize and remove different types of DNA adducts, which differ primarily in stereochemical structure. These studies are employing DNA templates with well-characterized DNA lesions within a single site on the template. Studies of DNA repair using site-specific lesions will advance our mechanistic understanding of structure/ function relationships involved in DNA repair, including the roles that DNA sequence and secondary DNA structure play in the recognition and removal of DNA damage by enzymes. In addition, these homogeneous templates are being used to elucidate the identity of human enzymes involved in the repair of DNA damage, which ultimately will help determine possible polymorphisms in the human population that may contribute to disease.

Mechanistic studies of DNA damage, changes in cellular proliferation, mutagenesis, chromosome aberrations, and tumor initiation will be conducted using in vivo and in vitro cellular systems, specific gene targets, and exposures to radon progeny alpha particles,

chemical carcinogens, and chemicals and radiation associated with waste cleanup of nuclear sites. The interaction between high- and low-linear-energytransfer radiation is being studied to identify potential synergistic interactions between these insults. Interactions between the effects of oncogenes, organic solvents, and radiation on the induction of cancers are also being evaluated. For interactions that are identified, additional studies will be conducted both in vitro and in vivo to identify health protection concerns during waste cleanup and other nuclear activities.

An important new direction in our research involves studies on the effects of perturbations in macromolecular structures and their subsequent effects on cell and tissue functions. These functional changes are key elements in the sequence of events leading from the initial interaction of radiation or chemicals with DNA to changes in gene expression and overt health effects. This research is integrating the advanced experimental techniques (such as nuclear magnetic resonance and mass spectrometry) for analyzing molecular structures and the advanced computational and modeling techniques and expertise in the EMSL with our DOE-OHER Biological Research and Radiological and Chemical Physics Research programs. It links these unique resources into a comprehensive research program focused on understanding molecular mechanisms by which DNA damage is caused, modified, and expressed.

Research on Radon and Other Alpha-**Emitting Nuclides** In vitro studies incorporating radiation biophysics, dosimetry, and molecular and cellular biology to understand the mechanisms leading to radiation damage at the cell level are integrated with in vivo doseeffect studies, dosimetry and risk modeling, and carcinogenesis research. This effort is expected to provide insight into the elevated relative biological effectiveness of alpha particles, the dose-rate effects observed in highlinear-energy-transfer radiation, and the variations in relative biological effectiveness observed for different biological endpoints. Emphasis will also



Computer modeling of macromolecular structures is being used to study the dynamics and stereochemistry of enzymes, DNA, and the interaction of DNA with regulatory proteins.

be placed on the development of molecular markers of radiation effects that can be used in epidemiological studies.

A mechanistic understanding of the radiobiology of radon-induced cellular and molecular damage is needed to extrapolate human risk in home environments from existing experimental animal and uranium miner data. This understanding can be derived by linking the in vitro data to the large database available from whole-animal experiments and epidemiological studies. Several major uncertainties exist in making the extrapolation of risk from the mines to the home environment. First, lung cancer occurred in miners who, for the most part, received cumulative occupational exposures of more than 100 working-level months. These exposures were accumulated over a short working history, whereas the residential exposures result in lower cumulative exposures protracted over the lifetime of the individual. Second, in the past, the mine environment had more particles in the air than do homes, resulting in an unattached fraction of radon progeny that differs in the two environments. Third, the miners were exposed to other potential carcinogens

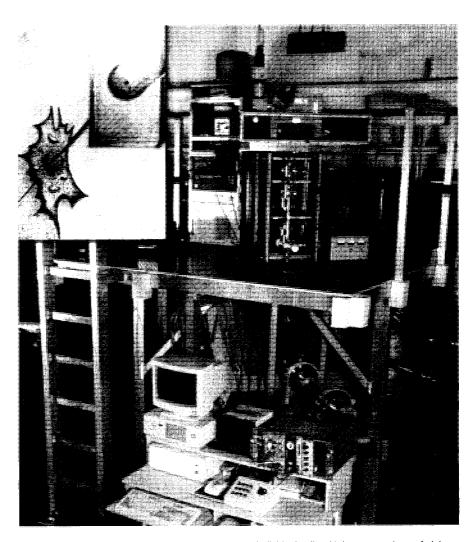
unique to the mine environment. Finally, there were a larger number of smokers among the miners than in the general population. On the biological side of the exposure-dose-response equation, there are some major differences that need to be addressed. The miners were primarily adult white males who were exposed only during the workday, whereas in homes, people of all ages and both sexes are exposed for prolonged time periods.

Radon research is focused on decreasing the uncertainties for extrapolation of experimental animal and uranium miner data to exposures of the general population. Studies on the role of cell proliferation in determining the number of transformed cells produced by radon exposure are being conducted using in vivo systems. These studies are providing essential data for modeling the carcinogenic process. Animal studies include exposures to radon progeny simulating the home environment for comparison with exposures simulating the mine environment. Data on biological damage are being used in kinetic and dosimetry models to estimate the radiation dose to the human respiratory tract cells from environmental levels of exposure. Methods are

being developed to estimate the exposure history of persons for radon epidemiology studies. Research is directed toward understanding the exposure-rate effect in carcinogenesis induced by radon decay products, including studies on the extent of DNA and chromosome damage and repair, the induction-promotion relationships associated with radon and cigarette-smoke mixtures, and the presence, if any, of unique molecular markers associated with radon-induced cancers. Lung cancer tissue from animal studies has been used to determine the role of the p53 tumor suppressor gene in radon-induced tumors. Archived tissues will also be used for assessing the effects of integrated exposure on radon progeny.

In a new series of experiments, strains of mice with widely varying incidences of spontaneous lung tumors are being studied for susceptibility to radoninduced lung cancer. The results of these experiments will test the hypothesis that genetic background modulates susceptibility to radon-induced tumors. If warranted from the results of these initial experiments, subsequent studies with backcrossed strains of mice will attempt to identify the genes that are involved in conferring susceptibility. The primary goal of these experiments will be to provide biomarkers for identifying populations with a higher than normal risk of developing lung cancer.

The microdosimetry of radon in the respiratory tract of humans and animals will be related to the specific energy distribution and "hit" probabilities for the sites and cells involved in lung cancer. This work, along with in vivo and in vitro dosimetry approaches, will advance the state of the art in radon lung dosimetry because current radiation protection methods of dose averaging do not allow comparison of relationships between dose distribution at the cellular or subcellular level and the resulting risk of lung cancer. Microdosimetry research includes calculational methods for assessing the alpha-particle dose to cultured mammalian cells exposed to radon and its decay products. There is increasing evidence that the alpha-particle rela-



Single-particle irradiator developed at PNL to irradiate individual cells with known numbers of alpha particles of defined energy. The part of the cell traversed by the particle (for example, the nucleus) can be precisely controlled (see inset).

tive biological effectiveness for radon-induced lung carcinogenesis is considerably less than 20, the value currently used for radiation protection dosimetry, and our research is focused on this issue.

Microdosimetric studies of energy deposition by radon decay products indicate that large doses occur in the small fraction of the cells that are traversed by an alpha particle, while most cells are undamaged. Evaluation of the biological effectiveness of these random events presents a difficult problem because of uncertainty in determining the numbers of cells actually traversed by alpha particles. To overcome these statistical uncertainties, studies of the effects of small numbers of alpha par-

ticles on individual cells has been undertaken using an alpha-particle microbeam. This microbeam, consisting of a highly collimated beam (<5 micrometers in diameter) from a tandem electrostatic accelerator, can be accurately positioned so that cells can be irradiated with known numbers of particles that pass through specified organelles, and each alpha particle is detected when it traverses the cell. Using the microbeam, the probabilities of cell death, micronuclei production, chromosome damage, and mutation are being determined as functions of the number of particles passing through the cell, the energy deposited per particle, and the time and distance between particle tracks. These data will provide specific predictions of the effects of the nonuniform irradiation produced by radon decay products and will provide the basis for evaluating mechanistic models of high-linear-energy-transfer radiation damage and repair. Future research will include studies on the relationship between the energy deposition pattern and damage at the molecular level. The microbeam facility is available for use by collaborators from other institutions, and several experiments are being planned that will utilize single-cell assay systems developed elsewhere.

PNL's approach to integrating the in vitro dosimetry and biological effects research with the in vivo carcinogenesis and dosimetry research will involve the use of an in vivo and in vitro rat respiratory tract epithelium model. Cells from various regions of the rat respiratory tract will be isolated and grown in tissue culture. These cells will be exposed to radon, and the frequency of cell killing, micronuclei induction, and chromosome aberrations will be measured at various doses and times after exposure. Next, cells from the same regions will be isolated following in vivo radon exposure and the same endpoints evaluated. The measurements will provide biological indicators of effects from in vitro and in vivo exposures. For the in vitro studies, cultures of human respiratory tract epithelium also will be compared with those of the rat, providing one means of extrapolating from experimental animal research to humans.

Life-span microdosimetric and pathobiologic studies of inhaled plutonium in rats and dogs, comparing metabolism and dose-effect relationship data for rats (life span approximately 3 years) with those for dogs (life span approximately 15 years), will provide insight into factors that must be considered in modeling and extrapolating animal data to humans. These factors will aid in predicting risks of low-level exposure to inhaled plutonium and thus will be useful in establishing standards for radiation protection. The results of these studies in rats and dogs exposed to inhaled plutonium and radon will be entered into the DOE National Radiobiology Archives (NRA) at PNL to preserve individual animal dose-effects data and tissues from life-span animal studies for future analysis.

The National Radiobiology Archives, developed and managed by PNL, 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 5 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. Initially, the archives will focus on materials from life-span studies in beagle dogs funded by DOE; subsequent archived material will be from studies with rodents and other species.

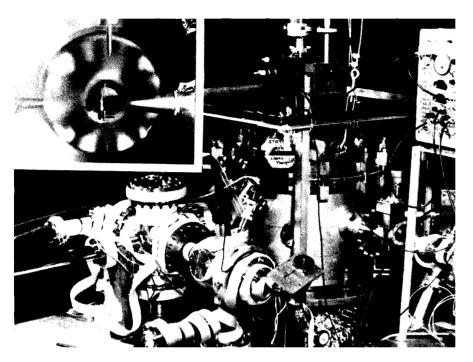
Jointly with staff at the Lovelace Inhalation Toxicology Research Institute and Argonne National Laboratory, we will develop methods to analyze data from long-term radiobiology studies in laboratory animals, focusing initially on National Radiobiology Archives data from studies on beagle dogs. The objective is to increase the information extracted from these studies and to use this information in assessing human health risks. The project includes applying state-of-the-art statistical methods to data generated by the DOE's radiobiology program, further developing both statistical methods and software, improving methods for estimating organspecific doses from internally-deposited radionuclides, and establishing an integrated approach for synthesizing data across DOE laboratories. Statistical analyses of life-span experimental data will focus on organ-specific carcinogenic risks, and will be accomplished by modeling the hazard, or agespecific risk, as a function of dose, age, and other factors. Standardized analyses will include calculating a measure of lifetime risk and its uncertainty.

Studies of Physical and Chemical Processes in Radiation Damage

Research in radiological and chemical physics at PNL is focused on obtaining a quantitative understanding of the fundamental physical and chemical processes that underlie radiation damage in biological systems. Emphasis is on understanding the effects of radiation quantity on the physical and chemical properties of energy deposition, and on the consequences of these effects on biological repair following the absorption of ionizing radiation in mammalian cells. These studies are directed toward obtaining a better understanding of the fundamental processes contributing to the increased relative biological effectiveness of high-linear-energy-transfer radiation and of alpha particles representative of radon exposure.

Current radiological and chemical physics studies include 1) detailed characterization of energy deposition by high-linear-energy-transfer radiation through measurement of ionization products in atomic and molecular constituents of biological material, 2) measurements of electron spectra following their transport in condensed phase targets, 3) development and testing of biophysical models of the effects of radiation and chemicals on biological systems, 4) investigation of the effects of macromolecular structure and chemical environment on radiation sensitivity, and 5) quantification of cellular and molecular response to ionizing radiation as a function of dose, dose rate, dose fractionation, and radiation quality. The modeling effort incorporates the results of our studies on ionization phenomena and dosimetry, as well as molecular and cellular studies on the effects of cellular repair phenomena. Of particular interest is understanding the effect of the initial spatial and temporal patterns of energy deposition on cellular damage and repair.

Emphasis is being given to the study of energy deposition and energy transport in condensed media. Theoretical and experimental studies of electron production and transit in foils and thin



Measurements of low-energy electron emissions from solids are leading to improved track structure models for predicting radiation-induced damage in biological systems.

films of biological material (i.e., water, DNA, etc.) provide information on the mechanisms of energy loss and electron transport relevant to charged-particle tracks in condensed material. The probabilities of specific energy transfer processes are being measured for particles in the energy range where they have their greatest biological effect. The resulting electron cross-section data is used in particle track simulation models in order to characterize the differences in energy deposition patterns of different radiations. Differences between processes in isolated molecules and in the condensed phase are being investigated by the fragmentation of DNA molecules as a function of the number of water molecules bound to specific DNA sequences. New studies are being developed to investigate the effects of macromolecular structure and dynamics on radiationinduced damage. Molecular models of the structure of DNA in the vicinity of specific types of base damage are being used to evaluate the changes in conformation, and to serve as a basis for investigating the interactions between damaged bases and repair enzymes that determine the outcome of repair processes. Such information is needed

to extend current models of energy deposition into cellular environments, thus providing a more rigorous predictive capability for the effects of highlinear-energy-transfer radiation. These studies will use new techniques in biotechnology to provide DNA targets of specific base sequence and structure. New experimental and theoretical capabilities evolving in the EMSL to model dynamic structural alterations introduced by reactions with radiation products will also be utilized. Experimental tests of the effects of torsional stress, temperature, and radical scavenging on the sensitivity of DNA at specific base sequences will be used to validate the results of the molecular modeling.

More stringent tests of evolving biophysical models will require the use of well-characterized biological targets, with greater emphasis on nonlethal effects. Specialized irradiation techniques, such as microbeam and synchrotron irradiation, will be combined with time-lapse video photography, flow cytometry, cell sorting, and molecular biology techniques to study the energy deposition in, and radiation sensitivity of, critical cell components.

The application of special DNA constructs such as supercoiled DNA plasmids and the use of repair-deficient mutants and specially designed hybrid cell lines will provide extensive new data on which to extend current biophysical models. One goal of these studies will be to determine the effects of clusters of energy deposition events on the inhibition of cellular repair processes.

Medical Internal Dosimetry and New Radioimmunoconjugates 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.

PNL 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). We are undertaking new research in radiochemistry and macrocyclic ligand chemistry, immunology, and production of novel alpha emitters to develop more effective alpha-emitting radioimmunoconjugates for cancer treatment. We are also studying new laser-based thermoluminescent dosimetry systems and associated instrumentation for direct measurements of dose and dose rates in the body from medically administered, high-dose levels of radiolabeled antibodies.

PNL 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.

Structural and Computational

Biology A program has been initiated to model structure/function relationships in cytochrome P450 and haloalkane dehalogenase enzymes, with a goal of redesigning these enzymes for a variety of applications in bioremediation and biotechnology. Starting from a structure determined by x-ray crystallography, molecular dynamics simulations are being performed on the docking of both native and nonnative substrates in the enzyme active site. Predictions are then made on the effects of modifications in the enzyme active site on substrate specificity and catalytic efficiency. Site-directed mutagenesis procedures are being used to genetically engineer enzymes with modified active sites, followed by tests to determine the resultant changes in catalytic functionality.

Coupled theoretical and experimental approaches are currently being used to redesign the cytochrome P450_{cam} enzyme, which hydroxylates camphor, to confer catalytic capabilities for other substrates of interest in bioremediation applications. Molecular dynamics simulations have been performed to obtain information on the complementary and dynamic motions involved in P450_{cam} interactions with its native camphor substrate and with norcamphor and other camphor analogs. On the basis of these simulations, predictions were made of specific amino acid substitutions in the P450_{cam} active site that would increase the enzyme's efficiency for hydroxylating norcamphor and would lead to preferential hydroxylation in the C-3 position of the substrate. In collaborative research with scientists at the University of Illinois, the validity of these predictions was confirmed by constructing mutant P450_{cam} enzymes using site-directed mutagenesis. Mutant enzyme in which the Phe-87 residue of P450_{cam} was replaced by a bulkier tryptophan residue, or Thr-185 was replaced by phenylalanine, exhibited an electron transfer coupling efficiency for a norcamphor substrate that was twice as great as the coupling exhibited by the native enzyme. Simulations of L-norcamphor and D-norcamphor bound to P450cam correctly predicted a difference in regiospecificity of hydroxylation

prior to the actual experimental testing of the mutant enzymes. Efforts are also under way to redesign P450_{cam} for dehalogenation of trichloroethane.

Human Genome Research Methods are being developed at PNL to aid in interpreting and understanding the vast amount of information being generated as a result of the human genome program. A graphics user interface called GnomeView has been developed to graphically represent 1) the hierarchy of available information from the chromosomal level, 2) the genetic and physical mapping level, and 3) the actual DNA sequence level. Color graphics images of database information provide a global view that can lead to new insights and discoveries about the nature of the human genome. Algorithms for efficiently encoding and rapidly accessing different hierarchical categories of genetic information have been developed using a network database management system. The chromosome graphics system can be used in a workstation environment. The system accesses database centers. such as GenBank and Genome Data Base, as primary information sources. Genetic information contained in human chromosomes has been rendered into color graphics. GnomeView is currently being beta tested at several universities and national laboratories and will soon become the primary informatics tool used in the DOE human genome research program.

New approaches are being developed at PNL with the potential for highspeed 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 an ion cyclotron resonance (ICR) 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 many 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 with masses as high as 2 megadaltons 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.

Analytical Studies PNL has several research programs focused on the development and enhancement of techniques for the analysis of chemical and elemental species of importance in research on environmental pollutants and human health effects. These methods generally concentrate on mass spectrometry and laser-based analytical methods. In addition to the fundamental study of analytical methods, PNL has initiated research into highresolution spectroscopy of small molecules to increase our understanding of photoionization mechanisms and pathways. We are also proposing to establish a facility at PNL for ultratrace bioanalytical research.

Mass spectroscopy research has focused on several key areas, one of which is the development of new methods for separation and detection of adducted constituents of DNA by capillary electrophoresis (CE). These approaches are based on techniques developed at PNL that combine capillary electrophoresis and mass spectrometry. The new capillary electrophoresis approach provides extremely high-resolution separations of thermally labile and charged substances such as DNA and possesses several advantages over other common separation techniques. Techniques such as these are required for DNA adduct characterization because of the small sample sizes and the extremely low concentrations that must be analyzed. The capillary electrophoresis/mass spectrometry technique provides extremely sensitive detection in the range of attomolar (10⁻¹⁸) to femtomolar (10⁻¹⁵) levels along with very high efficiencies. In addition, a new approach to mass spectrometric detection based on a unique orthogonal time-of-flight mass spectrometer is being developed for ultrasensitive detection.

Several efforts related to mass spectrometry research have been concerned with the analysis of large biomolecules in complex mixtures. PNL's Large-Molecule Mass Spectrometry project has focused on the use of highefficiency separations methods and the direct interfacing of these methods with mass spectrometry. Electrospray ionization, laser desorption, and other ionization methods are coupled with various separations techniques to provide new capabilities to detect, identify, and quantify compounds with very high molecular weights. This work, which has relevance to health effects research, is currently being developed as a component of the EMSL. Initial results indicate the potential for these methods to provide greatly improved sensitivity, extended molecular weight ranges, and previously unobtainable structural information. The capability has already been demonstrated for ultrasensitive analysis of macromolecules with masses of several megadaltons. In addition, it has been shown that noncovalently linked complexes of macromolecules can be detected under physiological conditions using ESI-MS. Powerful new methods for the characterization of protein-protein interactions and protein

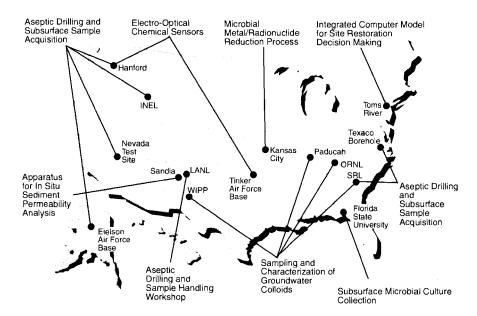
inhibitors are also being developed. Other applications that are being explored include the use of mass spectrometry techniques for the analysis of interactions between damaged DNA and repair proteins and for the chemical characterization of multiply damaged sites in DNA.

Environmental Research Environmental research is focused on developing a fundamental understanding of key processes controlling chemical behavior and biological stress in terrestrial and subsurface systems. This understanding drives the development of emerging new concepts for subsurface remediation and landscape-level impacts from environmental restoration. The research builds on PNL's technical strengths (geochemistry, microbiology, molecular biology, hydrology, and quantitative ecology), which are applied in interdisciplinary programs. Unique intermediate-scale and field facilities, in conjunction with mathematical modeling and remote sensing, are used to examine the integrated effects of environmental processes, validate predictive models, and extrapolate results to the system level. These efforts are reinforced by major new initiatives focusing on microbial biotechnology, environmental restoration, and global change.

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, the Environmental Science Research Center plays a special role in the DOE Subsurface Science Program (SSP) by exploring new concepts and approaches for understanding and restoring subsurface systems, supporting intermediatescale and field research to scale fundamental knowledge for applications in heterogeneous subsurface environments, reaching out to the scientific community to bring new ideas, scientific disciplines, and institutions into the Subsurface Science Program,

and promoting technology transfer to DOE sites and industry. Understanding how natural processes are coupled and scaled in heterogeneous subsurface environments helps ensure that fundamental knowledge is available for the timely resolution of long-term environmental problems faced by DOE. A major focus of Subsurface Science Program investigations by PNL 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 Hanford and other DOE sites. New emphasis is being placed on how these organisms may have adapted. evolved, and survived over millions of years under the austere environmental conditions of the deep subsurface. This research is 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 under microaerophilic 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 producing new products, such as dyes and antibiotics. As part of its new programmatic research in microbial biotechnology, PNL is participating in a consortium to generate DNA sequence information from microbes. The focus at PNL will be on obtaining the DNA sequence data required for developing new industrial, environmental, and energy-related molecular processes.

Examples of other Subsurface Science Program research under way 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



The PNL Environmental Science Research Center is responsible for transfer of fundamental knowledge developed in the Subsurface Science Program for application by DOE, other federal agencies, and industry.



This formation is the focus of a study of microbial origins in the deep subsurface. Thermal effects at the time of formation sterilized the structure and thus provide a mechanism for dating the time microbial life began.

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.

Understanding and predicting the longterm effects of human activities on ecological structure and function require new knowledge about how terrestrial systems operate from the molecular to the landscape level. PNL research in terrestrial sciences has long been committed to collaboration among the different scientific disciplines needed to understand how multiple natural processes act together and to interpret this information over unprecedented temporal and spatial scales. A new focus is the use of molecular techniques to examine specific mechanisms that control ecosystem responses to environmental change. Knowledge is also being developed from observations and experimental research at the lysimeter (intermediate) and field scales. 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.

Atmospheric and Climate Research

The objective of the DOE-OHER's **Environmental Sciences Division** (ESD) 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 PNL provides significant technical leadership. The Global Environmental Change 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.

PNL's Global Environmental Change Initiative, described earlier, directly supports the technical objectives of the Environmental Sciences Division on environmental change. Components of the Environmental Sciences Division represented at PNL include the ARM program; the Core Carbon Dioxide Research program; the Computer Hardware, Advanced Mathematics and Model Physics (CHAMMP) program; the oceans research program; 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. PNL 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.

PNL 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 (ACP) and the Atmospheric Studies in Complex Terrain (ASCOT) program. PNL 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. PNL'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 PNL focuses on studying basic geophysical processes and developing data that are critical for understanding global and regional climate change. PNL is supporting the DOE goal of increasing the reliability and scientific defensibility of general circulation models (GCMs) for predicting the timing and magnitude of climate change on regional and global scales by energy-related anthropogenic emissions. Current research at PNL 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

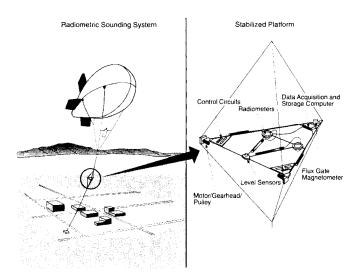
ocean and the atmosphere, the development of the next generation of computational resources for predicting climate change, and an assessment of the methods by which an anthropogenic signature might be found in current and future climate records.

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 general circulation models by enhancing the treatment of cloud radiative forcing and feedbacks in the atmosphere and the direct and indirect effects of aerosols. ARM is focused specifically on two aspects of that improvement: 1) the treatment in general circulation models of radiative transfer under clear sky, general overcast, and broken cloud conditions; and 2) cloud formation, maintenance, and dissipation in general circulation models. PNL is responsible for coordinating and integrating the field and laboratory measurement programs, modeling studies, and data analysis activities of

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. 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 general circulation models. These improvements are expected to greatly enhance the accuracy of long-term general circulation model predictions at the important regional scale.

The first ARM site is centered near the town of Lamont, Oklahoma, and began operation in May 1992. The next two sites are planned for the tropical western Pacific and the North Slope of Alaska. The occupation of these sites is scheduled to last 10 years. During the next few years, PNL will be engaged in a series of research projects that address key ARM issues. Research is continuing on the development and testing of improved procedures for parameterizing the radiative properties of clouds, and a new project has been initiated to study the effect of the southern Great Plains low-level jet on cloudiness over that region and how well these conditions are predicted by models. Research is also under way to improve methods by which point measurements can be extrapolated to give spatially-averaged surface flux values and to improve methods for accounting in models for the efforts of subgridscale variability. Data from a network of multi-spectral rotating shadowband radiometers are being used along with satellite remote sensing data to determine the quantitative relationships between clouds and their effects on radiative transfer. A tethered balloon profiling system for measuring radiative profiles through the atmospheric boundary layer is also nearing completion. This latter device is designed to obtain vertical profiles of upwelling and downwelling short-wave and longwave radiation, as well as a number of other important meteorological variables. The system will operate under a range of conditions, and it will enable observations to be made in a region of the atmosphere that is not easy to monitor with current remote sensing techniques.

During the next few years, data collected simultaneously by aircraft and at CART surface sites will be used to improve the methods by which point measurements can be extrapolated to give spatially-averaged radiative flux



A new tethered balloon instrument has been developed at PNL to measure vertical radiative fluxes as part of the DOE Atmospheric Radiation Measurement program.

values. Theoretical analyses of the parameterization of the volume-integrated effects of subgrid processes will be tested with data from CART sites. A principal goal of the ARM program is to improve the treatment of clouds in climate models, including their effects on radiative transport. Research has been undertaken to develop and test improved parameterizations of the effects of various types of clouds.

As the ARM program expands in the coming years to include satellites and unmanned aerospace vehicles (commonly known as UAVs), the efforts at PNL 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 PNL, along with the ARM data archive at Oak Ridge National Laboratory.

The goal of CHAMMP is to improve the computational throughput of early 1990s climate models by a factor of 10,000 before the end of this century. Scientists at PNL are participating in evaluating various massively parallel computer architectures and developing codes for the next generation of general circulation models and related models that take full advantage of these architectures. Considerable effort will be given to devising highly

efficient algorithms and parameterizations for atmosphere-surface exchange processes, ocean convection, and the integrated effects of clouds. Information theory will be used to determine the limits of predictability of climate changes due to internal and external forcing mechanisms.

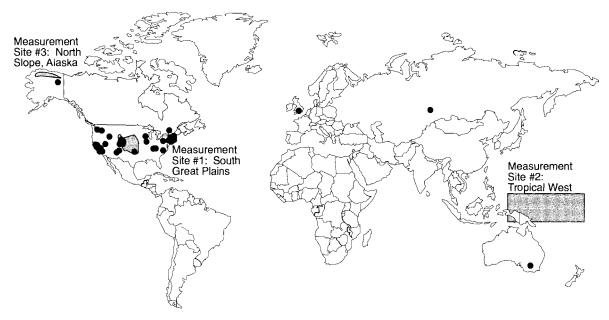
Convection processes, deep convection, and sea ice-convection interactions, are important transfer processes in the climate system. Oceanic deep convection is currently parameterized in ocean circulation models by physically unrealistic algorithms. These parameterizations limit the ability of ocean general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

Under the carbon dioxide program highresolution, three-dimensional process modeling is being performed by PNL 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.

In related research, turbulence modeling of the ocean surface mixed layer is being performed to examine how wind, waves, and surface heat flux affect the structure and growth of the 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 aimed at improving the representation of the surface mixed layer in ocean general circulation models. As with much of PNL's global change research, this work is intended to produce improved methods for parameterizing these processes in global-scale models.

PNL research in the ocean sciences component of the basic carbon dioxide program is 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 largescale 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



Atmospheric Radiation Measurement program facilities.

science team to guide the conduct of a global survey of carbon dioxide in the oceans, PNL is assisting the DOE in coordinating its research activities with other ocean programs by assessing the results of ongoing research and establishing priorities for future research in this area.

Carbon dioxide emissions research at PNL 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 its long-standing work on greenhouse gas emissions modeling. PNL 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 build-up of greenhouse gases, subsequent climate change, and on the global energy, industrial, and agricultural economy.

In another aspect of PNL's research on the socioeconomic effects of global environmental change, PNL 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) assess-

ments 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 is scheduled for completion in time for the next meeting of the IPCC in Berlin.

During the past year, PNL 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 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. It will be submitted to the U.S. Global Change Research Program for possible future implementation.

PNL research on global change addresses the reduction of key uncertainties in estimating the magnitude, timing, location, and impact of climate change in response to national and global energy-related emissions. These research projects build on the technical base established by other components of the Environmental Sciences Division, especially those in the atmospheric sciences program at PNL.

Atmospheric Sciences Research

Atmospheric research conducted at PNL is centered on two related areas, atmospheric chemistry and boundary layer meteorology. Major atmospheric chemistry studies are being conducted on the chemical processing, transport, and removal of air pollution in DOE's Atmospheric Chemistry Program. Atmospheric boundary layer research on surface energy exchanges over inhomogeneous surfaces and the interactions of thermally-driven circulations induced by local terrain features with larger scale flows is being carried out as part of DOE's ASCOT program. Much of our research in both of these long-term, multilaboratory programs is carried out in collaboration with other agencies and universities.

In the 1990s, the Atmospheric Chemistry Program is moving toward research on large spatial and temporal scales to address intercontinental and global pollution concerns. Studies over the North Atlantic and North Pacific Oceans and in the Arctic will investigate the oceanic and continental fates of energy-related pollutants on an international scale because of the extent to which energy production and use influence global atmospheric chemistry. Key areas of research will include processes regulating tropospheric ozone concentrations in pristine locations, the production of aerosols, the interactions of aerosols with clouds and radiation, and the exchange of material between the troposphere and stratosphere. PNL's 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.

The cornerstones of PNL's capabilities in its role in the Atmospheric Chemistry Program include:

- aircraft measurements over the large distances and depths in the atmosphere necessary to characterize globally significant gaseous and particulate species and their chemical and physical behavior
- global chemistry modeling of detailed chemical reactions taking place on scales from single-storm processing to transformations occurring over continental and global scales of motion.

Large-scale experiments on the tropospheric chemical processing and redistribution of contaminants will rely heavily on Battelle's Gulfstream-1 turboprop aircraft. This newly designated DOE research aircraft will be available to scientists in the DOE laboratory system as well as to university researchers participating in the Atmospheric Chemistry Program and other DOE research programs such as the ARM program. Real-time measurements of trace gas concentrations have recently been enhanced through the installation of a triple quadrupole mass spectrometer that permits analysis and real-time mapping of concentrations at parts-per-trillion levels of a broad spectrum of pollutants and naturally occurring gases. Aerosol concentration and size distributions are measured with two externally-mounted particle measuring probes for two size ranges of aerosols and cloud droplets, coupled with ultrafine particle counters. Further development of the research aircraft facility will include state-of-the-art real-time direct and remote sensing chemical detectors for measuring chemical fluxes in the troposphere.

Detailed descriptions of gaseous and aqueous-phase chemistry in storm models have been expanded to intercontinental and global scales. Global circulation dynamics are being coupled to advanced chemical transport models for assessing the magnitude and rate of chemical change and the global budgets of pollutants. Included in these models are the natural chemical emissions into the air from the ocean and biosphere. Future improvements to the models include better param-

eterizations of subgrid-scale cloud dynamics, chemistry, microphysics, and deposition. Adaptation of this modeling effort to high-performance, massively-parallel computer systems is also being carried out.

Advanced measurement and modeling capabilities will be crucial in studying the roles of anthropogenic and biogenic atmospheric chemicals in tropospheric ozone and aerosol budgets, especially over the oceans where striking differences from continental distributions prevail. Through the interaction of short- and long-wave radiative fluxes with aerosols, clouds, and trace gases over both continents and oceans, PNL's research supporting the Atmospheric Chemistry Program will be closely linked with the goals of the ARM program.

ASCOT is a multilaboratory program that is being phased out by DOE. PNL is a principal participant with responsibility for program direction and interlaboratory coordination. ASCOT involves scientific research in atmospheric transport and dispersion, focusing experimental, theoretical, and modeling efforts on atmospheric boundary-layer and mesoscale processes. A high priority in the ASCOT research program is to gain understanding that will permit forecasting of boundary-layer conditions hours in advance, given the transient airflow and turbulence structures that change abruptly under the influence of complex terrain and strong energy-transfer processes at the surface. To accomplish this objective, scientific emphasis in the ASCOT projects at PNL is centered on the measurement and modeling of energy exchange processes as they contribute to mesoscale circulation development and evolution.

PNL's ASCOT research, which previously focused on nighttime drainage and daytime transition conditions in isolated valleys, is now concentrated on the multiscale interactions of exposed valley circulations with overlying regional and synoptic airflows and on multiple valley systems. The final phase of the ASCOT program will be

the analysis of data from recent experiments on airflows in the vicinity of Oak Ridge, Tennessee, and DOE's Rocky Flats Plant in Colorado to understand the interaction between synoptic, regional-, and local-scale winds, which are thermally and mechanically driven.

As the ASCOT program winds down. PNL research in boundary layer meteorology and air-surface exchange processes will be redirected. Energy and mass exchanges between the earth's surface and the atmosphere are crucial to the earth's climate. Our research will emphasize their proper simulation in general circulation and climate models through efficient, accurate parameterizations. PNL will also develop a tighter coupling between atmospheric chemistry and boundary layer transport and dispersion processes. 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 interactions. We will apply our capabilities to measure and characterize the structure of the boundary layer to sitespecific investigations in which complex terrain exerts a significant control on the dispersion of pollutants.

PNL's research and program management activities in global change and atmospheric sciences are indicative of the coordination that exists between multidisciplinary research components at the Laboratory.

Basic Energy Sciences (KC)

Several areas of research are conducted under Basic Energy Sciences to support DOE energy, environmental quality, national security, and competitiveness core businesses.

Chemical Sciences PNL research programs funded by the Division of Chemical Sciences support the full spectrum of DOE core businesses (environment, energy, international competitiveness, and national security) by providing a fundamental understanding of chemistry and chemical physics. The new knowledge resulting from our research of basic chemical processes supports national initiatives, such as new mate-

rials technology, biotechnology, and advanced processing and manufacturing technology. Our basic research in chemistry and chemical physics increasingly is becoming focused on new ways to quantify problems and make informed decisions regarding DOE objectives in energy, environmental quality, and environmental restoration and waste management.

PNL receives programmatic funding from the Fundamental Interactions branch to develop basic understandings of kinetics, dynamics, molecular structure, and chemical reactions. Our primary focus is in condensed phase chemistry. Both experimental and theoretical studies on systems ranging from model systems to multidimensional matrices are conducted in an effort to understand complex chemical systems in both the natural and manufacturing environments. This research is being performed in the interim EMSL facilities.

Research supported by the Processes and Techniques branch focuses on two areas that directly relate to DOE energy and environmental business areas. First, PNL staff are involved in research to further the fundamental understanding of specific physical-chemical phenomena that are key to advanced separations methods and analytical techniques. This research is vital in the development of chemical separation and processing methods in supercritical fluids, and is key to advances in materials synthesis and manufacturing processes and development of new analytical methods that exploit mass spectrometric and x-ray absorption techniques of importance in waste analysis and processing technologies. Second, we are investigating the fundamental physical chemistry phenomena underlying energy conversion processes for coal. This research will help us understand the energetics and other chemical mechanisms involved in conversion processes (e.g., liquefaction) that will help the nation make more costeffective use of the energy in its coal reserves.

Molecular Theory and Modeling

Developing the knowledge base needed to address the environmental restora-

tion issues of the U.S. Department of Energy requires a fundamental understanding of molecules and their interactions in isolation (gas phase) and in liquids, on surfaces and at interfaces (condensed media). Research in the Molecular Theory and Modeling program involves the application of stateof-the-art methods to the solution of important environmental problems as well as the development of new theoretical methods and modeling and simulation techniques. The program is focused in four areas: cluster chemistry, solution-phase chemistry, separations chemistry, and interfacial chemistry. A common element in each of these focus areas is the need to understand molecular processes in aqueous solutions or at the interface between aqueous solutions and environmentally important materials, such as nonaqueous phase liquids, minerals, and glasses. In addition, there is a small research effort in gas-phase chemistry.

Modeling Aqueous Clusters Research in cluster chemistry is focused on the structure and properties of aqueous clusters and on the energetics and dynamics of molecular processes involving such clusters. Molecular clusters offer a unique opportunity to examine the transition from the gaseous phase to the condensed phase. 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 interaction 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 aqueous clusters. This approach is currently feasible for clusters involving six or less water molecules. In addition, methods used to simulate solution-phase processes are being tested for clusters against the more accurate methods. Current activities are focused on the structure and energetics of water clusters, anion-water clusters (H-, F-, Cl-, OH-, CN-), and salt-water clusters (LiF, LiCl, NaF, NaCl).

There are also activities in this area directed toward the development of improved techniques for describing the electronic structure of molecules.

Modeling Aqueous Solutions Research in solution chemistry is focused on the structure of molecules and the energetics and dynamics of molecular processes in aqueous solutions. In these studies equilibrium properties such as average structural properties (e.g., radial distribution functions and coordination numbers) and average energetics (e.g., enthalpies and free energies of formation) are obtained from standard statistical mechanical methods such as Monte Carlo and molecular dynamics simulations. In addition, time-dependent properties (e.g., residence time of solvent molecules in the first solvation shell and correlation functions) are also obtained from molecular dynamics simulations. Molecular dynamics simulations provide a well-developed framework for describing the dynamics of molecular processes in large complex systems. This method has been particularly effective in simulating the time dependent properties within liquids.

Methods for computing the rates of activated chemical reactions in solution are also being developed. These methods 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 reaction involve proton transfer 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 aqueous solvation of atomic and polyatomic ions, the energetics of ion association in water, and the effects of nonequilibrium solvation on activated chemical reactions.

Modeling Molecular Ligating Species
Research on molecular ligating agents
is concentrated 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 radionuclides.

Research in this effort is currently 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 application of molecular dynamics simulations with classical force fields to model the ion-crown ether association in aqueous solution. The third approach combines semiempirical electronic structure and classical force field methods in a hybrid quantum mechanical/molecular mechanical approach that is coupled with molecular dynamics to simulate aqueous solutions of ions and crown ethers.

Current activities are focused on the binding of alkali ions (Li⁺-Cs⁺) to 18-crown-6 ether and the modeling of the effect of counterions on the cation-crown ether binding.

Modeling Solid-Liquid Interfaces

Research on the solid-liquid interface is focused on molecular processes at the water-mineral and glass/ceramic-water interface. The first of these efforts is a joint project with staff in the Solid State Theory and Modeling Group and is important to understanding the binding of contaminants to the soil. The second provides information on the dissolution and degradation of materials that are being proposed for long term isolation of radionuclides.

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 the binding and dissociation of water on magnesium oxide surfaces and the modeling of bulk and surface properties of metal oxides based on the ab initio calculations.

Covalently bonded materials such as glasses are being treated using a hybrid of quantum mechanical and classical

force fields. Recently, a model potential that treats the bonding and non-bonding interactions separately was developed to specifically address the questions related to the geometric structure of covalently bonded liquids and amorphous materials. Current activities are focused on benchmarking these models for silicon surfaces and on extending these methods to binary mixtures.

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 have an impact on problems as important 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 is engaged in a significant effort that focuses on the dynamical aspects of aqueous solutions. No solvent is more important than water, and few have such a profoundly strong interaction with most dissolved molecules, the energetics of which often control aqueous reactions. The acidbase 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.

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, will be combined with sampling methods

ranging from molecular-beam to highpressure techniques.

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.

Supercritical Fluids Research The goal of our supercritical fluids project is to provide a basis for improved molecularlevel understanding of condensedphase 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 reaction processes 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. Much 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

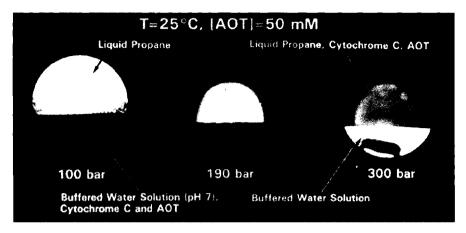
chemical separations and in catalysis. Practical application of this work is already materializing, with the development of reverse micelle technology for the textile industry, the use of micelle systems to model formation damage in petroleum reservoirs, and the incorporation of micelles in producing nanoscale particulate materials for industry.

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. 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.

New work in this area will investigate the use of a dual laser ablation system to separately and sequentially vaporize and ionize sample constituents for analytical observation. 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 to efficiently ionize the ablated material will allow optimization of both steps. Magnetic field confinement of ablated plume material is expected to dramatically enhance plume-sample fidelity and analyte sensitivity. Ultimately, application of this knowledge will result in improvements in rapid, remote, multicomponent analysis of solid samples.

Research is also conducted to develop a basic understanding of hightemperature surface chemistry in chemical analysis and to elucidate the fundamental physics and chemistry of new and novel ion sources for mass spectrometry. The work seeks to provide understanding of hightemperature surface processes which



Extraction of cytochrome C from an aqueous solution using a reverse micelle phase formed in propane.

control vaporization, dissociation, and ionization so that the sensitivity, selectivity, and reliability of analytical methods can be improved. Work in this program addresses the basic physics and chemistry of two new sources for mass spectrometry. The first involves a gentle, specific approach to form negative molecular ions through electron capture via photonexcited molecular electronic states. The second source explores the utility of a furnace-based, combined atomization-ionization source that incorporates a plasma discharge to facilitate uniform ionization of evaporated samples. This source, and others like it, may find particular utility for direct solids analysis.

Free Radical Chemistry of Coal

Research under the Free Radical Chemistry of Coal program develops fundamental understandings of reactions of coal-related organic structure under coal liquefaction conditions and detailed structural information for coal. The primary objective of the program is to improve the base of knowledge of the structure and reactivity of coal in order to provide a predictive basis for improving coal liquefaction processes based on the fundamental understanding (i.e., kinetics, mechanisms, and thermochemical data) of the chemistry of reactive organic intermediates. Studies undertaken by the program involve a substantial effort in organosulfur chemistry and address problems of use of high-sulfur coal in

liquefaction and combustion. Other studies of the free radical chemistry of coal-related molecules examine detailed molecular-level variables for optimization of liquefaction yields and product selectivities.

Present efforts have led to new insights into the molecular structure of coal and to the principles of organic reactivity that describe the complex chemical reaction mechanisms operative in coal conversion processes. Future efforts will further enhance the state of knowledge of the structure and reactivity of coal and will focus advanced methods in laser spectroscopies, kinetics of reactions of reactive intermediates, nuclear magnetic resonance spectroscopy, and quantum chemistry to develop a predictive molecular-level, global predictive basis for coal conversion chemistry.

Materials Sciences Materials research at PNL 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. New capabilities will build on a substantial base of expertise and experience in 1) thin-film optical materials and protective coatings and 2) synthesis and characterization of advanced nanoscale composites, ceramics, and intermetallics. 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 PNL. The effects of aqueous, gaseous, irradiation, and temperature environments are being evaluated.

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.

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.

Evaluation of the mechanisms of stress corrosion cracking in advanced materials is another research activity in this area. The performance of amorphous metals, metal and ceramic composites, structural ceramics, and polymers can be degraded by the environment. Research on the stress corrosion cracking behavior of metal-matrix and ceramic-matrix composites is currently ongoing.

Another research activity in the area of environmental effects on materials addresses surface reaction phenomena of ceramic materials in aqueous environments. This activity 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 molecularlevel 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.

Thin-film optical materials have long been an important area for PNL. The basic research that supports this area focuses on understanding the relationship between thin-film structure and optical properties. Dielectric films (having identical chemical composition) exhibit optical and electronic property variations. These variations are influenced by film microstructure and strain heterogeneity that develop in response to deposition conditions and interfacial interactions. This research focuses on the experimental identification of chemical, physical, and structural factors that influence the optical response of thin-film materials.

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 research focuses on two unique routes to making new materials. The first involves using inorganic polymers as coatings on submicron ceramic powder, a process that allows high-quality nanoscale composites to be made. The second approach involves mimicking biological processes to produce better materials.

Particle interactions and packing efficiency during consolidation are influenced by the presence of polymer molecules introduced during the dispersion stage of colloidal processing. Upon adsorption, polymer-polymer repulsive interactions between adjacent particles act to prevent particle aggregation and thereby maintain a

stable dispersion. Polymers also impart a lubrication property to the system and can moderate shearing forces between particles by controlling slip at the polymer-polymer or polymer-particle interface. Through these interactions, polymers can direct microstructural development of the ceramic, resulting in the evolution of a material with low void density and increased fracture toughness. Although substantial effort has been expended searching for the optimal organic processing aid, insufficient research has been directed to develop an understanding of the chemical forces responsible for this behavior.

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.

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.

PNL'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



Imitating the natural processes by which bones, teeth, and shells are grown at low temperatures can produce low-cost ceramic coatings with superior properties and adhesion to metal, glass, or polymer surfaces.

modified substrates, natural and synthetic polymers have been mineralized, and the mechanism for surface-promoted mineralization has been elucidated. Closely allied with biological mineralization is the formation of very small crystal grains produced in vesicles. PNL has grown crystals inside artificial vesicles and micelles with the objective of making monodisperse, submicron crystals for use in conventional sintered ceramic materials.

A new area of research at PNL involves the microstructural effects on materials deformation that includes superplastic deformation of lightweight materials. There is a new program this year which lends technical support to the USCAR program on lightweight vehicles.

The primary growth areas for materials research are synthesis, processing optimization for waste minimization, and materials/environmental interactions. These growth areas will be pursued in conjunction with the EMSL.

BES-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 PNL's participation in the DOE Center of Excellence for the Synthesis and Processing of Advanced Materials.

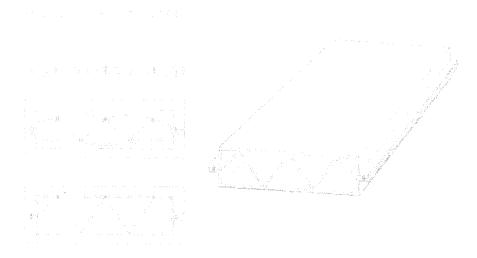
Engineering and Geosciences BESfunded engineering and geosciences research at PNL is focused on three key research areas: 1) geochemistry of mineral surfaces, 2) geoscientific data integration, and 3) radiative heat transfer mechanisms. The majority of research is focused on low-temperature geochemistry, 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. At DOE direction, research in aeronomy and

solar-terrestrial energy transfer and interactions has been completed and research in geoscientific data integration using virtual reality has been significantly reduced or discontinued.

A number of new theoretical and experimental investigations are underway exploring the geochemistry of the mineral-aqueous interface, the structure and reactivity of minerals, and the nature of complex fluids. Research projects on the structure and reactivity of minerals include a theoretical study of the interactions of ferric oxyhydroxide surfaces with water, an experimental examination of the growth rate of different crystallographic faces of calcium carbonate using atomic force microscopy, and a project on the quantum chemistry of layered silicates. Several of these projects contribute to the research portfolio of the Environmental Dynamics and Simulation program within the EMSL. With the assistance of LDRD funds, new concepts are being developed to relate the molecular-scale knowledge gained about growth of individual crystallographic zones of carbonates to electrostatic models of sorbate interaction on such surfaces, and to assess the structure and energetics of organic ligands at aqueous-mineral interfaces (e.g. alumina). A continuing effort is focused on expanding the solid earth geophysics programs, with emphasis on developing a new project which uses geologic process models as a basis for prediction of solute and colloid transport. A project was recently completed on the use of virtual environments to handle integration of large geoscientific data sets.

Researchers from the EMSL and PNL's Earth and Environmental Sciences Center have been funded by the BES Division of Engineering and Geosciences since FY 1993 to study the surface chemistry of carbonate minerals. The purpose of this program is to develop a fundamental, microscopic understanding of the structure and chemistry of carbonate surfaces.

Our focus is on how different surface sites influence crystal growth and dissolution and on interactions with impurities and contaminants found in the environment. The project involves



PNL researchers are collaborating with universities and industry to evaluate superplasticity in modified aluminum alloys.

an interdisciplinary theoretical and experimental effort in three areas: 1) development of semiempirical models for the structure and chemistry of the calcite cleavage surfaces; 2) vacuum studies of the structure and chemistry of the cleavage surface; and 3) comparison of surfaces in vacuum with those in model geochemical environments. The most recent efforts have focused on identifying the roles of different surface sites in the dissolution of calcite in water and on the influences of adsorbates and solution impurities on calcite dissolution rates at these sites. An atomic force microscope (AFM) equipped with a flow-through cell is being used to measure dissolution and growth rates in solution.

Advanced Energy Projects PNL periodically submits research proposals to the Division of Advanced Energy Projects; these proposals involve research and development concepts requiring further investigation to qualify for funding by other divisions.

Future submissions to the Division of Advanced Energy Projects are expected in such areas as energy conversion, fuels processing, power source effluent remediation, or fabrication techniques. During the past year, short "white papers" describing potential advanced energy projects were submitted for review. Discussions are continuing prior to submission of a peer reviewable research proposal.

Magnetic Fusion (AT)

The Magnetic Fusion program at PNL 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 PNL'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, vanadium alloys, SiC/SiC composites, copper alloys, and beryllium. The

tritium breeding performance of lithium ceramics (solid breeders) are also being evaluated.

This materials development program requires a research staff with expertise in radiation effects, facilities for handling and testing radioactive materials, and reactors for irradiating materials. PNL 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 PNL but also for the U.S. and international fusion community. Radiation experiments with joint PNL 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. PNL's international involvement includes participation in the ITER program and official international collaborations with the Japanese MONBUSHO program and with researchers in Russia. Also, the current international collaboration with MONBUSHO is scheduled to be complete in June 1995 but an extension to this collaboration has been negotiated. Funding for Phase III is expected to begin in April 1995 and is expected to be 30 percent more than Phase II. The structural materials effort at PNL is expected to remain constant for the next 5 years while there is some uncertainty regarding the future of the solid breeder task because of the loss of the Fast Flux Test Facility (FFTF).

DOE-ER Laboratory Technology Transfer Program (KU)

This program continues to grow in importance as a means of enhancing the contributions of the DOE laboratories, and specifically, technologies arising from laboratory programs, to U.S. competitiveness. The majority of the technologies supported by the program at PNL have linkages with Office of Energy Research funded activities. However, because of the strong linkage

of the Laboratory Technology Transfer Program to DOE's industrial competitiveness core business area, a detailed description of the program is presented later in the Industrial Competitiveness section of the Institutional Plan.

Nuclear Physics (KB/GB)

In FY 1994, experimental data were obtained for the half-lives, delayed neutron emission probabilities, average neutron energies, and beta-delayed charged particle emission properties of extremely neutron-rich nuclides in the light mass region (Li-Cl isotopes). This work provides experimental data for comparison to theoretical models of beta nuclides with unusual ratios of neutrons to protons. PNL staff are involved in discussions and planning for a National Radioactive Ion Beam Accelerator project, and Laboratory staff are also supporting the Canadian ISAC proposal to build an exotic beam accelerator facility at TRIUMF. In FY 1994 PNL received \$120,000 from the DOE Office of Medium Energy Physics in support of this research.

High Energy Physics (KA)

The measurement of the double-beta decay of germanium-76 is considered by most physicists to have 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 PNL; 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 (\$30 million worth) to the United States for fabrication into very large ultralow-background detectors by PNL. The first two of these detectors, weighing more than 2 kilograms each, have been installed in the Homestake Mine in Lead, South Dakota. A third crystal is being pulled, and after being fabricated into a detector, it will be installed in a newly completed underground laboratory in Canfranc, Spain. A total of at least five such large detectors are planned within the next few years. The goal of PNL and IGEX is to measure, or place meaningful limits on, the zero-neutrino doublebeta decay mode of germanium-76 for resolution of Grand Unified Theories.

A collaboration has been initiated including PNL and the universities of South Carolina; Zaragoza, Spain; and Buenos Aires, Argentina, to establish a "cosmion" experiment in the southern hemisphere. The design takes advantage of the maximum variation in the thickness of earth available in the southern hemisphere for an experiment observing diurnal modulation of interactions engendered by cold dark matter candidates as the earth passes through the galactic halo. The detector for this experiment has been fabricated by PNL and Princeton Gamma Tech and installed in an iron mine in Sierra Grande, Argentina. The goal of the experiment is to elucidate potential candidates for the missing (nonluminous) mass of the universe.

University and Science Education (KT)

An expanding program at PNL provides for support of students and teachers at the pre-university level and of students and faculty at the college level through the University Research Support program. The Office of Energy Research contributes a major portion of the funding for these programs, particularly at the pre-university level.

Science, Mathematics, Engineering, and Technology Education

Along the educational pipeline, from elementary school through postdoctoral studies, education programs at PNL aim to influence the quantity, quality, and diversity of students equipped to participate in science and engineering and to function productively in an increasingly technological society. PNL's educational activities include an array of educational 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 Pacific Northwest Laboratory provide a rich technical and human resource for enhancing the education of students and improving the education system.

Goals of PNL education programs are to increase the quantity, quality, and diversity of students preparing to participate as scientific and technical professionals in areas related to DOE and PNL 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 PNL's missions in energy, the environment, and economic competitiveness through interactions with universities.

PNL's education programs support four overarching goals:

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

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. Therefore, 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 PNL that target the traditionally underrepresented will 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.

Linkages will be strengthened between those at PNL who conduct education programs and those involved in recruiting and hiring new employees. Additional partnerships will be established among those within research centers who are seeking new employees to engage them in drawing from the pool of students in whom DOE and PNL have invested by way of laboratory research and training appointments.

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

Middle and High Schools and Two-Year Institutions At the critical middle school level, PNL's OPTIONS Program expanded in 1994 to additional middle schools in Washington and Oregon having high percentages of traditionally underrepresented ethnic minorities. OPTIONS provides direct interaction between PNL staff and the students and teachers in the schools to stimulate students' interest in science and enhance teachers' curricular resources and teaching strategies.

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.

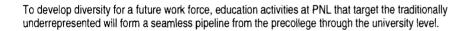
At the middle and high school levels, incentives and opportunities continue to be provided for students who participate in MESA, a statewide program to encourage minority students to prepare for careers in science and engineering. PNL staff continue to participate on the advisory boards of the local MESA center and as Vice Chair of the MESA State Board of Directors. This Laboratory investment is leveraged by Battelle, which recently 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.

The Columbia Basin College OPTIONS Scholars Program for

Multi-Cultural, Nontraditional Students, an extension of the middle school OPTIONS program, 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 PNL. Students who participate are from ethic 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. At the university level, OPTIONS Scholars may continue in the pipeline through internships at PNL and academic assistance at Washington State University at Tri-Cities.

Higher Education Under a Memorandum of Understanding, PNL 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. For the second year, PNL continued support for a senior staff member to serve full time at Heritage College, teaching and serving as the Chair of the Science and Mathematics Division. Other PNL staff are supported to instruct science courses. Additional support for students studying science and technology is provided under a \$50,000 award from Battelle to Heritage College. As a member institution of the Hanford Environmental Science and Engineering Consortium (HESEC) (described below), Heritage science and education faculty in collaboration with PNL are developing a basis for expanding the environmental science offerings to students.

The Hanford Environmental Science and Engineering Consortium forms a critical segment of the pipeline, drawing students from predominantly minority institutions into research participation and training at PNL. The partnership is dedicated to preparing increased numbers of environmental science and engineering professionals to address the myriad of complex environmental problems facing the nation. HESEC comprises 1) the major Hanford contractors including PNL, Westinghouse Hanford, ICF Kaiser Hanford, and the Hanford Environmental Health



Foundation, 2) five Historically Black Colleges and Universities including Alabama A&M University, Clark Atlanta University, Florida A&M University, Southern University, and Xavier University, and 3) Heritage College.

A goal of the Consortium is to improve each member institution's capability to produce trained and employable graduates in environmental sciences and engineering building on the combined resources of the Consortium members and the U.S. Department of Energy's Hanford Site. HESEC will provide support for internships at Hanford contractor sites for students and faculty at the member institutions. as well as investments in curriculum reform and basic research projects. HESEC also will provide outreach to the precollege communities surrounding the member academic institutions. The Consortium was established in 1993 and 1994, and continued growth will depend largely on available resources.

Other Institutions With Predominantly Underrepresented Populations In addition to partnerships with HBCUs represented in HESEC, PNL has Memoranda of Understanding with the following: Howard University, North Carolina A&T University, Prairie View A&M University, and Tuskeegee University. The Memorandums of Understanding allow PNL and the institutions to develop joint programs in science and engineering that include collaborative research projects, scientist and faculty visits and exchanges, and stu-

dent internships. In addition, PNL provides seed monies for developmental research, supports PNL 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 1995 and beyond include increasing support for education and training at HBCUs as well as developing stronger ties to institutions of higher education that have predominantly Hispanic or Native American students. PNL will also continue supporting minority internship and fellowship programs including the National Physical Sciences Consortium, the Minorities in Engineering program, the **Environmental Management Career** Opportunities for Minorities program, and the Native American/Hispanic program sponsored jointly by PNL and the Associated Western Universities, Northwest Division (AWU-NW).

Programs for Women To recruit and retain women in science and technology, PNL continues to develop programs that link the Laboratory's resources with women students. In 1994, PNL conducted the first "Take Our Daughters to Work Day," inviting young women in grades six through eight to spend a day learning about their options in the world of work, particularly in science and technology. Also in 1994, PNL staff assisted Heritage College in conducting a National Science Foundation-sponsored 4-week

summer program for middle school students. PNL women scientists worked directly with the young women sharing knowledge of science and science careers. Again in 1994 as in past years, PNL 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.

PNL continues to partner with the Washington Science Teachers Association and the Washington Office of the Superintendent of Public Instruction to develop workshops to train school teachers to deliver instruction free of gender bias. A guidebook will be produced and used to train teachers and to share with other DOE facilities and as part of DOE's Annual Review of Laboratory Programs for Women.

At the college level, PNL continues its collaborative program with Saint Mary's College, Notre Dame, Indiana, providing summer internships at PNL. PNL also provides financial and in-kind support for students participating in the Women in Engineering Program at the University of Washington.

Programs for Disabled New in FY 1994, is an effort to share science and scientists with students who are disabled or otherwise place bound. In partnership with an National Science Foundation-funded program at the University of Washington, PNL provides the linkage to the Internet for disabled students from the local community. In addition, PNL scientists tutor students and communicate electronically with disabled students across the state who participate in the program. In spring 1994, the participating students were provided face-to-face meetings with PNL scientists. We propose over the next 5 years to expand the impact of this program as part of Sharing Science with Schools program, currently funded by DOE as a classroom visitation program, to include an electronic mentoring network between students and PNL scientists. This component will provide a cost savings in travel and time as it augments the existing classroom visitation program, which

has reached more than 45,000 students and teachers in the schools since 1984.

Supporting the Schoolto-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. The Act calls for multiple, flexible educational and training pathways for precollege and postsecondary students. PNL education programs align with the national and state school-to-work agenda by proposing to establish a Technology Apprenticeship Program (TAP), providing paid internships at PNL connected to a program of instruction in the schools. This program will provide relevance and practical application to academic studies and increase students' ability to transition successfully to the world of work.

Hands-on, performance based, structured training and mentoring at the work site for students participating in the Technology Apprenticeship Program and will support the establishment of a program of instruction in the schools, based on career majors, that meets high academic and occupational standards and reflects the technology and training needs of the PNL work assignment. PNL will assist in setting up connecting activities that coordinate school-based learning with work-based learning.

The Technology Apprenticeship Program will also assist schools 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 technology into the mathematics and science curricula. 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 K-14 Level A foundation exists at PNL for supporting the school-to-work transition. At the precollege level, PNL supports career awareness presentations and workshops for students. At the community college level, PNL 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 1994, PNL participated in the formation 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.

Undergraduate and Graduate Links to the Laboratory Work Place At the university level, the school-to-work transition is supported by existing programs for students. Outstanding undergraduate students spend time at PNL 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 PNL scientists and engineers. During FY 1994 a record 86 students participated in SERS, and this number is expected to continue to grow during FY 1995 and beyond.

Through AWU-NW, PNL 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. PNL research staff strongly support the goal of the Lab Coop to enhance the training of outstanding university students. During FY 1993 more than 250 undergraduate appointees participated in the program, a more than 50 percent increase over FY 1990. The Lab Coop program is expected to continue healthy growth in the coming years.

At the graduate level, PNL supports Energy Research Fellowships for highly qualified students from nine regional universities and Clark Atlanta University in Georgia. The fellowship allows students to conduct course work on campus during the academic year and spend 3 months each year conducting research on-site at PNL. During FY 1994 ten graduate fellowships were awarded to M.S. and Ph.D. candidates studying a variety of research topics. During FY 1995 and beyond, the awards will continue to play a role in PNL's training of future scientists and engineers who are knowledgeable on issues of critical importance to DOE.

PNL 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 PNL and complete their academic requirements at the university.

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 the Department of Energy can best be achieved within a community educated to understand and value scientific research and development.

Therefore PNL'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. PNL'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.

PNL 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.

Based on the development of Washington State's statewide systemic initiative in FY 1992 and 1993, PNL 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. Overall efforts include teacher enhancement and preparation, curriculum and instruction, assessment of learning, accountability, and resource development.

Curricula Reform During FY 1994, PNL led an effort to promote curricular change through a Memorandum of Understanding among the Washington Science Teachers Association, the Washington State Mathematics Council, and the Washington Technology Education Association, purported to be the first such formal agreement in any state. Formalized in November 1993, this understanding recognizes the substantial interconnectedness of the three disciplines and the common goals of the associations to support the highest standards of teaching and learning in mathematics, science, and technology in Washington's schools.

PNL continues to promote curricula reform supported by DOE as part of the NSTC Teacher Enhancement Program through which DOE awarded



Middle and high school teachers visited PNL to sharpen their science and mathematics skills through a new Summer Teacher Enhancement program sponsored by DOE.

PNL support for 3 years (1994-1996) to continue conducting the National Teacher Institute in Materials Science and Technology. The intensive 20day 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 7 years by PNL 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 16 school sites in Washington and schools in 14 states 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, PNL continues to provide high-intensity training and research experiences, in addition to that sup-

ported by the NSTC initiative, for elementary, middle, and high school teachers using PNL scientists, engineers, and equipment. At the elementary school level. PNL received a second 3 years of funding from the National Science Foundation and DOE to implement the Science Alive program, a component of a DOE multi-laboratory elementary teacher enhancement program. The second 3 years focus 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 PNL and academic year workshops dedicated to producing long-term, sustained systemic change. Training includes 20 days in the summer and an additional 20 days during the academic year.

Based on Science Alive, PNL has assumed responsibility for developing models for providing training and research opportunities for teachers throughout Washington State. Under a second National Science Foundation award to the University of Washington and support from Washington State Eisenhower funds, scientist-teacher teams from PNL continue to assist in

training scientist-teacher teams from three participating universities and the Pacific Science Center. Based in part on their training at PNL, these teams in turn are providing training for elementary teachers throughout the state of Washington. The scope of this initiative is intended to affect not only the elementary teachers but the professional development of those college faculty who teach our future teachers and scientists.

Teacher Research Participation

DOE's Teacher Research Associates (TRAC), a national DOE program for middle and high school teachers, has provided 8-week summer research experiences at PNL for more than 240 teachers since 1986. This program has become a model for other federal agencies, universities, and industrial laboratories. PNL science education staff have assisted in the dissemination of the model program. In 1994 PNL science education manager participated as a panelist in a national interactive videoconference to showcase the TRAC program and promote scientific work experiences for teachers in every state. The program strengthens the content knowledge and instructional strategies of teachers, providing an avenue for rapid transfer of frontier science to the classroom.

In summer 1994, PNL began a component of the TRAC program to provide research experiences for 22 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, PNL continues to host a teacher from the University of Washington's Math/Science Fellows (formerly Ford Fellows) program. In 1994, PNL began a new teacher program 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.

PNL also supports a program to reach individuals who are preparing to be teachers. As a part of Washington

State University's academic program in the Tri-Cities, a Master's in Teaching degree is offered to those who have previously received bachelor's degrees in other disciplines and wish to teach. Last year DOE awarded Washington State University at Tri-Cities (WSU-TC) support for a cadre of teachers in that academic program who are from nontraditional or multicultural backgrounds. In 1994, PNL will provide summer internships for the targeted teachers and proposes to provide scientist mentors for the first year of their teaching. WSU-TC participates in statewide systemic reform including the project funded by DOE at the University of Washington to change the way teachers are prepared in the state of Washington. PNL is a partner in this project.

Middle Level Systemic Reform The OPTIONS program, funded at PNL since 1990, has refocused to align with statewide systemic reform. At the middle school level, three additional middle schools having high percentages of underrepresented ethnic minorities have been added to the original OPTIONS schools. Each participating school has been challenged to do whatever it takes in the school and district to ensure that all students achieve at the highest possible levels in mathematics, science, and technology education. Each district has developed a plan for systemic reform and funds have been awarded to carry out the plans. Options for systemic reform are being explored in collaboration with PNL research and education staff. To assist the reform, PNL has established computer laboratories at several middle schools providing DOE equipment not in use.

The results of OPTIONS are being and will continue to be evaluated by external evaluators from the National Center for Improving Science Education in cooperation with PNL education staff. Over the next 5 years, we expect to extend the opportunity to additional schools and strengthen the link between OPTIONS and the state education reform. Outcomes of the evaluation and assessment are intended to reveal best practices that can be applied to advance systemic reform throughout the state and nation.

Student Incentives and Opportunities

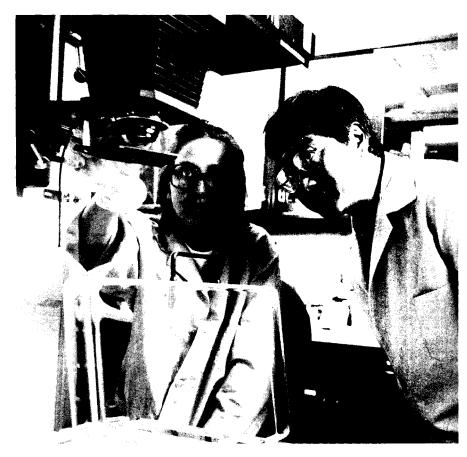
PNL continues to conduct programs at all grade levels to provide students with incentives to study mathematics, science, and technology, and opportunities to participate in hands-on laboratory activities and interact with PNL scientists. Major precollege and university level programs for students are conducted at PNL in Richland. Most student programs are described under other headings within this section of the Institutional Plan. Selected activities are being piloted in proximity to Battelle's Washington D.C. Office and are described below.

PNL continues to partner with the state of Washington to conduct a marine ecology institute for honors high-school students. The institute is part of a state program providing workshops in all disciplines for outstanding high school students. Since 1986, PNL has conducted this week-long workshop at its marine research facility at Sequim on the Olympic Peninsula. Each spring, PNL marine scientists work directly with students engaging them in handson environmental research activities.

In summer 1994, as in 1993, PNL hosted the DOE Energy Award Winners of the International Science and Engineering Fair, along with their teachers, for a week-long laboratory experience. PNL Science Education Center staff participate in selecting the winning projects. PNL also continues to participate in DOE's regional and national Science Bowl, providing judges, training for the regional judges, questions produced by scientists, and financial support for the event.

Under an equipment loan and distributions program, PNL provides DOE equipment not in use to elementary schools through universities, including a series of computer laboratories established at middle schools in Washington and Oregon and a pilot project to link an entire school district to Internet.

Education Programs at PNL's Washington D.C. Office Education programs conducted by PNL in Washington, D.C., parallel the model established by PNL in Richland. Provided are internships for undergraduate, graduate, and postdoctoral students



PNL's research partnerships with universities and institutions will build a stronger Laboratory with a diverse staff to handle today's leading problems.

and researchers. Precollege programs in Washington, D.C., include scientific and technical demonstrations and motivational seminars conducted in the schools by scientists and engineers and direct mentoring relationships with students. These programs work primarily to provide leadership and encouragement to students to pursue learning in mathematics, science, and technology and motivation to achieve at high levels. Plans are under way to develop a joint initiative between PNL's Washington D.C. Office and the District of Columbia Public Schools to put the resources of federal agencies and private companies to work to support systemic reform in mathematics, science, and technology education.

Building Strong Laboratory-University Partnerships

PNL 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 this multiprogram national laboratory are shared with colleges and universities throughout the northwest region and across the nation.

Integral to building strong Laboratoryuniversity partnerships are the more than 700 students and faculty who participate each year in educational appointment programs at PNL. 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 PNL to collaborate with a number of recognized experts in fields consistent with the business areas of PNL and DOE.

Agreements and Memoranda of Understanding

Collaborative Agreements and Memoranda of Understanding provide a firm

foundation for PNL's partnerships with universities and are primarily intended to enhance collaboration between PNL 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 PNL Affiliate Staff Scientists, and appointments of PNL staff as Adjunct and Affiliate Professors as well as guest lecturers at the universities.

PNL 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 Health Sciences University
- Oregon State University
- Portland State University
- · University of Washington
- · Washington State University.

Memoranda of Understanding are currently in place with the following universities throughout the country:

- California State Polytechnic University at Pomona
- · Colorado School of Mines
- East Tennessee State University
- Eastern Washington University
- · Heritage College
- Indiana University
- · Rutgers University
- · Saint Mary's College
- · SUNY Buffalo
- Texas A&M University
- · University of British Columbia
- University and Community College System of Nevada

- · University of Florida
- · University of Kentucky
- University of Texas at El Paso
- University of Pennsylvania
- William Marsh Rice University
- · Yale University.

The partnerships are defined and executed jointly by PNL and the college and university partners. Under the partnerships, new 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 5 years ago, joint research projects between PNL and universities have increased significantly. During FY 1993 PNL undertook more than \$7 million in subcontracts with universities, and the rate of growth is expected to increase steadily during FY 1995 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 PNL supports the establishment of new professorships at regional universities. In past years, PNL 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 1995 and beyond PNL expects to establish faculty programs and support curriculum development in advanced areas of environmental science and molecular science at regional universities.

PNL has recently initiated the DOEfunded Environmental Science and **Engineering Education Coordination** and Assistance Project (ESEECAP). The purpose of this program is to assist 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 recently approved, and a master's degree program has been under way for some time. 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.

Postdoctoral Fellowships

Postdoctoral fellows play a key role in PNL research activities, particularly in molecular sciences. PNL's activities at the postdoctoral level have grown significantly during 1993 and 1994, and represent the largest growth in university programs at PNL. The DOE Lab Coop program provided 1- and 2-year fellowships to more than 125 outstanding postdoctoral researchers.

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

Faculty Preparation and Enhancement PNL, jointly with AWU-NW, actively promotes opportunities to advance the knowledge and skills of university faculty in science and engineering. The intent of these programs is to bring fresh ideas into the Laboratory, and to stimulate the development of updated curricula that draws on interdiscipli-

nary approaches at PNL.

The PNL Affiliate Staff Scientist (PASS) program has undergone significant changes during FY 1994, and is expected to become a premier program during FY 1995 and beyond. PASS will allow PNL researchers to nominate university faculty collaborators for PASS membership, thus helping to formalize and enhance collaboration. PASS members will be allowed access to PNL facilities, as well as travel support provided by the host researcher. It is expected that the PASS appointments will open PNL's doors to university researchers and stimulate new ideas and research opportunities.

A counterpart to the PASS program, PNL staff members hold faculty joint appointments at university campuses. More than 200 affiliate professorships and lectureships, approximately one-half of which are held at university campuses around the country, are held by PNL staff. The remaining one-half are held at regional universities including WSU-TC located in Richland.

Evaluation and Capacity Building

Building on the past 2 years of participation in DOE's project to assist the laboratories in evaluating the quality and assessing the impact of their education programs nationwide, PNL expects to formalize a multifaceted approach to ensuring that goals and objectives are met for the full array of PNL's education programs. This opportunity for capacity building has added value to the education programs at PNL, 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.

Science, Mathematics, Engineering, and Technology Education

		Fiscal Year 1993 Total Women		Fiscal Year 19 Total Wome		
Te-oniversity Frograms	1041	VVOILEI	Min.	1000	Wollien	171111
Student Programs						
Student Research Apprenticeship Program	28	11	28	36	18	36
Inquiry Into Science	20	7	1	19	7	3
Marine Ecology Institute	11	8	0	10	8	1
CBC OPTIONS Scholars	2	7	9	12	7	7
Expanding Your Horizons/Career Conferences	1,100	900	500	1,250	650	500
Sharing Science with Schools ^(a)	5.200	2,300	3,000	8,000	4,000	2,000
Feacher Programs	3.200	2,500	5,000	0,000	1,000	2,000
Teacher Research Associates	42	18	10	46	24	5
Science Alive (National Teacher Enhancement Project)		18	10	24	19	3
Summer Research Internship	20	10	10	27	19	3
Program for Teachers	0	0	0	5	2	1
Preservice Partnership Program with WSU-TC	0	0	0	3	1	1
Materials Science/Technology Institute	45	20	4	45	20	4
Washington Systemic Initiative	270	180	20	120	75	6
	270	160	20	120	13	O
Special Programs	7.000	2 500	2 900	6 000	2.000	2.000
OPTIONS ISEF Award Winners	7,000 20	3,500 7	3,800 7	6,000 20	3,000 7	2,000
University Programs						
Undergraduate Programs	86	27	8	90	40	15
Undergraduate Programs Science and Engineering Research Semester (SERS)	86 160	,27 85	8 34	90 175	40 90	15 40
Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program	160	85	34	175	90	40
Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority)	160 4	85 0	34 4	175 4	90 0	40 4
Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority) Hispanic/Native American (minority)	160 4 7	85 0 2	34 4 7	175 4 7	90 0 2	40 4 7
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Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority) Hispanic/Native American (minority) GEM (minority) EMCORE EMCOM (minority) HBCU Programs (minority)	160 4 7 3 4	85 0 2 2 2	34 4 7 3 4	175 4 7 3 0 ^(b)	90 0 2 2 0	40 4 7 3 0
Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority) Hispanic/Native American (minority) GEM (minority) EMCORE EMCOM (minority) HBCU Programs (minority) Graduate Programs	160 4 7 3 4 2 10	85 0 2 2 2 2 2 2 3	34 4 7 3 4 2 10	175 4 7 3 0 ^(b) 2 10	90 0 2 2 0 2 3	40 4 7 3 0 2 10
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Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority) Hispanic/Native American (minority) GEM (minority) EMCORE EMCOM (minority) HBCU Programs (minority) Graduate Programs Laboratory Cooperative Program DOE Graduate Fellows National Physical Sciences Consortium (minority) PNL Energy Research Fellowships Postdoctoral Programs Laboratory Cooperative Program DOE Postdoctoral Fellows (various) Faculty Programs Laboratory Cooperative Program Laboratory Cooperative Program	160 4 7 3 4 2 10 102 6 2 12 126 2	85 0 2 2 2 2 2 3 50 2 1 4 38 1	34 4 7 3 4 2 10 10 1 2 3 28 0	175 4 7 3 0(b) 2 10 115 8 2 10 160 3	90 0 2 2 0 2 3 60 4 1 7 50 2	40 4 7 3 0 2 10 15 2 2 2 50 1
Undergraduate Programs Science and Engineering Research Semester (SERS) Laboratory Cooperative Program Life Gets Better (minority) Hispanic/Native American (minority) GEM (minority) EMCORE EMCOM (minority) HBCU Programs (minority) Graduate Programs Laboratory Cooperative Program DOE Graduate Fellows National Physical Sciences Consortium (minority) PNL Energy Research Fellowships Postdoctoral Programs Laboratory Cooperative Program DOE Postdoctoral Fellows (various) Faculty Programs	160 4 7 3 4 2 10 102 6 2 12 126 2	85 0 2 2 2 2 2 3 50 2 1 4	34 4 7 3 4 2 10 10 1 2 3 28 0	175 4 7 3 0(b) 2 10 115 8 2 10 160 3	90 0 2 2 0 2 3 60 4 1 7	40 4 7 3 0 2 10 15 2 2 2 2

⁽a) Underrepresented minorities(b) Program was eliminated by DOE effective 9/30/93.

Environmental Quality

The largest part of PNL's research, development, and deployment activities focuses on resolving environmental issues. As a multiprogram laboratory, PNL is well positioned to align the environmental quality business area with the other DOE core businesses and integrate activities to leverage resources to provide solutions which are more reliable and cost less. One example is the Environmental Molecular Sciences Laboratory under construction at PNL. This laboratory will house advanced research capabilities in experimental, theoretical, and computational sciences that will enable the development of new technologies to meet DOE's long-term environmental management goals. In this internationally important area, PNL's objectives

- provide a systematic results-oriented science and technology program that achieves cost-effective and timely cleanup of Hanford and other federal sites
- establish integrated methods for environmental monitoring to increase the accuracy and efficiency of determining the environmental impact of operations at DOE sites and elsewhere
- provide national leadership in risk assessment and public involvement programs to improve decision making to be fully implemented in the DOE environmental management complex
- provide technology and methods that enable DOE to ensure the protection of workers and the public in DOE's operations and support the establishment of risk-based environment, safety, and health standards.

PNL's scientific and technical activities of each DOE program office contributing to the environmental quality core business are described below. The descriptions also explain proposed new initiatives within these organizations.

Office of Environmental Management

PNL's major contributions to the Office of Environmental Management (EM) are in the area of science and technology development and deployment for waste site cleanup, waste management, and environmental restoration. Our work ranges from basic studies on interactions of hazardous substances with materials to technology demonstration and transfer.

DOE-EM is also responsible for several site support activities including the Public Safety and Resource Protection Program (onsite and offsite monitoring, cultural and wildlife resources, meteorological and climatological services), National Environmental Policy Act (NEPA) documentation, the Hanford Environmental Dose Reconstruction efforts and other activities. These are discussed under the Hanford Site Support section of this plan.

The estimated funding for DOE-EM is shown in the resource projections. The funding levels indicated also include work done by PNL for Westinghouse Hanford and the funding projections for the DOE-EM operating portion of the EMSL.

The EMSL is a primary element of PNL's efforts to provide fundamental research supporting the development and deployment of new technology for the characterization and restoration of Hanford and other DOE sites. While the work will be fundamentally state of the art, it will have a strong focus on the applied needs of the Hanford Site. EMSL is a joint venture between DOE-EM and DOE-ER. DOE-EM has provided initial funding for the construction design of the facility. Current and future construction funding will be provided by DOE-ER. The focus of EMSL support to DOE-EM will be on the resolution of Hanford problems such as treatment of tank waste, soil and groundwater cleanup, and providing for transfer of technology to the DOE-EM cleanup programs elsewhere.

EMSL research will increase our understanding of complex environmental

systems, thereby leading to new technologies to reduce costs, increase effectiveness, and decrease uncertainty in remedial actions. A comprehensive definition of the technological voids and gaps that could impede cleanup at Hanford was initiated, and a description of the roles that basic and applied research will play in meeting these needs was developed. Focusing EMSL research programs on DOE's environmental restoration and waste management needs strengthened the contextual framework for the facility and highlighted several previously unidentified needs. For example, major sensor development and advanced processing technology efforts have been established as part of EMSL-related research programs and linked to ongoing DOE-EM programs.

Technology Planning and Evaluation

PNL is developing systematic approaches to understand the magnitude of DOE's environmental problems; the interrelationships and interfaces important to cleanup and waste management activities; and mechanisms for prioritizing activities, methodologies for analyzing problems and solutions with multiple stakeholder participation, and mechanisms for evaluating progress against DOE-EM's goals. Our objective is to develop needs-driven, cost-effective programs.

Key to meeting this goal is to evaluate and reduce short- and long-term human health risks and protect/improve the quality of natural ecosystems found on DOE sites. To improve DOE's allocation of its environmental management resources for maximum risk reduction, PNL is assisting DOE in developing risk-based assessments for site cleanup scenarios and options and factoring risk impacts into DOE's decision making and environmental management policies and programs.

Hanford Integrated Planning and Support PNL is a member of the Hanford team responsible for implementing the Hanford long-range planning process. The process establishes a tiered set of technical planning documents for the site. This integrated planning process links Hanford goals to specific work elements.

PNL is committed to working with industry to 1) identify and demonstrate existing technologies that can be applied to the unique problems at Hanford and other DOE sites and 2) use the national laboratory system, industrial research and development community, and universities to develop and demonstrate the next generation of technologies.

The program plan will identify requirements for scientific research and technology development, demonstration, testing, and deployment activities, including meeting basic research needs (DOE-ER activities), applied technology development needs (EM-50 activities), and adaptation/demonstration/ deployment of more mature or proven technologies (EM-30 and EM-40 activities). Integration of Hanford's technology planning efforts and decisions (from the lowest, most detailed program-specific to the highest Hanford-wide cleanup strategies) will help to minimize work duplication, technology gaps, and science and technology conflicts. The Hanford Technology Program Plan will be continuously updated as new information becomes available on program baselines, alternative strategies, technology needs, and research and development results.

tions Office has endorsed the Hanford Advisory Board. A joint DOE/PNL/ Westinghouse Hanford Company team has worked with the stakeholder and keystone groups to develop this concept. The Hanford team has discussed this initiative with representatives

Hanford The DOE Richland Opera-

Stakeholder Participation at

from state agencies, local governments, Native American tribes, environmental groups, the Washington State Nuclear Waste Advisory Council, and the Oregon State Hanford Waste Board.

Technology Planning and Evaluation Support to DOE Headquarters PNL is supporting the Deputy Assistant Secretaries with assessing current and anticipated planning activities within DOE-EM. The team analyzed various activities with emphasis on those where efficiencies were not being obtained, and developed a series of options to resolve issues. DOE-EM operations office planning activities were also analyzed within the context of developing an integrated process at the headquarters level which sufficiently meets the needs of all involved parties.

PNL has been supporting the Office of Oversight and Self-Assessment (EM-20) through the development of comprehensive EM-20 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), and strategic change management.

PNL also provides technical support for DOE-EM Headquarters' Office of Waste Management (EM-30). Laboratory staff provide input into the development of a systematic approach to manage low-level radioactive mixed wastes across the DOE complex. PNL is also assisting DOE Headquarters in the evaluation of the operations offices' programs to ensure the compliant shipment of DOE's hazardous waste to offsite commercial disposal facilities.

PNL provides planning and evaluation support to DOE's Office of Environmental Restoration (EM-40) in the following areas:

- Identifying and analyzing current and emerging regulatory and institutional issues of concern to DOE's environmental restoration program, (e.g., institutional controls, land disposal restrictions).
- Identifying programmatic approaches and options for expediting site cleanup, and providing support to field organizations in implementing streamlined approaches. Activities include 1) collaboration with DOE operations offices and EPA regulators, 2) development of strategies for the integration of phased reme-

- dial investigation/feasibility studies, 3) analysis of options for expediting site cleanup through the use of RCRA corrective action authority, and 4) assessing DOE Orders that could be revised to expedite remediation activities.
- Supporting the DOE-EM Programmatic Environmental Impact Statement including collection of source-term descriptions and environmental settings data for restoration sites, development of a complexwide inventory of DOE's environmental restoration sites, engineering analysis, regulatory analysis of compliance agreements, and development of modifications to multimedia environmental pollutant assessment models.

PNL is also managing the development of the environmental restoration priority system for EM-40. The system has been used to allocate resources to DOE sites. Benefit will be measured by meeting regulatory and statutory requirements, reducing health risk, reducing environmental risk, minimizing socioeconomic and cultural disruptions, and acceptability to the public.

PNL supports the Office of Facility Transition and Management (EM-60) as a part of DOE-EM's decontamination and decommissioning objective. The effort builds on the approaches developed under the Hanford Mission Plan and the Fernald Transition Plan, and will be tested at the Rocky Flats and Savannah River plants. PNL is currently supporting integrated planning efforts at Rocky Flats.

PNL is currently providing guidance and support to determine the needs of EM-60 that can be met through development and implementation of models and supporting databases. Model review and development are designed to ensure answers are provided to meaningful issues, and are technically correct and practical in application. PNL also provides support and guidance to EM-60 by analyzing and reviewing policies and procedures established for its operation, methods by which it links to field organizations, and coordination with other DOE and federal organizations.

Integrated Risk Management

PNL is developing a program plan to assess risk from alternative strategies for remediation activities and risk to workers, the public, and ecosystems from the remediation activities themselves. Three major products intended are

- quantitative assessment of public health and worker safety and health risks for materials currently present on the DOE complex
- quantitative assessment of the public health, worker, and ecosystem risk that will result from remediation activities under alternative strategies for cleanup
- quantitative assessment of public health, worker, and ecosystem risk associated with remediation activities.

A key question is how to use risk assessment and risk management information in planning cleanup actions. The benefit of a risk management approach to planning is to demonstrate what each DOE-EM action, policy, regulatory driver, or new technology does in terms of cleaning up sites and impacting human health or the environment. To expand knowledge and technology related to chemical protection, PNL has established an initiative entitled, "Health Protection and Standards for Hazardous Chemicals," which is further described in the section. Office of Environment, Safety and Health.

Measurement Methods/Tools Development and Information Management

PNL provides support to DOE-EM in environmental modeling, data analysis, risk management, prioritization, information management, systems analysis, and education. The Tank Waste Information Network System (TWINS) links site-specific tank information from Rocky Flats, Oak Ridge, Savannah River, Idaho, and Hanford into a common system that is available to multiple users. Currently, tank data exist in many forms, from hard-copy records to isolated personal computers to fully networked onsite databases. Tank data cannot be retrieved easily or shared with other users efficiently. By

linking different databases, TWINS allows users to access, manipulate, and retrieve tank data from any of the high-level waste tanks at DOE sites.

The Hanford Environmental Information System (HEIS) has been designed and implemented to store, manage, and aid in the analysis of Hanford's environmental sampling data, which are crucial to environmental cleanup and restoration. The HEIS is a repository for storing data and includes tools for efficient data processing, mapping, and spatial data analysis; maps of the Hanford Site; and software for entering, viewing, reporting, and depicting data. HEIS is operated by PNL as a resource for the entire site.

PNL is developing 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, RAAS (Remedial Action Assessment System), will be used primarily in support of feasibility studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (or corrective measures studies under RCRA), and is intended to help implement established and newly developed technologies that emerge from demonstration, testing, and evaluation.

Environmental Restoration

PNL is a member of the teams evaluating, developing, acquiring, and adapting technology for Hanford Environmental Restoration and Decontamination and Decommissioning programs. The effort involves participating in and leading the technology baseline review and evaluation of innovative approaches for the environmental restoration and decontamination and decommissioning programs, and identifying and obtaining the technology required to meet program risk reduction, cost goals, and schedule milestones.

Technology acquisition involves partnering with developers throughout the federal agencies as well as industry and 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 EM-50 organization, 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 such diverse programs as advanced characterization capabilities, adaptation of commercially available borehole geophysical capabilities, application of the Hanford permanent isolation barrier system, application of the in situ vitrification process, and adaptation of several in situ treatment techniques to Hanford-specific problems. Although all programs are for site-specific requirements, DOE complex and industrial applications are also possible. These programs capitalize on PNL's expertise in analytical chemistry, geosciences, systems integration, and systems engineering.

PNL is also supporting Westinghouse Hanford Company in numerous Tri-Party Agreement-driven actions. Examples include treatability studies to determine and select remediation technologies at field sites, and the evaluation of ecological and health risks at specific sites.

PNL 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. PNL has supported a project



Advanced characterization capabilities include sampling and analytical technical development, contents modeling, and information management.

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 Operations and Technology Program

The purpose of the Waste Operations and Technology (WM) Program is to support the broad objectives of the **Environmental Management Program** with a specific focus on waste management support for cleanup and restoration of the Hanford Site. The principal purpose of the WM Program is to provide innovative, environmentally appropriate, timely, and cost-effective solutions to waste management problems of Hanford, DOE, other federal agencies, and the private sector. The scope of PNL WM spans technology development from conceptualization to implementation and commercialization.

The PNL WM Program includes highand low-level radioactive waste, haz-

ardous waste, and mixed radioactive and hazardous wastes in all physical forms and from all sources. The program has substantial expertise and significant current business in the principal phases of waste management operations including characterization, retrieval, treatment, transportation, storage, recycling, and disposal. Although PNL's expertise is broadly applicable to all phases of WM operations, development and deployment of waste treatment technology is the core capability of the WM Program. Maintenance, enhancement, and commercial application of this core capability is central to our plans for future development.

The WM Program is organized into four principal elements: 1) PNL operational compliance programs, funded under the DOE Office of Waste Operations (EM-30); 2) waste management science and technology support, including direct DOE-funded EM-30 activities and work order-funded projects and tasks from Westinghouse Hanford Company; 3) WM technology development which includes WM technology development and adaptation (excluding tanks-related work), funded

under the Office of Technology Development National Program (EM-50); and 4) waste management support to other DOE sites and other federal agencies. Waste management activities that primarily support the Hanford Tank Waste Remediation System (TWRS) program, the EM-50 Underground Tanks Technology Development Program, and the PNL Spent Nuclear Fuel supporting activities are managed in a separate PNL program. Additional detail on current activities and future plans in each of the WM Program areas are provided below.

PNL Operational Compliance Program

This program element has overall responsibility for ensuring safe and compliant facilities operations and management of wastes generated in PNL's research and development and site cleanup support activities. Included in this element are facility development, systems upgrades, environmental compliance oversight, surveillance, and maintenance. Rapidly changing regulatory requirements continue to result in increasingly demanding operational safety and environmental compliance requirements that provide a major challenge in the face of escalating budget constraints.

Key activities include cleanup of PNL hot cells and related facilities to remediate safety concerns and to renovate cells needed to support hot-sample analysis for Tank Waste Remediation System (TWRS), spent fuel characterization, and other future Hanford cleanup projects. A major planned activity is development of the Advanced Process Engineering Laboratory for scale-up and testing of key waste treatment processes being developed to support TWRS and other cleanup activities.

Waste Management Science and Technology Support PNL's primary waste management science and technology role is currently with the TWRS program, described below. The Solid Waste Technology Support (SWTS) Program supports the Westinghouse Hanford Solid Waste Program. Through collaborative efforts with DOE Richland Operations Office and Westinghouse Hanford Company, PNL recently established new science and technology

roles in the emerging Hanford Spent Nuclear Fuel Management Program and in the national spent nuclear fuel management program. Brief descriptions of these roles is provided below. Westinghouse Hanford Company also funds numerous PNL projects of varying size and duration that support the entire spectrum of site operation and cleanup programs.

PNL provides planning and science and technology support to the Hanford solid waste management programs. This support is combined within a single, integrated SWTS project to centralize management functions and increase synergies among the various tasks. Planning and management support includes identification, quantification, and classification of future solid waste streams that will require management at Hanford. PNL also maintains logistics modeling capabilities that are used in conjunction with waste inventory and forecast information to develop detailed estimates of future solid waste flows through the system. These capabilities, in conjunction with other analytical methods, provide the basis to analyze future solid waste storage, treatment, and disposal scenarios, and to evaluate feasibilities and impacts and determine preferred management options. Planning support is coordinated with Hanford mission planning and Hanford systems engineering activities to ensure compatibility among the various efforts.

Current science and technology activities include developing methods for determining radionuclide transport through soils under unsaturated conditions, measuring corrosion rates for waste container materials under typical storage and disposal conditions, and developing methods for quickly and accurately detecting and measuring corrosion-induced or mechanical flaws in solid waste containers.

Spent Nuclear Fuel Program Support

At the invitation of DOE Headquarters, PNL became involved in development of the national program to deal with management of spent nuclear fuel, special nuclear materials, and associated storage facilities left from past defense materials production programs across the DOE complex. The spent fuel and storage facilities are old, generally in poor condition, and are poorly understood. Based on capabilities and experience, PNL scientists obtained assignments on all four national spent fuel management program technical committees. PNL continues to work with DOE Richland Operations Office, Westinghouse Hanford Company, and DOE Headquarters in development of the national program, currently managed by the Idaho National Engineering Laboratory. PNL was assigned responsibility to prepare the Hanford section of the Spent Fuel **Environmental Impact Statement. This** activity is expected to continue through FY 1996.

PNL worked with Westinghouse Hanford Company in FY 1993 and FY 1994 to develop plans for the new Hanford spent fuel characterization program. In the spent fuel characterization project, PNL will work with Westinghouse Hanford Company to retrieve samples of fuel from the K basins for examination in the 327 Building fuel examination cells. Early emphasis will be on obtaining data to support interim storage in the pools to mitigate potential safety and operational problems. Later phases of the characterization project will address options for fuel stabilization, waste forms, and long-term storage and disposal. PNL will also provide support in evaluation of structural integrity, leakage, and safety issues concerning the K basin storage pools. In addition, PNL manages the Applied Technology Program Office (ATPO) for Westinghouse Hanford Company to independently coordinate assessment and/or development of appropriate technology for the newly established and expanded Hanford Spent Nuclear Fuel project.

The level of activity in characterization is expected to be stable for the next several years. Technical support for applied technology development, process development, and waste form development for the Hanford spent nuclear fuel disposal project is expected to grow significantly over the next few years.

WM Support to Other DOE Sites and Federal Agencies In addition to col-

laboration with the Idaho National Engineering Laboratory mentioned above, for the past decade PNL has provided technical support to the West Valley Vitrification Plant development. This activity is expected to diminish over the next few years as the plant comes on line. PNL has been a regular participant in the EM-30 Mixed Waste Treatment Program and has supported a number of initiatives in development of criteria and waste stream data needed to implement provisions of the Federal Facility Compliance Act (FFCA). Support to implementation of FFCA provisions and other WM support could be areas of growth at several sites including Oak Ridge, Pantex, and Rocky Flats.

WM Tasks in the Technology Development National Program The PNL WM program is responsible for all WM-related EM-30/50-funded technology development at PNL, except for tanks-related tasks, which are managed collectively in the TWRS program. EM-30-funded WM activities are described above. All EM-50-funded activities, including WM, are described collectively in the EM-50 section of this plan. To complete the WM Program description, a brief overview of EM-50 WM tasks is also included here.

PNL has funded tasks in several EM-50 integrated programs and integrated demonstrations, including leadership roles in two. PNL is responsible for coordinating the Efficient Separations and Processing Integrated Program, which includes several key tasks in advanced separations. PNL also has responsibility for coordinating the robotics tank waste retrieval task of the Robotics Technology Development Program, including a number of key technical tasks. A number of funded WM tasks are included in other integrated demonstrations and integrated programs including the Mixed Waste Integrated Program, the buried waste integrated demonstration, the Supercritical Water Oxidation Program, and the resource recovery project. PNL's involvement in the underground storage tank integrated demonstration is described separately.

PNL Initiatives

Integrated Environmental Monitoring

Fiscal year 1994 is the second year of the Integrated Environmental Monitoring (IEM) Initiative. The objective of the initiative is the development of a set of analytical procedures and software tools that can be used to improve monitoring network design decisions. Such decisions include the choice of monitoring locations, sampling frequencies, sensor technologies, and monitored constituents. The Integrated Environmental Monitoring Initiative is being designed to provide a set of monitoring alternatives that balance the tradeoffs between competing monitoring objectives such as the minimization of cost and the minimization of uncertainty. The alternatives provided are the best available with respect to the monitoring objectives, consistent with the physical and chemical characteristics of the site, and consistent with applicable regulatory requirements. The selection of the best monitoring alternative to implement is made by the decision maker after reviewing the alternatives and tradeoffs produced by the Integrated Environmental Monitoring process.

During FY 1993 the framework for the network design process was conceptualized, development of a numerical test bed for the process was initiated, and approaches were developed to target user needs. During the second year of the project, the framework was refined, a prototype tool set was assembled, a demonstration problem was defined with the help of potential customers, and work on the demonstration was initiated.

A framework for monitoring decision making was developed during 1993. This framework was refined to focus on critical tools for network planning. The process begins with identification of the monitoring objectives. The next step is to generate a set of monitoring alternatives that represent the tradeoffs that must be made between competing objectives. Several components are required to generate optimal monitoring network design alternatives. A conceptual model that represents the current understanding of the site ensures

that the monitoring alternatives are consistent with the physical and chemical characteristics of the site. An uncertainty assessment quantifies what is unknown and uncertain about site characteristics. The conceptual model, the uncertainty analysis, and the objective statements are combined in a decision model that provides the actual mechanism for the generation of optimal monitoring alternatives. The decision model is a mathematical statement of the monitoring network decision process. The outcome of the design process is a tradeoff diagram that will allow decision makers to choose between monitoring alternatives in a more quantitative way than is currently available.

Existing tools were selected for use in demonstrating the design process. Tools include a groundwater flow model, a contaminant transport model, a geostatistical evaluation package and an optimization algorithm.

A demonstration problem was chosen that has

- relevance and applicability to current Hanford monitoring needs
- good prospects of stakeholder (DOE, users, regulatory agencies, public) acceptance
- a demonstration that achieves results with the available resources.

Two processes were used to identify relevant monitoring issues for the Hanford Site and determine if the theme would have stakeholder acceptance. The first process was to interview technical staff and project managers involved in groundwater monitoring on the site. The second was to examine the regulatory environment in which the Integrated Environmental Monitoring tool set may be applied. Hanford's regulatory environment includes requirements of the Tri-Party Agreement and its revisions as well as RCRA and CERCLA requirements. The problem includes a waste site located near a high-quality river. The waste site may leak contaminants and the monitoring objectives are to minimize monitoring cost, minimize the probability that contaminants will

reach the river undetected, and maximize the advanced warning of a leak should one occur.

Advanced Recycling and Research **Complex** The Advanced Recycling and Research Complex (ARRC) concept, which has been under consideration for several years, has been targeted as a new WM Program initiative for FY 1994 and beyond. Conceptually, this initiative will involve a partnership among local, state, and federal government entities, industry, and university participants. The purpose of the ARRC would be to establish facilities to provide demonstrations of innovative technologies and systems of technologies for recovery, processing, and recycle of materials from industrial and municipal solid waste by establishing a state-of-the-art material handling, separation, and recycling facility in the Tri-Cities. The keystone of the ARRC facility would be a Terra-Vit™ glass melter to transform normally nonrecyclable residues into glass products for resale and beneficial use. Development of saleable products, certification of their safe use, and establishment of appropriate markets are also key objectives of the ARRC initiative.

We have two licensing agreements for Terra-Vit that will demonstrate elements of the ARRC concept. Other efforts are being made to integrate objectives of a number of DOE and Washington State initiatives including the EM-50 Minimum Additive Waste program and the federal advisory committee to develop onsite innovative technologies, which is joint with the Western Governors Association and with the Clean Washington organization. Potential industrial and university partners also have been identified.

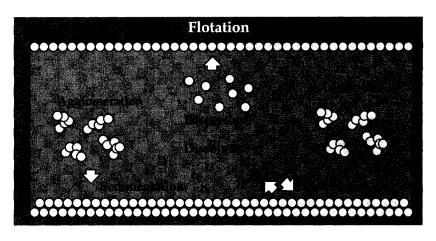
Environmental Sustainability Project In 1993 PNL established its Environmental Sustainability Project to help bridge Pollution Prevention (P2) efforts in PNL's own operations with Pollution Prevention services provided for others. In 1994 these efforts were significantly expanded with the establishment of the P2 Info Research Center. P2 Info is a service provided by PNL to the entire DOE complex to provide quick access to up-to-date

information on a variety of Pollution Prevention topics. A key function of P2 Info is to be the primary vehicle for updating information in the automated portion on DOE Pollution Prevention information infrastructure, the Energy Pollution Prevention Information Clearing House (EPIC). Also, in 1994 PNL established a national DOE demonstration program in Microscale Chemical Analysis. By drastically reducing sample size, microscale chemistry techniques can dramatically reduce waste generated in the laboratory. Beginning in 1995 the microscale technique demonstrated at PNL will be disseminated broadly to other DOE facilities.

Hanford Tank Waste Remediation System and Technology Development

In 1989 the U.S. Department of Energy entered into an agreement with the Washington Department of Ecology (WDOE) and the U.S. Environmental Protection Agency called the Hanford Federal Facility Agreement and Consent Order or Hanford TPA (Tri-Party Agreement). In March 1993, the three parties agreed to a 6-month joint examination of alternative proposals that may present a more reasonable approach to the overall cleanup. A revised agreement was formally signed in January 1994 that is based on the following technology assumptions:

- Retrieval, by hydraulic sluicing and/ or mechanical methods, of at least 99 percent of the liquid and solid wastes in the 28 double-shell tanks and the 149 single-shell tanks. Emplacement of subsurface barriers around some of the single-shell tanks, if technically feasible, may be necessary or desirable to prevent inadvertent release of liquid wastes into the environment during retrieval.
- Separation, by appropriate means, of solid and liquid waste fractions.
- Pretreatment of the solid (sludge)
 wastes by washing to remove
 sodium salts as well as certain critical constituents (e.g., phosphate,
 aluminum, chromium, sulfate) that
 limit waste loadings in glass. The
 assumption is that enhanced sludge



Colloidal phenomena dominate tank processing. Organics, ions, and soluble species control colloidal interactions.

- washing within double-shell tanks, coupled with blending of wastes, will provide a feed stream to a vitrification facility that will result in a reasonable volume of glass.
- Vitrification, in a high-capacity melter, of pretreated sludge to produce a glass form that is fully qualified for eventual disposal in an offsite geologic repository.
- The liquid waste portion, including sludge wash solutions and leaches, will be treated to reduce concentrations of cesium-137 and strontium-90 to the extent necessary to allow subsequent glassification of the liquid waste in a lightly-shielded facility. It is assumed that such vitrification will be performed in a facility separate from that used for the highlevel waste fraction and that the glass will be disposed of at the Hanford Site.

The proposed new TWRS technical strategy also provides for

Mitigation and eventual remediation
 of wastes in double-shell tanks and
 single-shell tanks currently with
 unreviewed safety questions. These
 tanks include those containing ferro cyanide wastes and those where
 flammable gas mixtures are expected
 or could be generated. Tank safety
 issues are assumed to be mitigated
 as required using in situ methods
 such as mixer pumps in flammable
 gas tanks or by retrieval and dilution
 of the wastes.

- Characterization of wastes prior to their retrieval in both single-shell tanks and double-shell tanks. Such characterization, which involves determination of chemical and radiochemical compositions as well as selected physical and chemical properties, is necessary to resolve safety issues and questions and for development of satisfactory technologies for retrieval, pretreatment, and vitrification of tank wastes.
- Continued and upgraded safe interim storage of wastes in the double-shell tanks and single-shell tanks.

The renegotiated agreement allows for continued development of certain alternative technologies, including

- processes for removal of longlived, mobile radionuclides (e.g., technetium-99) from the low-level waste stream
- sludge dissolution and advanced radionuclide separation processes
- processes for destruction of dissolved organic materials in certain waste streams.

PNL assumed a new, expanded role in supporting the cleanup of Hanford tanks on October 1, 1993. The TWRS Integrating Contractor (Westinghouse Hanford Company) named PNL to manage all technology development work for the program. Since October, major PNL efforts have concentrated on 1) establishing a technology development program with increased national



Complex mixtures of solids and liquids in tanks must be identified to facilitate processing.

involvement, building on recognized science and engineering capabilities at other DOE sites, within industry, and in universities; 2) ensuring that existing and planned technology development activities are directly linked with the systems-based requirements of the renegotiated Tri-Party Agreement; and 3) conducting public meetings with stakeholders to involve the impacted groups in technology development planning, decision making, and execution.

Extensive technology development activities are under way in support of the proposed new TWRS technical strategy in seven critical areas:

- · tank waste safety issues
- improved/upgraded tank farm operation
- · waste characterization
- · waste retrieval
- · waste pretreatment
- vitrification of the high-level waste portion

 vitrification of the low-level waste fraction.

The area of safety support is the highest priority within the program, with PNL focusing on the resolution of key safety problems, such as the potential for flammable gas concentrations, explosive mixtures of ferrocyanide, runaway organic-nitrate chemical reactions, overheating of tank contents, and the release of toxic/hazardous gases to work spaces. In waste characterization, the focus is on the development of enhanced sampling and analysis capabilities. In retrieval, enhanced sluicing, subsurface barriers, and alternative technologies are being developed. Pretreatment's emphasis is on solid/liquid separation, cesium/ strontium/technetium removal, organic destruction/thermal reconstitution, in-tank washing/leaching/caustic washing, and sludge processing. The vitrification focus is on glass formulation, product package evaluation, melter evaluation, feed and process refinement, and process/product development.

To specifically increase national involvement, PNL created the Tech-

nology Development Program Office with representatives from every national laboratory, the chemical industry consortium, and the university community to develop and direct the necessary TWRS technology development activities. PNL also assembled a multi-laboratory team which was selected by DOE to serve as the High-Level Waste Tank Remediation Focus Area Technology Lead Organization, a new concept for integrating all national technology development work supporting tank remediation.

All major FY 1994 technical products were delivered on schedule and within budget. PNL provided TWRS with technology advancements which will have high impact by drastically reducing costs for characterization (demonstrated the laser ablation/mass spectrometer screening analysis system on actual hot waste samples); greatly reducing high-level waste glass volume (demonstrated twice the flow sheet concentration of simulated waste sludges in borosilicate glass [50 percent versus 25 percent] in runs with the small-scale high-temperature melter); and enabling safe pipeline transport of radioactive slurries (developed an ultrasonic instrument which provides real-time measurements of the concentration of suspended solids in tanks and pipelines). In the down-selection of low-level waste melter concepts, PNL developed the process, chaired the technical panel, and passed on a ranking and recommendations of proposals from 16 industrial organizations to the Source Evaluation Board. PNL discretionary funds were used to provide in-depth understanding of sludge constituents and their rates of dissolution and provide DOE Headquarters with a document, A Systematic Look at TWRS Privatization, pointed toward a more rapid initiation of remediation and lower costs as the result of competition in the private sector. Other internal investments focused on three strategic, high-impact technical areas-Tank Waste Properties, Process Control, and Waste Forms—with linkages established with the Advanced Processing Technology Initiative and the Environmental Molecular Sciences Laboratory in order to build fundamental research capabilities.

Technology Development

The Office of Technology Development (EM-50) was established to develop and deploy new technologies that support the waste management, environmental restoration, and final facilities disposition responsibilities of EM-30, -40 and -60, respectively. These new technologies will provide solutions or improvements which reduce costs, accelerate schedules, minimize wastes, and/or improve the safety of cleanup activities. Currently, most technology development activities in EM-50 are organized into integrated programs and integrated demonstrations to focus on specific technical needs. PNL supports EM-50 by coordinating several integrated programs and integrated demonstrations and by performing technology development tasks for each of these program areas and several areas coordinated by other organizations. PNL staff also provide direct support to EM-50 through efforts to coordinate interactions among all program areas, planning and execution of program-wide initiatives such as the joint EM-40/50 industry outreach meeting, and establishment and execution of a broad, intersite Technology Implementation Initiative. PNL works cooperatively with the other Hanford contractors and contractors at other DOE sites to develop and implement the technologies this program is providing in support of EM-wide needs. For example, PNL's management staff who are supporting EM-50 are using their program contacts to help link Bechtel Hanford staff to the EM-50 programs and technologies which are applicable to Hanford's environmental restoration needs.

EM-50 Technical Program Coordination

Specific technical activities at PNL will evolve, over the next 5 years to support the EM-50 program. Current EM-50 technology development activities for the highest priority or nearterm needs will be completed and the technologies transferred to the user and industry for deployment. As activities are completed, efforts will be redirected to those technology needs that are increasing in priority. For example, there will be a reduction in technology development to support site character-

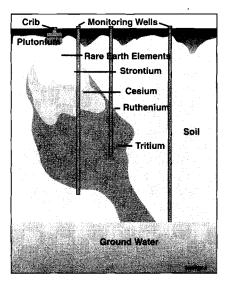
ization as new solutions are implemented; while there will be greater involvement in developing decontamination and decommissioning technologies, which will be needed as site cleanup operations are concluded.

In FY 1995 the EM-50 National Program will begin to transition from its centralized management approach using Integrated Demonstrations and Programs to a New Approach for Technology Development. This new approach, which was initiated in FY 1994, will build on many of the management and technical activities of previous programs. The new approach will further integrate technology development to emphasize the following five focus areas and three crosscutting technical areas

- · focus areas
- high-level waste tank remediation contaminant plume containment and remediation
- mixed waste characterization, treatment, and disposal
- landfill stabilization (soils and buried wastes)
- facility transitioning, decommissioning, and final disposition
- crosscutting technical areas characterization, monitoring, and sensor technologies
 robotics

efficient separations.

Management of these areas will be through a Headquarters-based management team which will set policy and priorities, a field implementation team which will provide technical direction and administration, and fieldbased site technology coordination groups which will have the responsibility for identifying needs, supporting implementation, and generally serving as check and balance for the National Program. The teams will be staffed by representatives of users, developers, industry, regulators, and other stakeholders to increase integration and to accelerate implementation of the new technologies.



Toxic byproducts and wastes that have resulted from past commercial and defense-related activities must be managed and treated.

The integrated demonstrations and integrated programs currently coordinated by PNL will be transitioned to the new approach. The affected programs include the Volatile Organic Compounds in Arid Soils (VOC-Arid) integrated demonstration, the Efficient Separations and Processing (ESP) integrated program, the In Situ Remediation Technology integrated program, and the Underground Storage Tank integrated demonstration. PNL also provides management/coordination support for the tank waste retrieval effort in EM-50's Robotics Technology Development Program, which is one of the crosscutting areas.

Many of the successful approaches developed and used in the PNLcoordinated integrated demonstrations and programs are being used as models to be incorporated into the new focus areas. Currently, PNL staff are directly involved in the implementation of the Tanks and Plume Focus Areas. PNL is the lead organization in the implementation team for the Tanks Focus Area and the senior staff involved in the VOC-Arid and In Situ Remediation programs are part of the implementation team for plumes, which is led by the Savannah River Operations Office. PNL staff will continue to provide coordination of the Efficient Separations Program, which

is one of the crosscutting focus areas. PNL staff expect to provide support to the other focus areas as they are implemented.

The activities of the VOC-Arid integrated demonstration are being transferred to the Plume Focus Area. The current technical activities are planned to be completed over the next 5 years. The activities are currently transitioning from technology demonstrations for detection/removal/destruction of volatile organics in the vadose zone to technology demonstrations targeting volatile organics in groundwater. By FY 1999 four remediation systems for enhanced removal or in situ destruction of volatile organics and associated contaminants will have been demonstrated. The Hanford effort will also initiate at least one field demonstration at an arid site other than Hanford and will establish commercialization and partnership plans for all of the technologies demonstrated.

All work in the Underground Storage Tanks integrated demonstration is being transferred to the Tanks Focus Area. Its current 5-year plan includes completing development of the light duty utility arm and transferring the system to EM-30; completing development of infrared spectroscopy and other characterization techniques and deploying them in the waste tanks at Hanford; and completing the specifications for the end effectors for tank waste retrieval (i.e., the first generation remote retrieval arm). The plan also includes demonstrations of advanced separation technologies that have been developed to provide low-level waste streams which can be "contact handled" for final treatment and disposal as a cost reduction and worker and public safety enhancement strategy. Some of these efforts may be redirected as the system-wide needs for tanks technologies are reevaluated by the new focus area teams.

The robotics tank waste retrieval effort will continue for several years, focusing technology development efforts on waste retrieval applications, specifically on improving autonomous controls, improve sensing including improved interpretation of sensor data, and

improving end-of-arm tooling. Accomplishment of these goals will lead to improved productivity and greater safety for workers and the public. PNL will continue to provide technical support to this effort as well as overall coordination of the complex-wide task supporting retrieval and the large, consolidated demonstrations of robotic retrieval systems in a major test-bed facility sited at Hanford.

Currently the Efficient Separations and Processing technical area is directed toward high-level waste separations. Over the next 5 years, increased emphasis will be placed on separation processes for low-level waste and hazardous chemicals. Efficient Separations and Processing will develop separation technologies for a spectrum of radioactive and hazardous defense wastes with a goal of transferring the technologies to industry to facilitate U.S. competitiveness in the world market. In addition, advanced separations technology development is a major focus at PNL and is a key component of the Advanced Processing Technology Initiative.

The activities of the In Situ Remediation integrated program are being transferred to the Plume Focus Area. The transferring PNL tasks include in situ treatment, subsurface barriers, and techniques to manipulate the subsurface to immobilize or detoxify contaminants. These and other PNL technologies which will be supported under research and development functions in the Plume Focus Area will be targeted toward field demonstrations and then deployment.

Technology Activities for EM-50 PNL is performing technology development tasks for many of the EM-50 program areas. Specific technologies under development at PNL 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 barriers for contaminants in the soil and groundwater, enhanced contaminant extraction 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, models for assessing subsurface performance and risks, and a new compact processing concept for rapidly providing facilities to begin treating tank wastes. PNL has, or is now developing, through the EM-50 program, over 75 technologies.

A major objective is to rapidly transfer technologies to DOE-EM operating programs. PNL is transferring several technologies including in situ vitrification, permanent isolation barriers system, and six phase soil heating. Other technologies are being closely coordinated with the operating programs to ensure this rapid transfer will occur. For example, EM-30 and EM-50 are jointly funding development of in situ and ex situ technologies for analyzing Hanford tank wastes. 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.

Technology Integration Activities for EM-50 PNL is actively involved in meeting the technology integration needs of EM-50's National Program and the specific needs of the activities at Hanford through the Hanford Technology Integration Program (HTIP). The objective of HTIP is to identify and build links with industry, universities, and other units of government to develop, adapt, and commercialize new, federally-funded and cost-shared technologies that have applicability to the special needs of the DOE complex and the broader needs of the private sector. PNL has initiated negotiations with numerous industries, firms, regional businesses, and units of government on behalf of the DOE-EM program. Two years ago, HTIP took on the responsibility for working with the integrated demonstrations and integrated programs at Hanford to develop industrial partnerships and achieve commercialization in 22 problem areas requiring innovative new technologies. Over the last 2 years,

partnerships with industry have been achieved in virtually all cases attempted (22) and, more significantly, 5 of the new technologies have completed demonstration and have been successfully commercialized. Over the next 5 years, efforts will be focused on commercializing the remainder of the technologies and establishing partnerships leading to commercialization for an expanded set of technologies.

Key to PNL's success is the twostaged approach to identifying industry partners and constructing effective partnerships. Holding interchange meetings with industry to inform them of needs and opportunities available for participation is the first stage of this process. To date, six highly successful interchange meetings have been held and a network of some 900 environmental firms established.

PNL proposes to expand its efforts to seek out and work with U.S. firms, industries, institutions of higher education, states and regional units of government, and other federal agencies that share common problems and/ or are engaged in developing or commercializing technologies that meet DOE needs. These efforts will be focused regionally, nationally, and internationally. A series of highly successful workshops have already been held to introduce Northwest firms to the waste management and environmental restoration problems facing the Hanford Site.

PNL directly supports the EM-50 International Technology Exchange Program by planning, data collection, and data dissemination. The program coordinates technology exchanges with other countries and provides a focal point for the flow of information on environmental restoration and waste management activities. Additional tasks are related to supporting exchange of information and personnel with various Russian organizations and with management of a major international conference on waste management and environmental remediation.

Solid Waste Initiative

For the past 5 years, PNL has performed solid waste modeling and

analysis in support of planning for Hanford's Solid Waste Programs. This modeling and analysis is focused on developing reliable projections of the quantities and characteristics of the solid wastes that will require management on the Hanford Site over the next 30 years. As a logical extension of this work, beginning in FY 1992, PNL undertook a Laboratory Directed Research and Development initiative to provide new capabilities for predictively modeling the long-term impacts of solid waste practices throughout American society. This capability will establish a basis for the analysis of alternative scenarios, to assess the impacts of current plans, and to evaluate modifications to these plans.

A Macro Material Flow Modeling (MMFM) concept and approach are being pursued to develop a predictive modeling capability that can be used as a total-systems oriented base for evaluating potential impacts from various sold waste system configurations and operating scenarios. This concept and approach include the entire life cycle of the major materials that are eventually identified as wastes, with consideration of the patterns of production and consumption that give rise to the wastes. This capability to model and understand material flows will later be coupled with other types of information to calculate the full range of impacts from solid waste management activities. To support this, linkages are also being developed with a range of organizations in the solid waste arena to provide an increased, detailed understanding of problems and opportunities as seen by those directly involved. Emphasis has been given to including the range of types of organizations involved (private vendors of services, municipal solid waste authorities, state governments, federal agencies, universities, and trade groups) to ensure a full range of views are recognized. However, the primary focus of these linkages is within the Northwest region of the U.S.

Because of the nature of this initiative, the potential applicability of the results reaches far beyond DOE-EM to include other DOE Headquarters organizations, other federal agencies, and state and regional organizations. All of these organizations have a strong interest in solid waste practices within our society. In addition, because of potential interactions with global environmental changes, this initiative is being carried out in collaboration with the Global Environmental Change Initiative.

Office of Environment, Safety and Health

PNL's participation in programs conducted by the Office of the Assistant Secretary for Environment, Safety and Health (ES&H) is expected to increase.

For the Office of Environment, assistance to the DOE is expected to expand in five areas. First, PNL will support the development and application of systems for more efficient information management and processing related to requirements of the CERCLA, or Superfund Amendment and Reauthorization Act (SARA), and of the RCRA. Second, PNL will continue to assist the DOE in developing public and environmental protection standards and will support the rule-making process. Third, PNL will develop methods to standardize the DOE's approach to risk assessment, including standardizing laboratory and computational procedures for assessing risk from exposure to hazardous chemicals. Fourth, PNL will provide support to the DOE training initiative. Finally, PNL will continue to assist the DOE with its evaluation of environmental compliance.

For the Office of Safety and Quality Assurance, PNL's participation in programs is expected to continue to increase. First, PNL's curriculum of training is being developed to improve the DOE's implementation of safety principles and practices in the work place and to address issues raised in Tiger Team appraisals and in the Occupational Safety and Health Administration (OSHA) inspections of the DOE's facilities. Second, PNL will assist in the Voluntary Protection Program (VPP) evaluations and in the development of an expanded Federal Employee Occupational Safety

and Health (FEOSH) program. PNL will also continue to assist in the analysis of accident reports to evaluate the technical adequacy of investigation, reporting, and compliance with the DOE directives.

For the Office of Health, the DOE's increased emphasis on worker and public health will expand the need for assistance in three areas. First, to complement the continuing work related to ionizing radiation, PNL will assist in developing performance assessment modules for monitoring nonradiological exposure and will assist in strengthening capabilities for assessing exposures to chemicals and to nonionizing radiation. Second, PNL will assist in developing and implementing measurement technology and epidemiological approaches for health surveillance of workers and the public, with particular emphasis on environmental cleanup activities. Third, PNL will continue to assist the DOE in its effort to strengthen and standardize health physics programs.

To expand knowledge and technology related to chemical protection, PNL has established an initiative entitled "Health Protection and Standards for Hazardous Chemicals." The need is motivated in two ways. First, monitoring of nonradiological as well as radiological worker exposures for their health protection is vital and is a responsibility of DOE. In addition, a system similar to the system for radiological exposures provides legal protection to DOE. Second, important financial consequences for DOE sites can be gained by relaxing cleanup standards that are outdated and not health-risk based. The objective of the initiative is twofold: 1) to develop capabilities to provide new knowledge for reducing uncertainties and conservatism in risk estimates for chemicals and 2) to better quantify worker and public exposures and, thus, health risks by developing personal monitors and dosimeters for chemicals. Risk estimates will be improved by developing toxicokinetic knowledge, by understanding genotoxicity, and by understanding how to incorporate this information on kinetics and thresholds into risk estimates. Risk estimates will

also be enhanced by developing better approaches to assessing risk from concomitant exposure to multiple agents. An outcome of the initiative will be capabilities to provide the DOE with a chemical health protection program for workers similar to the existing radiation protection program, and the ability to provide chemical exposure data for epidemiology and health surveillance activities.

Environment

Under the Deputy Assistant Secretary for Environment, PNL supports the Offices of Environmental Audit, Environmental Compliance, Environmental Guidance, and National Environmental Policy Act Oversight.

Environmental Audit PNL anticipates providing technical support to the Office of Environmental Audit as environmental audit policies, programs, and procedures are developed. Emphasis on coordinating and resolving crosscutting issues (i.e., issues that span several offices) will be key to developing successful methodologies. The development of systems to plan and track audits is complete. Assistance is being provided for audit training across the DOE complex. Updating of the Environmental Audit manual is under way.

Environmental Compliance The environmental compliance technical support project assists the Office of Environmental Compliance in fulfilling its oversight and technical assistance responsibilities to ensure that the DOE's facilities and operations comply with federal, state, and local environmental requirements and with the DOE's environmental orders and policies. The technical support provided by PNL assists the DOE's compliance strategies and facilities compliance divisions and spans the following areas:

- compliance methodologies development and technical analysis support
- review of key DOE compliance and policy documents
- day-to-day compliance activities support.

Assistance will be provided in several ongoing areas to help ensure that environmental documents receive consistent reviews from a policy perspective and that compliance reporting and review is consistent by 1) developing a manual for review of RCRA and CERCLA documentation, 2) identifying ways that will enable the Office of Environmental Compliance to track key CERCLA and RCRA corrective action decision points and to monitor activities in this area, and 3) supporting the development of a standard framework for reporting compliance information across the DOE complex.

As required under DOE Order 5400.1 (General Environmental Protection Program), each DOE site submits an annual environmental report and this data is combined to provide a summary of total radiological emissions and doses from the DOE's facilities. PNL is continuing to support the Office of Environmental Compliance in finalizing the 1989 Summary Report, preparing the draft 1990 Summary Report, and providing guidance to sites on preparing their annual site environmental reports.

Work will continue to provide technical assistance to the Office of Environmental Compliance in identifying evolving trends in compliance. Assessment and interpretation of sitespecific and complex-wide trends will be further developed, and the analysis of compliance assessment and negotiation issues will be further refined. PNL will also collect and evaluate compliance-related information, and will analyze compliance assessment and negotiation issues relevant to the DOE with a view toward identifying and defining trends in compliance implementation and compliance agreements.

Environmental Guidance PNL provides technical support in fulfilling the DOE's responsibilities for providing environmental guidance and policy information to the DOE complex. The technical support provided by PNL assists the DOE's RCRA/CERCLA and Air, Water, and Radiation Divisions, and spans the following four areas:

- development of innovative methods for presenting guidance
- review of key environmental legislation, regulations, and associated documents
- risk-based standards support
- environmental support and assistance.

A continuing PNL effort has been to develop methods for streamlining site characterization at the DOE's remediation sites. This effort integrates an observational approach with an engineering approach grounded in data quality objectives. The resulting integration is applied to the remedial investigation phase of the remedial investigation/feasibility study (RI/FS) process. PNL has completed a report containing guidance on techniques for streamlining the RI/FS process. These techniques will be applied to the Office of Environmental Guidance's RCRA corrective action guidance development effort.

Currently, PNL is developing a computerized version of a graphic approach to the environmental guidance document addressing SARA Title III, and the **Emergency Planning and Community** Right-to-Know Act. PNL will continue to provide technical support for developing new and updated guidance and strategies. While a major emphasis will be on developing a graphic approach to environmental guidance packages, PNL will also continue to provide technical support for preparing guidance materials in alternative formats, such as handbooks, guidance manuals, video training, memoranda, information briefs, and other formats.

PNL is supporting efforts by the Office of Environmental Guidance to team with other DOE offices, particularly the Office of Environmental Management, to develop implementation-orientated guidance. Teaming efforts include pilot workshops on the streamlining approach to environmental restoration at specific sites using actual site data/scenarios as a method for obtaining "real-life" validation of guidance, developing a "how-to" guidance on nonstatutory/regulatory RCRA permit conditions, and conducting implementation projects on integrating

natural resources values in environmental restoration activities. PNL is also providing support on natural resource/environmental restoration integration, and a phased approach to environmental restoration under CERCLA.

PNL will assess future environmental trends and proposed legislation and regulations to assist the Office of Environmental Guidance in establishing its near- and long-term priorities. As part of this effort, PNL will help determine how these trends may affect present DOE program priorities, needs, and requirements.

PNL is also providing technical support to the development and application of standards for environmental restoration, waste management, and decontamination and decommissioning. PNL is providing members of the DOE working group on risk-based standards with critical information for decisions regarding the development of new standards and the application of existing standards. Pending decisions by this working group, PNL will also support standards development. PNL will continue to support DOE in defining where standards are needed and where existing standards need to be adapted, particularly in the areas of human health risk and ecological risk.

PNL will also support DOE in developing an integrated program in risk assessment, risk management, and risk communication. This program will facilitate the use and acceptance of risk-based standards developed by DOE and other federal agencies for DOE sites.

Technical assistance is also provided to the Office of Environmental Guidance in fulfilling its environmental protection responsibilities for DOEcontrolled nuclear sites and facilities. Assistance is provided in four major areas: 1) environmental radioactivity and risk-based guidance support, 2) radioactive and mixed waste management regulation and guidance support, 3) quick turnaround assistance, and 4) project management. As site cleanup activities at the DOE's nuclear sites proceed, the DOE must provide technically credible, consistent guidance that is compatible with

other federal guidance and ensures public and environmental radiation protection. PNL activities are designed to be responsive to this need.

National Environmental Policy Act (NEPA) Oversight PNL continues to provide technical assistance to the Office of NEPA Oversight, and to operations office personnel, in efforts to better implement the requirements of NEPA for the DOE's projects. The application of SEN-15-90 has reinforced the importance of NEPA compliance across the DOE complex and the need for early involvement of the NEPA Office in developing complete and comprehensive NEPA documentation. This, in turn, has increased PNL's scope and level of effort in providing support to this effort. The program staff work closely with the Office of Environmental Guidance, Office of General Counsel, Office of Safety and Quality Assurance, and Office of Environmental Audit to assist in ensuring that all applicable federal, state, and local regulations are adequately addressed in NEPA documentation and review.

PNL technical support to the Office of NEPA Oversight emphasizes reviews of impact analyses, impact mitigation proposals and plans, and reviews of technology and regulations applicable to NEPA compliance. PNL also develops analysis and management tools and methodologies to help ensure that the NEPA process is conducted in a timely and consistent manner across the DOE complex.

Safety and Quality Assurance

The Deputy Assistant Secretary for Safety and Quality Assurance is responsible for managing and directing comprehensive programs to ensure nuclear and non-nuclear safety in all the DOE's activities. PNL conducts programs for the Office of Quality and Safety Programs, including

- technical safety appraisals and safety analysis reviews
- worker safety training and safety evaluations support
- support to site resident programs on performance-based assessments

- accident investigation review and guidance development
- technical support for chemical risk studies and chemical safety guidance
- program evaluation of the DOE Headquarters and operations office prioritization and self-assessment.

Technical Safety Appraisals and Safety Analysis Reviews PNL provides technical support and coordination of the health physics and emergency readiness, industrial hygiene, and nonionizing radiation performance objectives of the technical safety appraisals and operational readiness and safety analysis reviews conducted by the Office of Safety Appraisals.

Worker Safety Training and Safety **Evaluations Support** PNL supports the Office of Occupational Safety through development and presentation of worker safety training courses, centralized coordination of occupational safety and health training resources, and assistance in development of occupational safety and health training requirements and guidance. DOE has designated PNL as a lead laboratory for assisting the DOE with enhancing the nonradiological worker safety training program. PNL staff have developed several training courses to introduce workers, supervisors, managers, and safety and health professionals to the OSHA requirements for safety in the work place.

Support to the Site Resident Program on Performance-Based Assessments

PNL provides technical support to the resident program staff in the development of performance-based assessment guidance, the conduct and reporting of performance-based assessments, and the comprehensive integration of assessment findings.

Accident Investigation Review and Guidance Development PNL supports the Office of Performance Assessment through the review of significant safety Type A and B accident investigation board reports for technical adequacy and compliance with the DOE directives. This program also includes the development and issuance of accident

investigation guidance based on field experience and lessons learned, and conduct of operational and special assessments.

Technical Support for Chemical Risk Studies and Chemical Safety Guidance

PNL supports the Office of Risk Analysis and Technology by conducting a work place chemical accident risk study and by developing chemical safety guidance.

Technical support will be provided by PNL in publication of the Occupational Safety Observer, a monthly compendium that is the primary DOE conduit for industrial safety lessons learned. Distribution is expected to continue to grow to over 10,000 by end of FY 1995. PNL also provides technical support by coordinating the multilaboratory chemical safety vulnerability study for DOE.

Program Evaluation of the DOE Headquarters and Operations Office Prioritization and Self-Assessment

PNL is supporting the program evaluation staff in evaluating the DOE Headquarters line programs and operations office prioritization of occupational safety and health-related activities. PNL is also providing technical support to the DOE Headquarters line programs' self-assessment of occupational safety and health activities and programs. We will support DOE in accident investigations by developing a guidance document, a draft of DOE Order 5484.1, and an internal DOE procedure for supporting investigations. PNL will also provide technical and administrative assistance in the selfevaluation of Type A accident investigation board activities, and will evaluate the feasibility of applying an expert system to assist in performing accident investigations.

PNL also provides technical support through presentation of lessons learned seminars. These seminars provide a forum for DOE managers across the complex to meet and analyze significant safety incidents and develop plans for preventing similar incidents from occurring in the future. To extract lessons learned, PNL will evaluate the

feasibility of developing a computer system to review incident databases.

Health

The Deputy Assistant Secretary for Health develops and recommends policies and standards related to radiation protection, industrial hygiene, and occupational medicine for application in the DOE's facilities. PNL assists in efforts to implement policies and standards, to evaluate their impact, and to monitor for compliance. PNL also assists in development of a comprehensive data resource on workers to ensure effectiveness of health protection programs. In accomplishing this work, PNL conducts programs for both the Office of Health Physics and Industrial Hygiene Programs and the Office of Epidemiology and Health Surveillance.

PNL is continuing to develop capabilities to support new programs in the Office of Health, PNL is expanding its efforts in nonionizing radiation and is developing new capabilities to assist the 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 entitled, "Health Protection and Standards for Hazardous Chemicals," described above in the introduction to the Office of Environment, Safety and Health section.

Health Physics and Industrial Hygiene **Programs** The primary objectives of PNL's health physics and industrial hygiene programs are to 1) develop guidance to support requirements and good practices in operational programs; 2) solve technology problems in radiation and other measurements: 3) develop performance criteria and methods for implementing laboratory accreditation programs for radiation protection measurements, and provide technical support in the operation of such programs; 4) develop and operate a Secondary Calibration Laboratory for DOE; 5) provide technical support to

address key national and international issues affecting the DOE; 6) provide support and assistance through special studies; and 7) provide a lead-laboratory systems approach to meeting the DOE's needs.

Currently, five ongoing health physics projects are conducted by PNL as follows:

- Radiation Protection Guidance
- Worker Radiation Protection Technical Support
- · Worker Dosimetry Accreditation
- R&D Worker Exposure Assessment
- Hazardous Waste Worker Exposure Assessment.

Radiation Protection Guidance

(formerly Technical Support for Health Physics Policy and Guidance Development) PNL assists DOE in the development or revision of guidance to support the new radiation protection rule (10 CFR 835), DOE Orders, and the new DOE Radiological Control (RadCon) manual. These guides are designed to assist DOE sites in appropriate implementation of rules and guidance and to ensure quality and uniformity of practices. A new initiative will be direct technical assistance to support DOE operations.

Worker Radiation Protection Technical **Support** (formerly Health Physics Support and Assistance) The focus of this program element is on special technical studies associated with improving the capability and quality of current health physics programs, and assessing the expected impact of standards, regulations, administrative requirements, and engineering design actions on the DOE's radiological control programs. The project supports the development of new initiatives and capabilities, provides for quick turnaround specialized support, and supports development of guidance for establishing uniform protection programs throughout the DOE.

Worker Dosimetry Accreditation (formerly Laboratory Accreditation Support) This project provides a mechanism for the development of improved calibration and quality assurance with respect to radiation measurement technology. Resolving problems associated with measurements and methodologies requires a cooperative multilaboratory effort and fieldbased studies. Accordingly, a portion of project funds is used for the direct support of identified activities conducted at other DOE laboratories, private industry, and universities having the recognized and needed expertise. To assist in this effort, PNL has developed a world-class radiation calibration facility and is extending this to include calibration capability for quantities of interest in worker protection other than radiation. This calibration laboratory was recently accredited by the National Institute of Standards and Technology and is the only Secondary Calibration Laboratory within DOE.

Research and Development Worker **Exposure Assessment** (formerly Applied Health Physics Research) The Applied Research Project for Dosimetry and Measurement allows the DOE to identify and seek solutions to new health physics initiatives, which significantly advance the state of the art of personnel dosimetry and measurement systems, while maintaining a cognizance of "real" radiation protection problems within the DOE complex. The Applied Research Project focuses on problems that affect the determination of personnel doses and on developing improved, nearterm concepts.

Hazardous Waste Worker Exposure Assessment (formerly Health Physics Technical Support and Policy Review) PNL is assisting DOE in the development of guidance for assessment of radiation exposures to hazardous waste workers. This includes development of guidance and integration of guidance into assessment methods for other hazardous physical or chemical agents. In addition, the efforts involve database development and development of methods to correlate worker exposure with the task or job.

A new technical support area in industrial hygiene was initiated in FY 1992 and is continuing to expand. Three project areas active in FY 1994 follow:

- Industrial Hygiene Technical Support and Assistance
- Industrial Hygiene Technical Support
- Hazardous Chemical Consequence Assessment and Emergency Response Planning Guidelines Development.

Industrial Hygiene Technical Support and Assistance This project provides technical resources in industrial hygiene to assist DOE in analyses of needed improvements (e.g., reproductive and developmental chemical hazards, occupational noise exposure).

Industrial Hygiene Technical Support (formerly Industrial Hygiene Center for Physical Agents). This project provides technical support in developing a nonionizing radiation protection program for workers at the DOE's facilities. Efforts include assessing the current status of nonionizing radiation protection throughout the DOE community; assisting in the development of a comprehensive nonionizing radiation program for workers; assessing needed improvements in occupational nonionizing radiation protection programs; and analyzing the impact of standards, regulations, and engineering or administrative actions on such programs.

Hazardous Chemical Consequence Assessment and Emergency Response Planning Guidelines Development. This project provides consistent assessment of the consequences of hazardous material releases within the DOE complex. The project also assists the DOE in the development of emergency response planning guidelines and information packages for hazardous chemicals used in the DOE's operations.

Epidemiology and Health Surveillance Two areas of technical support are currently provided by PNL:

- Technical Support for Epidemiology and Health Surveillance
- Technical Support for Comprehensive Epidemiologic Data Resource (CEDR).

Technical Support for Epidemiology and Health Surveillance PNL will continue to support DOE in collaborative efforts related to nuclear worker studies at the International Agency for Research on Cancer (IARC) through 1) coordinating a new collaborative study of workers in several countries and 2) writing a book on cancer risk from exposure to low doses of radiation.

Through other work, PNL will continue to emphasize molecular approaches to epidemiology and health surveillance. In particular, PNL 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 the Comprehensive Epidemiologic Data Resource

The CEDR program was established to develop a public-use database containing information about workers at DOE facilities. PNL will continue to contribute to this program by providing data and documentation from studies of the health and mortality of workers at the Hanford Site and of their offspring, by expanding and documenting the Hanford worker database, by participating in the CEDR Provider Working Group in the areas of both data management and dosimetry, and by assisting in providing support to CEDR users.

Security Evaluations

The PNL program for the Office of Security Evaluations involves assessing the status and condition of safeguards and security programs at all major facilities of the DOE by making field inspections, evaluating trends and problems in specific areas, and reporting to DOE management on the conditions. PNL will continue to provide direct technical and field support to the Office of Security Evaluations by 1) participating in inspections and evaluations of field operations offices, 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. PNL activities will also focus on developing new tools and techniques that can be applied in the evaluation process.

Special Projects

PNL supports the Office of Special Projects in several areas. PNL assisted in summarizing the information and trends identified by the key findings and key concerns in the first 17 to 33 Tiger Team assessments. In addition, PNL provided technical support in revising the Tiger Team Guidance Manual. This manual provides guidance to Tiger Teams that conduct assessments at the DOE's facilities, and provides assistance in conducting self-assessments to the DOE Program and Operations Offices and site contractors.

In response to criticism by the General Accounting Office and the Inspector General's Office about information systems in the Office of Environment, Safety and Health, the Office of Environment is developing an overall management information network. PNL plans to support this effort. Additional support to provide trend analysis for the remaining Tiger Team assessments is anticipated along with trend analysis development for the action plans prepared in response to the Tiger Team findings. A facility profile database and system for the Hanford Site is expected to be developed and will serve as the prototype for facility profile databases and systems at other DOE sites.

Hanford Site Support

The DOE Richland Operations Office has assigned responsibility to PNL for environmental surveillance and oversight activities (surface and groundwater surveillance, meteorology and climatology, wildlife resources monitoring, cultural resource protection, and dosimetry coordination (see the following section); 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. PNL provides significant support to Hanford and its environmental restoration and waste management businesses, as described under the Office of Environmental Management section. PNL will continue to seek well-recognized research staff from universities to participate in Hanford environmental programs and to initiate and coordinate peer reviews of these programs by nationally recognized experts. Funding for Hanford Site support activities are included in the appropriate sections of the Resource Projections.

Public Safety and Resource Protection

The comprehensive environmental surveillance and oversight program for the Hanford Site that is assigned to PNL is independent of the management and operations contractor. This program includes

- characterizing and monitoring the radiological and nonradiological status of the environment
- assessing onsite and offsite environmental impacts of site activities, estimating corresponding radiological and nonradiological risks to the public, and predicting future impacts of known contaminant releases and planned activities
- identifying and recommending programs needed for timely and responsive action on present and future Hanford environmental issues
- preparing NEPA documentation for the site
- monitoring Hanford biological (fish and wildlife) and cultural resources
- supporting the DOE Richland
 Operations Office in public information efforts and in presentations
 to cognizant regulatory agencies on
 matters that pertain to these activities.

During 1993, PNL prepared environmental monitoring plans; conducted environmental monitoring and surveillance; calculated the radiological dose to humans onsite and offsite and reported the results in the annual Hanford Site environmental report; and implemented a program 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.

Occupational Protection

As part of Hanford's program to protect the health and safety of workers, PNL provides a complete assessment of occupational radiation exposure to ensure compliance with DOE Orders and federal regulations. PNL conducts a comprehensive program of occupational dosimetry, including assessment of internal and external dose, measurement of internally deposited radioactive material, calibration of monitoring devices, and documentation and reporting of this information. These programs strengthen PNL's health physics research programs by providing the means for identifying problems and areas for improving radiation dosimetry and measurement.

PNL supports the DOE Richland Operations Office with development and maintenance of a site-wide NEPA compliance plan and with preparation of complex environmental documents in support of facility construction, site remediation, and operations. PNL has prepared environmental impact statements for a variety of endeavors at the site.

Hanford Environmental Dose Reconstruction Project

The Hanford Environmental Dose Reconstruction (HEDR) project is a multiyear study established in 1987 to develop estimates of radiation doses people could have received from 1944 to the present from exposure to emissions from Hanford Site operations. In 1992, the management of the project was transferred to the Centers for Disease Control and Prevention.

The project is directed by an independent Technical Steering Panel consist-

ing of technical experts and members representing the states of Washington, Oregon, and Idaho; Native American tribes; and the public. The Centers for Disease Control and Prevention will use the HEDR dose estimates in the Hanford Thyroid Disease Study (HTDS) to determine whether regional thyroid disease can be linked to iodine-131 releases from Hanford operations. Preliminary data for the HTDS was available late in FY 1993.

Initially, scientists developed and tested an integrated computer model to determine if it was feasible to reconstruct early releases of radioactive materials and subsequent doses. The initial investigation was limited to atmospheric releases of iodine-131 that occurred from 1944 through 1947 and to waterborne releases of eight radionuclides from 1964 through 1966. Results were published in preliminary form and presented to the Technical Steering Panel in July 1990. In 1991 it was decided to expand the area of interest and to restructure the model to provide more flexibility.

Based on detailed information found on reactor and separations facilities operations, the iodine source term has been reconstructed and found to be about 70 percent larger than previously reported. The atmospheric dispersion and deposition model has been restructured. The environmental accumulation and dose models have been redesigned. Additional agricultural and food consumption information has been acquired. The full capability to estimate doses from releases of iodine-131 to the atmosphere was available in October 1993 to support the HTDS. Final doses from the atmospheric and Columbia River pathways were released to the public in April 1994. Preliminary results of the HTDS study are expected in January 1995.

Since June 1992, funding for the program has been provided by the Centers for Disease Control and Prevention. Funding for FY 1993 was \$4 million, and \$1.7 million for FY 1994. PNL's work has been completed and records are being transferred to the Centers for Disease Control and Prevention.

Energy Resources

As a multiprogram laboratory, PNL provides scientific knowledge and innovative technologies to many DOE programs directed toward achieving DOE goals, such as diversifying energy supply, using energy more efficiently, and reducing environmental impacts. PNL is focusing on improving the utilization of existing energy assets and developing a new generation of distributed energy systems. This focus provides the framework for utilizing PNL's core competencies to contribute to near-term DOE goals that address the current national energy infrastructure. It also establishes the context for providing leadership in an emerging national need for new distributed energy systems that will be central to the revolution now under way in the U.S. energy industry. PNL expects that the pressure to decentralize energy services will significantly influence U.S. energy policy and economic competitiveness in the 21st century.

Reflecting the link between energy, the environment, and the economy, PNL has focused its capabilities toward the following objectives:

- Understand the technological and policy issues that impact energy policy and global environmental change.
- Improve transmission, distribution, and utilization of electricity and gas.
- Reduce emissions and weight in motor vehicles.
- Reduce energy consumption and wastes produced in industrial processes.
- Improve energy efficiency and use in buildings.

PNL's scientific and technical activities in each DOE program contributing to the energy resources core business are described below. The descriptions also explain proposed new initiatives within these organizations.

Office of Energy Efficiency and Renewable Energy

Cost-effective, environmentally benign energy resources are critically important to the nation's economic productivity. In our efforts for the Assistant Secretary for Energy Efficiency and Renewable Energy, PNL draws upon its three core competencies (process science and engineering, energy systems development, and integrated environmental research) to develop and deploy efficient technologies to improve the efficiency of the buildings, transportation, and industrial sectors and to increase the reliability and utilization of the nation's vast transmission, distribution, and storage system assets.

The DOE-EE role is expanding and changing to address significant new challenges resulting from the Climate Change Action Plan, the Energy Policy Act, and DOE's new strategic plan which emphasizes energy resources, international competitiveness, and environmental quality. PNL plans to help DOE-EE respond to these new challenges both through current programs and through new initiatives. Through the Energy Technology Development Initiative which was described previously, we are enhancing Laboratory capabilities to address emerging needs in three of the Department's core businesses (energy resources, industrial competitiveness, and environmental quality as it relates to reducing the impacts of the energy system). We expect to continue to participate in developing collaborative efforts with the DOE and industry which access the capabilities of the laboratory system. In addition, we are exploring how DOE and the laboratory system can benefit from Battelle Memorial Institute's (BMI's) involvement with private-sector firms through its zero-discharge manufacturing business and through long-term relationships with organizations such as the Gas Research Institute. PNL plans to work with DOE-EE to determine if the BMI connections to the private sector can be used to help accelerate

deployment and/or leverage joint DOE/industry research programs.

New DOE-EE program initiatives are anticipated in areas that build upon these current efforts and also address key goals from DOE's environmental quality and industrial competitiveness core businesses. Selected highlights include

- expansion of PNL participation in the USCAR initiative
- support planning and implementation of the Chemicals Industry of the Future and the Refinery of the Future initiatives
- a new program to apply microtechnologies to building system technologies
- expansion of PNL support to DOE-EE's portion of the Climate Change Action Plan
- leadership in developing the National Electric and Magnetic Field Research and Communication Program (established by EPAct)
- continued support (internally funded) to the industry-led distributed utilities project, which includes Electrical Power Research Institute, Pacific Gas and Electric, and National Renewable Energy Laboratory
- expansion of programmatic support for science and engineering support of the utility transmission and distribution system. Support of electricity transmission and distribution research and development efforts will grow both with Bonneville Power Administration and with the Office of Utility Technologies. PNL also anticipates broadening this activity to bridge to the natural gas transmission and distribution system as well.

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 steady growth, reflecting modest growth in the current, base program.

Office of Utility Technologies

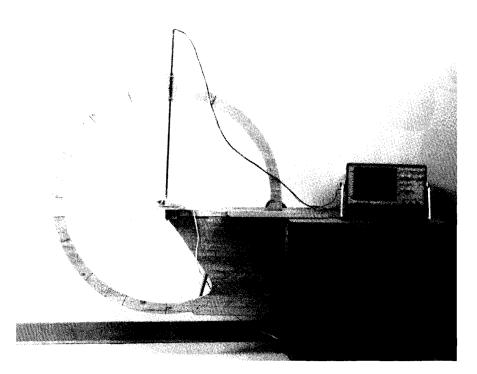
For the Office of Energy Management (EE-14), PNL conducts research

on potential biological effects of electromagnetic fields, energy storage technologies, wind resource characterization, and integrated resource planning; we lead the Management Analysis Program. PNL intends to participate in the proposed multilaboratory collaborative efforts with the utility industry in areas where PNL competency can lead to a substantial contribution.

Electric Energy Systems (AK) PNL will continue its basic research in electromagnetic field interactions on biological systems and in the identification of potential health effects in support of the National Institute of Environmental Health Sciences (NIEHS), as outlined in the National Electric and Magnetic Field Research and Communication Program. In addition, PNL will work with DOE and Oak Ridge National Laboratory to develop and implement a comprehensive electromagnetic field engineering program that includes electromagnetic field measurement and assessment and the development of mitigation strategies and materials.

The research effort currently under way for the Office of Energy Management includes comprehensive studies to assess possible biological effects of electric and magnetic fields related to the use of electric power. This research is designed to provide data to help set the maximum levels of exposure to those fields that are biologically acceptable for both workers and the general population. The 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. The work complements related PNL studies sponsored by the Electric Power Research Institute, Bonneville Power Administration, DOE, and the National Cancer Institute. It is expected that, as this program



Researchers can measure the electromagnetic field produced by household appliances in an effort to determine if there are any biological effects from electromagnetic field exposure.

responsibility shifts to NIEHS, PNL will continue to conduct this core research. In addition, PNL will employ its significant experience in public outreach to support the communications goals of the national program.

The National Electric and Magnetic Field Research and Communication Program, established by the Energy Policy Act of 1992, has a 5-year sunset provision. PNL has been investing its discretionary resources for the past several years in the development of engineering systems deemed important for supporting the engineering requirements of the national program. These include advanced exposure systems, electromagnetic field shielding materials, systems for characterizing the electromagnetic field signatures of electrical devices, and supporting technologies including computer "visioning" systems. Using these capabilities, PNL will work with Oak Ridge National Laboratory and the Office of Utility Technologies to develop an engineering program that can meet the needs of the national program on a timely basis.

PNL is in its second year of participation in the industry-led distributed

utilities project, which is investigating the potential for substantial penetration of targeted small generation, storage, and demand-side management devices within a utility's distribution system. PNL is funding its participation from its discretionary resources, with the intent of employing the expertise gained in this project and through substantial related work for Bonneville Power Administration, Electric Power Research Institute, and utilities to support the National Renewable Energy Laboratory and DOE in research and development that will help define the future configuration and operations of the nation's utility industry.

Under the Management Analysis Program, PNL is providing strategic planning, stakeholder outreach, and systems analysis support to the Office of Energy Management. The focus of this program is to help the Office conduct utility-related research that is highly responsive to the stakeholder community, and that will result in reliable and cost-effective energy delivery systems. The objectives of this program are to support continuous two-way communications with the stakeholders for utility research, develop a clear

understanding of industry research and development needs and to convert them into a long-term strategic plan, to develop metrics for evaluating the full range of the Office of Utility Technologies (and other) technologies, and conduct systems analyses to determine the appropriate roles for and the relative value of alternative energy storage and delivery technologies.

Energy Storage Systems (AL) The objective of PNL's Energy Storage Program is to identify and develop economically attractive advanced thermal energy storage technologies that contribute significantly to more efficient utilization of energy, contribute to national competitiveness or improved environmental quality, and are beyond the scope of current privately sponsored research and development efforts. Several new advanced thermal energy storage systems are under development. In one concept, molten salts are used in coal-fired plants to meet intermediate and peak loads. Use of molten salts and oils in cogeneration applications has been shown to be particularly attractive and is being investigated. Additionally, utilization of chill storage systems for gas turbine inlet cooling is also attractive, and co-funded efforts are now being initiated to develop this technology.

Efforts in seasonal energy storage are focused on understanding the geotechnical issues associated with storage of heat and chill in aquifers, and development and transfer of technology for aquifer chill storage to reduce summer peak electrical loads.

PNL 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. PNL 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.



PNL researchers are helping make wind power a commercially viable energy source. They are innovating techniques that credibly estimate wind power resources across the globe. The researchers' efforts were recognized by a Federal Laboratory Consortium award for Excellence in Technology Transfer in 1994.

Wind Energy (EB) PNL's major responsibilities in the Federal Wind Energy Program have centered on wind behavior research that is directly relevant to the development, deployment, and operation of cost-competitive wind energy conversion systems. This activity has included research on the turbulent wind encountered by a rotating blade as well as complex terrain and turbine wake influences on flow variability that affect siting and performance of wind turbine arrays.

In FY 1994 the Office of Utility Technologies made the decision to co-locate all wind energy research at the National Renewable Energy Laboratory. PNL has worked with, and will continue to work with the Office of Utility Technologies and National Renewable Energy Laboratory to ensure a smooth transfer of the program with minimum lost momentum. PNL will continue to

contribute to the DOE Wind Program as appropriate, seeking to utilize expertise in aerodynamics and electrical systems to assist industry in developing and sustaining international leadership in wind power technology development and implementation.

Integrated Resource Planning (EK)

Integrated resource planning is an important vehicle for meeting the nation's future energy needs in a cost-effective and environmentally responsible manner. DOE-EE has placed additional emphasis on this program. PNL's role in the program has concentrated on the performance of industrial demand-side management measures and in working with utilities to structure effective approaches to demand-side management.

As Bonneville Power Administration has in the Northwest, other federal

power marketing agencies are now planning to play an increasing role in the implementation of integrated resource planning. This trend is driven by a realization of the appropriateness of integrated resource planning and emphasized by the requirements imposed on power marketing agencies by the Energy Policy Act of 1992.

PNL has vast experience in integrated resource planning and implementing it in the Northwest, New England, and in several countries of Eastern Europe. Implementation experience has been through PNL's close working relationship with Bonneville Power Administration and other utilities in the Northwest and elsewhere. PNL is working with DOE-EE to clarify where our unique capabilities can provide value, particularly in areas of regional energy planning using integrated resource

planning approaches, demand-side management performance, industrial and load shaping demand-side management measures, and innovative marketing of demand-side management.

Office of Building Technologies (EC)

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

Economics and Systems Analysis Program (ESAP) PNL leads a multilaboratory collaborative activity to provide the Office of Building Technologies with a centralized point of contact for all planning and analysis activities. Major FY 1994-1995 activities include quantifying metrics of potential program performance, developing strategies for implementation of the Energy Policy Act and the Global Climate Change Action Plan, designing information systems to access buildings data, updating and revising buildings sector analysis tools, and analyzing emerging strategic issues in support of planning documents.

Building Systems Program PNL will also support the Office of Building Technologies' new Advanced Buildings for 2005 Initiative through ongoing Office of Building Technologies work and internal investments. "Design for Best Practices," as authorized by EPAct Section 2104, directs DOE to initiate programs to combine existing energy guidelines/handbooks, energy analysis programs, and expert system design advisors and embed them into commercial software using CRADAs, consortia, and industry collaboration.

The developed products will provide guidance to building designers and decision makers for implementing energy technologies and integrated design strategies. A program element will also be initiated to integrate commissioning and building system operation technologies with design tools to ensure efficient, cost-effective operation.

The PNL Building Systems Program (BSP) develops 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 Advanced Energy Design and Operation Technologies (AEDOT) and Building Operation Research projects.

Software resulting from collaborative efforts with the private sector in the AEDOT 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, construct, and operate buildings. The first AEDOT prototype, completed in a collaborative effort, demonstrates how a set of knowledgebased software tools can serve as a panel of consultants that automatically and continually evaluate a building design as it is developed by a designer and provide suggestions for improvement. A second collaborative project, with a private-sector firm and a university, has produced a software tool that integrates a heating and cooling loads calculation capability with a computer-aided design system to encourage use of energy analysis as part of the design process. This software tool will be distributed in December 1994 as part of a widely-used commercial computer-aided design package. Efforts in FY 1995 will continue development of the fundamental AEDOT technology with enhancements that will build on the heating/cooling loads module and will focus on offering enhanced capabilities to meet the needs of building designers and users of the software.

In the Building Operation Research project, a series of Building Operation workshops are planned to solicit input for DOE program planning. The goal of the workshops is to obtain private-sector involvement and 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. This effort will produce a program plan endorsed by important stakeholders, as well as initial projects to which "real players" from the private sector have committed to participate.

Building Energy Standards Program (BESP) PNL assists DOE with the development and implementation of building codes, standards, and guidelines to improve the energy efficiency of new residential and commercial buildings. These efforts involve partnerships with federal agencies, state and local governments, the building industry, building owners and developers, lending institutions, utilities, and public interest groups.

The standards, mandatory for federal buildings and voluntary for nonfederal buildings, continue to move from the development to the implementation arenas. In the coming year, the program will address new requirements in the 1992 Energy Policy Act, as well as continue ongoing development and implementation activities consistent with the Act. Major new activities will define the process for certifying state energy codes per Act requirements and support standards adoption efforts at the state and local levels. Efforts will continue to support standards development and issuance organizations with the promulgation of improved standards. The program will continue to work with federal agencies to adopt and implement improved standards. Technical support also will continue to the Department of Housing and Urban Development for the development and issuance of energy standards for manufactured housing and the Federal Loan Guarantee Program.

Federal Energy Management Program PNL, along with the National Renewable Energy Laboratory, Lawrence Berkeley Laboratory, and the Oak Ridge National Laboratory, are key participants in the Federal Energy

Management Program (FEMP). The main goal of FEMP is to facilitate effective energy management across the federal sector. PNL supports FEMP in the areas of information coordination, technical assistance, and new technology demonstrations as follows:

- developing analytic approaches and tools to support federal energy managers in the identification and implementation of specific projects at federal sites
- facilitating demonstration of new technologies at specific sites across the federal sector
- developing and presenting training courses on various analytic tools developed by FEMP
- coordinating (as requested) specific initiatives defined by DOE-Office of Building Technologies or Congress.

The primary analytic tool that has been developed for FEMP, with funding coordination from the Army Corps of **Engineers Construction Engineering** Research Laboratory, is the Federal Energy Decision Screening (FEDS) model that is an outgrowth of the federal energy decision screening process. The FEDS model provides a comprehensive approach to fuel-neutral energy resource planning and acquisition. Information obtained from the model can be utilized as the basis for negotiation of custom demand-side management programs with either the servicing utility or energy service contractor. The model has been applied at several specific locations and development is under way to increase the functionality of the model.

PNL also supports 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. The PNL efforts under FEMP are leveraged by PNL support for a similar program under the DOD Strategic Environmental Research and Development Program.

The first technology demonstration program (in FY 1992) evaluated 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.

Other new technology demonstration programs are in various stages of completion. They include a Seahorse gas hot water conversion system, natural-gas-engine-driven heating/cooling equipment for residential facilities, and a geothermal heat pump program. PNL is currently in the solicitation process to develop a broader list of new leading edge technologies to be evaluated in future years, including thermal energy storage systems and high R windows.

PNL presently is involved in the Federal Relighting Initiative (FRI). In FY 1993, the Federal Relighting Initiative toolkit was upgraded to meet the needs expressed by federal energy managers. PNL increased the number of presentations on the toolkit to federal energy managers, continued support to the DLA lighting catalog, improved coordination with the General Services Administration, and coordinated various projects with the U.S. Air Force Civil Engineering Support Agency. In addition, assistance was provided in the design of the Environmental Molecular Sciences Laboratory that is being constructed at PNL. Our role was to ensure that the most cost-effective life cycle energy technologies were incorporated in the design.

PNL also assists in the development and delivery of selected training programs for federal energy managers. During FY 1993, a total of three FEDS workshops were held. PNL also participated in the initial development of a customized utility demand-side management program at DOD sites where a FEDS assessment had been completed.

In the future, the incorporation of water efficiency and environmental externalities into the decision and technology selection criteria will be an emerging issue. The current FEDS model may be expanded to provide the user the ability to respond to issues regarding water resource management and water conser-

vation. Issues related to energy savings verification and retention protocols will also be of interest.

Building Equipment PNL is working with the Building Equipment Division to investigate the feasibility of applying microtechnologies to building equipment and systems. An initial effort involves use of microscale technology in heat pump systems to optimize design of the absorber and to control operation of absorption cycle heat pumps and chillers. Initial efforts are directed toward developing functional criteria and screening microscale sensing concepts to develop a conceptual design. Detailed design, fabrication, and testing will be conducted in FY 1995, with commercialization of the product anticipated in FY 1996.

Office of Industrial Technologies (ED)

PNL's role in supporting the Office of Industrial Technologies (OIT) ranges from program planning and evaluation to technology development and more fundamental research. Current technology development programs draw upon PNL's process science and engineering competency to recover energy from dilute industrial wastes, replace solvent cleaning with supercritical carbon dioxide, and develop alternative feedstocks. More fundamental efforts are directed toward developing computational chemistry and engineering tools for industry. All of these programs emphasize formal and/or informal collaboration with the private sector and all new programs and proposed initiatives are being conducted with partners across the laboratory system. For example, PNL is supporting Argonne as it helps the Office of Industrial Technologies develop the Refinery of the Future initiative. In addition, PNL is providing lead support to the Office of Industrial Technologies for developing a framework for its current and future chemicalsrelated programs that best meet industry's needs. The approach for this project is to engage chemical industry leadership in dialogue and to integrate input into the Office of Industrial Technologies' Industries of the Future initiatives. A first report, Developing a



Miniature heat exchangers may someday revolutionize the way we heat and cool our homes and buildings.

Chemical Industry Strategy: State-ofthe-Industry Profile, October 1994, overviews the industry and the driving forces shaping its future.

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. During FY 1994 an Industrial Onsite Demonstration Unit, which operates at 60 gallons per day, is being completed by the process licensee, Onsite*Ofsite, Inc. and will be operated by them under a CRADA with PNL. The unit will be used through FY 1997 for technology demonstrations and site-specific tests of industrial applications of TEES.

Another project, initiated in FY 1992, focused on the development of an environmentally safe cleaning technology which uses supercritical carbon dioxide to replace organic solvents typically used in precision metal cleaning. Under funding from the Office of

Industrial Technologies' Industrial Waste Reduction Program (IWRP), PNL is working with Inland Technology Inc. and the Boeing Company to develop engineering data required in the commercialization of supercritical fluid parts-cleaning technology. This project also involves two other national laboratories (Sandia and Los Alamos National Laboratories) and at least three additional industrial partners in a coordinated program. PNL's contributions to the program include the exploration of a novel hybrid cleaning approach (jointly with Inland) and measurement of mass-transfer parameters needed to scale the technology up to commercial sizes. This program was completed in FY 1994.

Alternative Feedstocks Program

PNL also participates in a joint effort of five national laboratories (Argonne National Laboratory, Oak Ridge National Laboratory, National Renewable Energy Laboratory, Idaho National Engineering Laboratory, and PNL) which seeks 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 1994, PNL performed laboratory testing of catalytic processes to directly convert or to upgrade biomass-derived feedstocks into commodity chemicals. A strong industrial component is included in the program such as the use of CRADAs with industrial process developers and a program review panel of industrial experts. Scale-up of the processes in conjunction with the industrial partners is the goal of the program in FY 1995 and beyond.

PNL 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 PNL staff in support of Office of

Industrial Technologies Advanced

Industrial Concepts Division (AICD).

Advanced Industrial Concepts Program

Staff in PNL's Applied Physics Center 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.

Program Support PNL plays an important role in providing technical planning and support 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 the Office of Industrial Technologies' technology transfer and tracking efforts.

Through the Industrial Energy and Environmental Analysis (IEEA) Program, PNL is developing or evaluating technical, economic, or policy information regarding industrial energy use and related environmental impacts. Key activities for FY 1994-1995 include improving Office of Industrial Technologies use of industrial energy models and databases, evaluating energy efficiency data from the energy analysis and diagnostic centers, developing a computerized energy technology analysis data system, characterizing the energy and environmental features of advanced technologies from the Office of Industrial Technologies, assessing the economic productivity impacts of the Office of Industrial Technologies process technologies, and developing metrics for the economic and environmental impacts of advanced industrial energy and waste minimization technologies.

In support of the Office of Industrial Technologies' technology maturation and tracking program, the goals for 1994-1995 include 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, PNL will support the Climate Change Action Plan as well as identify both primary and secondary impacts of the Office of Industrial Technologies' commercialized technologies.

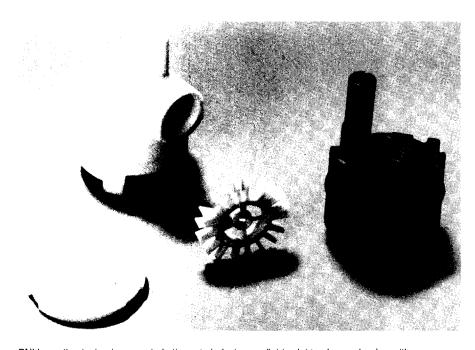
Office of Transportation Technologies (EE)

PNL is currently working with the Office of Transportation Technologies (OTT) and the automotive industry to develop lightweight metals and reduce emissions. These programs are under the umbrella of the U.S. Council for Automotive Research (USCAR). The programs focus on advanced forming technologies for lightweight metals and composites. Primary emphasis will be on aluminum alloys. Additionally, programs on reduced emissions for internal combustion engines are being developed. These programs focus both on reducing hydrocarbon generation in the engine cylinders and on trapping and destruction of hydrocarbons coming from the engine.

PNL continues an environmental support function with the National Renewable Energy Laboratory jointly sponsored with Transportation (biofuels) and Utility (biomass power) funds. 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. Processing tests to clean up products and effluents will continue through FY 1995. Scale-up based on these processing tests will be dependent on economic assessment of the results.

Office of Technical and Financial Assistance (EF)

For this office, PNL manages the Innovative Concepts Program (ICP), the States Inventors Initiative (SII), and the International Market Assessment Program.



PNL's coating technology can help the auto industry use lightweight polymers by depositing a protective coating on the plastic surface at low temperatures.

Innovative Concepts Program PNL 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 fair. Innovators are also given nonfinancial benefits such as the development of a one-page "tech brief" of their concept and the opportunity to attend a commercialization workshop. Over half of the 75 concepts that have been sponsored on this program have received substantial follow-on funding from industry and other government programs.

States Inventors Initiative PNL 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. The States Inventors Initiative has identified inventor organizations in various states. Grants have been awarded to 23 inventor organizations to support new methods to assist inventors.

International Market Assessment

Program PNL has conducted analysis of international energy markets for the Office of Technical and Financial Assistance (OTFA) for several years. The International Market Assessment Program is designed to develop information on the market characteristics,

technical needs, and economic potential of international markets for U.S. efficient end-use and renewable energy technologies. Work in FY 1993-1994 focused on improving analysis efforts to understand the potential to export U.S. advanced energy technology and technical assistance in key regions, including Eastern Europe, Central and South America, and the Pacific Rim countries. Strategies for U.S. firms to operate in foreign markets through joint ventures have been studied for Mexico and will be extended to other target countries. In addition, the International Market Assessment Program provides coordination and planning support to the U.S.-supported Energy Efficiency Centers in Poland, Russia, and Czechoslovakia.

Office of Planning and Assessment

(CE) PNL provides technical assistance to the Office of Planning and Assessment (OPA) in planning and applied analysis. In the area of planning, PNL's contributions include support in developing and implementing strategic and multiyear program planning activities, and conducting assessments of issues affecting DOE-EE programs and stakeholders.

PNL 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, participating in two interlaboratory total energy cycle analyses (bioethanol and electric vehicles), and conducting focused analyses of regulations to determine their impact on energy efficiency and renewable technologies.

As part of assessing the benefits associated with DOE-EE programs, PNL 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 competing DOE-EE programs and technologies and also facilitate comparisons between

Center Location

Центр по эффективному Moscow, Russia использованиию энергии

FUNDACJA NA RZECZ EFEKTYWNEGO WYKORZYSTANIA ENERGII

STŘEDISKO PRO EFEKTIVNÍ VYUŽÍVÁNÍ ENERGIE Prague, the Czech

北京能源效率中心成立 Beijing, China

Katowice and

Republic

Sofia, Bulgaria

Warsaw, Poland

ФОНДАЦИЯ «ЕНЕРГИЙНА ЕФЕКТИВНОСТ»

АГЕНСТВО З РАШОНАЛЬНОГО Kiev, Ukraine ВИКОРИСТАННЯ ЕНЕРГІЇ ТА ЕКОЛОГІЇ Translation

Center for Energy Efficiency (CENEf)

Foundation for Energy Efficiency

Center for Energy Efficiency (SEVEn)

Beijing Energy Efficiency Center (BECON)

The Energy Efficiency Foundation (ENEFFECT)

Agency for the Rational Use of Energy (ARENA-ECO)

Several Energy Efficiency Centers have been established with the support of various organizations.

DOE-EE technologies and more conventional choices. Finally, PNL is working with the Office of Planning and Assessment and other DOE-EE offices in developing an integrated information management system to facilitate access to the data, models, and other tools needed to conduct 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 5 to 10 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 Energy Policy Act of 1992 and recent Federal Energy Regulatory Commission decisions have deregulated the transmission and distribution of gas and electricity, opening these markets to much greater competition and encouraging many new players to enter these markets. The result will be continued pressure upon all utilities to reduce costs and increase customer service. This pressure is leading many utilities to restructure and adopt new business philosophies and priorities; this pressure is clearly impacting Bonneville Power Administration as well. In addition to industry restructuring pressures, recent drought conditions and increased demand upon regional water resources for fisheries, agriculture, and recreation further pressure Bonneville to reexamine its role and priorities.

In response to these dramatic changes, Bonneville Power Administration has embarked upon a review of a possible restructuring that would ultimately lead to becoming a government corporation similar to the U.S. Post Office and Amtrak. This decision will evolve over the next year or two and the final result is still uncertain. However, the clear message is that Bonneville will undergo dramatic change in the next 5 years.

PNL's 5-year plan for supporting the needs of Bonneville Power Administration has three major elements. First, we will continue our current programmatic support in areas that are of high strategic importance to Bonneville, including energy resource programs and environmental support of fisheries issues facing the hydropower system. Second, we will continue to invest in building PNL capabilities to serve the new Bonneville thrust in real-time power system control. Finally, we will reevaluate our current business practices to identify new processes that better meet the needs of Bonneville, both now and in its new structure. The foundational assumption supporting this plan is that Bonneville will remain a key client of PNL and we are adapting our science and technology services to ensure that we play a vital role in Bonneville's response to it new environment.

The recent drought conditions in the Pacific Northwest and depressed revenues from major retail customers have forced Bonneville to curtail many programs. This is expected to effect modest growth for PNL in FY 1995 and beyond.

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

Real-Time Power System Control

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 they will face in the years ahead. Reliably increasing the capacity of the present transmission system will require development and incorporation of new technologies for monitoring, analysis, and control of the power system. PNL is currently assisting in the development of advanced monitoring and analysis technologies for Bonneville. Development of sophisticated wide-area network monitoring will help gather much needed, time synchronized data enabling development of improved system models, and examination of dynamic behavior not presently well understood. Additionally, a new suite of analytical tools for examination of this data is being developed with Bonneville and researchers at the University of Colorado. Finally, a special controller is being developed for application at the EPRI-GE flagship device for power system control, the Thyristor Controlled Series Capacitance unit now undergoing acceptance testing at the Slatt Substation in north-central Oregon.

It is anticipated that the technology development and deployment by PNL in conjunction with Bonneville will continue for at least the next 5 years. It is reasonable that wide-area network monitoring systems will be deployed across the entire western U.S. 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. Additionally, improved monitoring will be incorporated in high-level on-line and realtime analysis and control of the power

system using many of the technologies currently under development, eventually including artificial intelligence systems.

Fish and Wildlife Programs

The Bonneville Power Administration is charged by the Congress of the United States to protect and enhance the fish and wildlife of the Columbia Basin while providing power to the region. PNL is an important scientific and technical resource to Bonneville for planning and implementing the Fish and Wildlife Program.

Today, many of the natural resources in the Pacific Northwest continue to decline. PNL is supporting Bonneville's efforts in many areas to reverse these trends, including fisheries habitat restoration and mitigation planning. To support these emerging Bonneville needs, PNL is targeting research in integrated environmental monitoring; computer based controls for natural resource monitoring facilities; image acquisition, processing, and data management; fisheries physiology; experimental design and hypothesis testing; facilities certification; fisheries genetics; and evaluation of electromagnetic exposures.

Regional Energy Resource Programs

PNL 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. Current and future efforts will focus primarily upon industrial and manufactured housing needs.

The Bonneville Power Administration Industrial Energy Savings Plan program is an industrial demand-side management program that makes acquisition payments to firms that install energy conservation projects in their plants. PNL is responsible for evaluating various aspects of the Energy Savings Plan projects. This

includes determining how much energy will be saved over the project's life, how much the savings cost Bonneville and the region in \$/kWh (levelized cost), if and how much of the project's savings will be reflected in reduced loads at the serving utility, and if the project would have been installed without the acquisition payment from Bonneville (i.e., is the project a free rider?).

A future priority for Bonneville Power Administration's industrial impact evaluations is estimating how much energy is saved over the long term (persistence of savings). PNL will be developing a methodology for evaluating this aspect of demand-side management performance.

The overall goal of the Industrial Demand-Side Management Project is to determine, confirm, and develop the conservation resources that can be achieved from operations and maintenance practices in Pacific Northwest industries. The project is currently establishing methodologies for process auditing, data acquisition, and data analysis. This will support evaluation of the operations and maintenance practices for electric energy resource potential of industrial air compressors and compressed air systems. Future activities will include industrial plant audits and baseline data acquisition, implementing audit recommendations, monitoring and analyzing results, and technology transfer.

About one-third of the new homes in the Pacific Northwest are HUD-code manufactured homes, built to a relatively loose national thermal code. Through technology and information transfer, PNL is assisting Bonneville Power Administration in sharing information on its energy-efficient manufactured homes program with the states, manufacturers, and other interested parties. In 1992, Bonneville initiated the Manufactured Housing Acquisition Program (MAP), a market transformation program directed at the home manufacturers. By paying the manufacturers \$2500 for each energy-efficient, electrically heated MAP home, Bonneville has succeeded in encouraging the manufacturers to build homes which use approximately half the energy required to heat a typical manufactured home. The saved energy is being 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 standards.

Because a new, tighter national code went into effect in October 1994. Bonneville Power Administration and manufacturers are looking at ways to modify the MAP. PNL will be assisting Bonneville in identifying the economic effects of the new code on the assumptions underlying the current MAP and helping develop creative ways to modify the program. PNL also has initiated work on a program evaluation of the impacts of MAP by collecting utility billing data and additional information from owners of manufactured homes. Information from this evaluation will be useful in assisting Bonneville and utilities in developing future conservation programs that aim to transform the market, rather than just affect selected situations.

Office of Civilian Radioactive Waste Management

PNL programs supporting the Office of Civilian Radioactive Waste Management (RW) cover several activities. Yucca Mountain Site suitability studies continued as did limited onsite activities. Activities were completed to transfer the PNL scope to the DOE-RW management and operations contractor.

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 (MRS) facility. The Systems Integration Program technology and program scope were successfully transferred to the management and operations contractor.

The PNL 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)

PNL 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 PNL under the Commercial Spent Fuel Management Program are continuing as independent projects. Focus of continuing research and development being done with PNL's involvement is on establishing technology that nuclear power utilities can use for interim spent fuel storage efforts.

PNL 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, PNL is responsible for evaluation, qualification, maintenance, and user support for COBRA-SFS and HYDRA-II which are "best estimate" thermalhydraulic 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 PNL 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. PNL supports 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. PNL 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, PNL helps in reviewing, reconciling, and disseminating the data on spent fuel inventory and projections that are collected for the utilities. These data form the bases for planning the waste management system.

Office of Policy

PNL provides assistance to the Office of Policy in the area of economic and policy analysis, both on major longrange studies and on short-turnaround issues as they emerge. As an example of the former, PNL has embarked on an ambitious project to increase international understanding of the challenge to and understanding of the role of social sciences as they address global climate change. Under the working title "Human Choice and Climate Change: A State-of-the-Art Report," this project has engaged an international team drawn from a wide range of the social sciences. This 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 first product of this global collaboration will be a paper analyzing the preliminary findings of the team; the paper will be distributed at the Conference of the Parties in Berlin, March 1995. The comprehensive book is scheduled to be published in December 1995.

PNL's extensive modeling capability provides another valuable input to the policy decision process. The Edmonds-Reilly Long-Term Global Energy-CO₂ Model, maintained and updated by PNL, has been used extensively in scenario analysis for numerous

studies of possible greenhouse gas control policies. In addition, significant improvements in the forecasting of greenhouse gas emissions are expected progressively over the next 2 years as PNL's efforts to develop the Second Generation Emissions Model come to fruition. Here, the overall objective is to relate all relevant human activities to resulting emissions of all the principal radiatively important gases. In a parallel effort, PNL has undertaken the analysis of the impacts of climate change on natural resources and human society in order to develop tools to provide an integrated assessment of resource sensitivity to climate change, to delineate the impacts of natural resource changes on a region's economic resources, and to evaluate the effectiveness of various adaptive strategies. Culminating these development efforts will be progressive integration into the Global Change Assessment Model (GCAM).

DOE has supported PNL's participation in the efforts of the Intergovernmental Panel on Climate Change (IPCC) in developing the second assessment. Specifically, the Office of Policy is providing funding to PNL lead authors and contributing authors on Working Group 2 in the areas of Energy Supply and Human Settlements. Zero-order drafts were developed in FY 1994, and authors attended several meetings as part of that process.

PNL is assisting the Office of Policy with several projects related to EPAct requirements. EPAct 1601 requires DOE to assess the extent to which the United States is responding to the National Academy of Sciences 1991 recommendations about greenhouse warming. EPAct 1604 requires DOE to assess alternative policy mechanisms for addressing greenhouse gas emissions. EPAct 1605(b) requires DOE to develop guidelines for a voluntary reporting program covering greenhouse gases.

For the EPAct 1601 requirement, PNL developed the assessment report that covered 18 recommendations of the 1991 National Academy of Sciences report and evaluated the progress, success, or failure of federal programs since that time.

For the EPAct 1604 requirement, PNL is developing a draft Report to Congress, containing a micro-level analysis of the potential implications and drawbacks of two categories of policy instruments that may be applied to reduce greenhouse gas emissions: economic instruments and energy efficiency standards.

For the EPAct 1605(b), PNL has been assisting the Secretary of Energy to prepare guidelines for the voluntary reporting of greenhouse gas emissions, emissions reductions, and carbon sequestration. The guidelines and six sector-specific supporting documents were published in October 1994. The reporting system is expected to have multiple future applications. Domestically, the reporting system should contribute to private-sector confidence that actions taken now to reduce emissions will be taken into account in possible future legislation. Internationally, the reporting program may help establish the extent of voluntary reduction activities in the United States for the purpose of implementing the U.S. Initiative on Joint Implementation (USIJI).

Starting in late FY 1994, the Office of Policy assumed leadership within DOE for developing the National Energy Policy Plan (NEPP). The Office of Policy has determined the focal point of the NEPP will be sustainable development. To obtain input on policy development, the Office of Policy has undertaken a series of public forums and also expressed interest in having the national laboratories participate. During the development and writing of the NEPP, PNL expects to provide support and input to help the Office of Policy form the theme of sustainable development and to ensure the NEPP is successful.

Office of Nuclear Energy

In FY 1995 PNL will increase its participation in the DOE-Office of Nuclear Energy International Nuclear Safety Program. Current and projected funding for the Office of Nuclear Energy (NE) programs are shown in the Resource Projections, Section 7.

PNL plans to increase its participation in DOE-NE 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; aging and plant life extension; and advanced reactor design review and certification.

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. PNL plans to participate in activities aimed at revitalizing nuclear power as these programs develop.

Nuclear Energy Research and Development (AF)

PNL supports the Office of Nuclear Energy in its efforts to assist the former Soviet Union in nuclear reactor safety. DOE-NE is the primary provider of technical assistance within the U.S. government. The nuclear reactor systems designed and constructed by the Soviet Union, particularly RBMK and VVER reactors, do not meet Western standards for nuclear safety. At the same time the former Soviet Union states have concluded that these reactors are required to provide energy to support their struggling economies. PNL has been designated as the primary DOE laboratory responsible for providing project management and technical and administrative support for the International Nuclear Safety Program. FY 1995 funds to be directed by PNL are expected to be \$57 million with continuing efforts at about this level throughout the planning period. The objective of the 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. Elements of the program include: Safety Regulation and Legislative Requirements, Plant Safety Enhancement, Management and Operational Safety, Engineering and Technology Safety, Fuel Cycle Safety, and Planning and Integration. The program will provide assistance to Russia, Ukraine, and other Central and Eastern European countries. Besides PNL, U.S. participants will

include other DOE Laboratories and U.S. industrial firms.

Uranium Enrichment (CD)

A program to assist Lawrence Livermore National Laboratory in demonstrating the viability of using Atomic Vapor Laser Isotope Separation (AVLIS) enriched uranium for production of commercial grade power reactor fuel was completed. The PNL work focused on processing UO₂ reduced from UO₃. PNL's role in the fuel qualification program for AVLIS-derived fuels concerned powder reduction, pellet fabrication, pellet characterization, irradiation demonstration, and the fuel supplier/utility interface.

Radioisotope Production and Use

PNL supports Hanford's role as the DOE's production and sales site for cesium-137, strontium-90, and other selected isotopes. PNL is developing separation processes for obtaining various isotopes for medical applications. In addition, work is under way to develop new compounds containing radioisotopes for specific treatment of selected organs or other body parts. The demonstration and fabrication of strontium source capsules is planned. PNL completed the destructive examination of a cesium-137 capsule to determine the cause of failure. PNL plans to continue its participation in the production and supply of radioactive isotopes.

Policy and Management (KK)

PNL provides technical services to develop and implement the DOE Draft Hazard Audit Procedure Guide at selected DOE facilities and to evaluate the feasibility of using deterministic risk assessment methodologies in the audit of DOE facilities. Trial implementation of the methodology has been undertaken to identify limitations, strengths, and completeness of the guide. PNL plans to provide assistance in upgrading the guide, as needed, to support proposed DOE Orders.

PNL provides technical assistance in developing appendices for the DOE

Procedure Development Safety Guide for the Office of Nuclear Safety Policy and Standards (ONSPS). This guide addresses human factors issues and management processes related to development, verification, and validation of procedures at existing DOE nuclear facilities. PNL provides the human factors and management skills needed to assist in developing evaluation guidelines and methodologies for DOE nuclear facility procedures.

Office of Fossil Energy

PNL's involvement in the DOE's Fossil Energy programs is expected to continue to increase because of the current DOE investments in research related to the natural gas and oil industry, environmental regulation, energy conversion, gas and coal chemistry, advanced materials development, and environmental effects of coal utilization.

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 national Gas and Oil Technology Partnership is to develop research solutions to problems that DOE and 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 5 years ago by the three Defense Program Laboratories (Sandia National Laboratories, Lawrence Livermore National Laboratory, and Los Alamos National Laboratory). With the implementation of the Advanced Computational Initiative in FY 1995 (ACTI), the partnership was expanded to include the Energy Research laboratories. The Advanced Computational Initiative program

focuses on exploration and production computing technology. It is funded at \$42 million for FY 1995 through the offices of Fossil Energy, Energy Research, and Defense Programs. PNL is committed to actively participating in the Advanced Computational Initiative. 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 Advanced Computational Initiative.

DOE has recently announced the Domestic Natural Gas and Oil Initiative to stimulate job creation, increase production, and reduce reliance on foreign oil. PNL plans to work with DOE-FE to understand how the environmental remediation and waste management experience (such as risk assessment, contaminant transport, environmental characterization, and monitoring) can be brought to bear on the environmental issues that these industries face. In a related initiative, DOE-FE and DOE-EE are focusing on both technical processing and environmental issues to ensure a continuation of a robust, highly competitive refinery of the future. The objective of the Refinery of the Future program is to help the domestic refinery industry remain competitive in the global marketplace and, in so doing, minimize environmental and energy cost impacts of refinery products and processes in the U.S. economy. The collaborative program is structured to be pursued with the industry to develop an advanced technology base that will support the evolution, development, and demonstration of a new generation of energyefficient and environmental acceptable processes that maximize the yield of environmentally acceptable transportation fuels and other high-value products and minimize the output of low-value products and waste streams. PNL plans to continue to work with DOE-FE and DOE-EE and the oil industry to develop this initiative and determine where the strengths of the laboratory system can be used to address technical issues in petroleum refining. PNL competencies that are relevant to this initiative include process science and technology (e.g.,

metal-oxide catalysts, methane chemistry, reaction engineering) and integrated environmental research (both remediation and waste management).

The Advanced Materials and Electrochemical Processes program which includes solid-oxide fuel cells, membranes, and catalytic processes for energy and environmental applications, continues to grow with a major effort being made to expand this program within DOE-FE and extend the program to better support industry. The program focuses on high-temperature materials related to electrochemical, catalytic, and membrane technologies for broad, clean, and efficient use of coal and other fossil fuels. The program emphasizes materials and processes related to catalysts and inorganic membranes for energy conversion, minimization of waste contamination, and synthesis of materials. These developing concepts can also be directly combined with other technologies to further enhance the beneficial use of fossil and other fuels.

Another program, "Advanced Materials for Solid-Oxide Fuel Cells" emphasizes the major generic issues of solid-oxide fuel cells performance and manufacturing. The research and development emphasizes critical issues of materials processing, fabrication, and performance. It is anticipated that PNL will expand its involvement with U.S. industry to provide development support for more efficient manufacturing of advanced solid-oxide fuel cells in areas of CRADAs and technology transfer. It is anticipated that PNL will expand research and development on solid-oxide fuel cells through involvement with U.S. companies in developing solid-oxide fuel cells. Programs also are being directed to provide support for more efficient manufacturing of solid-oxide fuel cells.

This research is associated with PNL'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.

PNL's research and development for solid-oxide fuel cells will continue in FY 1995 and beyond. These efforts will

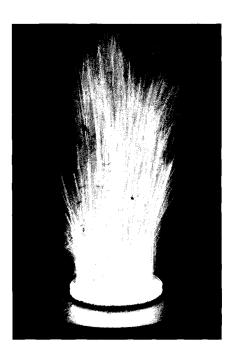
continue to expand and include CRADAs and private support with industry in areas of material synthesis, processing, fabrication, and performance for application to solid-oxide fuel cells.

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 PNL, projects are planned that will increase PNL's involvement in coal liquefaction technology development. PNL 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 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 PNL and Phillips Petroleum Company to develop a novel PNL 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 catalyst and provides opportunities to improve conversion of crude oil to transportation fuels.

National Security

PNL's national security activities are derived from and support the DOE's national security core business area. PNL has historically provided direct support to both the Hanford Site's purpose of defense materials production and support to other national security areas.



The glycine nitrate process creates very fine multicomponent ceramic oxide powders used to manufacture ceramic devices that operate at high temperatures.

The collapse of the Soviet Union and the end of the Cold War has resulted in rapidly changing national security policies and needs. The end of a single superpower adversary has brought a new set of national security challenges, marked by regional, ethnic, and national conflicts; an increased concern regarding proliferation of nuclear weapons and other weapons of mass destruction; treaty verification and arms control requirements; and maintenance of a technical base in support of DOE's national role in nuclear materials management and nuclear weapons stewardship.

PNL's national security objective is to integrate the full spectrum of technical knowledge at PNL 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
- improve operational effectiveness.

PNL'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.

PNL's national security work is conducted throughout the Laboratory, thereby ensuring the full resources of PNL 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.

Office of Defense Programs

PNL'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; technical support to the nuclear weapons complex; and participation in the DOE program for Department of State funded industrial partnering between national laboratories, U.S. academic institutions, and U.S. industries with institutes of the former Soviet Union.

The production of special isotopes (Materials Support [GE]) often requires the capabilities of several sites and contractors because of size, space, or other limitations. PNL has unique capabilities for handling long reactor fuel and reactor components. PNL continues to support the Mark-42 target program. The Mark-42 targets are used for the production of plutonium-242, americium-243, and curium-244.

PNL also assists Defense Programs in interpreting safeguards and security policies and identifying cost-effective implementation procedures for the Defense Programs complex. PNL also continues to provide technical support to the Defense Programs complex in specific materials support activities.

Office of Nonproliferation and National Security

PNL 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 Office of Nonproliferation and National Security provided support for the Laboratory to prepare a Conceptual Design Report and Validated Cost Estimate for the proposed construction of a new DOE facility at the Hanford Site dedicated to support of the Office of Nonproliferation and National Security and other classified work. Additional information on this activity is provided in the Site and Facilities section of the Institutional Plan.

Office of Research and Development

PNL's capabilities are applied to research, development, and application of state-of-the-art sensors and sensor systems and the statistical evaluation of their responses. Emphasis has been placed on nuclear radiation technologies and nondestructive testing, which are expected to have a significant role in formulating protocols and for monitoring existing armscontrol treaties. Remote sensing science and digital image processing have been developed for applications supporting treaty requirements.

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. PNL is focusing its national security technology capabilities to identify needs and develop technologies to monitor, detect, and analyze for indications of such proliferation.

Office of Energy Intelligence

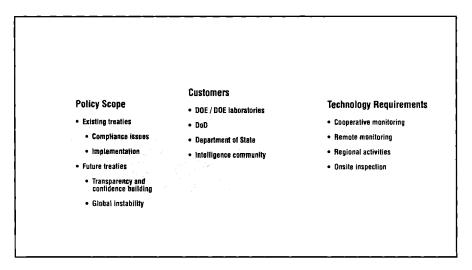
PNL directly supports the DOE Office of Energy Intelligence in areas of nuclear nonproliferation, energy assessment, and intelligence support. PNL performs intelligence data processing and analyses that address national issues in weapons materials production, nonproliferation, and energy resources, and other tasking 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, PNL applies its capabilities and technologies to perform intelligencerelated work for other government organizations.

Office of Arms Control and Nonproliferation

PNL directly supports the DOE's Office of Arms Control and Nonproliferation in specific areas of policy and technical analysis, export control, international safeguards, and nonproliferation policy. PNL activities are expected to increase during the planning period in support of national policies and interests in nonproliferation, treaty requirements, and nuclear disarmament.

PNL projects supporting the objectives of DOE's Office of Arms Control and Nonproliferation draw upon the Laboratory's substantial expertise in nuclear materials production, chemistry, physics, advanced materials, mathematical analysis, digital image processing, and analytical and sensor systems. PNL's extensive background and experience in nuclear materials production is used in support of the DOE for issues involving weapons materials production, proliferation, and disarmament. This experience also will be used to evaluate and perform a diversified role in the elimination of nuclear weapons material.

PNL's capabilities are applied in support of the DOE's role in developing



PNL supports many national needs in nonproliferation and treaty verification with advanced technology and technical analysis and training.

nuclear reactor and reprocessing sections of the Military Critical Technologies List. The Laboratory supports DOE efforts with the 17 Allied Nations' Coordinating Committee (COCOM) for multilateral export controls to former Warsaw Pact and certain other countries. PNL staff assisted COCOM by providing the technical justification for changes and modifications to the International Atomic Energy Agency list and the U.S.'s recommendations for nuclear dual-use export control. In addition, PNL provides other classified services to the DOE in the technology export arena and chairs a multiagency technical review group that addresses sensitive nuclear issues. PNL acts as a technical reviewer for the DOE on specific authorization requests by U.S. companies who wish to assist foreign atomic energy activities.

Office of Security Affairs

Activities for the Office of Security Affairs involve assisting in resource review activities to maximize efficiency of safeguards and security functions, assisting in the preparation of DOE sites for international treaty inspections, assisting in the enhancement of uniform application of safeguards and security requirements throughout the DOE complex by developing specific training courses, and conducting work in support of the Office of Counterintelligence.

PNL provides technical support to the Rocky Flats Plant, and specialized training for the DOE complex in the areas of Material Control and Accountability and Information Security.

PNL support to the Office of Security Affairs is expected to remain stable, but will require a greater degree of innovation as a result of major DOE efforts to

- develop new cost-effective safeguards and security measures
- support new DOE initiatives resulting from changes in business areas
- transition safeguards and security responsibilities to program offices under the auspices of SEN-60
- define new protection methods for the evolving threat scenario.

The Policy, Standards, and Analysis Division of the Office of Safeguards and Security is responsible for implementing and overseeing the DOE Information Security program. The DOE Headquarters has established PNL as an information resource center to assist in identifying approaches to developing and implementing an integrated protection program.

Office of Emergency Management

PNL 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. PNL also participates in the coordination with other government agencies led by this office.

Industrial Competitiveness

Industrial competitiveness is a crosscutting business area of the Department of Energy directed at "promoting economic growth and the creation of highwage jobs..." (Ref: DOE Strategic Plan). As a multiprogram laboratory, PNL believes that it has a vital role to play in achieving this goal. As an organization managed and operated by Battelle whose fundamental mission is "putting technology to work," PNL has a unique base of skills and experience that it can apply to assisting DOE in achieving its enhanced industrial competitiveness goals.

For over 25 years, PNL has been managed and operated under a unique partnership arrangement between DOE and Battelle that allows Battelle-owned facilities to be used in the conduct of federally-sponsored activities and DOE-owned facilities to be used in the conduct of activities sponsored by private industry. The contractual arrangement governing this partnership is called the Use Permit, which allows Battelle to contract directly with private industry for the conduct of research and development activities by PNL staff.

The Use Permit has proven to be a valuable mechanism for facilitating the use of PNL technical resources to assist U.S. industry and for tailoring available technology for application by industry. In the past 5 years, industry has provided \$66.5 million for research and development activities conducted under the Use Permit and an average of 180 companies per year have been assisted. PNL also has an extensive track record in encouraging the development of new "spin-off" companies. Almost 40 companies are currently in existence whose technical roots can be traced to PNL.

PNL's long history of working with industry provides us with a unique perspective from which to expand our efforts in accordance with the new national emphasis on industrial competitiveness. We have used this experience to assist in the development of major industry partnerships, expand our CRADA activities, and increase our emphasis on assisting small business.

PNL's industrial competitiveness purpose is directed at developing technologies, knowledge, and systems that combine public and private resources to measurably help modernize America's industrial infrastructure, enhance economic competitiveness, and create new jobs. Our objectives are to

- develop and implement partnerships with industry, other national laboratories, and academia that support the needs of U.S. industry
- balance market pull with technology push in Laboratory activities
- shorten the life cycle from research to deployment through crossfunctional parallel activities
- assist government and industry in moving from cleanup to waste minimization and pollution prevention (i.e., toward "sustainable development")
- leverage federal investments and the combined talents of the national laboratory system and Battelle to diversify the local Hanford and Northwest regional economies, strengthen their export potential, and create new high-wage jobs.

PNL's industrial competitiveness strategy for achieving these objectives is to fully integrate the industrial competitiveness mission throughout PNL, increase industrial awareness, provide technical assistance and collaborate with industry through partnerships (including CRADAs), and commercialize intellectual property. At PNL, we believe technology transfer is an integral part of everyone's job and are continuously developing new initiatives as a means of enhancing our performance.

Full Integration of the Industrial Competitiveness Mission Throughout PNL

Staff awareness of the industrial competitiveness program is achieved through various means. Technology transfer liaisons, for example, are assigned within the PNL research centers, and a CRADA facilitator is designated for each Program Secretary Office. These liaisons continuously inform and advise staff about technology transfer mechanisms, incentives, and important opportunities to perform collaborative research with U.S. industry.

PNL has an extensive Recognition and Rewards program that includes a royaltysharing program (modeled after the "best-of-the-best" from similar federal and industrial programs). An annual "Technology Transfer Day" at PNL also recognizes key contributors to the technology transfer process (e.g., those receiving patents and copyrights or the R&D 100 and FLC award winners during the past year). We are continually exploring ways to enhance our program such as by establishing a Labwide Award for Excellence in Technology Transfer and by increasing the breadth of our Rewards and Recognition program.

In the future, we plan to increase PNL staff awareness of the industrial competitiveness mission through a number of specific actions, including

- increasing the number of presentations on technology transfer throughout the Laboratory
- developing a management plan for CRADAs
- refining and expanding a CRADA and staff exchange guidance package for use by PNL staff
- establishing a laboratory-wide computerized technology transfer bulletin board
- establishing a new entrepreneurial program to improve technology transfer locally through increased formation of spinoff businesses

- exploring available technology transfer awareness courses, such as those offered by Oak Ridge Institute for Science and Education (ORISE) and Idaho National Engineering Laboratory for potential application at PNL
- increasing the number of trained technical transfer liaison staff
- developing an Intellectual Property Creation and Commercialization brochure for use by PNL staff.

Enhanced Industrial Awareness of PNL

To accomplish this objective, PNL produces and uses a broad range of communication mechanisms, from visits, telephone calls, tours of PNL research facilities, workshops, and other important one-on-one contacts to press releases, brochures, and exhibits at trade shows attended by thousands. These outreach techniques and other activities are designed to increase interactions significantly between PNL staff members and their industrial counterparts. We also take advantage of communication technologies such as video tapes, television programming, announcements for CRADA opportunities, and new relationships with trade associations.

As appropriate, we actively participate in DOE-wide and federal government outreach efforts, such as the Bobbin Show, NASA 2003, Society of Automotive Engineers (March 1993), and other forums for presenting PNL technologies. This year, we have initiated a Pacific Northwest Initiative that is designed specifically to enhance recognition of PNL as a valuable technical asset to industries located in the Pacific Northwest region. Memorandums of Understanding have been signed with the economic development departments of Oregon and Washington states.

PNL believes that awards and recognition are an important element of our outreach strategy, as well as being a means of recognizing and encouraging our research staff. For example, the R&D 100 awards program, sponsored by *R&D Magazine*, is a national peerreviewed competition that recognizes the 100 most significant new technological products of the past year. Between 1969, when the first PNL candidate was entered, and 1993 PNL has won 25 awards. Typically, announcement of these awards has led to several hundred inquiries from potential industry partners interested in commercially applying the award-winning technology.

The Laboratory continues to lead the competition in the Federal Laboratory Consortium's Award for Excellence in Technology Transfer. The FLC award recognizes "uncommon creativity and initiative in transferring technology that provides significant benefits to private industry or state and local governments." The competition is open to all of the federal laboratories—approximately 400—representing 14 federal agencies. Since 1984, the first year of the competition, PNL has won 23 awards, more than any other federal laboratory and almost twice as many as any other DOE Laboratory. In 1994, PNL received three awards, which are described below.

- Estimates of the Wind Resources -New and accurate windpower databases and technologies, now used by U.S. industry to assist enterprises worldwide.
- Capillary Electrophoresis-Mass Spectrometry Interface (CE-MS) -An interface between a liquid separations system and a mass spectrometer, initiates a new era of molecular-level research. Because it allows very precise structural analysis of ionic substances in solution, researchers can use CE-MS to investigate a broad range of molecularlevel interactions without destroying chemical bonds that critically affect a substance's behavior. This technology is already licensed to three companies.
- Fast, Adaptive Communications Software - Software that significantly increases the effectiveness of massively parallel computer systems. New algorithms were developed and coded for a set of global operations that would make user's applications run several times faster.

R&D 100 Award Winner (1994)



The ultrasonic microstructural analyzer may drastically reduce manufacturing time and save millions of dollars each year for machinery manufacturers. The UMA nondestructively examines the hardness depth of heat-treated steel components in seconds by using a high-frequency ultrasonic wave without destroying the component. Applications for the UMA are in the automotive industry, agriculture, mining, machine, tooling, engine manufacturing and any machinery that uses hardened steel components.

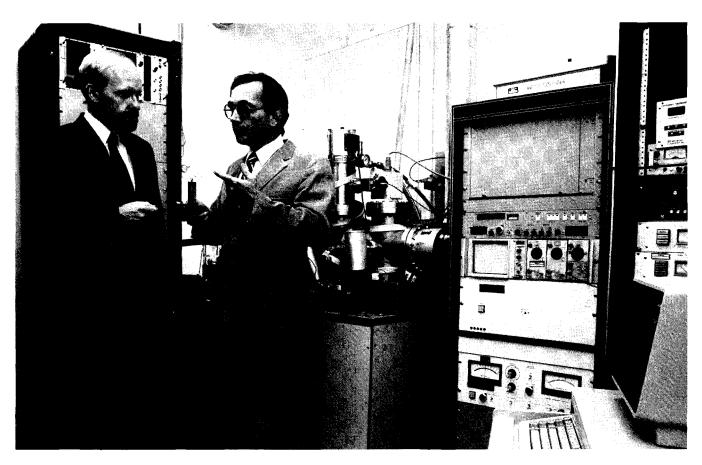
The technology was licensed to a major U.S. computing firm (Intel); then, through a CRADA, a partnership with Intel was implemented that will advance high-performance computing across the nation.

Providing Technical Assistance and Collaborating with U.S. Industry

This objective has two major features: 1) managing the delivery of technical assistance to the private sector (especially to small businesses) and to state and local governments, and 2) increasing collaboration between PNL staff and their counterparts in industry and universities. As a national laboratory, PNL believes that fulfillment of this objective is the most important element of efforts to assist U.S. industry. Activities to achieve this objective fall into six major categories: technical assistance, use of facilities, personnel exchanges, CRADAs, major industry partnerships, and reimbursable work for industry.

Technical Assistance

Technical assistance, in the lexicon of PNL's industrial competitiveness program, is defined as short-term efforts



Capillary Electrophoresis-Mass Spectrometry allows precise structural analysis of ionic substances in solution. By using CE-MS, researchers can study molecular interaction without destroying chemical bonds that critically affect substance behavior. In 1994 PNL researchers received a Federal Laboratory Consortium award for Excellence in Technology Transfer which recognized their efforts to transfer the technology.

focused on assisting companies, local governments, or trade organizations with specific technical problems. PNL continues to expand its technical assistance with U.S. firms, especially those in the Pacific Northwest. PNL's most recent expansion is the creation of an Office of Small Business Programs. This new office is managed by a fulltime PNL staff member with research and industrial experience, who serves as a window to PNL and DOE laboratory system capabilities. The office works with the region's small and medium sized businesses, with emphasis on women-owned and minority businesses, to help them launch new commercial products, expand their production, address key technical problems, and be more competitive in the commercial world.

A key service that PNL can provide a firm is up to 4 days of an engineer's or scientist's time to address specific prob-

lems. This activity is largely supported with funds supplied by the DOE Office of Energy Research - Laboratory Technology Transfer Program, which is described in more detail below. PNL staff members are often able to provide valuable solutions to a small firm within the allotted resources. We are seeing a greater use of the program as outreach to small and medium-sized businesses is expanded in the Hanford Economic Transition Program.

PNL's Office of Small Business Programs also assists small businesses through the SBIR and STTR programs. In addition, PNL will assist small firms by making available unique equipment at PNL, special analytical services, literature searches, and, in some cases, may loan equipment. Traditional technology transfer mechanisms such as CRADAs, staff exchanges, and licenses, are also used. This new office is closely coordinated with the State's Small Busi-

ness Development Center located at Washington State University, which has offices in every community college in the state of Washington. The Office of Small Business Programs also coordinates with the Washington Alliance for Manufacturing and with the Business Assistance Center at the Washington Department of Community, Trade, and Economic Development. This coordination allows all of the organizations to leverage their respective resources and provide a more complete service to the region's businesses. An example of the successful implementation of this coordinated approach was the joint conduct of two workshops in FY 1994 to identify mechanisms to meet the needs of women-owned and minority small businesses. More than 400 such firms attended the two workshops, and all attending firms indicated that the workshops met or exceeded their expectations. PNL's role in this

network of support for small business is to serve as the source for technology and technical assistance. The office is currently working to establish similar coordination with analogous agencies in the states of Oregon, Idaho, and Montana.

Use of Facilities

PNL has one DOE-designated user facility-the Fitzner/Eberhardt Arid Lands Ecology Reserve—which is primarily used by academic and DOE laboratory researchers. In addition, PNL has extensive specialized equipment and facilities that have been used by industry to address specific technical problems. PNL equipment was used during early development, for example, to test and shape a titanium-based composite manufactured by a local company. The composite is now being used in numerous products ranging from wheelchairs to golf clubs. A catalogue of these facilities and equipment has been prepared for distribution to firms interested in using them.

PNL is developing specialized equipment at its facilities that can be used by industry partners. This equipment includes a superplastic forming press, a materials extrusion facility, a materials coating facility, and a fluid dynamics laboratory. In addition, the Environmental Molecular Sciences Laboratory (EMSL) is under construction at PNL. We intend this facility to be a major DOE-designated user facility. Collaborations between industry and PNL technical staff who will eventually occupy the EMSL are already under way.

Personnel Exchanges

Nearly all of PNL's formal personnel exchanges are conducted with support from the Office of Energy Research - Laboratory Technology Transfer Program (ER-LTT). PNL 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 PNL from approximately seven different companies and one university. In addition, we have sent eight of our staff members to industry.

The following personnel exchanges were conducted in FY 1994:

- Freeborn Tool Company, Spokane, Washington
- USCAR Operations & Maintenance Partnership, Detroit, Michigan
- USCAR Environmental Research Consortium, Detroit, Michigan
- Reaction Engineering International, Denver, Colorado
- Meier & Associates, Kennewick, Washington
- Montana Indian Manufacturing Network
- Ft. Belnap Industries (a Native American-owned business)
- Pacific Western Services (a minority-owned business)
- R. Lynette & Associates, Redmond, Washington
- Oceaneering Space Systems, Houston, Texas.

Four of these staff exchanges are with small companies in the Pacific Northwest, and two are with consortia representing the Big Three vehicle manufacturers. This demonstrates the versatility of the staff exchange program. Two of these exchanges led to the development of successful follow-on proposals for CRADAs. Another is helping to identify potential commercial applications for PNL-developed sensor technology.

PNL will continue to actively pursue personnel exchanges as a means of fostering industrial interactions, particularly with minority and womenowned businesses. An exchange to integrate automotive supply companies with the cooperative efforts of the DOE laboratories and the automotive manufacturers will be conducted in FY 1995. In addition, 5 to 10 other exchanges will be conducted.

Cooperative Research and Development Agreements (CRADAs)

CRADAs provide an important new mechanism for PNL and other DOE

laboratories to assist U.S. industry. At PNL, the creation of CRADAs is energized by an organization charged with forming partnerships, a staff that desires to work with industry, and a supportive DOE Richland Operations Office that reviews and approves PNL's proposed CRADAs in a few days to a few weeks.

PNL has made numerous verbal and written announcements inviting partners to enter into CRADAs, and by the end of 1994, more than 200 companies had indicated a desire to enter a CRADA with PNL. In FY 1994, PNL signed and initiated 28 CRADAs, giving a total of 55 signed CRADAs with a combined total value of \$34.5 million since the authority to enter into CRADAs was received in 1990. Numerous other partners have been identified and the agreements are awaiting funding. Still other agreements are in various stages of evolution. A few of PNL's active CRADAs are listed below, along with the relevant DOE supporting Office.

- Phillips Petroleum Research Separating metals from spent catalyst will be developed to provide opportunities to evaluate the technology and determine whether or not to proceed with further development (funding office is the Office of Fossil Energy)
- Ft. Stewart (U.S. Army), Atlanta
 Gas Light Co., Public Service Co.
 of NC, Gas Fired Products, Inc. Install, operate, monitor, and evaluate a domestic outdoor natural gas
 conversion kit for an electric water
 heater (funding office is the Office
 of Energy Efficiency and Renewable Energy)
- General Motors Biomimetic coating of fuel pump parts (funding office is the Office of Energy Efficiency and Renewable Energy)
- Halliburton Logging Services Explore the application of borehole
 geophysics technology for DOE
 site characterization (funding office
 is the Office of Environmental
 Management)

- Water Development Corporation -Investigate the use of sonic drilling techniques for DOE site characterization and restoration activities (funding office is the Office of Environmental Management)
- Beckman Instruments To develop and commercially apply a new device for measuring flow rates in unsaturated soils (funding offices are the Office of Environmental Management and the Office of Energy Research - Laboratory Technology Transfer Program)
- Digital Instruments Inc. To develop a state-of-the-art near-field optical microscope (funding office is the Office of Energy Research -Laboratory Technology Transfer Program)
- GM/MARC Analysis Res. Corp. -Superplastic forming modeling and simulation (funding office is the Office of Energy Research -Laboratory Technology Transfer Program).

Funding support for 30 of the 55 CRADAs currently ongoing at PNL has been provided by the Office of Energy Research - Laboratory Technology Transfer Program. This program continues to grow in importance as a major element of the PNL's efforts to assist U.S. industry.

PNL has several other CRADAs that are in varying stages of development. For example, 13 additional CRADAs have been funded by the Office of Energy Research - Laboratory Technology Transfer program and are currently in various stages of negotiation with the industry partners. Partners range from DuPont and Electric Power Research Institute to various small businesses. PNL is continuing to work with its DOE program sponsors to obtain support for additional CRADAs.

Major Industry Partnerships

Both Congressional legislation and Administration policy have reinforced the importance of establishing major partnerships between DOE laboratories and other organizations as a means to enhance U.S. industrial competitiveness through improved technology transfer. For example, the recent report Technology for America's Economic Growth: A New Direction to Build Economic Strength directs federal agencies to act as partners with industry wherever possible. DOE has responded to this emphasis by initiating funding support for several major industry partnerships and by establishing a new Office of the Deputy Undersecretary for Industrial Competitiveness to guide and manage such partnerships.

PNL has been a key participant in the development of several major industry partnerships that are currently ongoing between the Department, its laboratories, and major U.S. industries. We continue to believe in the value of these partnerships as means of addressing the needs of key U.S. industries through an industry-led research and development agenda. Several specific research projects have already been initiated within the context of ongoing major industry partnerships and several more are planned. Examples of these projects include

- AMTEX Demand Activated Manufacturing Architecture (DAMA) To define, develop, integrate, and deliver an information system structure to be used by all elements of the U.S. textile industry.
- AMTEX Textile Resource Conservation Project (TReC) To assist
 the U.S. textile industry in developing and implementing technology
 to conserve their resources. Funding for PNL efforts within both of
 these projects is being supplied by
 the Office of Energy Research Laboratory Technology Transfer
 Program.
- 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. Funding for this and three other companion projects with the Low Emission R&D Partnership is being supplied by the DOE Office of Energy Efficiency and Renewable Energy.

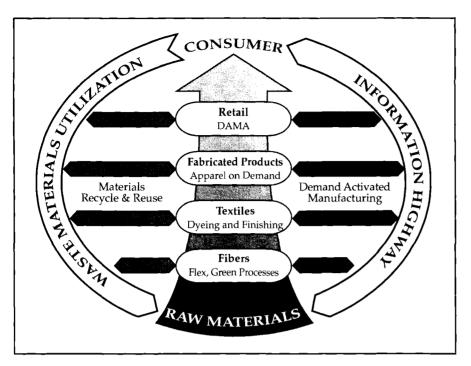
 USCAR - Environmental Research Consortium - Instrumentation for High-Speed Analysis of Vehicle Emissions - To develop new technology for rapid and accurate measurement of low-levels of specific compounds contained in vehicle exhaust. Funding for this project is being supplied by the Office of Energy Research - Laboratory Technology Transfer Program.

PNL believes that the establishment of successful partnerships with U.S. industry and other external organizations is an essential element of its future. It has been a leader in establishing major industry-led partnerships, such as those mentioned above. PNL's interest in such partnerships is a reflection of its long-standing commitment to serving industry and "putting technology to work" that is now receiving so much emphasis in federal and DOE policy.

We propose Technology Research Partnerships (TRPs) as a continuing initiative to foster partnerships among DOE, its laboratories, and industries that are critical to the U.S. economy. Our focus is on the rapid deployment of federally supported waste management and pollution prevention technologies. This year, the following partnerships are incorporated within the context of the initiative:

- the Chemical Industry Environmental Technology Partnership (CIETP)
- the Mining Industry Partnership
- the petroleum industry "Refineryof-the-Future" and Natural Gas and Oil Technology Partnerships.

Joint research and development activities between DOE laboratories and U.S. industry can be most effective when performed through a coordinated, industry-driven process. Working through industry consortia facilitates fairness of opportunity for industrial participants. Working through an industry-driven agenda ensures that activities are focused on industrial needs. Participation by multiple laboratories provides an opportunity for the unique capabilities of each laboratory to be effectively utilized.



A strategy for the textile industry competitiveness is to make revolutionary advances simultaneously throughout the integrated industry in quality, cost responsiveness, and environmental sustainability.

The three partnerships listed above are in various stages of development, and closure has not yet been reached on the scope of their activities or anticipated resource requirements. However, each represents a partnership in which PNL plays a key role in bringing the capabilities of the DOE laboratories to bear on important problems of major U.S. industries. We expect such partnerships to be an important element of PNL's future.

Chemical Industry Environmental Technology Partnership (CIETP) The U.S. chemicals industry represents more than 23 percent of the world's total chemical production with 1993 revenues exceeding \$300 billion. Increasingly, environmental issues have been negatively impacting industry revenues and robbing research and development investments. In 1993, environmental compliance costs exceeded research and development budgets.

In response, PNL and Battelle are supporting the chemical manufacturing industry in forming the Chemical Industry Environmental Technology Partnership (CIETP, pronounced

SeeTip). CIETP's goals are to identify and prioritize the industry's environmental issues (restoration through pollution prevention) and focus existing public and private resources to solve those issues through collaborative efforts. The resources saved will then be used to renew the industry and provide for long-term competitiveness.

CIETP, as a closely held corporation, will provide a forum for the industry to work together and proactively collaborate with others. The legal form ensures protection from liability and antitrust issues while also allowing the execution of contractual relationships involving services, joint funding of projects, and collection and distribution of intellectual property. With the DuPont Company leading the effort, CIETP's founding members include Air Products and Chemical, AKZO Nobel, and Imperial Chemical Industries (ICI).

CIETP has been endorsed by the American Chemical Society and is currently pursuing incorporation. While CIETP pursues the incorporation process, it is also establishing its first projects. Three are in the recycling area, two in restoration, and one in monitoring technology. CIETP intends to pursue contractual relationships with federal partners to work on these concerns. Eventually, it is intended that the resources of DOE, DOD, EPA and their laboratories will be applied to work in collaboration with CIETP on problems of mutual interest and concern.

Mining Industry Partnership Our nation's economy and manufacturing industry depend on a secure and competitive supply of raw materials, including minerals and metals. Unfortunately, many of the world's mineral resources are located in areas where political instability represent potential threats to supply. Domestic participation in this industry is therefore essential for the United States to ensure some degree of independence from foreign control over supply and costs.

The minerals and metals industry is an \$87 billion enterprise that employs over 500,000 U.S. workers. It recently has recovered from a protracted period of recession, thanks in part to commodity price increases, favorable currency exchange rates, reduced labor costs, and new applications of production technology. Unless a strategy building on areas of U.S. comparative advantage is pursued, the current competitiveness of the domestic industry versus foreign competitors is likely to be transitory. Cost-cutting measures have already yielded most of their possible benefits. The future competitiveness of the domestic industry will depend on technology development.

The domestic mining industry is burdened with a series of inherited problems, including abandoned mine sites and a reputation of being environmentally insensitive. The industry has also identified significant research needs in Exploration, Drilling and Excavation, Mineral Processing, and Smelting and Refining. Many of the DOE business areas are well aligned with the problems faced by the industry. The Mining Industry Partnership would take advantage of this synergy to develop and transfer technologies and solutions to the mining industry though active collaboration. Common issues

such as groundwater contamination, can be solved through collaborative efforts with federal stakeholders (e.g., DOE defense materials production sites).

The purpose of the Mining Industry Partnership is to provide the domestic mining industry the research and technology base required to sustain a healthy industry. The partnership and the research will be heavily driven by industry. Industry will identify its prioritized needs to the Partnership, and the Partnership will guide the appropriate federal sector resources, including the DOE laboratories, the U.S. Bureau of Mines, and other federal sector participants (in conjunction with industry stakeholders) to conduct the necessary research and development. DOE and DOI are drafting a Memorandum of Understanding which will allow the DOE laboratories and the U.S. Bureau of Mines to formally coparticipate in the partnership. Currently the federal sector is represented in the partnership by DOE laboratories and DOI organizations, including the Bureau of Mines and the Geological Survey.

The mining industry is composed of proud, independent companies. The companies are fragmented and extremely competitive. Therefore, no one individual or organization speaks for industry. The current challenge is to identify an industry champion, someone who speaks for industry. With the support of the industry champion, the Partnership will gain trust and momentum within industry. Once such trust and momentum is achieved, PNL plans to increase its efforts to work with the industry and with the DOE to define an appropriate role for the DOE and its laboratories in addressing industry research and development needs. PNL is working closely with the Northwest Mining Association and regional mining companies primarily in Washington and Idaho, uncovering common areas of interest and technology development needs.

Refinery of the Future Initiative and the Natural Gas and Oil Technology Partnership The natural gas and petroleum industry is an integral part of the U.S. economy. This industry

accounts for \$300 billion of consumer spending (5.5 percent of the Gaseous Diffusion Plants) and produces 99.8 percent of the transportation fuels used, 73.9 percent of the industrial energy consumed, and 60.5 percent of all residential and commercial energy. Over the last 20 years payments for imported oil have accounted for over 60 percent of the trade deficit, and that number is expected to rise to 70 percent by the year 2000.

The natural gas and oil industry is not a monolithic, uniform industry, but a highly diversified and extended business community involved in the discovery, extraction, refining, and marketing of petroleum and petroleum products. The industry requires a technology base adequate for operations on any scale.

Regulatory compliance has become a major cost item that reduces the profitability of operations and thus, is 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.

PNL and other DOE laboratories have extensive capabilities that could be used to assist the U.S. oil and gas industry in addressing industry-wide problems. Examples of these capabilities include

- facility decommissioning methods and sensor technology
- regulatory performance and risk assessment methodologies
- various processing technologies, such as PNL's Petroleum Sludge Treatment (PST) process
- new types of catalysis methods
- modeling and visualization of environmental phenomena using state-ofthe-art computational technologies.

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 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 5 years ago and involves the three Defense Program laboratories (Sandia National Laboratories, Lawrence Livermore National Laboratory, Los Alamos National Laboratory). With the implementation of the Advanced Computational Initiative (ACTI) in FY 1995, the partnership was expanded to include the Energy Research multiprogram laboratories. The ACTI program focuses on exploration and production computing technology. Specific technical areas incorporated in the partnership include 1) seismic processing, 2) reservoir performance and enhanced recovery modeling, and 3) data systems, fusion issues, and visualization. It is funded at \$42 million for FY 1995 through the offices of Fossil Energy, Energy Research, and Defense Programs. PNL is committed to actively participating in the Advanced Computational Initiative. We have the 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 Advanced Computational Initiative.

The Refinery of the Future Initiative is a new effort that has been driven by an industry-derived technology road map for research objectives. It involves the Office of Industrial Technology (EE) and the Office of Natural Gas and Petroleum Processing (FE). Argonne National Laboratory is acting as the primary coordination point for laboratory efforts related to the initiative.

The program has five strategic goals:

- environmental stewardship
- process efficiency
- process flexibility
- yield improvement
- feedstock flexibility.

The research and development programs pursued will promote collaborative research between the industry, national laboratories, and academia in

order to take advantage of the relevant expertise and centers of excellence that exist within these organizations that can augment the capability of the industry. Collaborative program implementation arrangements that are compatible with the unique requirements and sensitivities of the industry will be pursued.

Funding requirements for support of the activities incorporated within the partnerships are still evolving. PNL resource requirements within the partnerships will be a subset of these overall requirements. It is anticipated that future funding support for PNL activities within the Natural Gas and Oil Technology Partnership will be derived from ER and/or FE funds provided to support the partnership and managed by the Bartlesville Program Office of FE. Funding for the Refinery of the Future Initiative will likely be derived from programmatic funds through EE. Support for initiating and establishing non-programmatic activities or new partnerships will likely be sought from the Office of the Undersecretary for Industrial Competitiveness once the charter for this Office is better known.

Reimbursable Work for Industry

Reimbursable work for industry is research and development conducted by PNL staff that is fully funded by industry. As such, this represents perhaps the purest form of industry-led activity involving the laboratories. At PNL, nearly all such work is conducted under the Use Permit, which is a unique partnership between Battelle and the DOE that has served industry and the national interest well during its more than 25 years of existence. It also draws upon the skills and capabilities resident in Battelle's private commercial/industrial business.

PNL's strategy with regard to reimbursable work for industry is to conduct such work when it can meet the needs of our industry partner better than the use of other mechanisms, such as CRADAs. Examples of situations where this could occur include projects with extremely short time horizons, projects where obtaining cost-shared federal funding is difficult

or impossible, and projects where the industry partner desires to maintain the confidentiality of project results for more than the 5 years allowed by the CRADA agreements. In FY 1994, PNL initiated such projects with 74 industrial companies at a total contract value of \$17.5 million. Comparable figures in FY 1993 were the initiation of projects with 78 companies at a total value of \$15.3 million. In addition to these new projects, PNL averages 100 ongoing projects with industry per year. We believe that the increased interest from industry in using the laboratories to improve their competitiveness will increase the level of reimbursable work for industry in the future.

Protection and Commercialization of Intellectual Property

This element of our strategy accelerates technology development throughout the Laboratory and rapid deployment to industry. It is a means by which we can add additional value to technology that is developed at PNL by enhancing the potential for our industry partners to apply such technology in the commercial world. It also provides an indication of the uniqueness that PNL can bring to bear on addressing a specific industry need. Finally, it provides an opportunity for both the federal government and Battelle to have part of the funds that they have invested at PNL returned for supporting future efforts.

PNL's philosophy is to commercialize selected technologies as rapidly and broadly as possible. The most frequently used method is licensing. A PNL license agreement is normally nonexclusive unless the technology would not otherwise achieve commercialization. This strategy allows PNL to have multiple licenses for some technologies. Where an exclusive agreement is required, the scope of a license is limited by fields of use and territory to achieve the broadest benefit of the technology.

In FY 1993, PNL efforts in this area resulted in more than 22 new licenses for U.S. industry for commercial application. Plans to accelerate and expand

the commercialization opportunities include the strategies outlined above, i.e., enhanced industrial awareness of PNL as a technical resource and continued development of PNL technologies through CRADAs and the Use Permit. Also, the Laboratory is taking additional steps to identify potential intellectual property early in the invention process, to evaluate its potential value, protect selected high-value inventions, and encourage their early development. The technology transfer staff works closely with PNL research staff to encourage this early identification and facilitation of valuable ideas.

PNL is expanding its comprehensive strategy for evaluating and protecting intellectual property aimed for commercialization. The Intellectual Property Protection Committee develops detailed plans for new technologies selected from invention reports submitted by staff members. We have detailed processes to evaluate inventions based upon both technical merit and commercial potential. Patenting, including foreign coverage, has increased significantly in the past several years from an annual average of 10 U.S. applications to 25 per year. From 1989 to 1993, PNL received 98 patents.

We are currently working on improving the speed and communication associated with our patent evaluation processes after an invention report is submitted for evaluation. In addition, we are in the process of developing a program to be more proactive in returning inventions to PNL staff members that Battelle and DOE have elected not to pursue patents on.

The Laboratory has experienced a general upward trend in patent and software license agreements in recent years. Some inventions are broad enough to be licensed for several fields of use. Royalties generally lag behind the licensing activity but follow a parallel trend. The lag occurs because royalties depend upon product sales, and development of the product and its successful introduction into the market usually take several years.

Contributing to the significant growth in licenses has been PNL's software

Technology Transfer Effort

(Budget Authorization \$ in Thousand)

	1993	1994	1995	1996	1997	1998	1999	2000
Outreach Activity(a)	1,700	1,800	2,000	2,000	2,000	2,200	2,400	2,400
Patent/Licensing Activity ^(a) CRADA Funding - Federal:	2,500	2,400	2,400	2,400	2,400	2,600	2,600	2,600
Office of Energy Research ^(b) CRADA Funding - Federal:	1,800	13,000	18,000	21,000	22,000	22,000	22,000	22,000
Other	1,300	1,500	3,000	5,000	7,000	10,000	13,000	15,000
CRADA Funding - Private Industry	500	700	800	900	1,100	1,500	2,000	2,500
Total CRADA Funding(c)	3,600	15,200	21,800	26,900	30,100	33,500	37,000	39,500
	Staffi	ng (Full-T	'ime Equi	valents)				
Outreach Activity	5	5	6	6	6	7	8	8
Patent/Licensing Activity	18	18	18	18	18	19	19	19
CRADA Activity ^(d)	6	7	7	7	7	7	7	7
Total Staffing ^(e)	29	30	31	31	31	33	34	34

⁽a) Represents internal and external funds budgeted for crosscutting technology transfer activities, including labor and other costs.

Licensing Income and Use

(Budget Authorization \$ in Thousand)

****	1993	1994	1995	1996	1997
Number of New Licenses ^(a)	293	280	285	290	295
License Income	980	500	600	700	950
Use of Income					
Invention Administration	536	350	390	450	550
Scientific or Applied R&D	415	100	150	180	320
Awards	29	50	60	70	80
Education/Training	0	0	0	0	0
Total	980	500	600	700	950

⁽a) In FY 1993, the total of new licenses includes 271 Government Use Agreements.

⁽b) Includes CRADAs performed with institutional support funds, spinoff CRADAs, and the AMTEX partnership. A significant part of the AMTEX Partnership CRADA funding will be utilized by other DOE-ER laboratories.

⁽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 PNL staff conducting crosscutting technology transfer activities.

technology transfer program to commercialize and distribute federally sponsored software. PNL has developed a systematic process to evaluate software for commercialization potential. If approved for commercialization, the PNL software is copyrighted to protect the interests of the government and PNL. Software which is not commercialized can be released outright for the public benefit. An important objective of software technology transfer is to reinvest the income to make the process financially sustainable.

An integral component of software commercialization is leveraging the resources and expertise of business partners (licensees) to effectively market and distribute PNL-developed software. The major licensee selection criteria are technical expertise and reputation, compatibility of their product line and industry focus with the software, ability to market and distribute software as evidenced by their sales/marketing channels and track record, size and type of customer base, and the overall terms and conditions. Joint development projects with industry are also undertaken to address market requirements. At PNL, collaboration with partners is an ongoing activity that continues even after a contract is signed.

An example of effective partnering is PNL's licensing of the CINDY code to Canberra Industries, a major leader in the nuclear health physics market. Canberra has actively marketed and sold this software worldwide since 1993.

The Laboratory's software portfolio will continue to grow. Over the next year, the PNL Manager of Software Products will be actively working with PNL staff to improve effective software technology transfer.

Laboratory Directed Research and Development Program

The relevance and value of a DOE multiprogram laboratory lie in its abil-

ity to apply science and technology to national needs that fall within the business 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 it if 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

The process of selecting LDRD projects at PNL is led by the Senior Director, Science and Technology. He leads discussions with line managers and senior scientific staff that lead to recommendations on the selection and allocation of LDRD funds to meritorious projects submitted by PNL research staff and management. These recommendations form the basis for the Laboratory Director's decision on these allocations. The Director also specifies a planned level for total LDRD funding during the next fiscal year, which is submitted to DOE for approval. Planned LDRD levels for PNL are shown in the table.

Projects are reviewed for technical merit by line managers and/or scientific staff, and in some cases by external peer reviewers. Written guidance pertaining to the criteria and guidelines for LDRD projects provided in DOE Order 5000.4A are widely distributed to PNL staff and managers through a formal PNL LDRD Guide and other correspondence. Adherence to the criteria of 5000.4A is further ensured through reviews by the office administering the program. 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.

Scientific and Technical Investment Areas

PNL's LDRD Program supports new and innovative projects throughout the Laboratory; however, PNL's core competencies are targeted for emphasis. These are

- · integrated environmental research
- process science and engineering
- · energy systems development.

While emphasis is placed on the above core competencies, LDRD funding also is allocated for projects judged to have high scientific/technical merit that are independently proposed by individual researchers or small, multidisciplinary teams within PNL research centers.

PNL plans to continue to focus the majority of its LDRD investments in the development of scientific and technical areas that underlie the three core competencies. Examples of such areas include the environmental sciences, biological sciences, computer and information sciences, chemical and materials processing, and energy technology.

Selected Highlights of FY 1993 and FY 1994 LDRD Projects

In FY 1993, 142 LDRD projects were selected for support through PNL's LDRD project selection process.

Laboratory Directed Research and Development

(Budget Authorization \$ in Millions)

Current Program	1993	1994	1995 ^(a)	1996
Total LDRD Funding	11.8	13.8	16.0	17.0

⁽a) The estimated amount for FY 1995 represents the maximum budget level approved by DOE. The estimated amount for FY 1996 is a forecast that is subject to future DOE approval.

Selected highlights of the results of these projects follow:

- A project entitled "Complex Modeling of Complex Physical Systems" resulted in the enhancement of the ability to study environmental processes through the use of massively parallel computing architectures and advanced numerical methods. The environmental processes include spatially-distributed hydrologic process modeling for heterogeneous watersheds, global chemistry modeling, and computational investigation of subsurface heterogeneity. Significant improvements in the speed and accuracy of addressing these computationally intense problems resulted form the application of parallel processing methods developed in this LDRD project.
- Research on "Transportation Materials" resulted in the development of a low-cost alloy having vastly improved superplastic forming rates and superplastic forming elongations compared to available alloys. Testing of a modified alloy containing manganese and zirconium additions demonstrated elongations of 450 percent at a strain rate that is more than 10 times that of current commercial alloys.
- A project entitled "Elastic Properties, Solution Chemistry, and Electronic Structures of Oxides, Silicates, and Carbonates" resulted in the first demonstration of the reliability of treating ionic minerals at the Hartree-Fock (first principles) level of computational investigation. Minerals studied using the Hartree-Fock

- computational methods included stishovite and other SiO₂ phases, perovskite phases, iron and iron oxides, and boehmite.
- Research in "Organic Conversion" resulted in a fourfold increase in the capacity of a low-temperature plasma process developed through previous LDRD work to destroy perchloroethylene and carbon tetrachloride. Tests using the process indicated a destruction efficiency of 91.6 percent for carbon tetrachloride at expected field operating conditions. Additional experiments demonstrated the ability of the corona to degrade ethylenediaminetetraacetic acid.
- A project entitled "Spectroscopy Techniques for Analysis of DNA Damage" demonstrated that electron migration occurred in aqueous solutions of DNA and that differences in the extent of migration occurred as a function of DNA strandedness and base sequence. This project also resulted in the development of synthetic methods to generate modified DNA products identical to those introduced following exposure to ionizing radiation. The detection of radiationinduced cross-links between DNA and proteins at doses as low as 1 gray was also demonstrated.
- A project in "International Reactor Safety" led to the development of RELAP5/MOD3 model of an RBMK Russian nuclear reactor. The model was used to evaluate a set of RBMK loss-of-coolant accident events. Feedback from Russian

scientists indicated that they found this work to be extremely valuable in analytic efforts to improve the safety of the RBMK reactors.

More extensive information on the technical highlights of PNL's LDRD Program is reported in PNL's Annual Report on Laboratory Directed Research and Development.

Work for Other DOE Sites

PNL 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 as well as numerous institutional areas such as safety and security. As previously reported, PNL has supported the environmental restoration of the DOE Laboratory for Energy-Related Health Research near Davis, California. This activity has been a model for other decontamination and decommissioning activities and has saved DOE several million dollars by streamlining the decontamination and decommissioning activities.

As the primary developer of waste vitrification technology, PNL continues to transfer the technology for treatment of nuclear and other hazardous wastes at DOE sites. PNL is providing direct support to other sites in areas such as high-level waste vitrification processes, waste form qualification, and innovative waste treatment technologies. As reported previously, since project inception in the early 1980s, PNL has

been a technology partner providing major support to the West Valley Demonstration Project in New York State. In addition, tests have been conducted and are continuing to support decisions on whether to in situ vitrify buried low-level and transuranic waste in the trenches at Oak Ridge National Laboratory, A multi-hundred-tons treatability test will be conducted in a radioactive liquid waste seepage pit during FY 1995 in support of the Record of Decision for closure of sites at Oak Ridge. This test is the culmination of 9 years of collaboration between PNL and Oak Ridge National Laboratory targeted to remediation of Oak Ridge National Laboratory pits and trenches.

At Pantex, PNL is providing extensive support for a broad range of environmental, safety, and health functions while instituting advanced technologies to support plant operations. PNL staff are developing strategies and techniques to modernize disassembly operations and process improvements to achieve dose reduction, as well as preparing transportation safety documentation.

PNL also provides major safeguards and security support to the Albuquerque and Rocky Flats DOE operations offices where PNL assists in identifying and implementing programs that meet evolving DOE needs. Principal activities include evaluations and reviews of organizational structure, program effectiveness, strategic planning, and development of process improvement practices and procedures.

PNL will continue supporting other DOE sites over the next several years as the Laboratory transfers some of the new technologies being developed for the Hanford Site. In the long term, the level of support is expected to decline.

Work for Others

In addition to contributing to the implementation of the DOE Strategic Plan, upon request, PNL performs work for other federal agencies (WFO) in selected scientific and technical areas in accordance with DOE polices. Work undertaken for

other federal agencies accounted for about 16 percent (\$75 million) of the Laboratory's total budget in FY 1994. It is expected to remain at about this level in FY 1995 and to increase by about \$10 million by the end of the planning period, FY 2000. 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 PNL. 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

PNL's work for the DOD utilizes the Laboratory's capabilities in advanced materials, analytical chemistry, environmental characterization, and automation technologies. The level of activity for DOD in FY 1994 was \$50 million and this level is expected to be about the same in FY 1995; increasing slightly beyond. PNL is currently working in the following technical areas:

- treaty verification and technology assessment
- information sciences and architectures
- advanced materials and process development
- sensors, electronics, and automated systems
- systems analysis and technology evaluation
- environmental science and waste technology
- analytical chemistry and radionuclide applications.

PNL 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 the DOE, is performed

for a number of DOD clients in support of national security needs.

PNL supports Navy, Marine, Army, and Air Force research and development needs for systems integration using the Laboratory's capabilities in information sciences, networking architectures, and software development. PNL develops and evaluates advanced tactical command, control, and communication networks for the Marines and Army, 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.

PNL expects to continue providing support for the DOD in advanced materials and process development. The Kinetic Energy Projectile Program supports design, analysis, testing, and development of advanced munitions and manufacturing techniques for the Army's Armament Munitions and Chemical Command. Studies of composite materials and other unique materials are performed for many other DOD clients. Other materials work for the DOD includes developing optical and other coatings technologies that include high-efficiency and selectivity reflective coatings, and high-quality coatings of very largescale optics (currently up to 2 meters).

Sensors, electronics, and automated systems development work is also expected to continue. PNL is developing sensors for chemical, environmental, and biological measurement, and imaging technology for DOD. PNL directs a program with Advanced Research Projects Agency ultrawide band and impulse radar technology. Millimeter wave, radio frequency, electroptical, and fiberoptic technologies are being 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. PNL is developing a telerobotic system for disposal of explosive ordinance for the Navy.

PNL 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 within the Army; evaluation of organizational 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.

PNL is the lead laboratory for energy management within DOE for the DOE's Federal Energy Management Program (FEMP). Under FEMP, PNL has developed and is deploying a model program for installation-wide energysystem modernization. Software tools and methodological approaches are being developed for rapid assessment of the energy resource potential at each installation. PNL 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.

PNL maintains world-class capabilities in environmental characterization and analysis of impacts on a variety of ecosystems from arid lands to wetlands and estuaries. All services, most notably the Army Corps of Engineers, seek out PNL for specific analyses, and for development and synthesis of preven-

tion and mitigation technologies to minimize deleterious environmental impacts.

PNL 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 PNL to meet measurement and testing requirements. Historical and unique PNL skills in analyzing radionuclides support specialized DOD needs.

As part of the Chemical Demilitarization Program, Congress has mandated that the U.S. Army provide support to assist the civilian population in dealing with the effects of an event involving the accidental release of chemical munitions. The program is referred to as the Chemical Stockpile Emergency Preparedness Program (CSEPP). For the first several years of its development, the Federal Emergency Management Agency, acting as agent for the Army and because of its national role in emergency preparedness, managed the program. Under FEMA management, PNL developed several emergency management decision support software systems.

Currently the U.S. Army has the lead in this program. With continued support from FEMA, the Army continues this leadership role, directing the development of a computing system which will support state and local emergency management agencies as well as U.S. Army Chemical Storage Depots and FEMA in dealing with CSEPP emergencies. PNL is doing developmental work for both FEMA and the Army under this program.

Nuclear Regulatory Commission

PNL's work for NRC program offices, the NRC supports regional offices, and several administrative offices. The work covers all aspects of nuclear safety regulations. The level of activity for NRC was \$14.8 million in FY 1994 and the level is expected to increase slightly in FY 1995 and beyond.

The NRC Office of Nuclear Reactor Regulation (NRR) has established the Standard Review Plan Update and Development Program (SRP-UDP) to update the Standard Review Plan (NUREG-0800), which is used by NRC staff to review applications for license and/or design certification concerning nuclear power plants or modifications thereto. PNL is assisting the NRC 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. During FY 1995 and FY 1996 the SRP-UDP emphasis will be in two areas 1) comparison of the current industry consensus codes and standards with those cited in the NRC regulatory documents, and 2) development of the integrated impacts that will be used for the revision of the 218 SRP sections. Revision of the SRP sections to incorporate appropriate integrated impacts continues in FY 1995 and will be completed in FY 1996.

The Nuclear Plant Aging Research (NPAR) Program addresses issues associated with the reliability of safetyrelated equipment, plant life extension, and license renewal. The objectives of the PNL work on nuclear plant aging research are to identify, evaluate, and mitigate safety-related aging problems associated with nuclear power plant structures, systems, and components through analysis of data collected during offsite investigations and laboratory assessments. PNL is assisting the NRC in developing and implementing an integrated plan for addressing issues of aging and license renewal and in preparing necessary documentation supporting the license renewal rule. The NPAR Program will conclude in FY 1995, and PNL anticipates providing continued assistance to the NRC in 1996 and beyond with future license renewal activities including the review and assessment of license renewal applications.

PNL provides technical support for assessing existing electrical and mechanical codes and standards for the construction, qualification, inspection, and testing of certain proposed advanced reactor concepts. The project is currently focused on IEEE and ASME. PNL may provide additional assistance to the NRC on the applicability of other existing codes and standards to these advanced reactor designs.

PNL provides assistance to the Office of Nuclear Reactor Regulation in regulatory and licensing activities in the siting and environmental protection areas, including the Environmental Standard Review Plan update and development effort. PNL provides ongoing multidisciplinary managerial and technical expertise to assist the NRC in its licensing reviews for early site permits and operating reactors, and in updating regulatory guidance.

PNL provides specialized multidisciplinary technical assistance to the Office of Nuclear Reactor Regulation to support the NRC staff in developing a database program that can be used to manage the NRC's construction inspection program for the Bellefonte Unit I and future plants. In FY 1995 and FY 1996 the database program will continue to be adapted for use with future reactors. The database program will be upgraded to include new modules for scheduling and text retrieval.

PNL will be providing an expanded role of technical assistance to the Office of Nuclear Material Safety and Safeguards (NMSS) in the area of Regulation of the Gaseous Diffusion Plants (GDP) at Portsmouth, Ohio, and Paduccah, Tennessee, which are being operated by U.S. Enrichment Corporation (USEC) through a lease arrangement by the DOE. For the next several years, PNL 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 NRC in developing the specific technical and inspection criteria and guidance and assisting with the reviews and inspections. This assistance may take the form of help provided to region staff, Office for Analysis and Evaluation of Operational

Data, or other NRC offices, and the GDP resident inspectors.

PNL provides technical assistance to NRC 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 PNL has provided to the NRC on shortturnaround analyses and addenda to previous decommissioning analysis reports should continue on a task basis. Current and future work for the NRC 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 nonfuelcycle facility reports to reflect current financial and regulatory conditions.

PNL provides testing support to the Operator Licensing Branch in licensing commercial power plant nuclear reactor operators and senior reactor operators and in evaluating facility operator requalification programs. PNL provides this support annually to approximately 300 to 400 candidates at 50 sites nationwide, supporting all five regions and headquarters. PNL has 18 fully certified examiners qualified to administer exams in all pressurized water reactors, boiling water reactors, and nonpower/research reactors. Workload may decline up to 10 percent during the next 5 years due to regulatory changes for administration of NRC requalification examinations. The broad background of the operator licensing examiners and their specialized training provide a pool of staff able to support a wide variety of other activities for both the NRC and DOE. The examiners will be beneficial in the performance of the following types of activities: maintenance and training inspections, risk analysis, risk management, simulator evaluations, emergency preparedness assessments, and individual plant examinations.

PNL is supporting the Office of Nuclear Reactor Research in evaluating past reactor operator crew examinations to identify trends and patterns in operators and crew ability on the job. PNL will evaluate variables such as operator education and experience to attempt to infer from these the effects on operator ability on the job and to compare results to human reliability analysis methods used in current probabilistic risk assessments. PNL will estimate relationships between performance shaping factors and operator error probability and provide guidelines based upon this analysis to be used by analysts to estimate error probabilities for performance shaping factors and plant-specific tasks.

PNL is assisting the NRC with three closely related projects to provide regulatory analysis support for the materials licensee-related activities and power reactor-related activities, to update and revise the Regulatory Analysis Guidelines, and develop a Regulatory Analysis Technical Evaluation Handbook. PNL is also tasked to perform the in-depth technical analyses necessary to support NRC decisions on safety issue resolution. These analyses include probabilistic risk assessments and cost analyses that provide the information for NRC staff to support regulatory decisions.

PNL provides technical support to the NRC in drafting environmental impact statements for low-level waste sites. PNL is in consideration for a series of environmental assessments at several uranium sites in New Mexico through the Office of Nuclear Materials Safety and Safeguards.

PNL radiation protection projects include calculating fractional transfer of radionuclides from a pregnant woman to embryo/fetus and developing dose factors for the embryo/fetus for determining the content of radionuclides as a function of the stage of gestation.

PNL will continue to assist NRC in a wide variety of activities related to emergency preparedness. Activities

include observing and evaluating emergency preparedness exercises and reviewing exercise scenarios; conducting inspections of utility emergency preparedness programs, emergency plans, and procedures; providing technical assistance in the resolution of a wide range of emergency preparedness licensing actions and issues such as evacuation time estimates; and providing technical input relative to near-term severe accident mitigation capabilities.

The nondestructive evaluation programs at PNL have provided the engineering databases to support the NRC'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 inservice inspections; optimizing inservice 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 NRC 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 NRC staff to assess inspection performance at reactor sites; and 6) developing information on computer-based ultrasonic systems to enable NRC staff to understand and audit inspection results. The nondestructive evaluation technologies under study at PNL include ultrasonics, eddy currents, and acoustic emission. We anticipate that when the advanced light water reactor designs proceed, we would be involved in the same type of work identified above for the new designs.

PNL is providing technical assistance to the Office of Nuclear Regulatory Research to determine the physical and/or chemical processes that result in concentration of radioactive materials released to sanitary sewer systems. PNL will suggest strategies for changes in the NRC sanitary sewer disposal regulations, if 10 CFR 20.3003 is found to be insufficient to prevent

future incidence of radioactive material in waste water treatment plant sludge material at levels that could pose risks to a member of the public.

Environmental Protection Agency

PNL conducts research to assist EPA in its central role of environmental regulation in the U.S. The level of activity for EPA was \$3.3 million in FY 1994 and this level is expected to decrease slightly in FY 1995 and beyond. We 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. PNL is conducting research to investigate the causes and effects of global climate change, and we expect that EPA will continue its support for such research in its Global Climate Research Program. The Laboratory is also involved in analyzing the effectiveness of the acid rain controls imposed by the 1990 Clean Air Act Amendments. PNL provides 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. PNL is also developing and demonstrating methodologies and technologies to understand and mitigate risks associated with hazardous materials. The primary areas of research that PNL will conduct for the EPA 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
- analysis and modeling of hazardous waste transport and fate in soil, water (both fresh and marine), air, and biota
- research, evaluation, testing, development, and demonstrations of alternative or innovative hazardous waste treatment and radon mitigation technologies

- analysis of the effects of toxic and hazardous chemicals on terrestrial and aquatic ecological systems, including the marine environment
- determination of the relative importance for wildlife of the various potential exposure routes (e.g., inhalation, dermal adsorption, direct food ingestion) of pesticides
- design and analysis of ecological indicators to assess environmental status
- modeling the formation, transport, and impacts of acid rain and evaluation of strategies to control it.

Health and Human Services

PNL's major Health and Human Services program is conducted for the National Toxicology Program. The National Toxicology Program is a program of the National Institute of Environmental Health Sciences, a component of the National Institutes of Health, which is part of the Department of Health and Human Services. PNL has established a center of excellence in inhalation technology and toxicology for the National Toxicology Program that is consistent with, and complementary to, our longstanding research efforts conducted for the DOE. This program has strengthened PNL's 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 general 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, the National Institute of Environmental and Health Sciences, and the Centers for Disease Control's National Institute for Occupational Safety and Health. The total government-sponsored inhalation toxicology program at PNL is currently funded at \$8 million to \$11 million per year, of which less than 2 percent has been funded through Work for Others agreements under PNL's 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.

PNL 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.

National Aeronautics and Space Administration

PNL is performing work for the National Aeronautics and Space Administration (NASA) in a number of areas related to the DOE's business areas. A continuing program is the development of a Space Station Leakage and Impact Detection System.

Another continuing program is the development and fabrication of radiation dosimetry instrumentation for the shuttle and Space Station Freedom. This work is being performed for NASA/Johnson. Approximately \$1 million has been funded to date and it is anticipated that NASA/Johnson may fund a prototype followed by a subsequent system for field test.

NASA is also funding work at PNL for the development of ultralight fabric heat-pipe radiators for space applications. Fabrication has been demonstrated for prototypes and it is estimated that radiator systems based on this concept will be 40 to 60 percent lighter than systems currently being used.

PNL is also working with NASA on the development of ultralight fabrics to shield space vehicles and Space Station Freedom from orbital debris and micrometeoroids. The fabrics will be used to shield piping, tanks, and other critical components. NASA/PNL studies indicate a potential for millions of dollars in cost reductions through use of these fabrics.

Other PNL work for NASA includes a continuing program on monitoring chemical releases from upper atmospheric rockets, radiological measurements on the Long Duration Exposure Facility satellite samples, and development of rotocraft simulator standards. PNL is also planning a future, major collaborative effort with NASA in global change as an extension of PNL's DOE program in this area.

The increasing emphasis in NASA on smaller, cheaper, and faster missions to the moon and Mars, and the emphasis on small, unmanned scientific missions as necessary precursors to manned missions in space will afford opportunities for applications of ground-penetrating radar, sensors, diagnostics, microtechnologies, robotics, powerbeaming, and other technologies developed for DOE applications.

Federal Emergency Management Agency

PNL will continue to support the Federal Emergency Management Agency (FEMA) through the development of automated 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. When complete, it will support any UNIX-based open system hardware set. It is the foundation of the multiple-hazard system. The initial product release will take place in December 1994. Follow-on development has been approved and is being funded. FEMA has funded an extension of the FEMIS/CSEPP development effort designed to port v1.0 of the FEMIS to their primary platform (IBM RISC) so that, when complete,

the FEMIS can be initially implemented on two platforms. FEMA may implement the FEMIS system nationally once it is completed and may manage it until it is replaced with something better.

Additional PNL support could take the form of development 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 12 years into the future.

Other Federal Agencies and Nonfederal

Several other federal agencies fund work at PNL. They include the Departments of Agriculture, Commerce, Housing and Urban Development, Interior, State, and Transportation and the National Science Foundation.

PNL's work for nonfederal organizations (i.e., commercial entities) under the 1830 operating contract was \$0.4 in FY 1994 and is expected to be about \$0.6 in FY 1995.



Critical Success Factors

Battelle's traditional values serve as a guidepost on the quality journey at PNL. 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 Battelle 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 Battelle that also is growing and advancing in capabilities for serving societal needs.

Earnings – For Battelle 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 PNL'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 PNL to successfully carry out its mission. These elements are discussed in this section of the plan.

Human Resources

Human Resources is committed to developing and implementing a program that satisfies the needs of the Laboratory while meeting all internal and external requirements. Major elements of Human Resources include general laboratory personnel programs and affirmative action/equal opportunity employment programs.

Laboratory Personnel

Areas receiving special attention are recruiting and retaining high-quality staff, enhancing staff development, and developing a reward system that supports the Laboratory's strategic goals.

Staff Development

Laboratory management is moving forward with a formal total quality/ process improvement effort. The effort relies on initiation of several training programs that support a "just in time" approach to engage staff and management in process improvement. Training includes skills development and critical soft-side needs, such as team building, conflict resolution, group process, and communication. Programs are designed to positively influence

personal and organizational behavior. The "principles of excellence," seven culturally derived principles that characterize excellence in research and development continue to provide focus for staff development.

As a part of management processes, 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/empowerment of staff and management to maximize personal and professional growth while maintaining strategic alignment with the purposes of the Laboratory. Thus, the staff development review serves as both the means by which the Laboratory connects its work effort to its goals and objectives and the means for identifying individual and organizational developmental needs.

The staff development review process serves as an integral element of the Laboratory's newly established centralized training and development system. This system includes the Laboratory-wide training and development catalog, a computer-based tracking and records system, an integrated training and development program, and a framework for a manager-leader development program. The system provides for the integration of professional development and compliance-oriented training and development programs.

Given the critical role of the staff development review process, it is essential that the process be evaluated periodically to ensure that it continues to meet the needs and expectations of the Laboratory. Recently, the staff development review process was evaluated by a cross-functional, Laboratory-level team to ensure that the outcomes of the process directly support the Laboratory mission/vision. Recommendations from this team have resulted in

Laboratory Staff Composition(a)

(Full- and Part-Time Employees)

Occupational Codes	Total # (%)	PhD	MS/MA	BS/BA	Other
Managers	492 (10.5)	129	156	143	64
Technical Staff	1984 (42.5)	521	549	683	231
Administrative Specialists	493 (10.6)	11	85	277	120
Technician	225 (4.8)	0	0	13	212
All Other	1473 (31.6)	0	7	97	1369
Totals	4667	661	797	1213	1996

⁽a) Data as of August 31, 1994.

a new staff development process being tested in FY 1995 for use across the Laboratory.

Additional staff development efforts/ targets include career development workshops, personal and organizational assessments, educational assistance programs, expansion of the training and development curriculum, enhancement of the learning environment, and a training and development approach that promotes "applied learning" by focusing on real-time business requirements and issues.

Human Resources is designing and developing a career planning and development model that will enhance PNL's ability to attract quality staff and develop its current work force. Initial focus will be on scientists and engineers; continuing with technical managers (project, program, and line) and technical specialists. Models will then be developed for the remaining PNL population.

Staffing

The U.S. work force continues to change as we move through the 1990s. Historically, fewer technical graduates have been available to fill the increasing numbers of technical positions; however, economic conditions of the

past few years have expanded the available talent pool for most research positions. PNL's continuing demand for candidates with advanced degrees and senior level staff requires ongoing emphasis on the recruitment of these candidates. See the Laboratory Staff Composition table for a breakdown of staff by job category and education.

PNL's Human Resources continues to focus on establishing new, innovative methods to identify highly qualified candidates and to implement an effective recruiting program within the Laboratory. New methods of recruiting candidates have been developed and are now in place, enabling PNL to identify and approach individuals with unique skill sets that match closely with the requirements of specific positions. Individuals identified using these new techniques do not usually respond to the conventional recruiting methods. To improve its delivery of services, the Staffing Department has recently implemented a new organizational structure. It has decentralized recruiting services by reassigning recruiting staff to work directly with their clients. It also created a position dedicated to sourcing candidates for hard-tofill positions.

An expanded and more comprehensive approach to college recruitment

also has been initiated to further enhance the Laboratory's competitive position for hiring the top technical graduates. Campus recruiting activities continue to include HBCUs and schools with large minority populations. In addition, developing ongoing relationships with schools is a major focus. These relationships will enhance PNL's visibility on campus, and with time, will result in higher-quality students seeking employment with us. College Relations is now focusing its recruitment efforts at those schools with which we have professional relationships through subcontracted research projects and Memorandums of Understanding. PNL is engaged in program development and/or active recruitment activities with Florida A&M University, Tuskegee University, University of New Mexico, and New Mexico Highlands University. We are using the services of Associated Western Universities, Northwest (AWU-NW) to bring minority and female science and engineering students into the Laboratory for summer and other internship positions. This will allow us to expand our recruiting of qualified females and minorities.

Aggressive recruiting efforts are expected to continue at PNL especially since the recession seems to

be diminishing thus making more job opportunities available for technical staff. In particular, we forecast a future where staff will need to perform in a multidisciplinary environment where lines between scientific and technical disciplines are increasingly blurred. In addition, program management skills will become increasingly important as we strive to enhance our role as a manager of partnerships involving the DOE, its laboratories, universities, and private industry.

Compensation and Benefits

PNL 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. PNL has developed multiple job evaluation systems that are periodically reviewed and modified to ensure that all Laboratory positions are defined and valued in a manner that is internally equitable and externally competitive. A new career ladder for our scientists and engineers has been developed to better define their respective levels and to better relate their system to the one used for management and other professionals. In addition, important initiatives are currently being pursued to more closely integrate career management and planning with job ladder design. 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. In conjunction with Battelle Memorial Institute, 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, such a program can help manage the cost of future benefits.

Affirmative Action and Equal Employment Opportunity

The strength of PNL lies in its staff members and the unique talent and insights they bring to the Laboratory. PNL's vision is that all staff members be valued for their diversity and treated with mutual respect and dignity. Work force diversity encompasses differences in education; upbringing; personal experiences; job category; cultural background; age; religious belief; physical needs, strengths, and limitations; family situations and obligations; and myriad other factors that make each of us unique individuals. Work force diversity, therefore, refers to much more than race and gender. All PNL staff are working together to create a work environment where

- productivity, efficiency, and creativity are optimized
- staff members perceive that they are valued for their unique talents, insights, and contributions
- true equal opportunity exists for all staff with a work environment free of harassment
- the work environment allows flexibility
- staff and managers emulate PNL diversity values in all work interactions.

The Workforce Diversity Program Office at PNL is focused on an 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. We also want to enhance PNL's ability to attract and retain qualified women and minority staff. Our activities center around four major areas: special programs, training, compliance, and community outreach. The following two Equal Opportunity

tables provide a breakdown of staff by race and gender.

Strategic Planning and Evaluation

For us to move closer to our vision of managing diversity, we constantly evaluate the effectiveness of our programs. PNL initiated a three-phased strategic planning and evaluation effort. During Phase I, data were gathered through internal planning sessions, a cultural assessment, and focus groups to determine the current effectiveness of our diversity effort. The objective was to establish a benchmark against which we could measure progress toward work force diversification. The assessment was designed to determine how employees perceived the quality of their work environment and whether the perceptions differed across subgroups of employees. For example, responses by minority females were compared with those by white females, and so forth. In addition, the study compared the perceptions of PNL employees and those of employees of other organizations in the consultant's database. A total of 447 PNL employees responded to the questionnaire, and about 60 participated in eight focus groups. Together they represented male and female, white and minority (Asian, African American, Hispanic, and Native American) employees.

The results show that staff perceptions of the work environment at PNL were similar to those of employees at other organizations surveyed by the consultant. This could be viewed as a positive indication that the work climate at PNL is no worse than the work climate at other organizations. However, in most cases the database represents responses given by individuals prior to any kind of diversity intervention. We, on the other hand, have already made significant investments in initiatives such as the Staff Diversity Enhancement Program, Equal Employment Opportunity and Affirmative Action training, and the Dimensions of Diversity Program. Therefore, although our

Equal Employment Opportunity(a)

(1994 Full- and Part-Time Permanent Employees)

													Asi	an/		
			Min	ority			l				Na	tive	Pac	ific	Staff with	
Occupational Codes	Te	otal	To	tal	W	hite	Bla	ack	Hisp	anic	Ame	rican	Islar	ders	Disabilities	
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F	l L	
Managers	412	80	24	3	388	77	 7	1	4	1	8	0	5	1	l 17	
Technical Staff	1594	390	107	37	1487	353	14	9	24	8	11	2	58	18	54	
Administrative Specialists	206	287	25	19	181	268	8	4	11	8	2	2	4	5	12	
Technicians	137	88	9	6	128	82	0	0	8	3	1	1	0	2	2	
All Others	404	1069	44	115	360	954	11	27	25	55	5	15	3	18	28	
Totals	2753	1914	209	180	2544	1734	40	41	72	75	27	20	70	44	113	

Occupational Codes	Tota	 al%	Mino Tota	•	% V	 Vhite	% В	lack	% His	spanic	% N Ame	ative rican	% Asiar Islan	/Pacific ders
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Managers	83.7	16.3	4.8	0.6	78.9	15.7	1.4	0.2	0.8	0.2	1.6	0.0	1.0	0.2
Technical Staff	80.3	19.7	5.4	1.9	74.9	17.8	0.7	0.5	1.2	0.4	0.6	0.1	2.9	0.9
Administrative Specialists	41.8	58.2	5.1	3.8	36.7	54.4	1.6	0.8	2.2	1.6	0.4	0.4	0.8	1.0
Technicians	60.9	39.1	4.0	2.7	56.9	36.4	0.0	0.0	3.6	1.3	0.4	0.4	0.0	0.9
All Others	27.4	72.6	3.0	7.8	24.4	64.8	0.7	1.8	1.7	3.7	0.3	1.0	0.2	1.2

⁽a) Data as of August 31, 1994.

results are positive by comparison, we might reasonably expect the results to be more positive than those of organizations that have undertaken little or no education in diversity.

The results indicate that we are still in the beginning stages of learning to manage diversity. We have developed an action plan that addresses the issues highlighted by this cultural assessment. A report detailing the activities of components of PNL has been prepared. Phase II included a synthesis of this data and a priority-setting process.

Phase III, which included program planning for the next 3 years, has been concluded, and we have established measures by which we can evaluate progress toward our goal of managing diversity at PNL.

Compliance

Although the focus of PNL's diversity programs is not mere compliance, compliance-related activities can be used to enhance our ability to measure and manage diversity. 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. Since 1989, the percentage of women at the Laboratory has increased from 36.9 percent to 40.7 percent and the percentage of minorities has increased from 5.5 percent to 8.1 percent. Our goals are set on an annual basis according to an eight-factor analysis computed individually for each of our 26 job groups. This analysis, based in part on the

Civilian Labor Force statistics and consistent with equal employment opportunity guidelines, takes into account internal availability, local statistics, and national availability for specific types of occupations. A summary of our availability statistics, which represents the appropriate benchmark for analyzing the composition of our staff, can be found in PNL's FY 1995 Affirmative Action Plan. Because many of our professional positions are difficult to fill, especially with few women and minorities available, the staff at PNL become critical to helping us find a diverse applicant pool for these types of positions.

In response to the Americans with Disabilities Act of 1990, a process has

Equal Employment Opportunity

(1989 Full- and Part-Time Permanent Employees)

Occupational Codes	To		Mino	-	33 /1	hite	 Bla	alr	Uisponia		itive	Pac	ian/ cific	Staff with
Occupational Codes Gender	M	F	M	F	M	F	M	F	Hispanic M F	M	F	M	F	Disabilities
Managers	240	29	T 12	0	228	29	1 3	0	1 0	5	0	3	0	8
Technical Staff	1029	174	32	7	997	167	2	1	5 0	5	0	20	6	37
Administrative Specialists	107	133	10	7	97	126	4	0	3 3	1	1	2	3	6
Technicians	157	89	4	4	153	85	1	1	2 2	1	0	0	1.	8
All Others	329	645	34	48	295	597	11	14	19 22	2	4	2	8	15
Totals	1862	1070	92	66	1770	1004	21	16	30 27	14	5	27	18	7 4
Occupational Codes	Tot	tal %		ority al %	% \	White	 %:	Black	% Hisp	anic	% Na	ative rican		sian/Pacific slanders
Gender	M	F	M	F	M	F	M	F	M	F	M	F		<u> </u>
Managers	89.2	10.8	4.5	0.0	84.7	10.8	1.1	0.0	0.4	0.0	1.9	0.0	1	1.1 0.0
Technical Staff	85.5	14.5	2.7	0.6	82.8	13.9	0.2	0.1	0.4	0.1	0.4	0.0		1.7 0.5
Administrative Specialists	44.6	55.4	4.2	2.9	40.4	52.5	1.7	0.0	1.3	1.3	0.4	0.4	(0.8 1.3
Technicians	63.8	36.2	1.6	1.6	62.2	34.6	0.4	0.4	0.8	0.8	0.4	0.0	(0.0 0.4
			1											

been defined for placing staff with disabilities who can no longer perform the essential function of their jobs with or without reasonable accommodation. When possible, staff will be reassigned to positions with comparable status and pay. The process requires a thorough review of all vacant positions to determine if the staff member is qualified for reassignment.

All Others

Staff Diversity Enhancement Program

The purpose of this program is to enhance PNL's ability to attract and retain quality staff members who are minorities and women. The 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). Over 170 staff members participate in this program.

30.3 61.3 1.1

14

2.0

2.3

0.2

The committees have sponsored scholarships, helped with Laboratory placement, proposed Laboratory-wide solutions to issues, joined professional societies (like the Society for Hispanic Professional Engineers, National Society of Black Engineers, Society of Women Engineers, and the American Indian Science and Engineering Society), and participated in diversity training.

An overall task force meets on a quarterly basis to take action on proposals. The task force is chaired by the Manager of Workforce Diversity Programs and is attended by the chairperson for each of the seven committees,

the Laboratory Director, the Director of Human Resources, and other members of the Upper Management Team.

0.2

0.8

0.4

An evaluation of the effectiveness of the Staff Diversity Enhancement Program (SDEP) in FY 1994 identified the need to restructure. A proposal team has recommended an enhanced SDEP model that will increase management leadership and accountability for diversity; increase diversity awareness, training, and communication; and ensure an inclusive approach to valuing and managing diversity. The proposed model is currently being reviewed with anticipated implementation during FY 1995 and FY 1996.

Awareness Training

To meet the changing needs of the Laboratory, several training programs focus on diversity. Quarterly, we offer

33.8 66.2 3.5

4.9

management classes in equal employment opportunity and harassment awareness in the work place. A shorter version of the course on sexual harassment awareness in the work place is being given to staff.

Concepts and tools for managing diversity are currently being integrated into PNL's Leadership Training Program and Total Quality Program. 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 expected to occur during FY 1995.

The Diversity Advisor Program (DAP) for PNL's upper management team will be piloted in FY 1995. A senior manager will be paired with a staff member who can provide insight and experiences in a specific diversity area that has been identified as a growth opportunity. We expect to increase the abilities of our upper management team members to identify and manage their diversity strengths and limitations and enhance their leadership in diversity.

Other Activities

In addition to training, special programs, and compliance activities, PNL 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 Conference, the Hispanic **Engineers National Achievement** Awards Conference, and the Black Engineer of the Year Conference. Former Director Dr. William Wiley, received the 1994 Black Engineer of the Year award, which was presented at the national conference in Baltimore, Maryland.

Career Fairs/Job Placement Activities

In FY 1993 and 1994 the Laboratory participated in the following career fairs and job placement activities:

- 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).

PNL also participates 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 PNL and may include entry-level work in the technician and clerical areas.

As mentioned in the Staffing section of this Institutional Plan, we currently have Memoranda of Understanding with several colleges with high minority enrollment. Specific minority recruiting events and/or job fairs targeted to the college population in which PNL participated in FY 1993 and 1994 follow and can be found in PNL's FY 1995 Affirmative Action Plan.

- Florida A&M University
- · WSU Minority Career Fair
- AISES Conference
- · Heritage Job Fair
- GEM
- SHPE
- · New Mexico State University

- MIT Minority
- University of Washington Minority Job Fair.

As shown in the Core Business Areas section of this Institutional Plan, PNL 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: Mathematics, Engineering and Science Achievement (MESA); and National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM).

Environment, Safety, and Health Management

Environment, safety, and health (ES&H) are areas that have always been important at PNL. With recent increased emphasis in this area, PNL has augmented its ES&H program. In particular, we have directed our attention toward ensuring that the Laboratory culture places environment, safety, and health as its number one operational priority. Simultaneously, increased emphasis was placed on ensuring discipline within the operation of our programs and facilities. The most significant challenges confronting PNL include older facilities that are in need of upgrades and modifications to meet current standards; legacy materials including plutonium, spent nuclear fuel, a few chemicals and mixed waste; implementation of the Nuclear Safety Management Rules (10 CFR 830, 834, and 835); and integration of Conduct of Operations into the Laboratory's activities and operations, including research. Perhaps the most difficult challenge is meeting the demand for ES&H program improvements and pressure to fully comply with requirements within a constrained

budget. New DOE Orders, Directives, and Rules require additional resources to implement. These requirements are often more demanding than those of the past but no additional funding is provided.

The ES&H program at PNL is described below. Many of our initiatives and ongoing efforts are aimed at the most cost-effective solutions to problems.

ES&H Goals and Objectives

A comprehensive Laboratory ES&H Plan that contains long- and short-term goals was developed for FY 1994 and approved by the Laboratory Director. Each technical center and functional directorate within the Laboratory then revised and updated its own plan with goals supportive of the Laboratory plan. These goals flowed down to each staff member so that individuals' responsibilities formally include specific environment, safety, and health-related goals. The Laboratory goals for FY 1994 were as follows:

- The Pacific Northwest Laboratory will continue the efforts begun in previous years to reduce, reuse, and recycle materials from daily operations (e.g., office wastes and hazardous chemicals) in such a way that the Laboratory is recognized as a leader in environmental sustainability.
- · Organizations engaging in activities that could expose staff to chemical and physical hazards will, in coniunction with the Laboratory Safety Department, implement an improved process to identify, evaluate, control, and communicate to workers the hazards associated with new or ongoing activities to ensure that workers are protected from injury. This system will be based upon detailed work place exposure assessments, job hazard analyses, and job hazard breakdowns. The line management of these organizations will have primary responsibility for implementation of the improved process.
- Each organizational component shall evaluate and implement methods to

increase individual staff member involvement and participation in the ES&H program.

- The Pacific Northwest Laboratory will reduce the number of reportable motor vehicle accidents in CY 1994.
- The Pacific Northwest Laboratory will achieve a measurable reduction in job-related recordable and lost time accidents in CY 1994. A 10 percent reduction in the Lost Workday Rate and the Lost Workday Case Rate has been established as an indicator for success in 1994.

PNL also has several long-term goals aimed at improving our compliance with DOE Orders and improving the safety and health program. These goals include

- completing a graded safety analysis for PNL-operated nuclear facilities
- continuing to upgrade and modify facilities to meet current environment, safety, and health requirements through use of general plant projects and line item funding
- implementing the principles of the Occupational Safety and Health Administration's (OSHA's) Management Guidelines (Voluntary Protection Program) to improve worker safety and health
- minimizing the amount of hazardous waste that must be disposed of by redistributing and reusing materials and by substituting nonhazardous materials where possible
- achieving continuous improvements in environment, safety, and healthrelated areas.

Current Conditions

The ES&H program at PNL is developed to comply with federal, state, and local regulations, as well as DOE Orders. PNL has placed a major emphasis on implementation of the Hanford Site Radiological Control Manual (HSRCM) during the past 2 years. PNL also continued to emphasize OSHA requirements during the past year. The past year has been one of particular emphasis on industrial hygiene and chemical safety. The

Laboratory also must comply with the Washington State Department of Ecology regulations, particularly as related to the Resource Conservation and Recovery Act (RCRA); the operation of treatment, storage, and disposal facilities for hazardous chemical wastes and any discharges to the environment via air or water. One of PNL's few significant environmental compliance issues is the configuration of tanks within our facilities that offer the potential for accumulating radioactive mixed waste. A proposed FY 1999 project would reconfigure these tanks to meet RCRA inspection criteria. The substantial environmental restoration problems at the Hanford Site are the responsibility of the site management and operations contractor. A Tri-Party Agreement (TPA) has been signed by the DOE, the EPA, and the state of Washington and provides the scope and schedule of cleanup activities at the site for the next 30 years. In this regard, PNL provides resources and support to the overall Hanford cleanup activity.

PNL is currently in compliance with DOE requirements for NEPA documentation. The PNL NEPA Program Plan (PNL-MA-9) documents our approach to the implementation of these regulations, including those related to Office of Energy Research goals.

ES&H Policies, Organization, and Management

The Laboratory's policy is to provide a safe and healthful working environment and to operate in a manner that ensures protection of the public and the environment. Our policy is to comply with the letter and spirit of all environmental, safety, and health laws, regulations, and DOE Orders.

Staff members have a basic responsibility for their own safety. The Laboratory provides a safe and healthful work place; however, staff members ultimately control their actions in the work place and, therefore, have responsibility for their own safety and that of their coworkers.

Line managers are fully responsible for the safety performance of their staff members. Annual performance appraisals for all personnel include evaluations of ES&H performance. PNL's Management Guide identifies performance standards for ES&H. Line management accountability includes recognizing and correcting potential health and environmental hazards of the work conducted, addressing employees' concerns, implementing control procedures and practices to eliminate hazards or reduce them to as low as reasonably achievable, and providing a safe and healthful work place. Line management is also responsible for implementing job-specific safety requirements and for providing the requisite staff training.

The Director of Facilities and Operations is delegated the responsibility and authority to monitor the implementation of the Laboratory ES&H program, assess its effectiveness, resolve potential conflicts, and provide periodic status reports to the Laboratory Director. This level of management attention underscores the Laboratory's commitment to environmental, safety, and health issues.

Specific actions taken during the past year in the environment, safety, and health areas are as follows:

Increased employee participation— The ES&H program is integrated in the daily operations and activities of the Laboratory through employee involvement. PNL has been working to increase employee participation during the past year. Efforts in this area include involvement in the development of the lock and tag program, involvement in the JSA/ hazard identification and management programs, participation on committees up to and including the Executive ES&H Council, participation in the Environmental Sustainability Project, and manual change request forms. PNL also has involved workers in the development of SOPs, test plans, RWPs, etc.

PNL has an active Safety Concerns program that openly encourages employees to identify problems and bring them to the attention of management and/or the Laboratory Safety Department.

- ES&H policies, manuals, and plans— The revised Laboratory ES&H plans were developed. Numerous procedures and operating manuals have been updated to reflect new and changing requirements.
- Increased staffing, a total of 12 additional full-time equivalents (FTEs)—
 Professional staff were added within the Laboratory Safety Department to ensure that our programs and facilities comply with environment, safety, and health requirements.

 Staff have been added to Occupational Safety, Industrial Hygiene, and Radiation Protection (to meet DOE Radiological Control Manual requirements).
- Self-assessments—The performance assurance group has implemented processes to ensure formalism and internal consistency on selfassessments. This group has begun tracking performance indicators, analyzing for root causes, and conducting trend analyses for communication to the line organization. This group conducts several independent assessments of the ES&H program each year.
- Corrective Action Tracking System—The Corrective Action Tracking System (CATS) was developed to track and manage audit/assessment findings and subsequent corrective actions. It was designed to centralize the coordination effort of assessment, condition, and action data and automate the transfer of information among participants to provide the most effective, efficient means to accomplish the tasks involved. This system is now being implemented to replace a more cumbersome compliance database.
- Training—During the past 2 years, PNL has placed considerable emphasis on development of training for managers and supervisors. This training (managers' ES&H awareness [MESHA]) is directed toward helping managers understand their role and responsibilities

- for implementing the ES&H program in the work place. The MESHA modules are directed toward specific aspects of the ES&H program (e.g., lock and tag, radiation work, etc.). This helps ensure that training for each line manager is specific to the type of hazards that exist within that manager's assigned work space and provides him/her tools to better evaluate the safety of workers.
- Chemical Management System—
 A central, computerized chemical inventory was established for the Laboratory to enhance management's efforts to ensure environment, safety, and health compliance. The Chemical Management System was a management initiative and was developed with the involvement of representatives from across the Laboratory.

PNL nominated the Chemical Management System as a DOE Occupational Safety and Health Worker Protection Pilot (OSHWPP) program. Thirty other programs were also nominated from other DOE facilities. DOE (Office of Environment, Safety and Health - EH) selected four of those model programs (including the Chemical Management System) to participate in transferring the programs to other DOE sites. PNL was paired with Brookhaven National Laboratory to transfer and implement the Chemical Management System. PNL and Brookhaven National Laboratory representatives are working together on implementing the system at Brookhaven. In addition to the OSHWPP-supported transfer of the system to Brookhaven, PNL provided the system (in whole or in part) to the National Renewable Energy Laboratory, Lawrence Berkeley Laboratory, and Argonne National Laboratory.

On February 3, 1994, PNL was presented with a DOE award recognizing the selection of the Chemical Management System as an OSHWPP Model Program. The award was presented by Peter Brush (Deputy Assistant Secretary for Environment, Safety and Health) and Roy Gibbs (Director, Office of Occupational Safety).

Staffing and Budget in Laboratory Safety Department

(Budget Authorization \$ in Millions)

Fiscal Year	FTEs	Budget
1989	77	5.1
1990	90	5.9
1991	105	7.3
1992	115	8.6
1993	125	11.6
1994	137	13.7

Environmental, safety, and health training topics are too extensive to be fully listed here. However, examples offered to staff and management include

- · low-level waste generator training
- · respiratory protection training
- crane, hoist, and rigging safety
- radiological control
- hazardous waste operation training
- · lock and tag.

The Laboratory Safety Department, which has the responsibility to develop and monitor the ES&H program for PNL, has grown significantly during the past few years (see Staffing and Budget table). This growth represents PNL's increased commitment to ES&H. In addition, substantial investments that are external to the Laboratory Safety Department have been made at PNL to improve safety.

Continued growth is expected in the department to meet new requirements such as 10 CFR 835 "Occupational' Radiation Protection" and new industrial hygiene and occupational safety orders being promulgated by DOE Headquarters and other regulatory agencies. Generally, the future growth would not be anticipated to be as great as during the past few years. At some point, an optimum investment must be achieved. At that point further investments would result in only marginal improvements.

ES&H Plans and Initiatives

The Laboratory continues to correct environment, safety, and health deficiencies as well as noncompliance conditions within our facilities. A program has been identified to correct these deficiencies and is described in the Site and Facilities section. A brief description of the status of PNL's ES&H programs and plans follows.

Nuclear Safety

PNL operates three nuclear facilities. An intensive effort is currently under way to revise the safety analysis for these facilities. PNL has actively worked to reduce inventories in our facilities to lower the category or eliminate the facility from the list of nuclear facilities entirely. During the past year, three facilities have been removed from the list of nuclear facilities. Annual appraisals are conducted on all nuclear facilities. Any deficiencies or noncompliance issues were identified and corrective actions were developed and are being tracked to completion. Extensive training on operational safety requirements, radiation safety, waste management, etc., has been conducted for staff associated with these facilities. PNL has also increased the focus and implementation of Conduct of Operations in these facilities.

A substantially increased level of effort will be required during the next several years to reach full compliance with DOE Orders 5480.21, 5480.22, and 5480.23 in the nuclear safety area. As the Nuclear Safety Rules are issued, the necessity for compliance with these requirements will also increase. Major changes have been implementated for revised policies in the area of safety analysis, technical safety requirements, and evaluations of unreviewed safety questions. Implementation plans to prepare and revise safety analyses and technical safety requirements have been prepared and were submitted to DOE. These implementation plans will be modified once the Nuclear Safety Management Rules are finalized.

General Operational Safety

The PNL operational safety program is being further enhanced. We are executing our plan for implementation of DOE Conduct of Operations Order (5480.19). This plan employs a graded approach to implementing a Conduct of Operations program based on the hazard classification or risk of the facility. This approach allows us to concentrate efforts on controlling the most significant hazards. In addition, the Tiger Team identified a number of areas where operational safety could be improved. These areas are related principally to improved management systems, better procedures, improved communications, and improved self-assessments.

PNL focused considerable effort on improving the risk assessment process used to review work conducted at the Laboratory. The new risk management process and documentation was used for the past year. It is now being reviewed and revised to reflect needed changes.

A Laboratory-wide training initiative has been established; an integral part of this initiative is training related to safety and environmental compliance. During the past year, 9300 attendees received classroom training related to safety and environmental compliance.

Many other staff have received training through the use of videos, reading assignments, and computer-based training. Because managers must lead the expected cultural change, they need to be knowledgeable of the desired endpoint and understand ways of reaching that endpoint. MESHA training provides both the broad framework and the specific requirements that managers need to know to implement an effective ES&H program.

Occupational Safety and Health

PNL has continued to focus on correcting deficiencies identified in PNL self-assessments and corroborated by the Tiger Team and Progress Assessment Team in the areas of industrial hygiene and occupational safety. We have defined a comprehensive industrial hygiene program that involves chemical hazard identification, exposure monitoring, record keeping, etc. PNL has implemented a baseline assessment primarily using existing resources.

The industrial hygiene group developed a tool for line management to use for reviewing the work place to determine if exposure monitoring is needed. Industrial hygienists are available for consultation. The final product is reviewed by a hygienist, and monitoring is scheduled if needed. Results are logged into a database to track exposure monitoring data. During the past year, nearly 800 individual laboratories and operations were assessed using this tool.

A formal Chemical Management System has been implemented that provides inventory records for all chemicals used in the laboratories. The Chemical Management System is based on a software program designed to inventory and track chemicals used by an organization. The system is particularly well suited to the research and development environment. It provides staff a tool to purchase chemical products and track inventories. The Chemical Management System provides management with information about the hazardous properties of their

inventory and the status of compliance with a number of health and safety requirements.

In the area of occupational safety, we have revised the eye protection program, the lock and tag program, the hearing conservation program, and procedures for illness and injury record keeping and reporting.

The occupational medical contractor at Hanford is the Hanford Environmental Health Foundation (HEHF). The HEHF has become increasingly involved in assessments of the work place. HEHF will accumulate results of any exposure monitoring conducted, provide medical advice to the contractor, and interpret the data. This will require additional financial resources from PNL to support HEHF and additional PNL staff time for interfacing with the occupational medical personnel. PNL expects substantial increases in requests for funding for HEHF during the next few years.

PNL made significant progress meeting the Hanford Site Tiger Team Corrective Action Plan. PNL's planned actions are 95 percent closed. Two capital projects are currently proposed for correcting Tiger Team findings: FY 1993 Life Safety Code Compliance provides immediate correction of code noncompliance in four multiprogram laboratory and support buildings. FY 1995 Line Item, Electrical Safety Rehabilitation will provide replacement of deteriorated wiring and outmoded equipment in multiprogram buildings. These projects are significant efforts to close out physical deficiencies. PNL has also made significant progress on the corrective actions from the Progress Assessment Team visit. Nearly 86 percent of these items are completed.

In addition, other corrective actions include making required replacements and/or repairs to a number of individual tagged-out cranes as they are required for program use. Many of the remaining open items require additional resources to complete. The level of resources necessary is substantial and will lead to further increases in

costs to programs. Because of this, alternative methods of funding are being sought. These alternatives include proposals to the DOE Office of Energy Research (the ES&H Support subprogram proposal, for example), the Office of Environmental Management through activity data sheets, and the ES&H Management Plan. Funding, however, is not expected for these activities until at least FY 1995. The ES&H Management Plan (see the ES&H Plan Funding Request table) has a major focus in industrial hygiene and occupational safety and includes the elements of the previous corrective action plans such as "Tiger Team" expense and capital construction projects. PNL has characterized environment, safety, and health problems in detail. Corrective action plans for alleviating facility and operation deficiencies have been developed, and proposals have been submitted.

- Operating—Includes proposals to prepare as built/essential drawings; provide asbestos survey and abatement; and FY 1995 and FY 1996 proposals for additional eyewash stations, flush points, and safety showers. Funding has been authorized by DOE-ER for several items including a Safety and Health Information Management System (SHIMS), enhancement to the Chemical Management System, improvement to computer-based training, pollution prevention, and MEL-FS ES&H projects.
- General Plant Projects (GPP)—
 Composed primarily of discrete
 corrective activities required to
 bring DOE-ER facilities into com pliance with ES&H regulatory
 requirements.
- General Purpose Facilities (GPF)—
 A life safety code compliance project to correct environment, safety, and health inadequacies in PNL's multiprogram laboratory facilities.
- Capital Equipment and General Purpose Equipment (GPE)—Includes items that are associated with the

ES&H Plan Funding Request(a)

(\$ in Millions)

		Fiscal	Year	
	1993	1994	1995	1996
Expense	0.0	0.0	0.5	7.0
Capital	1.9	1.8	0.8	1.3

⁽a) Includes all items covered in the ES&H Management Plan.

ES&H Management Plan

(\$ in Millions)

	Au	Authorization			P	lanning (Case	
	1993	1994	1995	1996	1997	1998	1999	2000
Core Program	15.3	16.0	17.4	18.6	19.3	20.0	20.8	21.3
Compliance Program	0.55	1.1	1.0	13.1	11.8	12.2	12.3	12.6
Improvement Items	0.0	0.0	0.06	0.4	0.4	0.4	0.5	0.5
Total for Laboratory	15.85	17.1	18.5	32.1	31.5	32.6	33.6	34.4

DOE-ER request for ES&H Subprogram support for air sampling and monitoring systems and, in FY 1994, for industrial hygiene monitoring equipment. Funding for FY 1995 has been authorized for refrigerant replacement equipment. No general purpose equipment funding is included.

 Laboratory Overhead—A summary of ES&H program funding needs is shown in the tables. The "core" program is funded with Laboratory overhead.

Note that the Progress Assessment Team used these criteria to review the worker safety and health program. Additional resources will be required to achieve the level of performance outlined in the model program. In addition, numerous new orders are expected in this area over the next 2 years. These orders will require additional resources if the Laboratory is expected to achieve compliance.

These new orders cover areas such as hazard communication, laboratory standard, nonionizing radiation, carcinogens, ergonomics, noise, beryllium biohazards, asbestos, reproductive hazards, respiratory protection, indoor air quality, and confined space entry. All of these topical areas are currently covered by existing regulations (primarily OSHA).

Improvement activity data sheets include new actions, over and above core and compliance activities, that will raise the level of safety and health performance, lower the level of safety and health risks at a site or facility, and help the facility move toward excellence in safety and health performance (i.e., computer-based training).

As identified in the ES&H Management Plan table, a PNL initiative to obtain DOE-ER funding for significant portions of the backlogged environment, safety, and health requirements began in FY 1994 with

the submittal of FY 1995-1996 Field Work Proposals (FWPs). The initiative includes significant areas of operations and activities within PNL's Facilities and Operations organization. PNL will continue to give a high priority to funding environmental, safety, and health activities; however, additional requirements will generally result in higher costs. PNL must receive direct funding for implementation of additional requirements.

Radiation Protection

PNL participated in the development of the Hanford Site Radiological Control Manual to meet requirements of DOE Notice 5480.6 DOE Radiological Control Manual (RadCon). PNL also prepared an implementation plan to meet the requirements of this manual and has been working toward full implementation. We expected to have the RadCon Manual fully implemented by June 1994. We did not achieve this

goal because of failure of line management to completely implement provisions of the RadCon Manual and failure of the radiological control organization to adequately enforce the manual. New requirements in the areas of radiological conditions posting, training for radiation workers and radiological control technicians, enhanced surveys of work sites, and revised radiation work permits and other provisions have required increased resources. The cost of our radiation protection (i.e., radiological control) program has increased by 20 to 25 percent beginning in FY 1993. The Radiological Control Manual requires a continual investment of \$0.5 to 1 million each year to meet the full intent of the manual. We do not expect significant reduction in doses (current average doses below 35 mrem for radiation workers) or contamination incidents (less than 30 per year) as a result of instituting the Radiological Control Manual; therefore, cost savings are not expected. The substantial investment results in minimal improvement to the existing radiation protection program. Implementation of the HSRCM was a major focus during FY 1993 and FY 1994.

During the next year, PNL will be developing an implementation plan to meet the requirements of 10 CFR 835. This rule may require a small additional investment of resources to fully meet its requirements.

Environmental Protection

Within the 300 Area, where many PNL-assigned facilities are located, a schedule for cleanup exists that was defined in the Tri-Party Agreement.

Through effluent monitoring plans, near-term efforts are directed toward cessation of effluent discharges in the soil column from process-related functions within facilities. In support of this activity, PNL minimized liquid effluent release from all facilities to meet the initial Tri-Party Agreement milestone. We also are incorporating improved effluent monitoring and installing sensors to monitor both liquid and airborne releases.

PNL conducted an extensive review of facility releases (airborne and liquid) and developed facility effluent monitoring plans where required. Sampling of airborne and liquid effluent will be conducted as specified in these plans. A program to implement extensive improvements to the radiological stack monitoring systems has been completed. The new stack monitors are in compliance with EPA regulations for sampling radiological airborne emissions (40 CFR 61).

The PNL Waste Minimization and Pollution Prevention Awareness Plan consists of a Laboratory-level plan and specific waste minimization plans for ensuring ongoing waste minimization activities in the operations organizations. The Environmental Compliance section within the Laboratory Safety Department oversees the implementation of the PNL waste minimization program and documents progress in meeting the waste minimization goals of the Laboratory. PNL intends to strengthen the system for reporting waste minimization progress throughout the Laboratory. PNL developed and implemented a pollution prevention training program that instructs research staff in regard to a wide variety of pollution prevention techniques and also incorporates researcher waste generation data in a unique way. Waste types include low-level radioactive waste (LLW), radioactive mixed waste (RMW), radioactive liquid waste system wastes (RLWS), and hazardous waste (HAZ). PNL is incorporating advice and information from the waste generator's perspective into the overall administration of the waste minimization program to more accurately document the extent of waste minimization activities throughout the Laboratory, to identify areas of potentially significant waste reduction, and to apply waste minimization techniques. PNL has received funding for enhancement of the waste minimization program through the DOE-EM Five-Year Plan.

The waste generation database (WGD), developed during FY 1993, incorporates all the currently used waste management databases into a database system that allows users to

identify trends in waste generation data for any organizational component. Pollution prevention coordinators in various PNL facilities can use the waste generation database to track the generation rates of all waste types coming out of their facilities. In addition, data from the waste generation database is electronically embedded (via spreadsheets) into the slides used in the pollution prevention training class. These slides show the waste generation trends for the particular organization that is receiving the training and the trends are used in brainstorming sessions in an attempt to identify pollution prevention opportunities.

PNL has been focusing additional resources on meeting DOE National Environmental Policy Act (NEPA) implementation requirements. DOE requirements issued during FY 1992 in a letter from DOE-EH include a significant increase in the number of Information Bulletins that must be prepared. The categorical exclusion for bench-scale research has the effect of requiring Information Bulletins for all laboratory research and development projects. These projects each handle a small quantity of chemicals or radioactive materials that would not have any significant impact on the environment either individually or collectively. PNL has developed a strategy to meet the intent of the new requirement in a cost-effective manner. PNL has embarked on an effort to develop generic Information Bulletins for specific categorical exclusions. These generic Information Bulletins are expected to cover the majority of work that would require this type of documentation. Without acceptance of this approach, PNL programs would experience delays in starts and increased costs.

Other issues include

 Air Toxics Implementation— Continued rule making under the Clean Air Act Amendments of 1990 is expected at least through 1995. This in turn will affect the Washington State program for air toxics (WAC 173-460), which is currently in final stages of

Waste Minimization Plan Funding

(\$ in Millions)

	Fiscal Year										
	1993	1994	<u>1995</u>	1996	1997	1998	1999	2000			
Capital Requirements											
DOE-ER (Office of Energy Research)	0	0	0.5	0.1	0.1	0.2	0.2	0.2			
DOE-EM	0	0	0.5	0.1	0.1	0.2	0.2	0.2			
Operating Requirements											
DOE-ER (Office of Energy Research)	0.7	0	0.5	0.5	0.6	0.6	0.7	0.6			
DOE-EM	0.0	0.4	0.4	0.4	0.5	0.5	0.5	0.5			
Total for Laboratory	0.7	0.4	1.0	1.1	1.3	1.5	1.6	1.5			

development. Current drafts of WAC 173-460 call for full regulation of laboratories such as PNL and were the subject of extensive DOE/PNL comments. The outcome of these rule-making efforts is still uncertain.

- RCRA Permitting—PNL's ability to test innovative environmental remediation technologies in the field is limited by RCRA permitting requirements. PNL and DOE Richland Operations Office are presently studying alternative permitting approaches that will support the intent of the requirements while preserving operational flexibility during research and development efforts. EPA has been approached about using research development and demonstration permits to implement this strategy. Such a permitting strategy will necessitate major changes in permitting for several PNL facilities.
- Hanford Site Permit—PNL is subject to the provisions of the Hanford Site Permit issued by the Washington State Department of Ecology. This permit will necessitate some changes to our operations particularly for those specific treatment, storage and disposal units named in the permit.
- Ozone Depleting Substances— In response to the Secretary of

Energy's memorandum of July 29, 1992, PNL has reviewed the use and potential replacement of ozone-depleting substances in its operations. Because of concerns regarding cost or availability of substitutes, further review and feasibility analysis are expected to be required.

Performance Indicators

PNL has used performance indicators for years to monitor ES&H program performance and effectiveness. Some of these performance indicators include accident and injury statistics, property and fire damage, off-normal events, skin contamination, radiation exposure, volume of waste disposed, etc. PNL uses data in a number of these areas to identify trends and to establish corrective actions when trends indicate the need.

The Laboratory Safety Department provides PNL line managers with a review of their organization's performance on a quarterly basis. This review includes identification of trends (if appropriate) and recommendations for actions to improve performance or prevent reoccurrence of an accident or injury. Off-normal events for the Laboratory are reviewed on a regular basis to identify adverse trends.

Environmental Restoration and Waste Management Activities

The DOE and PNL are committed to achieving compliance with applicable laws, regulations, and federal facility agreements aimed at protecting human health and the 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 (see the Waste Minimization Plan Funding table), and 3) coordinate a focused research and technology development program for application to waste management and environmental protection. DOE-EM is consolidating environmental cleanup, compliance, and waste management activities identified in the Five-Year Plan.

The Resource Projections section of this Institutional Plan identifies all the Laboratory activities requested from DOE-EM, including those shown in the Five-Year Plan. The following funding highlights are included in the Environmental Restoration and Waste Management Five-Year Plan funded by EM:

DOE-EM ES&H Funding Requests

(\$ in Millions)

A	uthorizat	tion		Planning Case			
1993	1994	1995	1996	1997	1998	1999	2000
5.1	10.1	11.7	13.3	12.6	13.6	13.5	13.0
2.7	1.9	0.8	0.3	0.3	0.4	0.3	0.4
	1993 5.1	1993 1994 5.1 10.1	5.1 10.1 11.7	1993 1994 1995 1996 5.1 10.1 11.7 13.3	1993 1994 1995 1996 1997 5.1 10.1 11.7 13.3 12.6	1993 1994 1995 1996 1997 1998 5.1 10.1 11.7 13.3 12.6 13.6	1993 1994 1995 1996 1997 1998 1999 5.1 10.1 11.7 13.3 12.6 13.6 13.5

DOE-EM Landlord ES&H Funding Requests

(\$ in Millions)

	Authorization			Planning Case				
	1993	1994	1995	1996	1997	1998	1999	2000
EM-60 Capital Total	5.1	3.5	4.8	6.1	3.6	6.8	7.4	2.6
EM-60 Expense Total	0.4	0.8	1.5	5.5	4.9	5.0	4.5	4.3

- General Purpose Facilities—Comprises major facility compliance/ renovation upgrades to strategically important DOE laboratories in the 329 Building.
- General Plant Projects—Comprises
 discrete corrective activities required
 to bring DOE-EM facilities into compliance with environment, safety,
 and health regulatory requirements.
 Typical projects include life safety
 upgrades (including electrical
 switchgear and distribution systems repairs and/or replacements
 and/or upgrades), high-efficiency
 particulate air (HEPA) filter housing
 upgrades, sampling systems installations, and fire protection upgrades.
- General Purpose Equipment— Includes waste minimization program equipment and storage tank upgrades for radioactive mixed waste.
- Operating—Includes preparation of air and sewage monitoring, NEPA compliance program, effluent monitoring, waste minimization, facilities

conduct of compliance operations requirements, essential drawings, liquid waste source control, waste management operations, PNL laboratory surveillance and maintenance, and cleanup of production support laboratories assigned to PNL.

Specific facility upgrades are discussed further in the Site and Facilities section of this plan. Examples of corrective actions include polychlorinated biphenyl (PCB) cleanup and removal and installation of radioactive and nonradioactive effluent monitoring systems and radioactive exhaust air samplers for air and sewage monitoring activities. Environmental restoration activities include NEPA compliance program surveillance, and maintenance of radioactive facilities. Waste management activities include waste management operations and storage tank upgrades. Waste minimization has increasing requirements for internal studies and documentation activities that result in new oversight and regulatory responsibilities.

Hanford Site-Wide Funded ES&H

The Hanford Site Landlord Program (EM-60) enhances the Hanford Site general purpose infrastructure in support of the 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 service; 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 projects are 325 and 324 buildings Facility Compliance, Whole-Body Counter Facility, and Building Utility Replacement.

General plant projects activities include fire protection upgrades, work place air monitoring, 325 Building system improvements, and hot cell refurbishments.

Operating-expense funded activities include National Electrical Code (NEC) compliance activities and preparation of Safety Analysis Reports for PNL-operated nuclear facilities.

Significant PNL financial resources are devoted to environment, safety, and health activities. However, the requirements are so numerous and costly that the overhead funding cannot bear the entire burden of these added requirements. PNL organizations are aggressively seeking direct funding via proposals to the appropriate Program Office for requirements that are beyond the reach of the overhead budgets. The effects of failing to obtain direct funding for these activities may be a limited or delayed remediation of deficiencies; the levels of surveys, reviews, and revisions of procedures would have to be substantially reduced; and the Safety Analysis Report upgrade program could be impacted unfavorably if supported only with indirect funding because of the competing needs.

Information Resource Management

PNL's information technology challenge is to develop knowledge, firmly based on the access to and use of key data and information. Therefore, we invest in information technology to enhance effectiveness in conducting our business.

We have implemented four key information technology strategies: empowering the user, defining and meeting the information technology needs of the Laboratory, making effective use of information technology, and ensuring cost effectiveness.

Empowering the User

Users achieve scientific, engineering, and technical excellence by having

- convenient access to required information, regardless of the physical location of the resources, information, or the user
- tools, training, and expertise to manipulate information appropriately
- the ability to choose the work style best suited to the task, rather than be constrained by tools and methods
- simple methods to communicate and collaborate with other individuals, work groups, external businesses, and institutions.

Defining and Meeting Information Management Needs

PNL's business strategies drive its information strategies. PNL's managers and staff have the primary responsibility to translate their requirements into plans and actions for managing information as an important and strategic asset. To this end, information systems requirements will be

- clearly and concisely stated
- consistent with established standards for development, design, implementation, operation and maintenance
- consistent with regulatory requirements and the needs of PNL's customers.

Effective Use of Information Technology

PNL manages information technology as a strategic resource while continuously evaluating technology advances seeking improved capability to meet our mission objectives. We maintain an effective Integrated Computing Environment (ICE) infrastructure that provides

- utility, where the underlying technology is invisible to the user
- standard services to enable local, national, and international communication and collaboration
- standards and guidelines, facilitating information interchange

- electronic methods for accomplishing routine business functions, reducing the use of paper
- uncompromised production reliability and stability, while allowing the evaluation and exploration of advanced technology.

Cost Effectiveness

We establish internal processes that enhance the efficiency of the computing environment to

- assign the true costs for computer systems and services to those receiving the benefit of those systems and services
- assist users in managing resources to ensure that acquisitions and upgrades are conducted in a disciplined manner and in a way that enhances PNL's capabilities
- continuously evaluate internal services and benchmark levels of support and services with other laboratories, universities, and the private sector.

Environment and Accomplishments

Information technology continues to play a significant and growing role in support of PNL's research, development, and technology transfer activities both as the Hanford Site research and development contractor and as an DOE-ER multiprogram laboratory. While the Laboratory is making significant progress in developing an effective and efficient computing and telecommunications infrastructure, much remains to be done. Major computing and information technology resource investments include

- local, regional, and national network infrastructure expansion and upgrades
- scientific and engineering computing with emphasis on high-performance computing, modeling, simulation, and technology collaboration
- administrative information systems with emphasis on enterprise-wide information resource management, seamless systems integration, and distributed client-server computing

 multiprogram, multilaboratory collaboration and leadership as well as outreach to the academic and industrial communities.

Infrastructure

PNL's Integrated Computing Environment is the basic infrastructure that provides the computing, network, information, and service resources which support scientific and engineering research, development, and technology deployment, management of the business, and access to scientific and technical information. The integrated computing environment comprises the internal networks and access to external networks as well as the attached computing resources from office workstations to supercomputers. It supports file, print, communications, information, and access services for the workstation, midrange, mainframe, and supercomputing environments and provides specialized input/output and support services for planning, design, development, and operations.

Over 8000 office, laboratory, and portable workstations with an installed value of over \$60 million are in use. Ranging from IBM PCs and compatibles to Macintosh and RISC architecture UNIX systems, workstations are used for software development, science, engineering, and business computing, word processing, desktop publishing, spreadsheets, databases, electronic mail, project management, personal scheduling, multimedia applications, data acquisition and control of laboratory instruments, field use, as well as providing access to people, information, and systems across local and national networks.

Voice communication is provided by an InteCom IBX S/80 digital voice/data telephone system serving the 45 percent of PNL staff who are located in private facilities. The Hanford Site Integrated Voice and Data Telephone System serves the remaining 55 percent of staff who are located in DOE facilities. In FY 1993, voice messaging was made available on both of these systems.

PNL's Local Area Network is based on multiple FDDI backbones and nearly

100 ethernet segments serving over 5000 workstation connections (a 25 percent increase in FY 1993) and supported by 113 servers. In FY 1993, the network was converted to TCP/IP. PNL is connected to the Energy Sciences NETwork (ESNET) by an FTS-2000 T1 circuit to Livermore, which is scheduled to be increased to T3 according to the current DOE-ER upgrade plan. The link also supports DOE-EM traffic from other Hanford contractors in accord with a Memorandum of Understanding between DOE's ER and EM offices.

T1 service is also available between PNL's Richland, Washington, campus and Seattle, Washington, for access to the National Science Foundation's regional research and education network, NorthWestNet. This provides Internet access backup for the ESNET link and direct access to PNL from the regional and national universities as well as industry and the international community via Internet.

Video conferencing is supported by a Battelle privately owned PictureTel 4000 facility with switched 56k service to compatible sites. Similar systems are located at Battelle's corporate and PNL's Washington, D.C., offices providing an alternative to travel for meetings and collaboration. Two large screen rear projection systems with direct video and computer interfaces were installed in conference rooms to increase the effectiveness of presentations.

High-performance graphics workstations (e.g., Silicon Graphics, Intergraph, and others) give access to advanced tools for still-frame and full-motion three-dimensional color visualization. A multimedia laboratory was established in FY 1993 which 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 are being replaced with individual and/or clustered high-performance workstations for both scientific and administrative computing. Two clusters are operating (IBM and HP) and two more (Sun and IBM) will be added in FY 1994. A limited

VAX capability has been retained for legacy applications requiring VAX compatibility.

Supercomputing requirements are satisfied by high-performance workstations, a small Intel Gamma parallel processor, remote access to Los Alamos and Argonne, NERSC at Livermore and Florida State for vector supercomputing, and through PNL's participation in the Concurrent SuperComputing Consortium with access to the Intel Delta at Cal-Tech. A Kendall Square Research KSR2 system with 64 processors, 2.56 GBytes of main memory, and 40 GBytes of disk storage was installed in the interim EMSL facilities in the second quarter of FY 1994. A collaboration (CRADA) with KSR will yield another 16 processors in the third quarter of FY 1994 and PNL will obtain title to these processors as part of the CRADA.

The Business Information Systems infrastructure is distributed across three environments. A large-scale, IBM-compatible system operated by the Hanford Operations and Maintenance contractor is used for off-primeshift batch processing. A midrange Sequent S81 parallel processor running Oracle under UNIX and operated by PNL is used for on-line management and project reporting. Network servers are used for transaction processing and user access to information distributed from the Sequent using Sybase client-server relational database technology and front end tools (e.g., Business Objects, OMNIS 7.0).

An Electronic Forms, Routing, and Authorization (EFRA) infrastructure was prototyped in FY 1993 for roll out in FY 1994 where forms/documents are electronically created, authorizing signatures are authenticated, and the document routed for further signatures and reviews without moving paper in the Laboratory.

Scientific and Engineering Computing

Scientific applications are developed and/or used in most major disciplines with key activities in computational chemistry modeling and simulation, environmental contaminant characterization, transport and remediation models (atmospheric, oceanic, surface water, and subsurface), global climate and coupled atmospheric/ocean models, environmental database development, and thermal hydraulics fluid-flow modeling and simulation. These applications were previously described in their respective core business area of this Institutional Plan. Some selected highlights include

- Advanced thermal-hydraulics simulations and analysis codes for wastetank remediation.
- Atmospheric models for contaminant transport and dispersion, chemical and physical transformation, and deposition to determine the continental and oceanic fate of air pollutants.
- Development of experimental data systems and measurement technologies to improve the performance of atmospheric General Circulation Models.
- Genetic engineering software toolkit for isolating, displaying, and manipulating genetic elements for cloning simulation, genetic sequence analysis, and database management.
- Models which simulate the movement of water, contaminants, and sediment in oceans, estuaries, and rivers.
- Improvements in radon transport modeling, establishing a national archive for radiobiology information, and modeling cellular responses to genetic damage.
- Special-purpose data acquisition, database, and a three-dimensional graphics system for the analysis of energy use in homes, apartments, and commercial buildings including software development for analyzing the energy efficiency of buildings during the design phase.
- High-resolution, three-dimensional, subsurface modeling tools for application on massively parallel computers supporting the design and evaluation of in situ waste treatment technologies at the Hanford Site.

 Computer modeling of microbial enzymes making a major contribution to understanding the basis for rational enzyme redesign using genetic engineering with potential for environmental cleanup applications.

A strategy was first developed in FY 1992 to support network-based text and image processing as the first steps toward providing end-user capability to integrate text and images and to provide access to text/image databases and information. Hardware and software pilots were selected, prototyped, installed, and made available to end-user organizations and library staff. An on-line library electronic access system was moved into production status in FY 1993, and new functionality is being added as electronic library materials become available.

Business Information Systems

Information systems development is based on an annual budgeting process consistent with the enterprise-level strategies developed as a part of the WISDM whole systems model 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 are entered only once at the point of origin and made electronically available for reuse in multiple applications.

New systems are implemented using network-based client-server technology. The SQL server is the preferred technology for enterprise applications, and front-end tools provide the user interface and database access. Middleware tools are required to support all three mainstream PNL platforms, IBM PC and compatibles, Macintosh, and UNIX. Accomplishments in the development of business information systems include

- Development of Information
 Distribution Manager (IDM), a
 network-server-based system and
 client tools for electronic distribution of business information. Information distribution manager
 provides more timely and effective
 access to information (on-line,
 downloadable, with custom user
 views and easy reporting) and reduces the demand for
 paper and fiche reporting.
- Implementation of a central property tracking and barcode system by which property tagging was moved from an end-user responsibility to a central receiving function.
- Implementation of a Compliance Deficiency Tracking System which provides an inspection and corrective action status, tracking, and reporting capability.
- Development completed for an electronic purchase requisition entry system which front-ends an electronic purchasing system providing electronic entry, routing, and authorization of purchases. The system is being piloted in a small group.
- Development of a Software Scanning tool and database which identifies and reports all software installed on a user's workstation and is used to ensure compliance with commercial software licensing requirements.
- Following requirements development, acquired PeopleSoft human resources software through a competitive acquisition. Initially installed at the end of FY 1993, this system was fully implemented in FY 1994.
- Implementation of a Statutory and Regulatory Information system in Topic with text search and retrieval capability from an on-line database which contains current statutory and regulatory requirements of DOE, NRC, and EPA. The database is updated via downloads from source data subscriptions for regulatory information.

 Completion of the Radiation EXposure System (REX), which supports the Hanford Site radiological protection programs by maintaining and reporting individual Hanford worker and visitor radiological records in accordance with DOE Orders and American National Standards Institute (ANSI) standards, was completed. REX is the official repository for Hanford radiation exposure data, provides data for research, and is used to schedule and track radiation dosimetry activities.

Collaboration and Outreach

Within the DOE's Energy Research program, PNL staff are providing 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.

Cooperative Research And Development Agreements (CRADAs) have been established with 1) Intel to improve interprocessor communications in massively parallel supercomputers through application of performance modeling and applications-directed interface design, 2) Kendall Square Research for the development of computational chemistry codes for massively parallel computers, and 3) the University of Oregon and ASG, Inc. to integrate a PNL-developed energy analysis module into a commercial computer-aided design system to encourage energy analysis as part of the building design process.

PNL staff are collaborating with Argonne National Laboratory and five industrial firms; Allied Signal, Amoco, DuPont, Exxon, and Phillips, developing scalable algorithms on PNL's Kendall Square KSR2 and Argonne's IBM SP1 parallel systems for grand challenge applications in computational chemistry.

PNL 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.

PNL staff are active on DOE committees and with the regional universities including participation in EXERSUG, ESNET steering, and site coordinator's committees; chairing the ESNET network authentication task force and participating in the network authentication pilot program; co-chairing the Scientific Computing Information Exchange (SCIE) group of multiprogram laboratories; serving on the executive board and technical committee of NorthWestNet; and serving on the policy board and technical committee of the Concurrent SuperComputing Consortium.

Educational outreach includes network design assistance to local school districts and Heritage College (a minority institution); participation on the building design task force for the consolidated library at Washington State University Tri-Cities; providing ESNET access to local high schools participating in the National Educational Supercomputer program at NERSC; providing Internet access for local high school students under the Disabilities, Opportunities, Internetworking and Technology (DO-IT) program, and for teachers and students of the Kennewick, Washington, school district in a pilot project which supports a network access plan being developed by the Office of the Superintendent of Public Instruction to extend Internet access to the common schools of Washington State; and, in cooperation with DOE Richland Operations Office, providing 20 IBM computers, color monitors, and 2 laser printers for a computer laboratory at Park Middle School in Kennewick, Washington, under the PNL/DOE Science Education Equipment Loan program.

Technology Transfer and Sharing

PNL's Chemical Management System, which maintains an inventory of all chemicals being held and their locations, was selected by DOE for transfer to Brookhaven National Laboratory under the Occupational Safety and Health Worker Protection Pilot Program and is also being transferred to Lawrence Berkeley Laboratory, the Idaho National Engineering Laboratory, and the National Renewable Energy Laboratory. Interest in acquiring this technology also has been expressed by the Stanford Linear Accelerator Laboratory, Rocky Flats, Fermi, California State University, Fullerton, and the University of California at Santa Cruz.

Software distributed to other sites included Compliance Deficiency Tracking System, an inspection and corrective action tracking system (Ames Laboratory); Software Scan license compliance program and database (DOE Headquarters-Security Affairs, Idaho National Engineering Laboratory, Raytheon Services-Las Vegas, and DOE Richland Operations Office); Popfon, an on-line, networkbased telephone directory system, to DOE-SAN and the Department of Defense; and MEPAS, a multimedia environmental pollutant assessment system, was transferred to a small college for use in a degree program to train workers in waste site cleanup.

Commercialized software includes ReOpt, a remedial operations code that provides information on nearly 700 environmental contaminants and 88 remediation technologies; CINDY, an internal dosimetry code; and ChernoLit, a bibliographic database on the Chernobyl accident.

Major Goals and Near-Term Strategies

PNL's network strategies are guided by the Laboratory's Information Technology vision established for the Integrated Computing Environment mentioned earlier. These include

- establishing and maintaining local area, Hanford Site, and Internet connectivity for all appropriate staff at all local and remote locations
- ensuring stability and reliability
 of the Integrated Computing
 Environment infrastructure are
 uncompromised and that network
 performance is acceptable
- continuously evaluating emerging technology and adding local area and Internet functionality that makes the infrastructure transparent, easy to use, adequately protected, and supports emerging applications (e.g., multimedia).

PNL is nearing its connectivity goal so only a modest number of new connections was added in FY 1994. However, continued network planning is required for the EMSL facility which will be completed in FY 1998 and for a new 400-staff office building occupied in FY 1995.

The main focus in the next 2 years will be improving the reliability and performance of the network and continuing to expand its functionality. The oldest segments of the cable plant will be replaced along with upgrading to network devices which can be remotely monitored and controlled, adding more PC and Macintosh servers to improve performance, pilot the transition from OS/2 to NT Advanced Server, and add a redundant X.500 directory server. An additional FDDI ring, dedicated to application server file transfer, graphics, and replication services for distributed applica tions, is being considered to improve performance.

Upgrades and/or new functionality being added includes unattended workstation backup and restore services; server generated passwords with automatic expiration completing the transition to user-level security started in FY 1993; implementing the WinSock Application Programming Interface (API) software for new applications requiring TCP/IP transport (e.g., Gopher agents); implementing a PNL Gopher server and expanding bulletin board access piloted in FY 1993; upgrading PC/Macintosh/ UNIX integrated file services, e:mail

and calendar/scheduler services, Macintosh Keyserver; selecting and implementing a local area network (LAN)-based software distribution and inventory system; and evaluating next-generation network architectures, remote access protocols, distributed network management software technologies, and alternative architectures for PC and Macintosh servers.

A key strategy is to further downsize the business systems infrastructure and migrating the few applications that remain on the IBM mainframe and replacing the Sequent IRM database system with dual Sparc servers was piloted in FY 1994 with a production transition in FY 1995. In addition, a pilot project to develop a document management infrastructure supporting document archival, advanced searching, and integration with standard desktop software will also be initiated.

Site and Facilities Laboratory Description

The Pacific Northwest Laboratory serves a dual role—it is one of the five DOE multiprogram energy research laboratories, and it is the research and development center for the Hanford Site. Because of the dual role, PNL's general purpose facility and equipment needs are shared. Facilities with historical or current missions primarily supporting Hanford Site activities (Hanford Support) are part of the Hanford Site Landlord Program, under the purview of the Office of Environmental Management (EM). All other multiprogram needs are under purview of the Office of Energy Research (ER).

The Pacific Northwest Laboratory consists of a collection of buildings measuring 198,000 square meters (2.1 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 19,000 square meters (0.2 million square feet)
- Battelle-leased facilities 40,000 square meters (0.4 million square feet).

Through formal arrangement with the DOE, these facilities compose the PNL Consolidated Laboratory and are used by over 4600 Battelle employees to perform work for the DOE, other federal agencies, and private industry.

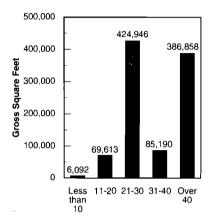
The Laboratory space distribution table illustrates that PNL's Richland facilities are located primarily in two areas—DOE facilities located in the 300 Area and leased space located offsite. The 300 Area, in which many PNL facilities are located, is adjacent to the city of Richland, Washington, and occupies 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. Most of the leased space is located in north Richland, adjacent to the 300 Area and Battelle-owned facilities. The other DOE-owned facilities are located in different operating areas on the Hanford Site.

The remaining graphics and text focus on the 113 DOE-owned buildings. The figure showing the age of Laboratory buildings illustrates that 90 percent of PNL's DOE-owned facilities, based on area, are over 20 years old, and 49 percent are over 30 years old. All of PNL's strategically important laboratories, as well as the major office/support facility, are now over 20 years old. Only 600 square meters (6380 square feet) are less than 10 years old. The average age of the 113 DOE-owned buildings is 25 years.

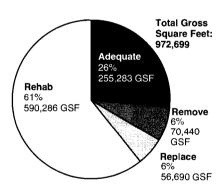
Facility condition overviews have been completed on all of PNL's facilities. Facilities in each condition category shown in the figure are defined by the DOE's Real Property Inventory System's condition codes combined with engineering and planning evaluations. The figure illustrates that approximately 61 percent of the facilities require some rehabilitation or are in process of being rehabilitated. Included in this category are some of

FY 1994 Laboratory Space Distribution

	Area						
Location (million)	square feet (million)	square meters (million)					
Main Site (300 Area)	1.0	0.90					
Leased (Offsite)	0.2	0.18					
Total	1.2	1.08					



Laboratory area and age distribution (years).



Condition of Laboratory space.

PNL's major laboratories (324, 327, and 331 buildings). Currently, major construction projects are funded and the compliance-related work under way for 325, 326, and 329 buildings. Projects are in place for 324 and 331 buildings as well. Full funding and timely completion of these projects will measurably improve plant condition.

A number of facilities remain in the replacement and removal categories. Progress has been made to reduce the number of buildings on inventory that are unsatisfactory for one reason or another. Current replacement candidates include the accelerator laboratory complex. These laboratories were previously considered adequate, but deterioration and changed programmatic requirements to develop the single-particle irradiator into a more accessible and functional user facility will necessitate relocation to other facilities. FY 1995 candidates for removal without replacement include three small storage buildings (331F, 2718E, WBF1), two monitoring stations, and the 331J Incinerator Building. The 6652C, Space Science laboratory, located on the Fitzner/ Eberhardt Arid Lands Ecology Reserve has been placed in "stand-by." This action was prompted by safety concerns for PNL staff traveling on treacherous winter mountain roads and the ability to isolate 6652C research activities to two small structures which can be monitored remotely.

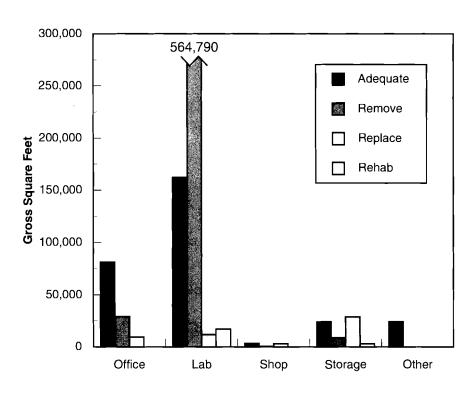
The figure showing the use and condition of Laboratory space illustrates in greater detail the condition of all of the Laboratory's facilities. As described in DOE Order 4320.2, "Capital Asset Management Process," PNL comprises the following building functional units: administrative, storage, service, laboratory, accelerator, and other. By far, laboratory space is the predominant type of space at PNL. Included in this category are laboratories (both nuclear and non-nuclear) for chemistry, materials, environmental and biological research, computation, electrical/elec-

tronics, applied physics, and general purpose research.

As programs and research methodology change, the look, feel, and function of laboratory space must also evolve. PNL is experiencing a shortage of appropriate laboratory space. In some instances the existing space is outdated or deteriorated. In other cases, it is not well located to other related work or support space. The need for renovations exists in the 331 Building, among others, where underutilized contaminated laboratory space is expensive to renovate. Funding is being sought through line item requests to the cognizant Secretarial Office to accomplish these needed renovations to turn inadequate or underused space into modern laboratories. Replacement laboratory space is also being sought in instances where the current building's life cycle is at a practical end or the location of the facility is counter to long-term planning or impacted by other Hanford activities. Proposed laboratory renovations and replacements are documented later in this section.

PNL's DOE-owned office space is concentrated in three permanent facilities (337 Building which is 21 years old and the 3764 and 3762 buildings which are converted World War II-era barracks-now 50 years old) and 26 trailers, as well as some office space within laboratory buildings. Most of this office space is now considered adequate, but will require extensive renovation in less than 5 years. Trailers compose the majority of space that needs to be replaced. New facilities to replace trailers and relocate staff out of inadequate office buildings are proposed.

The remaining space is a mixture of shops, storage buildings, and 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. There are plans to replace several small, aged, and scattered storage buildings with a new facility after FY 2000. PNL's facilities inventory also



	Adequate	Remove	Replace	Rehab	Total
Office	81,293	29,261	9,603		120,157
Lab	162,408	564,790	11,765	16,984	755,947
Shop	3,365	608	3,200		7,173
Storage	24,137	9,176	28,806	3,000	65,119
Other	24,303				24,303
Total	295,506	603,835	53,374	19,984	972,699

Use and condition of Laboratory space.

includes a collection of other structures (such as meteorological towers, fencing, irrigation systems). In general, condition of these structures is considered adequate. The replacement value of PNL's facilities inventory is summarized in the table, Facilities Replacement Value. The FY 1993 data comes from the Real Property Inventory System (RPIS2), a nationwide computerized inventory of DOE's property holdings. The replacement value of \$620 million for buildings is due to the extensive array of research, engineering, and computational laboratories operated by PNL. New replacement values are being computed based on industry

standard indexes appropriate to these facilities. Significant, additional replacement value is represented by the Hanford landlord utilities infrastructure inventory, but that responsibility is assigned to the Hanford Management and Operations contractor, not to PNL.

Facilities Plans and Options

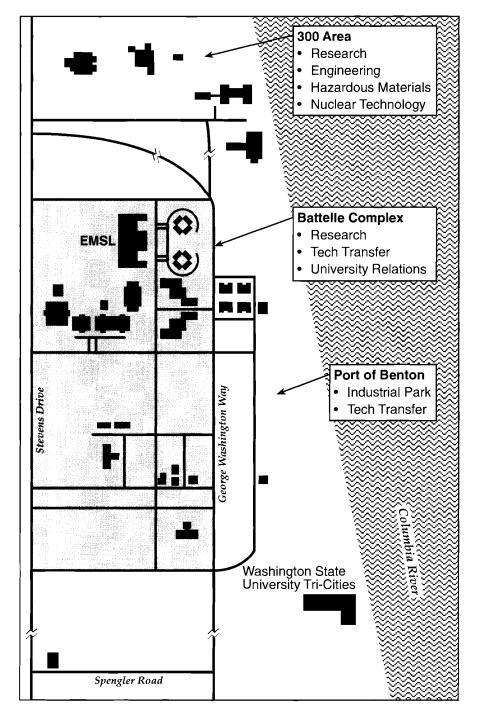
A national center for science and technology in the Pacific Northwest is being built around PNL. The Tri-Cities Science and Technology Park integrates capabilities for basic science, applied research and development, and technology applications.

Facil Replacem	
Facilities Type	Replacement in FY 1993 \$ (millions)
Buildings	620
Utilities	5
All Other	6
Total	631

The Park (see the figure) encompasses the DOE facilities of the 300 Area to the north, the research and development laboratories owned by Battelle Memorial Institute in the south, as well as Port of Benton and Washington State University Tri-Cities facilities, a total of 50 companies and organizations employing a total of 8000 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 2600 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, many of them in need of upgrades ranging from general repairs to major renovations and removal. Coupled with changing programmatic requirements and inadequate locations, renovation of many of these facilities is no longer considered cost-effective. The 300 Area Site Development Plan calls for locating new laboratory facilities in the southern portion of the area, demolishing these older facilities in



The Tri-Cities Science and Technology Park encompasses the 300 Area to the north and WSU-TC facilities to the south.

the north, and then restoring their sites. In the interim, corrective actions are needed to ensure compliance with environmental, safety, health, security, and operational requirements. The proposed withdrawal of Westinghouse Hanford from the 300 Area is consis-

tent with Hanford's cleanup mission. At some time in the future, PNL could become the only 300 Area landlord. Until that time, DOE Richland Operations Office, PNL, and Westinghouse are working together to design and construct an efficient,

reliable 300 Area infrastructure that satisfies current and future needs. An FY 1994 engineering study established a 15-year schedule for WHC's 300 Area withdrawal as the most cost-effective. The long-range plan for addressing the existing deficiency backlog and modernization needs of these facilities hinges on developing, maintaining, and integrating the necessary funding support from several sources to systematically accomplish the required upgrades and replacements over a period of several years. Limited funding has extended the period of time required to complete planned projects to correct deficiencies to well past the current planning period.

General Purpose Facilities Plans

With the exceptions of a permitted waste facility, all of PNL's facilities are considered general purpose. This means the facilities and equipment are used by two or more DOE programs. PNL's future development plans and options are inseparably linked with national DOE strategies, the Energy Policy Act of 1992, the Facilities Management 48 CFR Part 970, and guided by strategic initiatives being pursued at Hanford. By focusing on health and safety of the public and workers and focusing on the other vital elements of these plans as well-energy, environment, education, economy, and national securitythe Laboratory will achieve its vision of becoming a national center for science and technology. PNL's planning emphasis is to

- Ensure PNL 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 PNL'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.

In recent years, PNL's facility upgrades have been focused on solving four general problem areas 1) increased compliance with environmental, safety, and health regulations; 2) infrastructure deterioration; 3) changing purpose of some PNL facilities; and 4) shortage of adequate laboratory and office space. Progress to date in each of these areas follows.

Environment, Safety, and Health Regulatory Compliance The Laboratory has undergone numerous audits, reviews, inspections, and surveillances to assess 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, actions set forth in the Hanford Federal Facility Agreements (Tri-Party Agreement), and other environment, safety, and health assessments. The reviews focused on overall operations, documentation, agreements, planning, and the facility's performance.

The Environmental, Safety, and Health Management section in this plan identifies the results of these reviews. Facility-related deficiencies and proposed corrective actions have been included in several funding plans, and are described in this section under Facilities Resource Requirements.

Facilities Infrastructure Deterioration

Modern facilities and equipment are essential to support a viable research program at PNL. Consistent with the strategic objectives of the Laboratory, a modernization plan is developing, in conjunction with asset-based life cycle planning to anticipate facilities and infrastructure requirements for the next 20 years. As mentioned earlier, 90 percent of PNL's facilities are over 20 years old. Many of these facilities have been appropriately maintained and some partially renovated. However, others need major reprogramming, restoration and renewal, or replacement. Removal has been planned for others. Some facilities and building systems have exceeded their design life and are wearing out or becoming obsolete. When funds are made available, these activities will proceed according to plan.

Facilities infrastructure upgrades include the 300 Area exhaust system upgrades, HVAC control upgrades, fire protection compliance and fire alarm upgrades, as well as improvements to vacuum systems. For other infrastructure components and facilities, the cost associated with major restoration approaches the cost of constructing a new replacement facility. PNL has identified replacement facilities as a more cost-effective approach to resolving aging facilities infrastructure problems in some instances. Consistent with the latest 300 Area Site Development Plan, these new facilities are planned to be located in the southern-most portion of the 300 Area. Renewal of the existing infrastructure and strategic facilities in the vicinity of Cypress Road also ties to that concept and coordinates with the Hanford Management and Operations contractor's infrastructure renewal planning. The planned and scheduled connection to the City of Richland's water and sewer systems will be in FY 1995.

Mission Support To fulfill PNL's mission, it is necessary to continue efforts to modernize and expand PNL facilities. Enhanced facilities are

required to support PNL's science, technology, and educational initiatives that will help DOE achieve its goals.

In keeping with PNL's stategy to concentrate scarce financial resources on strategically important facilities that support overall Laboratory initiatives, facility improvements are focused on these major facilities. We have identified needed improvements to ensure compliance with environment, safety, and health requirements, and in providing adequate space for staff and operations.

Adequate Space PNL's acquisition of adequate office space increased about 0.92 million square meters (0.1 million square feet) last year. This has been done primarily by obtaining leased office space. In recent years, through competitive procurement, Battelle has selected a developer to construct a total of four office buildings 50,000; 60,000; and two at 100,000 square feet on Battelleowned property. The developer leases the land from Battelle, and Battelle privately leases the buildings from the developer. From start to finish (approval, procurement, lease negotiation, and construction) the first two facilities were occupied in less than a vear. Construction was started on the third building in 1992 and it was occupied in June 1993. Ground breaking took place in November 1993 for a fourth office building; construction was completed in October 1994 and it is fully occupied.

A key element in solving the problem of inadequate laboratory space is the renovation of aging labs and the replacement of ones that do not warrant the high cost of certain renovations.

General Purpose Facilities

This program provides major construction project line item support for the rehabilitation and replacement of the general purpose facilities assigned to PNL by 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.

General Plant Projects

Discrete, ongoing corrective activities are required to bring facilities supporting the energy research and environmental management business areas into 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, vertical openings, and improving exit corridors to current standards; air monitoring improvements; and cooling tower replacements, compressed air system replacement, HVAC controls replacement, and air conditioning upgrades. General Plant Project requirements are not duplicated in the construction line items. PNL requests \$3.5 million per year from Energy Research for FY 1995-2000 multiprogram General Plant Projects requirements. From Environmental Management, PNL requests \$4.0 million per year.

General Purpose Equipment

PNL's multiprogram general purpose equipment requirements fall into two broad capital support categories: general purpose equipment for PNL support services and non-programmatic 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 many 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 \$1.0 million in FY 1994, not enough is available for state-of-the-art technological improvements beyond that needed to support priority items.

PNL's Hanford Support general purpose equipment requirements are included in the Environmental Restoration and Waste Management Five-Year Plan. In general, PNL's Environmental Restoration and Waste Management general purpose equipment funding requirements are over \$2.5 million yearly.

Facilities Resource Requirements

PNL's Capital Asset Management Process (CAMP) program systematically identifies facility requirements, develops life cycle management plans for individual facilities, evaluates priorities of facility requirements and initiates development of capital projects. Energy Research MEL-FS program supports PNL's preparation of the laboratory Integrated Facilities Plan which meets DOE Order 4320.1B "Site Development Planning" and DOE Order 4320.2 "Capital Asset Management Process (CAMP)" planning requirements. PNL's capital facility requirements, as currently authorized and projected, are summarized in the Major Construction Projects table. The overall multiyear program plan for PNL

- is consistent with the DOE constrained budgetary guidance
- assumes a long-term effort will be necessary to fund and implement full requirements of PNL
- 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. PNL's project priority setting process uses the basic methodology contained in DOE Order 4320.2, "Capital Asset Management Process (CAMP)." The deficiencies, purpose,

and need of each project are evaluated using guidance criteria given in one or more of four basic categories: Health and Safety, Environment/Waste Management, Safeguards and Security, and Programmatic. 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 PNL's coordinated multiyear LIFP plan is significant because the funding of the DOE programs at PNL is relatively diverse and the program relationships at the Hanford Site are complex. PNL 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. NEPA documentation has been approved unless otherwise noted.

Programmatic Line Item Construction
Funding PNL has five programmatic
line item construction projects: the
Environmental Molecular Sciences
Laboratory (EMSL); National Security
Technology Center; the Radioactive
Liquid Waste System Replacement &
ACL Support Facility; the 325 Building Laboratory Renovation; and 340
Building Replacement. They are
briefly described below.

Environmental Molecular Sciences Laboratory (91-EM-100) The Environmental Molecular Sciences Laboratory will be an approximately 19,000-square-meter (200,000-square-foot), state-of-the-art research facility. It will support directed basic and applied research in the environmental molecular sciences. A wide range of research will be performed in the Environmental Molecular Sciences Laboratory 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 60 visiting scientists and includes a seminar area that will accommodate 100 people.

National Security Technology Center (96-AN-XXX) This \$10.4 million line item proposed for FY 1996 will provide a new facility designed to conduct classified activities. The facility will be approximately 3,000 square meters (30,000 square feet) of computer operation areas, office, and support areas. The building will have a service life of at least 30 years and will be located in the south 300 Area. Approval of a NEPA Categoric Exclusion is expected in December 1994.

Radioactive Liquid Waste System Replacement & ACL Support Facility (97-D-XXX) EM-30 This FY 1997 line item has a total estimated construction cost of \$10 million and will provide upgrades to the radioactive liquid waste system (RLWS) that serves the 325 "B" hot cell complex, which is critical to Hanford mission support. This facility will be reconfigured and modified to separate radiation control areas from the nonradiation control areas, increase office space, and provide facility access for people with disabilities for the Analytical Chemistry Laboratory's operations support.

325 Building Laboratory Renovation (98-D-XXX) EM-30 This FY 1998 line item totals \$6.5 million and will provide a modification of essential laboratory space in the 325 Building for the Hanford mission support activities of the chemical process section.

340 Building Replacement (99-D-XXX) EM-30 This FY 1999 project has a preliminary estimated construction cost of \$10 million. It will replace the function of the current facility to handle and load from the RLWS line for shipping and will configure the system to be compliant with RCRA inspection criteria. PNL laboratory facilities that are currently supported

include those in 324, 325, 326, 327, and 329 buildings. Capabilities to handle an increased volume of waste on a continuous schedule is required though waste reduction methodology is used. Research activity in these facilities is expected to increase during the planning period. The NEPA Action Description Memorandum will be submitted during conceptual design in FY 1997.

Multiprogram Energy Laboratories-Facilities Support Program The Multiprogram Energy Laboratories-Facilities Support (MEL-FS) Program is designed to maintain infrastructure integrity at the DOE's multiprogram energy laboratory facilities. The strategy of the MEL-FS Program is to maintain operations in a safe, costeffective, 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. The MEL-FS Program is composed of three subprograms from which PNL requests funding support

- General Purpose Facilities (GPF)
- Environment, Safety, and Health Support
- · Inactive and Surplus Facilities.

General Purpose Facilities Subprogram

The General Purpose Facilities subprogram provides construction support for the rehabilitation and replacement of general purpose facilities. These construction projects are directed at general purpose facilities which include general-use service and support facilities such as administrative space, general office/laboratory space, and utility systems. The General Purpose Facilities subprogram also provided operating funds to support PNL general purpose facilities planning and management activities. These included implementing the condition assessment surveys, preparation of PNL's FY 1994 LIFP, and assembling the MEL-FS program response to Section 2203 (d) of the Energy Policy Act of 1992, Public Law 102-483. The

table identifies PNL's General Purpose Facilities requirements. A brief description of those requirements follows.

Safety Compliance Modifications, 326 Building (92-E-601) This FY 1992 line item has a total estimated construction cost of \$8.6 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 PNL's 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), National Fire Protection Association (NFPA) Requirements, National Electric Code Requirements, and State of Washington Requirements.

Multiprogram Laboratory Rehabilitation (95-E-310) This 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 lifespan animal research. Experiments included exposure to chemical carcinogens and radiation. Changes in DOE objectives have resulted in a surplus of fragmented space for animal research and a shortage of chemistry and/or dry laboratory space or multipurpose space. Although some animal studies will continue to be performed, the required space will be consolidated and significantly less than now allocated in two separate areas within the building. This project will demolish the 331A Building and lead to a decrease in building operating costs. The old facilities will be converted to critically required general chemistry laboratories. Some modifications to support utilities also will be done.

Building Replacement II (97-E-XXX) This FY 1997 line item has a total estimated construction cost of \$9.6 million. This project will consolidate and relocate to the 331 Building Complex, DOE research programs currently conducted in four scattered, World War IIvintage facilities. The principal activities of these facilities include 1) the single-particle irradiator for studying the biological effects of low doses of alpha particles; 2) positive ion and electron irradiation of atomic, molecular, and cellular targets, directed toward understanding the biological response and evaluating the radiobiological consequences of different types of radiation; 3) mono-energetic neutron exposures of neutron dosimeters and dosimetry materials in support of program development and testing of neutron dosimetry concepts; and 4) use of positive ion beams in the characterization of ion-induced damage in various materials. This project will replace deficient Buildings 3745A (Electron Accelerator), 3745B (Positive Ion Accelerator), 3746 (Radiological Physics), and 3746A (Radiological Physics Lab) with an addition to the 331 Building. It will provide the wet laboratory space and cell culture facilities needed to conduct studies on biological specimens irradiated in the microbeam. The NEPA Environmental Assessment Finding of Significant Impact (EA/ FONSI) will be submitted to DOE-RL in December 1994.

Environment, Safety, and Health Support Subprogram The Environment, Safety, and Health Support subprogram provides support necessary to correct deficiencies identified in internal reviews and inspections that are related to DOE Energy Research facilities responsibilities. Comprehensive assessments initiated this subprogram, which examined environmental, safety, and health performance of DOE facilities. The assessments were conducted by a team of specialists from various DOE offices, contractors, and consultants. The subprogram was designed to alleviate increases in laboratory overhead rates and General Plant Projects, General Purpose Equipment, and General Purpose Facilities funding levels associated with correcting selected deficiencies that were identified. PNL's initial remediation action plan was successfully completed. A few capital construction projects continue in progress (see the following examples).

Life Safety Code Compliance (93-E-317) This FY 1993 line item has a total estimated construction cost of \$2.4 million and corrects immediate Life Safety Code compliance problems in several aged multiprogram laboratories at PNL. 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 the DOE Order 5480.4 (Environmental Protection, Safety and Health Protection Standards) and the DOE Order 6430.1A (General Design Criteria). Changes in the construction of PNL facilities are needed to comply with the requirements of the Life Safety Code. Failure to comply with the Life Safety Code jeopardizes the 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 FY 1995 line item has a total estimated construction cost of \$6.8 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, and emergency lighting.

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 Orders 5480.4 (Environmental Protection, Safety and Health Protection Standards) and 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.

Environment, Safety, and Health Support Subprogram Capital Equipment Requirements Capital equipment requirements are driven by regulatory compliance or provide for a significant cost savings in operations. FY 1993 and FY 1994 funding of \$136,000 has provided effluent monitoring equipment required to upgrade air sampling systems, industrial hygiene air video image scopes for detection of asbestos, and a confined space gas detection unit. Out year capital equipment requirements would allow for reclaiming and recycling chlorofluorocarbon refrigerants, and provide opportunities to prevent pollution.

Environment, Safety, and Health Support Subprogram Operating Requirements
At the request of the DOE Office of Energy Research, PNL submitted its Environment, Safety, and Health Support operating requirements for MEL-FS facilities by proposal for funding in FY 1995 and FY 1996. It is coordinated with requirements expressed in the Environment, Safety, and Health Management 5-Year Plan.

Inactive and Surplus Facilities **Subprogram** PNL's Inactive and Surplus Facilities 5-Year Plan provides for the identification, management, surveillance and monitoring, maintenance, characterization, cleanup, removal, and reutilization or transfer of all surplus general purpose facilities related to the DOE Energy Research program activities. Some facilities will be cleaned up and reused, others will be removed to make way for new construction, while others will be transferred to the DOE Environmental Restoration's Decontamination and Decommission program. Environmental Assessments will be done on a facility-by-facility basis. The FY 1995 and FY 1996 projects

can be accomplished immediately upon funding since they are not dependent on other projects.

Specific facilities have been named, categorized, and prioritized through efforts including the DOE secretarial initiative Surplus Facility Inventory and Assessment Project; and initiation of the Capital Asset Management Process's Condition Assessment Survey. This was accomplished consistent with the planning processes of the FY 1994 Laboratory Integrated Facilities Plan, the current Hanford Mission Plan, and the Hanford Site Development Plan update.

PNL is requesting operating funds for these activities via a Field Work Proposal submitted to the Multiprogram Energy Laboratories-Facilities Support Inactive and Surplus Facilities Subprogram (KG-03). As shown in the surplus facilities plan listing, PNL has identified projects for the next 3 years. In FY 1994, surplus assets were removed using MEL-FS KG-03 funds: 320 Trailer 1, 7000 linear feet of 331 pasture fence, and 500 fence posts.

In FY 1995, budgeted activities include cleanup of the 331 Building's Inhalation Suite for reuse and removal of the 331F Building.

In FY 1996, proposed activities include the following:

- characterization and demolition of the 331J Building and Incinerator
- characterization, cleanup, and transfer of the 6652-O Building to Hanford Site decontamination, decommissioning, and demolition programs
- characterization, cleanup, and transfer of the 3731 and 3731-A Buildings to Hanford Site decontamination, decommissioning, and demolition programs.

Environmental Management Funding

The PNL 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 PNL's general purpose Hanford Support facilities (318, 324, 325, 327, 3723, 3730, 3760, 622R, and 747A). An assortment of trailers, small storage buildings, meteorological facilities, and some surplus facilities round out the Environmental Management Landlord inventory of 29 facilities.

These facilities support the Hanford Site environmental restoration and waste management mission, including meeting Tri-Party Agreement milestones, the Hanford Waste Vitrification Program, the Tank Waste Remediation Systems, and Spent Fuel and Disposal Systems. Also, PNL's site service responsibilities include 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. The construction projects are proposed in PNL's 5-year (FY 1995-2000) DOE Environmental Management Program Plan.

329 Building Compliance (91-E-322)

The total estimated construction cost for this FY 1991 project is \$9.1 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:
1) 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, the state of Washington Administrative Code Chapter 402-80 (Monitoring

and Enforcement of Air Quality and Emission Standards for Radionuclides); 2) replace corroded service piping; 3) 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 requires that hazardous materials cannot be released in a liquid effluent (extensive corroded piping holds the potential for releasing radioactive constituents); 4) upgrade the fire protection system to meet National Fire Protection Association 13; 5) replace a portion of the building electrical system to meet NFPA 70 (the National Electric Code); 6) establish laboratory and corridor fire separation to comply with NFPA 101, which is a mandatory requirement of DOE Order 6430.1; 7) provide access for the physically disabled to comply with 41 CFR 101.19.6 (Uniform Federal Accessibility); and 8) 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 EPA 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 the 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. This facility is a vital laboratory, and its support is required for Hanford to meet its Tri-Party Agreement commitments (Milestones M-04 and M-10) in regard to the analysis work associated with the Double-Shell and Single-Shell Tank

Major Construction Projects - FY 1995-2000 Planning Period

(Budget Authorization \$ in Millions)

	Total Est.		Fiscal Year						
	Const. Costs	1993	1994	1995	1996	1997	1998	1999	2000
FUNDED CONSTRUCTION									
General Plant Projects									
General Plant Projects (KP)(a)		2.0	2.8						
General Plant Projects EM-60 (EW)(a)		3.5	3.5						
Environmental Management Projects (EW)									
329 Building Compliance	9.0	2.5	1.7						
325 Facility Compliance/Renovation	6.0	1.5	3.5	1.0					
Multiprogram Energy Laboratories-									
Facilities Support Program Projects (KG)									
Safety Compliance Modifications,									
326 Building	8.5	3.0	1.9	1.9					
Life Safety Code Compliance	2.4	0.5	1.0	0.5					
Program Related Projects									
Environmental Molecular									
Sciences Laboratory ER (KP)	207.9	28.5	32.0	40.0	50.0	35.1			
Total Funded Construction		41.5	46.4	43.4	50.0	35.1			
		1110			20.0	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,			
BUDGETED CONSTRUCTION									
General Plant Projects				2.0					
General Plant Projects (KP)				2.0					
General Plant Projects EM-60 (EW)				2.5					
Multiprogram Energy Laboratories-									
Facilities Support Program Project (KG)				0.4	2.5	• •			
Multiprogram Lab. Rehab.	6.1			0.4	2.7	2.9	0.1		
Electrical Safety Rehab.	6.8			0.2	1.5	1.5	1.5	2.1	
Environmental Management Projects (EW)	- 0					• •			
324 Facility Compliance/Renovation	5.8			1.5	3.5	0.8			
Program Related Projects									
National Security Technology Center (AN)	10.4				2.0	6.4	2.0		
Total Budgeted Construction				6.6	9.7	11.6	3.6	2.1	
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)					4.0	4:0	4.0	4.0	4.0
Multiprogram Energy Laboratories -						.,,	.,,		
Facilities Support Program Project (KG)									
Building Replacement - II	9.6					1.0	4.8	3.8	
Environmental Management Projects (EW)									
Building Utilities Replacement	3.8				1.0	2.8			
Personnel Dosimetry Facility	9.0					,	4.2	4.8	
Program Related Projects									
RLWS Replacement & ACL Support									
Facility EM-30 (EW)	10.0					1.9	6.0	2.1	
325 Bldg Laboratory Renovation EM-30 (EW)	6.5						1.5	5.0	
340 Bldg Replacement EM-30 (EW)	10.0							4.0	6.0
Total Proposed Construction					8.5	13.2	24.0	27.2	13.5
Total Construction		41.5	46.4	50.0	68.2	59.9	27.6	29.3	13.5
				20.00					10.0

Programs. 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 gloveboxes; 4) remove the B-Unit stack sampler; 5) upgrade the fire sprinkler system; and 6) install a P-10 gas system.

324 Facility Compliance/Renovation (96-D-XXX) This FY 1996 line item has a total estimated construction cost of \$6 million. This activity focuses on renovation of major building systems in an aged, but strategically important, Hanford Support laboratory. This project is necessary to support Tri-Party Agreement commitments for Milestones M-03, M-04, and M-06. Much of the work in the building is associated with the DOE-EM business area. 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.

Building Utilities Replacement, 300 Area (96-D-XXX) This FY 1996 line item has a total estimated construction cost of \$3.8 million. This project will replace deficient and substandard electrical, mechanical, utility, and structural systems in general purpose buildings within the 300 Area. Many of the buildings' operating utility, electrical, and mechanical systems are more than 40 years old and need upgrading for safe, reliable operation and to meet current standards. These upgrades will extend the useful life of these major facilities to support the DOE-EM business area.

Personnel Dosimetry Facility (98-D-XXX) This FY 1998 project provides a 2500-square-meter (25,000-square-foot) facility with a total estimated construction cost of \$9 million. Laboratories, operating areas, shielded in vivo counting cells, electronic maintenance

shop, and office space are included. It will house four programs that measure, assess, document, record, and report workers' and visitors' radiological exposures under the following Hanford programs: In-Vivo Measurement, Hanford Internal Dosimetry, Hanford External Dosimetry, and Hanford Dosimetry Records.

Maintenance Funding PNL recognized the DOE-wide effort to provide maintenance funds on a life cycle basis in response to asset-based assessment and planning efforts described in DOE Order 4320.2 "Capital Asset Management Process." The program included establishing standards, methods, procedures, data collection systems, database architecture, and training, along with life cycle surveys of facilities to establish maintenance requirements. PNL will continue to be faced with tightening budgets that require better prioritization, cost control, and management of maintenance. In response, PNL will rely on a graded approach to assist the decision-making process in managing limited maintenance resources.

Consolidated Information Center

The Hanford Technical Library, managed by PNL for the DOE, represents a unique information resource. The library is located within the 300 Area on the Hanford Site.

More accessible, but less comprehensive, is the library at the WSU-TC campus, adjacent to PNL. PNL has proposed consolidating the two libraries minimizing duplication and overlap through the use of shared staff 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 would be located in leased space in a new building on the WSU-TC campus and be

called the Consolidated Information Center. The new building would also include a conference center and an Environmental and Technology Resource Center that would be managed by WSU. The library facility would be operated by PNL, in conjunction with WSU-TC. The DOE Public Reading Room, which is currently managed by PNL and located on the WSU-TC campus, would also be located in the new library.

The Washington State Legislature appropriated \$1.4 million in 1993 to begin the architectural design work. This is currently under way.

The Consolidated Information Center would be tied into the Hanford Local Area Network so that staff and users would 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 resources through WSU and the Center for Information and Technology, would create a unique and very valuable set of resources. This consolidation would also make the resources available to a much larger community and would make PNL's research experiences more available to WSU students and faculty. Visitors, the general public, and businesses in the region would have access to information resources that are not now available because of facility constraints and security considerations. 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 would 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.

Consolidated Information Center

(Budget Authorization \$ in Millions)

	Fiscal Year								
Current Programs	1994	1995	1996	1997	1998	1999			
Operating	1.8	1.9	2.0	2.2	2.3	2.4			
Move and Relocation	0.0	0.0	0.0	0.4	0.0	0.0			
Capital Equipment	0.0	0.0	0.1	0.1	0.1	0.1			
Total	1.9	1.9	2.1	2.7	2.4	2.5			

Summary

Over the past several years, PNL has made significant contributions to Hanford long-term planning efforts such as the Hanford Site Development Plan, 300 and 200 Area Development Plans, the Site Master Plan, and the South 300 Area Infrastructure Study. To aid in implementing such plans and enhancing the ability of the Laboratory to accommodate today's research needs, PNL conducts near-term planning in Operational Management, and Facilities Management. In particular, PNL is in the process of implementing the Master Site Plan for PNL facilities, which includes the replacement of some buildings as well as making improvements to the rest of the aging infrastructure occupied by the Laboratory. Implementation of these plans, along with integrated business planning, aims to further achieve the Facilities and Operations goals to provide technical resources and oversight needed for safe, secure, environmentally compliant, and reliable Laboratory operations, and provide the facilities needed for the Laboratory to be successful in its mission.

Communication and Trust

PNL is supporting DOE in its transformation to a new culture in emphasizing communication and incorporating trust as an underlying value. For PNL to maintain credibility as a DOE national multiprogram laboratory, we 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 within PNL, with our customers, and our stakeholders is essential in pursuing PNL's vision of becoming a world-class laboratory. Successful managers at PNL 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.

PNL's efforts to improve communications and build more trust include

Conveying the message of DOE's Strategic Plan, where PNL is focusing its efforts and in contributing to the achievement of DOE's goals to staff and external audiences.

Timely communication of the information that staff need to make informed decisions.

Active involvement of participants from across the Laboratory in planning and implementing activities to achieve quality and improve productivity.

A comprehensive program to gain recognition of the accomplishments in the Laboratory and its staff internally, locally, regionally, and throughout the U.S.

Improve the public understanding of the value of science and technology.

Commitment to and leadership on Secretary O'Leary's initiative on Openness. This includes the clearance and release of all Hanford documents pertaining to Human Subjects research, and those historical Hanford DOE documents which need to be declassified and made available to the public.

PNL is providing leadership in supporting the Office of Environmental Management in key communication and public involvement activities and initiatives. These include

- supporting DOE in conducting public involvement in good faith
- developing prototype training courses for DOE and contractor employees
- incorporating stakeholder acceptability criteria in technology development and demonstration efforts
- developing a new means of electronic communication to provide information on current environmental monitoring efforts and results, past environmental exposures, and ongoing technology development and demonstration programs.



Resource Projections

The expansion in laboratory efforts reflected in the resource projections is based on the assumption that we will successfully implement the initiatives proposed in our Institutional Plan that were accepted in principle by the DOE. This represents a considerable

challenge in light of the federal budget picture for the coming years. 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 1993 and FY 1994 are actual values.

Laboratory Funding Summary

(Budget Authorization \$ in Millions)(a)

				Fisca	ıl Year			
	1993	1994	1995	1996	1997	1998	1999	2000
DOE Effort	328.0	404.4	405.8	426.4	465.4	495.1	506.4	515.1
Work for Others	78.3	75.3	76.6	79.0	80.8	83.3	84.7	86.7
Total Operating	406.3	479.7	482.4	505.4	546.2	578.4	591.1	601.8
Capital Equipment	25.9	23.5	26.1	28.2	29.7	38.6	38.1	38.7
General Purpose Equipment-GPE	2.0	1.5	1.9	3.1	1.7	1.8	1.8	1.9
General Plant Projects-GPP	6.0	6.3	4.5	7.5	7.5	7.5	7.5	7.5
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.0
Program Line Items	28.5	32.0	40.0	50.0	35.1	0.0	0.0	0.0
MEL-FS ^(b) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0
Total Laboratory Funding	478.2	551.1	560.4	602.9	631.1	644.4	660.3	655.9

⁽a) Budget authorization escalated through FY 2000.

⁽b) Multiprogram Energy Laboratories-Facilities Support.

Laboratory Personnel Summary

(Personnel in FTE)

				Fisca	ıl Year			
	1993	1994	1995	1996	1997	1998	1999	2000
DOE Effort	1543	1724	1739	1782	1904	1983	1974	1952
Work for Others	348	324	320	320	320	319	315	313
Total Operating	1891	2048	2059	2102	2224	2302	2289	2265
Capital Equipment	33	31	29	36	36	48	47	46
General Plant Projects-GPP	9	9	6	9	9	9	9	8
Landlord Line Items	8	7	4	6	7	14	18	7
Program Line Items	39	42	52	63	43	0	0	0
MEL-FS ^(a) Construction	5	4	4	5	7	8	7	0
Total Direct	1985	2141	2154	2221	2326	2381	2370	2326
Indirect	1712	1769	1725	1685	1675	1700	1700	1700
Total Laboratory Personnel (FTE)	3697	3910	3879	3906	4001	4081	4070	4026

⁽a) Multiprogram Energy Laboratories-Facilities Support.

Funding by Secretarial Officer (Budget Authorization \$ in Millions)(a)

					l Year			
	1993	1994	1995	1996	1997	1998	1999	2000
Office of Energy Research								
Operating	51.7	69.2	61.8	66.4	68.4	70.3	72.2	73.
EMSL Operating	0.0	0.0	0.0	2.0	20.0	42.7	44.8	47.
Capital Equipment	10.3	10.0	12.2	12.7	12.2	12.7	12.7	12.7
EMSL Capital Equipment	0.0	0.0	0.0	0.0	2.0	10.4	10.9	11.:
General Purpose Equipment-GPE	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
General Plant Projects-GPP	2.0	2.8	2.0	3.5	3.5	3.5	3.5	3.5
MELS-FS ^(c) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0
Program Line Items	0.0	32.0	40.0	50.0	35.1	0.0	0.0	0.0
Total	68.5	117.9	120.0	139.8	147.6	147.0	151.0	148.9
Office of Environmental Manageme	nt							
Operating	187.8	222.6	185.0	193.0	204.0	203.0	204.0	205.
Capital Equipment	13.0	12.1	11.8	14.0	14.0	14.0	13.0	13.
General Purpose Equipment-GPE	1.0	0.5	0.9	2.1	0.7	0.8	0.8	0.
General Plant Projects-GPP	4.0	3.5	2.5	4.0	4.0	4.0	4.0	4.
Program Line Items	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.
Total	240.3	243.9	202.7	217.6	228.2	233.5	237.7	228.
Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	17.6	22.7	25.0	26.5	28.3	29.3	30.4	30.
Capital Equipment	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.
Total	17.6	22.8	25.2	26.7	28.5	29.5	30.6	31.
Office of Civilian Radioactive Waste Management								
Total Operating(b)	-2.9	0.2	1.0	1.0	1.2	1.3	1.5	1.:
Assistant Secretary for Environment, Safety and Health								
Operating	15.4	19.9	19.9	22.2	24.2	25.2	26.2	26.
Capital Equipment	0.4	0.0	0.1	0.1	0.1	0.1	0.1	0.
Total	15.8	19.9	20.0	22.3	24.3	25.3	26.3	26.
Assistant Secretary for Defense Prop	grams							
Operating	2.6	2.2	1.0	1.0	1.0	1.0	1.0	1.
Operating								
Capital Equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4

Funding by Secretarial Officer (contd) (Budget Authorization \$ in Millions)(a)

				Fisca	ıl Year				
	1993	1994	1995	1996	1997	1998	1999	2000	
Office of Science Education & Technical Information									
Total Operating	1.0	1.7	3.0	3.1	3.3	3.4	3.6	3.8	
Office of Nonproliferation and National Security									
Operating	27.0	30.2	24.5	24.9	25.5	26.1	26.7	27.3	
Capital Equipment	1.7	1.3	1.8	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	28.7	31.5	26.3	26.1	26.7	27.3	27.9	28.5	
Assistant Secretary for Nuclear Energy									
Total Operating(b)	-0.4	0.6	57.9	60.4	62.9	65.4	67.9	70.4	
Assistant Secretary for Fossil Energy									
Total Operating	1.9	1.7	2.1	2.2	2.3	2.4	2.5	2.0	
Office of Policy									
Total Operating	3.0	1.4	1.5	1.5	1.5	1.6	1.6	1.0	
Other DOE Organizations									
TA Nat'l Energy Information System	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
BPA	3.0	1.8	1.9	2.0	2.1	2.2	2.3	2.4	
Total Operating	3.0	1.9	2.1	2.2	2.3	2.4	2.5	2.0	
Other DOE Sites									
Total Operating	20.3	30.1	21.0	20.0	20.5	21.0	21.5	22.0	
Total DOE Programs									
Operating	328.0	404.4	405.8	426.4	465.4	495.1	506.4	515.	
Capital Equipment	25.9	23.5	26.1	28.2	29.7	38.6	38.1	38.7	
General Purpose Equipment-GPE	2.0	1.5	1.9	3.1	1.7	1.8	1.8	1.9	
General Plant Projects-GPP	6.0	6.3	4.5	7.5	7.5	7.5	7.5	7.5	
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.0	
Program Line Items	28.5	32.0	40.0	50.0	35.1	0.0	0.0	0.0	
MEL-FS ^(c) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0	
Total	399.9	475.8	483.8	523.9	550.3	561.1	575.6	569.2	

Funding by Secretarial Officer (contd)

(Budget Authorization \$ in Millions)(a)

				Fisca	l Year			
	1993	1994	1995	1996	1997	1998	1999	2000
Work for Others								
Nuclear Regulatory Commission	16.6	14.8	16.5	17.5	18.3	19.3	20.2	21.2
Department of Defense	51.0	50.0	50.0	51.0	52.0	53.0	54.0	55.0
Environmental Protection Agency	1.8	3.3	2.5	2.5	2.5	3.0	2.5	2.5
NASA and Other Federal Agencies	8.9	6.8	7.0	7.0	7.0	7.0	7.0	7.0
Other - Non Federal Agencies	0.0	0.4	0.6	1.0	1.0	1.0	1.0	1.0
Total	78.3	75.3	76.6	79.0	80.8	83.3	84.7	86.7
Total Laboratory Funding								
Operating	406.3	479.7	482.4	505.4	546.2	578.4	591.1	601.8
Capital Equipment	25.9	23.5	26.1	28.2	29.7	38.6	38.1	38.7
General Purpose Equipment-GPE	2.0	1.5	1.9	3.1	1.7	1.8	1.8	1.9
General Plant Projects-GPP	6.0	6.3	4.5	7.5	7.5	7.5	7.5	7.5
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.0
Program Line Items	28.5	32.0	40.0	50.0	35.1	0.0	0.0	0.0
MEL-FS ^(c) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0
Total	478.2	551.1	560.4	602.9	631.1	644.4	660.3	655.9

⁽a) Budget authorization escalated through FY 2000.

⁽b) Negative balances result from deobligation of prior year uncosted funds.

⁽c) Multiprogram Energy Laboratories-Facilities Support Construction.

Direct Personnel by Secretarial Officer (Personnel in FTE)

	1993	1994	1995	Fisca 1996	l Year 1997	1998	1999	2000
Office of Energy Research	1//0	177,1	1770	1//0	1777	1//0	1///	2000
Operating	240	295	296	314	395	493	496	494
Office of Environmental Management								
Operating	871	949	894	906	927	898	876	854
Assistant Secretary for Energy Efficiency and Renewable Energy								
Operating	82	97	121	124	129	130	131	129
Office of Civilian Radioactive Waste Management								
Operating	5	1	5	5	6	6	6	6
Assistant Secretary for Environment, Safety and Health								
Operating	71	85	96	104	110	111	112	109
Assistant Secretary for Defense Programs								
Operating	12	9	5	5	5	4	4	4
Office of Science Education & Technical Information								
Operating	5	7	15	15	15	15	16	16
Office of Nonproliferation and National Security								
Operating	125	129	118	117	116	115	115	114
Assistant Secretary for Nuclear Energy								
Operating	1	3	62	72	81	90	98	106
Assistant Secretary for Fossil Energy								
Operating	9	7	10	10	10	11	11	11
Office of Policy								
Operating	14	6	7	7	7	7	7	7

Direct Personnel by Secretarial Officer (contd)

(Personnel in FTE)

				Fisca	l Year			
	1993	1994	1995	1996	1997	1998_	1999	2000
Other DOE Organizations								
Operating	14	8	9	9	10	10	10	10
Other DOE Sites								
Operating	94	128	101	94	93	93	92	92
Total DOE Program	1543	1724	1739	1782	1904	1983	1974	1952
Work for Others								
Nuclear Regulatory Commission	74	64	69	71	72	74	75	76
Department of Defense	226	215	209	207	206	203	201	199
Environmental Protection Agency	8	14	10	10	10	11	9	Ģ
NASA and Other Federal Agencies	40	29	29	28	28	27	26	25
Other - Non Federal Agencies	0	2	3	4	4	4	4	4
Total	348	324	320	320	320	319	315	313
Laboratory Direct								
Operating	1891	2048	2059	2102	2224	2302	2289	226
Capital Equipment	33	31	29	36	36	48	47	40
General Plant Projects-GPP	9	9	6	9	9	9	9	8
Landlord Line Items	8	7	4	6	7	14	18	•
Program Line Items	39	42	52	63	43	0	0	(
MEL-FS ^(a) Construction	5	4	4	5	7	8	7	(
Total Laboratory Direct	1985	2141	2154	2221	2326	2381	2370	2326
Total Laboratory Indirect	1712	1769	1725	1685	1675	1700	1700	1700
Total Laboratory Personnel (FTE)	3697	3910	3879	3906	4001	4081	4070	4026

⁽a) Multiprogram Energy Laboratories-Facilities Support.

				Fisca	l Year			
	1993	1994	1995	1996	1997	1998	1999	2000
Office of Energy Research								
Magnetic Fusion (AT)	5.1	3.4	3.8	3.8	3.8	4.0	4.0	4.0
High Energy Physics (KA)	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Nuclear Physics (KB)	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Basic Energy Sciences (KC)	11.2	11.3	12.0	14.0	15.5	17.3	19.2	20.0
Biological/Environ Research Prog Dir (KR)	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Advisory & Oversight Program Dir. (KF)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ER Laboratory Technology Transfer (KU)	2.1	16.0	9.0	10.5	11.0	11.0	11.0	11.0
Multiprogram Energy Laboratories (KG)	0.0	0.1	0.5	1.6	1.6	1.5	1.5	1.6
Energy Research Analysis (KD)	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Biological & Environmental Research (KP)	32.6	37.5	36.0	36.0	36.0	36.0	36.0	36.0
EMSL Operations (KP - BER)	0.0	0.0	0.0	2.0	20.0	42.7	44.8	47.
Operating	51.7	69.2	61.8	68.4	88.4	113.0	117.0	120.
Capital Equipment (AT)	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Capital Equipment (KC)	1.6	1.1	1.0	1.5	2.0	2.5	2.5	2.:
Capital Equipment (KP)	8.4	8.7	11.0	11.0	10.0	10.0	10.0	10.
EMSL Capital (KP - BER)	0.0	0.0	0.0	0.0	2.0	10.4	10.9	11.3
Capital Equipment	10.3	10.0	12.2	12.7	14.2	23.1	23.6	24.2
General Purpose Equipment-GPE (KP)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
General Plant Projects-GPP (KP)	2.0	2.8	2.0	3.5	3.5	3.5	3.5	3.3
Multiprogram Energy Laboratories (KG)	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0
Program Line Item (EMSL)	0.0	32.0	40.0	50.0	35.1	0.0	0.0	0.0
Total Funding	68.5	117.9	120.0	139.8	147.6	147.0	151.0	148.9
Direct Personnel								
Operating	240	295	296	314	395	493	496	494
Capital	13	13	16	16	18	30	31	31
General Plant Projects-GPP	3	4	3	4	4	4	4	4
Multiprogram Energy Laboratories (KG)	5	4	4	5	7	8	7	0
Program Line Items	0	42	52	63	43	0	0	0
Total Direct Personnel	256	312	315	334	417	527	531	529

	1993	1994	1995	Fiscal 1996	l Year 1997	1998	1999	2000
Office of Environmental Management					·			
Technical Development (EW)	33.3	28.4	32.0	35.0	37.0	40.0	37.0	35.0
Waste Management (EW)	111.4	160.6	119.0	122.0	130.0	129.0	133.0	135.0
Waste Management (EX)	14.5	10.0	13.0	12.0	14.0	14.0	14.0	14.0
Environmental Restoration (EW)	27.6	23.3	21.0	24.0	23.0	20.0	20.0	21.0
Environmental Restoration (EX)	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total Operating	187.8	222.6	185.0	193.0	204.0	203.0	204.0	205.0
Capital Equipment (EW)	13.0	12.1	11.8	14.0	14.0	14.0	13.0	13.0
General Purpose Equipment-GPE	1.0	0.5	0.9	2.1	0.7	0.8	0.8	0.
General Plant Projects-GPP	4.0	3.5	2.5	4.0	4.0	4.0	4.0	4.
Program Line Items	28.5	0.0	0.0	0.0	0.0	0.0	0.0	0.
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.
Total Funding	240.3	243.9	202.7	217.6	228.2	233.5	237.7	228.
Direct Personnel								
Operating	871	949	894	906	927	898	876	854
Capital Equipment	18	16	11	18	17	17	15	14
General Plant Projects-GPP	6	5	3	5	5	5	5	4
Program Line Items	39	0	0	0	0	0	0	0
Landlord Line Items	8	7	4	6	7	14	18	7
Total Direct Personnel	942	977	912	935	956	934	914	879

					l Year			
	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Energy Efficiency and Renewable Energy								
Electric Energy Systems (AK)	1.1	2.3	1.2	1.2	1.2	1.3	1.3	1.4
Electric Energy Systems (AL)	1.4	1.1	1.4	1.4	1.4	1.4	1.4	1.4
Geothermal Systems (AM)	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Hydrogen Research (AR)	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Solar Energy (EB)	1.5	1.3	0.3	0.0	0.0	0.0	0.0	0.0
Buildings Sector-EERE (EC)	7.6	11.6	8.1	8.7	9.9	10.3	11.1	11.0
Industrial Energy Conservation (ED)	4.1	3.6	5.5	6.5	7.0	7.2	7.4	7.6
Transportation Sector (EE)	0.3	1.0	5.0	5.2	5.3	5.5	5.6	5.8
Tech & Financial Assistance-EERE (EF)	1.3	0.3	1.2	1.2	1.2	1.3	1.3	1.4
Utility Sector (EK)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Policy And Management (EH)	0.0	0.2	1.0	1.0	1.0	1.0	1.0	1.0
Policy And Management (KK04)	0.0	0.7	1.0	1.0	1.0	1.0	1.0	1.0
Operating	17.6	22.7	25.0	26.5	28.3	29.3	30.4	30.9
Capital Equipment	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Funding	17.6	22.8	25.2	26.7	28.5	29.5	30.6	31.1
Direct Operating Personnel	82	97	121	124	129	130	131	129
Office of Civilian Radioactive Waste Management								
Nuclear Waste Fund (DB)	-1.2	-0.2	0.5	0.5	0.7	0.8	1.0	1.0
Civilian Radioactive Waste R&D (DC)	-1.7	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Total Funding ^(b)	-2.9	0.2	1.0	1.0	1.2	1.3	1.5	1.5
Direct Operating Personnel	5	1	5	5	6	6	6	6
Assistant Secretary for Environment, Safety and Health								
Environmental, Safety and Health (HA-01)	15.1	16.1	16.0	18.0	20.0	21.0	22.0	22.0
Program Direction (HA-04)	0.0	0.0	0.2	0.5	0.5	0.5	0.5	0.5
Office of Security Evaluation (HS)	0.3	2.9	2.0	2.0	2.0	2.0	2.0	2.0
Nuclear Safety Oversight (NS)	0.0	0.7	1.5	1.5	1.5	1.5	1.5	1.5
Radiological Oversight (NR)	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Operating	15.4	19.9	19.9	22.2	24.2	25.2	26.2	26.2
Capital Equipment (HA-01)	0.9	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment (HS) ^(b)	-0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	15.8	19.9	20.0	22.3	24.3	25.3	26.3	26.3

	40	Fiscal Year						
	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Defense Programs								
Materials Production (GE)	2.6	2.2	1.0	1.0	1.0	1.0	1.0	1.0
Worker & Community Transitn Prog. (GG)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Operating	2.6	2.2	1.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Funding	3.1	2.2	1.0	1.0	1.0	1.0	1.0	1.0
Direct Operating Personnel	12	9	5	5	5	4	4	4
Office of Science Education & Technical Information								
University & Science Education (KT)	0.0	1.7	3.0	3.1	3.3	3.4	3.6	3.
Univ. & Science Education - Defense (KV)	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
Total Funding	1.0	1.7	3.0	3.1	3.3	3.4	3.6	3.
Direct Operating Personnel	5	7	15	15	15	15	16	16
Office of Nonproliferation and National Security								
Emergency Managemnt Division (GB0506)	0.0	1.6	1.5	1.5	1.5	1.5	1.5	1
Verification & Control Technology (GC)	20.5	17.3	15.3	15.6	15.9	16.2	16.5	16.
Nuclear Safeguards & Security (GD)	2.5	3.8	3.1	3.2	3.3	3.4	3.5	3.0
Expt Control, Nonprolif & Safeguards (GJ)	0.5	2.7	2.4	2.5	2.6	2.7	2.8	2.5
Intelligence (NT)	3.5	4.8	2.2	2.1	2.2	2.3	2.4	2.
Operating	27.0	30.2	24.5	24.9	25.5	26.1	26.7	27.
Capital Equipment (GC)	1.5	1.3	1.6	1.0	1.0	1.0	1.0	1.
Capital Equipment (GD)	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.
Capital Equipment (NT)	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.
Line Item (GC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.
Total Funding	28.7	31.5	26.3	26.1	26.7	27.3	27.9	28.
Direct Personnel								
Operating	125	129	118	117	116	115	115	114
Capital Equipment	2	2	2	2	1	1	1	1
Total Direct Personnel	127	131	120	119	117	116	116	115

	Fiscal Year							
	1993	1994	1995	1996	1997	1998	1999	2000
Assistant Secretary for Nuclear Energy								
Nuclear Energy R&D (AF)	0.0	0.2	57.5	60.0	62.5	65.0	67.5	70.0
Uranium Enrichment (CD)	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy & Management (KK)	-0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Total Funding ^(b)	-0.4	0.6	57.9	60.4	62.9	65.4	67.9	70.4
Direct Operating Personnel	1	3	62	72	81	90	98	106
Assistant Secretary for Fossil Energy								
Coal (AA)	1.7	1.3	1.9	2.0	2.1	2.2	2.3	2.4
Petroleum (AC)	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Funding	1.9	1.4	2.1	2.2	2.3	2.4	2.5	2.6
Direct Operating Personnel	9	7	10	10	10	11	11	11
Office of Policy								
Policy, Planning & Analysis (PE)	3.0	1.4	1.5	1.5	1.5	1.6	1.6	1.6
Total Funding	3.0	1.4	1.5	1.5	1.5	1.6	1.6	1.6
Direct Operating Personnel	14	6	7	7	7	7	7	7
Other DOE Organizations								
Nat'l Energy Information System (TA)	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Bonneville Power Administration	3.0	1.8	1.9	2.0	2.1	2.2	2.3	2.4
Total Funding	3.0	1.9	2.1	2.2	2.3	2.4	2.5	2.6
Direct Personnel	14	8	9	9	10	10	10	10
Other DOE Sites								
Total Funding	20.3	30.1	21.0	20.0	20.5	21.0	21.5	22.0
Direct Personnel	94	128	101	94	93	93	92	92
Total DOE Programs								
Operating	328.0	404.4	405.8	426.4	465.4	495.1	506.4	515.1
Capital Equipment	25.9	23.5	26.1	28.2	29.7	38.6	38.1	38.7
General Purpose Equipment-GPE	2.0	1.5	1.9	3.1	1.7	1.8	1.8	1.9
General Plant Projects-GPP	6.0	6.3	4.5	7.5	7.5	7.5	7.5	7.5
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.0
Program Line Items	28.5	32.0	40.0	50.0	35.1	0.0	0.0	0.0
MEL-FS ^(c) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0
Total Funding	399.9	475.8	483.8	523.9	550.3	561.1	575.6	569.2

	Fiscal Year								
<u> </u>	1993	1994	1995	1996	1997	1998	1999	2000	
Total DOE Programs (Contd)									
Direct Personnel									
Operating	1543	1724	1739	1782	1904	1983	1974	1952	
Capital	33	31	29	36	36	48	47	46	
General Plant Projects (GPP)	9	9	6	9	9	9	9	8	
Landlord Line Items	8	7	4	6	7	14	18	7	
Program Line Items	39	42	52	63	43	0	0	0	
MEL-FS ^(c) Construction	5	4	4	5	7	8	7	0	
Total Direct Personnel	1637	1817	1834	1901	2006	2062	2055	2013	
Work for Others									
Nuclear Regulatory Commission				•					
Operating	16.6	14.8	16.5	17.5	18.3	19.3	20.2	21.2	
Direct Personnel	74	64	69	71	72	74	75	76	
Department of Defense									
Operating	51.0	50.0	50.0	51.0	52.0	53.0	54.0	55.0	
Direct Personnel	226	215	209	207	206	203	201	199	
Environmental Protection Agency									
Operating	1.8	3.3	2.5	2.5	2.5	3.0	2.5	2.5	
Direct Personnel	8	14	10	10	10	11	9	9	
NASA and Other Federal Agencies									
Operating	8.9	6.8	7.0	7.0	7.0	7.0	7.0	7.0	
Direct Personnel	40	29	29	28	28	27	26	25	
Other - Non Federal Agencies									
Operating	0.0	0.4	0.6	1.0	1.0	1.0	1.0	1.0	
Direct Personnel	0	2	3	4	4	4	4	4	
Total Work for Others									
Operating	78.3	75.3	76.6	79.0	80.8	83.3	84.7	86.7	
Direct Personnel	348	324	320	320	320	319	315	313	

Resources by Major DOE Areas (contd)

(Budget Authorization \$ in Millions)(a)

	Fiscal Year								
•	1993	1994	1995	1996	1997	1998	1999	2000	
Total Laboratory Funding									
Operating	406.3	479.7	482.4	505.4	546.2	578.4	591.1	601.8	
Direct Personnel	1891	2048	2059	2102	2224	2302	2289	2265	
Capital	25.9	23.5	26.1	28.2	29.7	38.6	38.1	38.7	
Direct Personnel	33	31	29	36	36	48	47	46	
General Purpose Equipment-GPE	2.0	1.5	1.9	3.1	1.7	1.8	1.8	1.9	
General Plant Projects-GPP	6.0	6.3	4.5	7.5	7.5	7.5	7.5	7.5	
Direct Personnel	9	9	6	9	9	9	9	8	
Landlord Line Items	6.0	5.2	2.5	4.5	5.5	11.7	15.9	6.0	
Direct Personnel	8	7	4	6	7	14	18	7	
Program Line Items	28.5	32.0	40.0	50.0	35.1	0.0	0.0	0.0	
Direct Personnel	39	42	52	63	43	0	0	0	
MEL-FS ^(c) Construction	3.5	2.9	3.0	4.2	5.4	6.4	5.9	0.0	
Direct Personnel	5	4	4	5	7	8	7	0	
Indirect Personnel	1712	1769	1725	1685	1675	1700	1700	1700	
Total Funding	478.2	551.1	560.4	602.9	631.1	644.4	660.3	655.9	
Total Personnel	3697	3910	3879	3906	4001	4081	4070	4026	

⁽a) Budget authorization escalated through FY 2000.(b) Negative balances result from deobligation of prior year uncosted funds.(c) 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 Contracts utilizing the subcontracting process in acquiring equipment, materials,

supplies and services. The table below reflects actual subcontracted amounts for FY 1993 and FY 1994 and projections for FY 1995 and FY 1996.

Small and Disadvantaged Business Procurement

The Laboratory is committed to support the socioeconomic objectives of

the DOE and has established procedures and programs that ensure meeting those objectives. PNL received the Secretary of Energy's FY 1992 award for achievement in meeting and exceeding the Laboratory's small business goals. All subcontracting plan goals for FY 1993 and FY 1994 were met.

Subcontracting and Procurement Table

(Dollar Amounts in Millions)

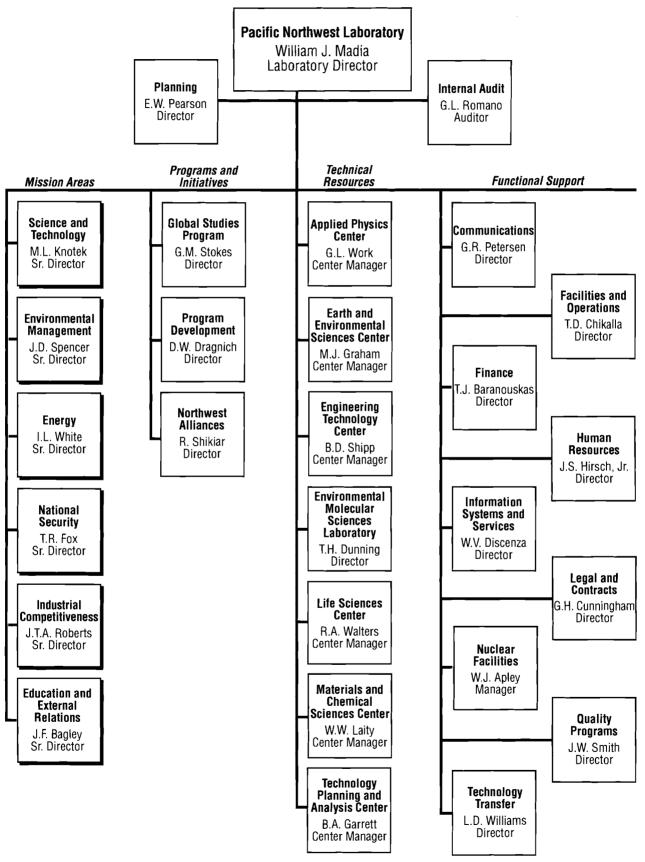
	Fiscal Year						
	1993	1994	1995	1996			
Obligated	179.0	210.0	215.0	215.0			
Subcontracting and Procurement from:							
Universities	5.2	6.0	6.5	6.5			
All Others	164.8	195.0	198.5	198.5			
Other DOE	9.0	9.0	10.0	10			
Total External Subcontracts and Procurements	179.0	210.0	215.0	215.0			

Small and Disadvantaged Business Procurement Table

(Dollar Amounts in Millions)

	Fiscal Year					
	19	93	1994			
Procurement from Small Business	110.3	61.6%	132.5	63.1%		
Procurement from Disadvantaged Businesses	12.4	6.9%	21.2	10.7%		

Organization Chart of the Pacific Northwest Laboratory





Acronyms and Abbreviations

ACE Achieving the Competitive Edge
ACL Analytical Chemistry Laboratory
ACP Atmospheric Chemistry Program
ACTI Advanced Computational Initiative

AEDOT Advanced Energy Design and Operation Technologies

AICD Advanced Industrial Concepts Division

AISES American Indian Science and Engineering Society

AMTEX American Textile Industry

American National Standards Institute **ANSI** Application Programming Interface API Atmospheric Radiation Measurement **ARM** ARRC Advanced Recycling and Research Complex Atmospheric Studies in Complex Terrain ASCOT American Society of Mechanical Engineers **ASME** Advanced Technology Development ATD **ATPO** Applied Technology Program Office Atomic Vapor Laser Isotope Separation **AVLIS**

AWU-NW Associated Western Universities Inc., Northwest Division

BES Office of Basic Energy Sciences
BESP Building Energy Standards Program

BMI Battelle Memorial Institute
BPA Bonneville Power Administration

BSP Building Systems Program

CAMP Capital Asset Management Process
CART Cloud and Radiation Testbed
CATS Corrective Action Tracking System

CE capillary electrophoresis

CEDR Comprehensive Epidemiologic Data Resource

CERCLA Comprehensive Environmental Response, Compensation, and Liability Act

CFC chlorofluorocarbon

CFD computational fluid dynamics

CHAMMP Computer Hardware, Advanced Mathematics and Model Physics
CIETP Chemical Industry Environmental Technology Partnership

CINDY Code for Internal Dosimetry
CLC capillary liquid chromatography
COE Cooperative Office Education

CP/MAS cross polarization/magic-angle spinning COCOM Allied Nations' Coordinating Committee

CRADA Cooperative Research and Development Agreement
CSEPP Chemical Stockpile Emergency Preparedness Program

CVD chemical vapor deposition CZE capillary zone electrophoresis

DAMA Demand Activated Manufacturing Architecture

DAP Diversity Advisor Program

DHHS Department of Health and Human Services

DNA deoxyribonucleic acid DOD U.S. Department of Defense DOE U.S. Department of Energy

DOE-CE Office of Conservation and Renewable Energy

DO-IT Disabilities, Opportunities, Internetworking and Technology

EBR-II Experimental Breeder Reactor-II

EE Energy Efficiency and Renewable Energy EFRA Electronic Forms, Routing, and Authorization

EM Office of Environmental Management

EMSL Environmental Molecular Sciences Laboratory

EPA U.S. Environmental Protection Agency

EPAct Energy Policy Act

EPIC Energy Pollution Prevention Information Clearing House

EPR electron paramagnetic resonance
EPRI Electric Power Research Institute
ER Office of Energy Research

ER-LTT Office of Energy Research - Laboratory Technology Transfer Program

ESAP Economics and Systems Analysis Program

ES&H Environment, Safety and Health ESD Environmental Sciences Division

ESEECAP Environmental Science and Engineering Education Coordination and Assistance Project

ESI-MS electrospray ionization mass spectrometry

ESNET Energy Sciences NETwork

ESP Efficient Separations and Processing ESRC Environmental Science Research Center

EXERSUG Executive Committee of Energy Research Supercomputer Users Group

FCCSET Federal Coordinating Council on Science, Engineering and Technology

FDDI fiber digital data interface

FE Fossil Energy

FEDS Federal Energy Decision Screening

FEOSH Federal Employee Occupational Safety and Health

FEMA Federal Emergency Management Agency

FEMIS Federal Emergency Management Information System

FEMP Federal Energy Management Program
FFCA Federal Facility Compliance Act
FFTF Fast Flux Test Facility

FLC Federal Laboratory Consortium
FRI Federal Relighting Initiative

FTE full-time equivalent

FTICR Fourier transform ion cyclotron resonance

FT-ICRMS Fourier transform ion cyclotron resonance mass spectrometry

FY fiscal year

FWP Field Work Proposal

GCAM Global Change Assessment Model

GChM Global Chemistry Model GCMs general circulation models GEC Global Environmental Change

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
HEDR Hanford Environmental Dose Reconstruction
HEHF Hanford Environmental Health Foundation
HEIS Hanford Environmental Information System

HEPA high-efficiency particulate air

HESEC Hanford Environmental Science and Engineering Consortium

HSRCM Hanford Site Radiological Control Manual

HTDS Hanford Thyroid Disease Study

HTIP Hanford Technology Integration Program

HUD Department of Housing and Urban Development

HVAC heating, ventilation, and air-conditioning

IAEA International Atomic Energy Agency

IARC International Agency for Research on Cancer

IBS Integrated Baseline System
ICP Innovative Concepts Program
ICR ion cyclotron resonance

IDM Information Distribution Manager

IEEA Industrial Energy and Environmental Analysis
IEEE Institute of Electrical and Electronics Engineers

IEM Integrated Environmental Monitoring

IEMIS Integrated Emergency Management Information System

IGEX International Germanium Experiment IGBP International Geosphere Biosphere Program

IIS Inquiry into Science

INEL Idaho National Engineering Laboratory
IPCC Intergovernmental Panel on Climate Change

IRM International Research Monitoring

ITER International Thermonuclear Experimental Reactor

IWRP Industrial Waste Reduction Program

LAMPF Los Alamos Meson Physics Facility

LAN Local Area Network

LANL Los Alamos National Laboratory
LBL Lawrence Berkeley Laboratory

LET linear-energy-transfer

LDRD Laboratory Directed Research and Development
LLNL Lawrence Livermore National Laboratory

LLW Low-level radioactive waste

MAP Manufactured Housing Acquisition Program

MEL-FS Multiprogram Energy Laboratories-Facilities Support
MEPAS Multimedia Environmental Pollutant Assessment System
MESA Mathematics, Engineering and Science Achievement

MESHA Manager ES&H Awareness
MIMD multiple instruction, multiple data
MMFM Macro Material Flow Modeling
MOU Memoranda of Understanding
MSCF Molecular Science Computing Faci

MSCF Molecular Science Computing Facility
MTS Medical Technologies and Systems

NAS National Academy of Sciences

NASA National Aeronautics and Space Administration

NE DOE Office of Nuclear Energy NEC National Electrical Code

NEPA National Environmental Policy Act

NEPP National Energy Policy Plan

NERSC National Energy Research Supercomputing Center NFPA National Fire Protection Association

NIEHS National Institute of Environmental Health Sciences

NIH National Institutes of Health NMR nuclear magnetic resonance

NMSS Office of Nuclear Material Safety and Safeguards
NN Office of Nonproliferation and National Security
NOBChE National Organization of Black Chemical Engineers

NOESY Nuclear Overhauser Effect Spectrometer

NPAR Nuclear Plant Aging Research NRA National Radiobiology Archives NRC Nuclear Regulatory Commission

NREL National Renewable Energy Laboratory

NRR Nuclear Reactor Regulation

NSBE National Society for Black Engineers

OGCM ocean general circulation models
OIT Office of Industrial Technologies

OHER Office of Health and Environmental Research ONSPS Office of Nuclear Safety Policy and Standards

OPA Office of Planning and Assessment

ORISE Oak Ridge Institute for Science and Education

ORNL Oak Ridge National Laboratory

OSHA Occupational Safety and Health Administration

OSHWPP Occupational Safety and Health Worker Protection Pilot

OTD Office of Technology Development

OTFA Office of Technical and Financial Assistance
OTT Office of Transportation Technologies

P2 Pollution Prevention

PASS PNL Affiliate Staff Scientist

PC personal computer PCB polychlorinated biphenyl

PETE Partnership in Environmental Technology Education

PG&E Pacific Gas and Electric PML polymer multilayer

PNL Pacific Northwest Laboratory
PST Petroleum Sludge Treatment
PVD physical vapor deposition

RAAS Remedial Action Assessment System

RadCon Radiological Control

RBE relative biological effectiveness

RCRA Resource Conservation and Recovery Act

REX Radiation EXposure System

RI/FS remedial investigation/feasibility study

RMW Radioactive Mixed Waste

RLWS Radioactive Liquid Waste System RPIS2 Real Property Inventory System

RTDS Rapid Thermal Decomposition of precursors in Solution RW Office of Civilian Radioactive Waste Management

SARA Superfund Amendment and Reauthorization Act
SCIE Scientific Computing Information Exchange
SDEP Staff Diversity Enhancement Program
SERS Science and Engineering Research Semester
SHIMS Safety and Health Information Management
SHPE Society of Hispanic Professional Engineers

SII States Inventors Initiative

SISR Surface/Interface Structure Reactions
SLAC Stanford Linear Accelerator Laboratory
SMES superconducting magnetic energy storage

SNL Sandia National Laboratory SQL Standard Query Language

SRP-UDP Standard Review Plan Update and Development Program

SSP Subsurface Science Program
SWE Society of Women Engineers
SWTS Solid Waste Technology Support

TCD Tank Characterization Database

TCP/IP Transmission Control Protocol/Internet Protocol

TES thermal energy storage

TOF time of flight

TOGA-COARE Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment

TPA Tri-Party Agreement

TPAC Technology, Planning, and Analysis Center

TRAC Teacher Research Associates

TReC Textile Resource Conservation Project
TRP Technology Research Partnership
TVA Tennessee Valley Authority

TWINS Tank Waste Information Network System

TWRS Tank Waste Remediation System

USCAR U.S. Council for Automotive Research

USEC U.S. Enrichment Corporation

USIJI U.S. Initiative on Joint Implementation

VOC-Arid Volatile Organic Compounds in Arid Soils

VPP Voluntary Protection Program

WDOE Washington Department of Ecology
WFO work for other federal agencies
WGD Waste Generation Database
WHC Westinghouse Hanford Company

WM Waste Operations and Technology Program WSU-TC Washington State University at Tri-Cities

XAS x-ray absorption spectroscopy