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OAK RIDGE NATIONAL LABORATORY

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The Oak Ridge National Laboratory Since January 1, 1996: A Progress Report

Office of Planning and Special Projects

April 1998

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL-27 (3-95)

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The Oak Ridge National Laboratory Since January 1, 1996: A Progress Report

Office of Planning and Special Projects

April 1998

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6285
managed by
Lockheed Martin Energy Research Corporation
for the
U.S. Department of Energy
under contract DE-AC05-96OR22464

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FOREWORD

In January 1996, the Oak Ridge National Laboratory (ORNL) was presented with a unique opportunity. The Department of Energy established a new contract for ORNL's management and operation with Lockheed Martin Energy Research Corporation, placing ORNL on an equal footing with the Department's other multiprogram laboratories and setting in motion a process for establishing a new management arrangement for ORNL—an arrangement that supports the performance of research and development (R&D) in the most cost-effective and efficient manner possible consistent with the environment in which ORNL does business.

This progress report describes our efforts to take good advantage of this opportunity.

- In carrying out our primary task—the conduct of R&D in support of Department of Energy missions and other national needs—we have been effective in advancing the frontiers in key areas of science while providing innovative technological solutions to important problems. In addition to applying our resources to long-range, large-scale problems, we share them with other national laboratories, other research institutions, schools and universities, and industry.
- We are also pursuing initiatives that will enable ORNL to play a leading role in three increasingly important scientific fields: the use of neutrons to study the properties of materials; the exploration of the structure, organization, and function of genetic material; and the linking of powerful computers across high-performance networks to solve challenging scientific and technical problems.
- We are implementing new ways to carry out our work safely and protect the health of our workers and the environment in which we operate. The prime operational imperative of ORNL is the health and safety of all its employees, guest scientists and engineers, visitors, and the general public.
- We are working to improve our efficiency and cost-effectiveness through a Laboratory-wide reengineering effort that was initiated in March 1996 and is focused on critical areas for reduction of costs and improvement of business practices. This effort is effective and is beginning to pay off with new systems, tools, and practices that provide our staff members with better ways to do their jobs.

Continuing success in all of these tasks—delivering science and technology, securing new capabilities, and improving our ability to operate safely and efficiently at reasonable cost—is essential if ORNL is to survive and prosper in the complex and rapidly changing environment in which we must compete. This is a challenging assignment, but it is one that we are well equipped to handle, as demonstrated by our progress during the last two years. Many challenges remain, and we will continue to support and work in partnership with the Department of Energy in managing and operating ORNL as a leading R&D institution.

Alvin W. Trivelpiece
Director, Oak Ridge National Laboratory,
and President, Lockheed Martin Energy Research Corporation
April 1998

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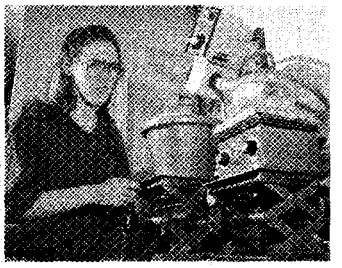

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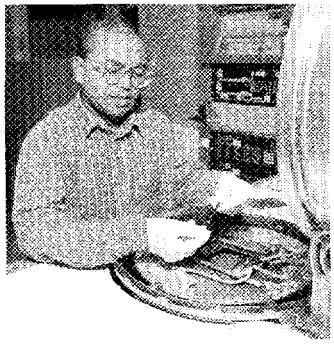

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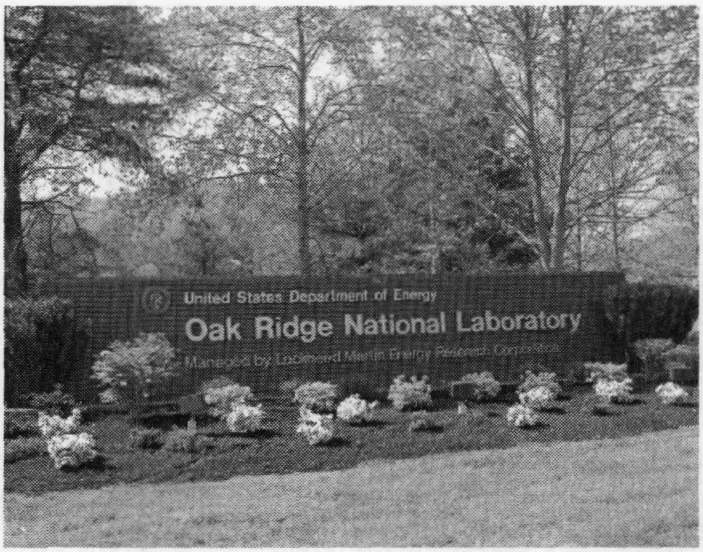
Purpose of this Report

This progress report describes events that have taken place at the Oak Ridge National Laboratory (ORNL) since January 1, 1996, when Lockheed Martin Energy Research Corporation (LMER) became the Laboratory's management and operating (M&O) contractor.

- Section 1 summarizes the circumstances under which the M&O contract was transferred to LMER and the expectations for ORNL that were established at the time of this transfer.
- Section 2 describes ORNL's efforts during the past two years to meet the expectation that it will deliver cost-effective scientific and technological performance to the Department of Energy and the nation. This section presents a sampler of ORNL's scientific and technical accomplishments and discusses efforts to acquire, sustain, and expand the resources that the Laboratory needs to conduct high-quality research and development (R&D) and to increase the availability of its capabilities and facilities to the nation and the world.
- Section 3 focuses on the functions that support the operation of ORNL as a science and technology laboratory. This section discusses the status of activities undertaken since January 1996 to improve ORNL's ability to operate in a safe and environmentally responsible manner, manage its business functions so as to provide the maximum return on the taxpayers' investment, foster communication and trust among stakeholders, and be a good neighbor in the community.
- Section 4 presents areas in which ORNL must take action to ensure its ability to survive and prosper in the complex and rapidly changing environment in which it operates. This section describes near-term actions, some of which are already under way, and continuing challenges that will require significant effort in the years to come.

This report is not intended to provide a comprehensive description of the Laboratory's R&D activities and operations, nor does it constitute a rigorous "self-assessment." Its purpose is to supply ORNL staff members with a common perspective on the overall state of the Laboratory, a summary of key events that have occurred since January 1, 1996, and a general understanding of activities that are being undertaken to continuously improve performance while sustaining ORNL as a leading R&D institution.

INTRODUCTION



On January 1, 1996, Lockheed Martin Energy Research Corporation (LMER) was assigned the responsibility for management and operation of the Oak Ridge National Laboratory (ORNL) under a cost-plus-fixed-fee contract with the Department of Energy (DOE). This arrangement was established at the request of Dr. Martha Krebs, director of DOE's Office of Energy Research (DOE-ER), who has the responsibility for management oversight of ORNL. Before this time, ORNL was managed under a cost-plus-award-fee contract between DOE and Lockheed Martin Energy Systems, Inc. (LMES), which also managed other DOE facilities and programs in Oak Ridge, Tennessee; Piketon, Ohio; and Paducah, Kentucky.

Lockheed Martin Corporation, the parent company of both LMER and LMES, created LMER in December 1995 to provide for the independence and creativity needed by ORNL's scientists and engineers. Under the previous contract, ORNL was not free to establish the management structure most suitable for operating a national laboratory. The present arrangement was established to improve ORNL's ability to deliver the scientific knowledge and technological solutions that are its principal products in a better, faster, and more cost-effective manner.

The contract between DOE and LMER establishes the formal expectations for LMER's management and operation of ORNL. Additional expectations have been articulated by Dr. Krebs, speaking for DOE-ER; by Dr. Al Narath, president and chief operating officer of Lockheed Martin Corporation's Energy and Environment Sector when LMER was created; and by Dr. Al Trivelpiece, president of LMER and director of ORNL.

LMER and DOE's Oak Ridge Operations Office (DOE-ORO) have also worked together to establish performance-based metrics that focus on the issues and goals of most importance to ORNL and DOE. These efforts are guided by a set of partnering principles that outline how business will be done. The current metrics are collected as "Critical Outcomes, Objectives, and Performance Indicators" and provide a "road map" for LMER and an objective basis for DOE-ORO reviews of LMER's long-term performance.

These expectations span a wide range of areas. Foremost among them is that under LMER's management, ORNL will deliver cost-effective scientific and technological performance to DOE and the nation. Expectations in the areas of scientific integrity, intellectual resources, research facilities, partnerships, and communication of the value of ORNL's work are explicitly linked to improving the Laboratory's ability to secure sponsorship for its programs, to conduct high-quality research and development (R&D), and to increase the availability of its unique capabilities and facilities to the nation and the world.

Other expectations address the functions that enable ORNL to deliver science and technology: its operation in a safe and environmentally responsible manner, the cost-effective management of its business functions so as to provide the maximum return on

The Oak Ridge National Laboratory (ORNL) is a multiprogram science and technology laboratory managed for the U.S. Department of Energy (DOE) by Lockheed Martin Energy Research Corporation. Located in Oak Ridge, Tennessee, ORNL carries out research and development in support of the major missions of DOE: science and technology, energy resources, environmental quality, and national security. ORNL is a primary performer of DOE-sponsored research and development in basic energy sciences, energy efficiency, environmental science and technology, nuclear physics, and biological sciences. It also performs other work for DOE, including isotope production, information management, and technical program direction, and provides research and technical assistance to other sponsors when such work is consistent with its DOE-sponsored programs. To carry out these assignments, ORNL currently employs a staff of about 5,000 people and has an annual budget of approximately $500 million.

INTRODUCTION

ORNL-ORO Partnering Principles

- *DOE oversight will move from "prescription and permission" management to performance evaluation.*
- *DOE will not duplicate oversight responsibility that resides in other agencies.*
- *The intent of oversight will be to assess contractor management systems, commensurate with the risk to DOE.*
- *The DOE/Laboratory complex will institute outcome-based management assessment and apply best management practices and commonly accepted industry standards.*
- *Laboratory contractors have full responsibility and accountability for all of their administrative, programmatic, and regulatory functions.*
- *DOE's role is scientific program definition, stewardship, planning and funding of Laboratory programs and infrastructure, and performance review.*
- *Consolidate management activities by eliminating redundancy and integrating functions to achieve cost effectiveness.*

—James C. Hall, Manager, Oak Ridge Operations Office, U.S. Department of Energy, and Alvin W. Trivelpiece, Director, Oak Ridge National Laboratory, January 11, 1996

the taxpayers' investment in the Laboratory, its actions to communicate and build trust with the public, and its role as a good neighbor in the community.

The underlying intent of these expectations is to equip ORNL to prosper in a rapidly changing world. The circumstances in which the Laboratory finds itself are considerably different from those in which it operated even ten years ago. Following the end of the Cold War, which provided much of the justification for federal investment in R&D over the last 50 years, the role of the national laboratories was called into question. The ensuing and continuing debate on the appropriate role of government in R&D also reflects an intense focus on reducing the federal budget deficit and federal spending of all kinds.

At the same time, there is a growing realization that science and technology are essential to economic growth and improvements in the quality of life. In addition, dramatic increases in energy demands throughout the world and concerns about how human actions may be affecting the environment are triggering calls for R&D to address these issues.

In this complex and changing environment, the role of ORNL, and of the national laboratories in general, is evolving and will continue to evolve. The formation of LMER was aimed in part at providing the freedom and flexibility that ORNL must have in order to anticipate and address changing needs and priorities.

Thus, a key step in LMER's formation was a comprehensive review of ORNL's processes for getting work done. This review revealed that some activities were not optimized for performance in a research environment and that many of the practices common to best-in-class performers had not been implemented at ORNL. Soon after the new contract was established, the Laboratory's senior managers chartered a large-scale effort to reengineer major support processes at ORNL. This reengineering effort, which will continue into fiscal year 1999, is aimed at increasing ORNL's effectiveness in executing its mission assignments and serving its customers.

This progress report reviews ORNL's status in terms of the expectations established when LMER was assigned to manage and operate the Laboratory. It describes steps taken with the aim of improving ORNL's ability to carry out its mission assignments, to operate safely and efficiently, and to function as a leading research institution.

In its primary role, the performance of DOE-sponsored R&D, ORNL has been highly successful under the DOE-LMER contract established in January 1996. As discussed in Sect. 3, improvements have been made in many operational support areas; in others, much remains to be done. Actions to address continuing challenges are planned or, in many cases, already under way, as described in Sect. 4. An expanding and improved partnership with DOE will be a critical part of ORNL's path forward.

ORNL Operational Imperatives

- Conduct all operations with due regard for the health and safety of all employees, guest scientists and engineers, visitors, and the general public.
- Conduct all operations in a safe and environmentally responsible manner.
- Adhere to the highest professional and ethical standards in all activities.
- Support the execution of research and development missions with efficient, cost-effective business practices and support services.
- Acquire and sustain the intellectual and physical resources needed to explore challenging scientific and technical problems and provide innovative solutions.
- Collaborate with universities, industries, other Department of Energy laboratories, other federal agencies, and state and regional organizations to create new opportunities.
- Communicate the value of ORNL's research and development activities to a broad audience.
- Respect the value of other people's time.

2 Delivering Science and Technology

The Oak Ridge National Laboratory (ORNL) is in the knowledge business. It is engaged in "bringing science to life" through the creation of new knowledge, the invention of new tools and techniques, the analysis of complex situations involving science and technology, and the design, construction, and operation of research facilities used by scientists and engineers from around the world.

Because ORNL is a Department of Energy (DOE) national laboratory, its efforts are focused on delivering scientific understanding and technological innovations that contribute to the success of DOE's missions and to the nation's science base. In addition to supporting DOE's missions, ORNL undertakes work for other sponsors and supports a small number of innovative research and development (R&D) ideas through its Laboratory Directed R&D (LDRD) Program. ORNL's ability to carry out these tasks rests on its intellectual and physical resources and on a deep commitment to scientific integrity.

By working in partnership with other institutions, ORNL is leveraging its resources, transferring knowledge and technology to the private sector, and providing educational opportunities for the next generation of scientists and engineers. ORNL also "brings science to life" by communicating the value of its R&D to its neighbors, its sponsors, and the taxpayers whose support is essential to sustaining ORNL's capabilities.

2.1 Scientific and Technical Accomplishments

During the past two years, ORNL has produced a variety of high-quality, leading-edge scientific and technical accomplishments. It has also selected a few major initiatives through which it is exploring new directions in key areas of science. By linking basic and applied research and by fostering collaborations that cross disciplinary, organizational, and institutional boundaries, ORNL has leveraged its resources and created value for its sponsors, both within and beyond DOE. Its LDRD program has produced a number of innovations with high potential for advancing the frontiers of science and technology and attracting new funding to the Laboratory. ORNL's accomplishments are "bringing science to life" through their impact on national needs and concerns and have been recognized with significant numbers of honors and awards. The Laboratory's performance has received high marks from its customers.

These achievements were realized during a challenging period for science and technology in general and for the national laboratories in particular. The national investment in R&D declined by 5% in constant dollars between 1994 and 1997, in part as the result of efforts to reduce the federal budget deficit. Legislative attempts to restructure or abolish DOE and to close one or more national laboratories have created high levels of concern and uncertainty throughout the national laboratory system. ORNL has faced the additional challenge of maintaining and enhancing its R&D productivity during the transition to a new contractual arrangement that places clear responsibility and accountability for the Laboratory's future on its managers and staff members.

In sustaining the flow of major scientific breakthroughs, useful new technologies and data, and ideas for new directions in science and technology during this challenging period, ORNL has convincingly demonstrated its strengths as an R&D institution. Continuing improvements in its effectiveness, arising from the actions taken as part of the transition, should pave the way for similar advances.

2.1.1 Programmatic Accomplishments

ORNL is engaged in basic and applied R&D that supports DOE in addressing its major missions: supporting U.S. leadership in science and technology, fostering a secure and reliable energy system, restoring and protecting the environment, and contributing to national security. Basic research provides new insights into the nature of the physical

world. These insights are the foundation for technological innovations, which in turn give rise to economic and social benefits. DOE-sponsored basic science at ORNL spans a variety of disciplines and contributes to the enhancement of the scientific knowledge base, sustaining U.S. leadership in key areas. Applied research and technology development address specific issues but often lead to new knowledge and innovations that can be extended to solve problems beyond the original field of investigation.

Providing Leadership in Science and Technology

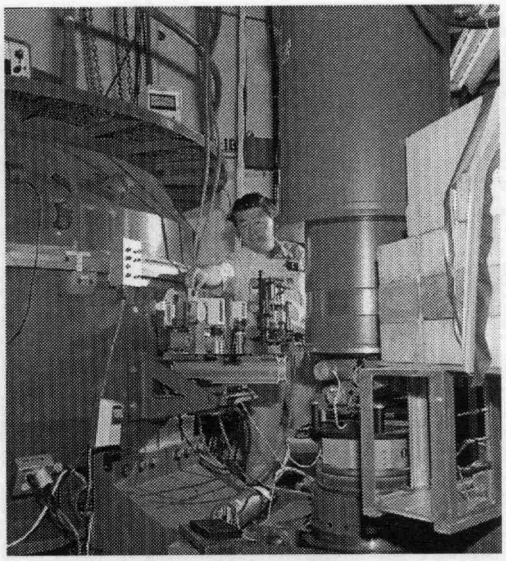
Physical and neutron sciences

ORNL's broad technical foundations in the physical sciences support programs for studying the fundamental properties of matter at the atomic, nuclear, and subnuclear levels and for developing and operating experimental devices in support of these studies.

Determining neutron capture rates for stellar models. Microscopic grains of silicon carbide (SiC) found inside some meteorites may be "fossil" flecks of dust containing elements that were synthesized inside stars on the asymptotic giant branch (AGB), the final evolutionary stage of most stars. If this hypothesis is correct, then the study of this "fossilized stardust" could lead to new insights into the inner workings of AGB stars, the origin of the chemical elements, and the formation of the solar system. High-quality neutron capture reaction rates are crucial ingredients in the stellar model used to describe the origin of the SiC grains. ORNL researchers are using the Oak Ridge Electron Linear Accelerator (ORELA) to determine the rates for certain key reactions at the low temperatures required by the newest, most successful stellar models. Initial experiments (on isotopes of neodymium) showed that the stellar model was in precise agreement with the meteoric SiC data. More recent measurements (on isotopes of barium) have revealed a substantial discrepancy between the stellar model and the isotopic pattern of barium inside the meteoric grains. Experiments on other elements are under way at ORELA with the aim of obtaining a better understanding of the origin of this presolar stardust.

Exploring the quantum world. Studies of the growth of thin films of silver on gallium arsenide, used in semiconductors, revealed that a critical or "magic" thickness of silver is needed to ensure the formation of an atomically flat overlayer. ORNL researchers found a way to explain this phenomenon by invoking the quantum nature of the conduction electrons within an ultrathin metallic overlayer. Because the fabrication of heterostructures with atomically smooth interfaces has tremendous technical significance, work is under way to exploit this "electronic" growth mechanism in metallic heterostructures and to examine how quantum size effects alter the physical properties of the structures. An integrated experimental and theoretical effort in quantum engineering of metallic thin-film growth will quantify the electronic growth mechanism and explore the electronic and magnetic properties of quantum-confined systems of metal/semiconductor and metal/metal multilayers, placing ORNL in a leadership position in a field that is at the forefront of fundamental and applied science.

Understanding nuclear structure. In support of the Laboratory's nuclear astrophysics research, ORNL researchers have developed a new computational technique for solving the interacting nuclear shell model. Conventional numerical methods effectively limit solving this model to light nuclei ($A < 20$ nucleons), because the numerical effort increases tremendously with the mass of the nucleus. The new method recasts the shell-model problem in terms of a path integral over auxiliary fields. As a result, numerical effort is dramatically reduced and the model can be solved for heavier nuclei ($A > 50$). The new technique has been applied to calculations of electron capture rates in the isotopes of iron. ORNL researchers found large differences between their calculations and earlier, highly truncated calculations. Accurate calculation of these



Y. Tsunoda from Waseda University in Tokeyo adjusts a triple-axis spectrometer equipped with a cryomagnet at the HFIR.

rates is important because they are key inputs for understanding the evolution of supernovas.

Discovering new effects in materials. A new discipline, solid-state surface chemistry, is evolving from studies of crystal surfaces conducted using a scanning tunneling microscope. These studies revealed that electrons at the surface form their own structure, called a charge density wave. This effect, which occurred as the crystal surface was cooled, had been seen inside bulk material but never at the surface of a crystal. This work, conducted in collaboration with the University of Tennessee, has given rise to speculation about the possibility of manufacturing surfaces and interfaces tailored for desirable electronic and magnetic properties.

Exploring superconductivity. Neutron scattering experiments at ORNL's High Flux Isotope Reactor (HFIR) are shedding new light on a particular class of superconducting material (yttrium–barium–copper oxide, or YBCO) and casting doubt on previously held ideas. Previous experiments using techniques such as light scattering and photoemission indicated that signs of superconductivity appeared at much higher temperatures than the actual superconducting transition temperature. ORNL researchers have used neutrons from the HFIR to examine high-quality YBCO crystals provided by the University of Washington. They found no evidence of superconductivity above the actual transition temperature.

Using neutron scattering to improve the environment. ORNL's experience in the use of small-angle neutron scattering is supporting the development of environmentally friendly methods for synthesizing plastics. Analytical information from small-angle neutron scattering experiments conducted at the HFIR was used to characterize a number of different micelles (clusters of surfactant molecules) and determine their effectiveness in suspending different monomers in supercritical carbon dioxide to enable the formation of polymers. The ORNL–University of North Carolina team that conducted this work received a Presidential Green Chemistry Challenge Award for its innovative use of carbon dioxide in the polymerization process.

The discoveries of tomorrow will be made possible by the scientists of today, and by our continued commitment to their passionate quest.

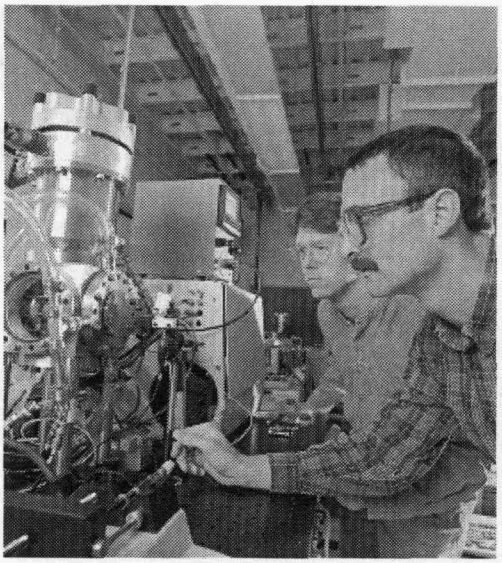
—President Bill Clinton, December 16, 1997

Chemical science

ORNL's expertise in chemistry and chemical processing reflects the fact that chemical transformations and conversions are fundamental to many modes of energy production and storage. The Laboratory's broad capabilities support the investigation of a diversity of issues in health, energy, and the environment.

Examining molecular structure with mass spectrometry. ORNL researchers are making major advances in applying mass spectrometry to large biomolecules, such as proteins and DNA fragments. These advances are based on new techniques for transferring these fragile molecules from biological media into the gas phase as charged ions for mass spectral analysis. Ongoing research is revealing new information on the application of both of the key complementary techniques for doing this: electrospray ionization and matrix-assisted laser-desorption ionization. In addition, new trapped-ion

techniques allow the gas-phase ions not only to be detected but also to undergo selective chemical reactions with other neutral species or other ions, resulting in much better structural information based on chemical reactivity and chemical fragmentation.



Scott McLuckey adjusts an electrospray ion trap mass spectrometer as Jim Stephenson observes.

Treating nuclear wastes. Basic research is contributing to the development of processes for treating high-level nuclear wastes, which are stored in tanks across the DOE complex. ORNL is bridging the gap from fundamental studies on the molecular recognition of specific metal ions by binding agents, or ligands, to applied research on designing and developing solvent extraction processes for treating these wastes. Understanding, at the molecular level, how a given ligand chooses among metal ions has allowed the synthesis of new tailored extractants and combinations of extractants that offer significant promise for concentrating modest amounts of radioactive materials while rejecting massive amounts of innocuous materials, such as sodium and nitrate. Understanding the basis of factors such as solubility, thermodynamics, and chemical stability has made it possible to tailor the ligand design to incorporate the structural features needed for process and cost efficiency.

Exploring new pathways for photosynthesis. The Laboratory's photosynthesis research builds on the 1995 discovery by ORNL scientists that photosynthesis can occur with just one light reaction, rather than two. In addition to challenging the established two-reaction model, this discovery triggered intense interest because of its implications for increasing the maximum efficiency of thermodynamic conversion of light energy into chemical energy, potentially leading to greater productivity in plants used as food or fuel. Recent work implies a doubling of the maximum thermodynamic conversion efficiency and demonstrates the sustained photoevolution of hydrogen and oxygen in mutant algae.

Materials science

ORNL's strengths in advanced materials R&D support the development of ceramics and composites, metals and alloys, surfaces and thin films, polymers, superconductors, and new techniques for materials processing and characterization. Its work in understanding, predicting, and designing materials makes possible the development of materials with specific and well-defined properties.

Cutting the cost of integrated circuits. ORNL researchers have developed a process for economically synthesizing a silicon-on-insulator (SOI) material targeted to replace bulk silicon in manufacturing integrated circuits because it is easier and faster to fabricate such circuits on SOI. Industry analysts estimate that the replacement will result in cost savings of $4 billion over the next 8 years. Until now, however, the high cost of synthesizing SOI has discouraged its use. The ORNL process involves a modification of an existing process that uses oxygen-ion implantation to form the buried insulator of the SOI material. The modification makes it possible to form the SOI material with a much thinner insulating layer, significantly reducing its cost. Researchers expect this cost reduction to accelerate the use of SOI, giving the United States a competitive edge in

Linda Horton explains ORNL's materials research to Senators Bill Frist of Tennessee and Pete Domenici of New Mexico (R).

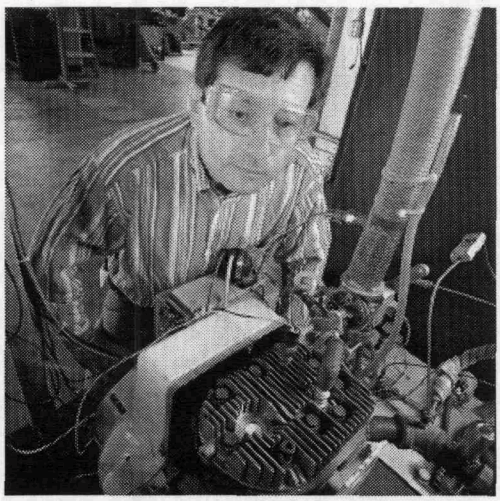
continuing the historic rate of increase in circuit integration.

Making lighter parts for automobiles. A process called metal compression forming, developed by ORNL and Thompson Aluminum Casting Company of Cleveland, Ohio, makes it possible to produce pore-free cast aluminum alloy components with properties comparable to those of forged parts at about one-third their cost. The process will allow the use of cast aluminum alloy parts in safety-critical structural applications requiring high tensile strength and ductility and high fatigue strength, particularly for automotive applications. Cast aluminum alloy components weigh about half as much as similar steel, cast iron, or ductile iron components, so the weight of safety-critical automotive components (e.g., engine mount brackets, steering knuckles, and control arms) can be reduced without sacrificing strength. The metal compression forming process received a 1997 R&D 100 award.

Developing new alloys for high-temperature applications. The success of ORNL's intermetallics R&D programs was confirmed in a recent evaluation by the National Materials Advisory Board of the National Research Council. This evaluation recognizes the contributions of both the research and the program management to the commercialization of ORNL-developed alloys, such as the nickel aluminides that can be used in devices operating at 1200°C. Current research directions include efforts to develop ultrahigh-temperature intermetallic silicides that can operate at 1500°C for applications such as advanced turbine blades, heat exchangers, pressurized gas turbines, energy conversion plants, and high-temperature glass-molding devices.

Engineering science

ORNL's activities in engineering science involve the application of fundamental aspects of chemical, mathematical, and physical sciences to the development of practical solutions for engineering problems.



Stuart Daw experiments with an engine to produce data for "noisy chaos" engine models.

Using chaos theory to improve process efficiency. A new approach to applying chaos theory in practical situations is expected to lead to improved understanding, monitoring, and control of many key energy-related processes, especially those involving combustion. Potential benefits include higher fuel efficiency, reduced emissions, reduced cost of electricity, and a more competitive position for U.S. manufacturers of boilers, automobiles, and gas turbines in the world market. This approach, called "noisy chaos," is based on the recognition that most complex physical systems reflect many coupled processes occurring at different

scales of space and time. In spite of this complexity, the most important processes can often be described with simple deterministic nonlinear models that are stochastically perturbed through their parameters or boundary conditions. Such perturbations are dynamic in the sense that they operate through, rather than just being superimposed on, the nonlinear determinism. Model predictions account for both deterministic and stochastic features seen in real measurements.

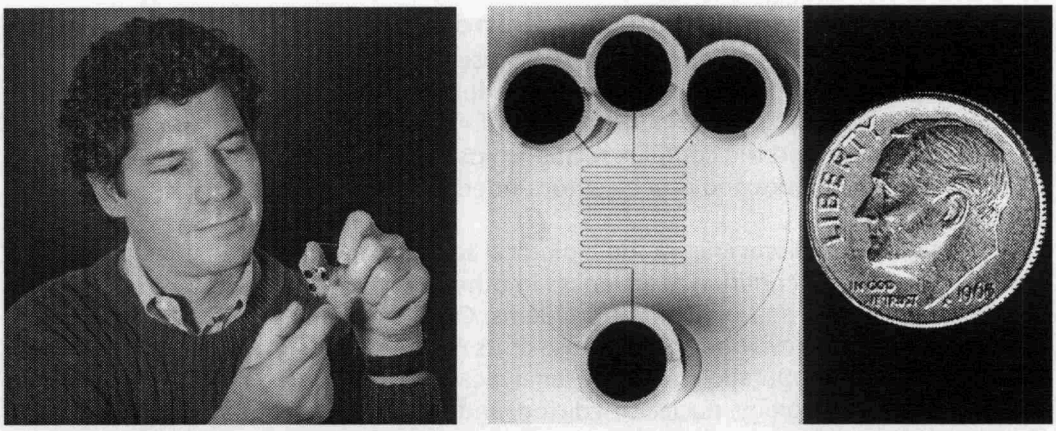
Preventing explosions in metal casting. ORNL researchers have developed and applied a technique for preventing metal-water explosions (also called steam explosions) in the casting of aluminum and other metals. These explosions cause many serious injuries and fatalities every year, along with millions of dollars in damages (a steam explosion can easily destroy a large building). They are also a significant concern in certain types of postulated nuclear reactor accidents. Despite their severity, there has been virtually no understanding of what triggers an explosion, in part because such explosions destroy the equipment conventionally used to study the triggering phenomenon. The ORNL technique creates an environment in which triggering can be closely instrumented and studied without the danger of an actual explosion. This approach, which has been in use for only a few months, is already producing insight into the physics of steam explosions.

Instrumentation and measurement sciences

ORNL develops a variety of measurement, monitoring, and control systems, drawing on strengths in microelectronics and photonics, signal processing and simulation, analytical chemistry and chemical physics, materials characterization, robotics, engineering, and sensors for physical, chemical, biological, and radiological phenomena. Laboratory researchers integrate these capabilities to design and implement new instruments and methods for obtaining, processing, and analyzing information.

Analyzing automobile engine performance. ORNL researchers have developed a diagnostic technique that could make it easier and less expensive to detect failed or malfunctioning fuel injectors in an internal combustion engine. Because the engines in virtually all of today's automobiles are equipped with fuel injectors that periodically require cleaning or replacement, this technique could lead to consumer savings. The method involves electrical signature analysis, a technique that enables technicians to look at voltage and current waveforms supplying the electrically actuated fuel injector solenoid coil. The current and voltage are affected by the power required to move the injector core and by the position and velocity of the core. These effects are embedded in the electrical signature, and changes in the signature from "good" to "bad" conditions can be detected and displayed.

Laboratory-on-a-chip. ORNL researchers have developed a "laboratory-on-a-chip," a microfabricated device that performs chemical and biochemical procedures under computer control using minuscule quantities of samples and reagents. Using this integration of concepts from microfluidics, analytical chromatography, and micromachining, both chemical reactions and chemical separations traditionally carried out on a macroscopic scale can be performed. The chip offers a number of advantages: it uses much smaller amounts of materials than conventional methods; it requires less labor, since it is computer controlled; and it works fast, performing a DNA analysis, for example, in 5 minutes instead of the hour required by conventional analytical techniques. Several high-technology startup companies have the chip as their focus, and investments of $100 million to $200 million over the next 3 years are expected. Potential uses include rapid medical screening, DNA fingerprinting, environmental monitoring, and identification of drug candidates for pharmaceutical research.



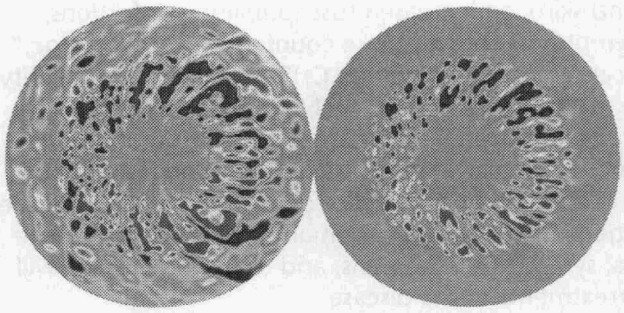
ORNL researcher Mike Ramsey and his colleagues have produced a "laboratory-on-a-chip" with applications in genetic screening, DNA fingerprinting, and drug research.

Fusion energy sciences

The goal in magnetic fusion energy research is to contain the charged particles that make up an ionized gas, or plasma, long enough and at high enough temperatures for fusion reactions to take place. Because a major cause of heat loss from the plasma is turbulence, both experimental and theoretical efforts focus on reducing this phenomenon.

Improving the performance of fusion devices. In experiments on the DIII-D tokamak, a fusion device in San Diego, an ORNL-led team of researchers showed that turbulence can be almost eliminated by properly controlling the temperature, density, and current profiles in the plasma. Application of their conclusions led to record performance in DIII-D. Theoretical models developed at ORNL show that these results can be explained by spontaneously driven shear flows in the plasma, which break up the eddies in the turbulence.

Understanding plasma turbulence. ORNL researchers have deepened the understanding of turbulent transport processes in fusion plasmas by applying the concepts of self-organized criticality. This approach presents possible explanations for some of the transport behavior observed in a wide variety of fusion experiments. The turbulent eddies that induce most plasma transport are very localized in space. However, they can cause correlated transport across long distances, in the same way that avalanches in a sand pile can move sand particles from the center to the edges of the pile. This model resolves some of the mystery underlying these transport phenomena, improves the understanding of the empirical transport scaling laws, and suggests new techniques for improving and controlling performance in fusion experiments, thereby advancing the quest to develop fusion as an energy source for the future.



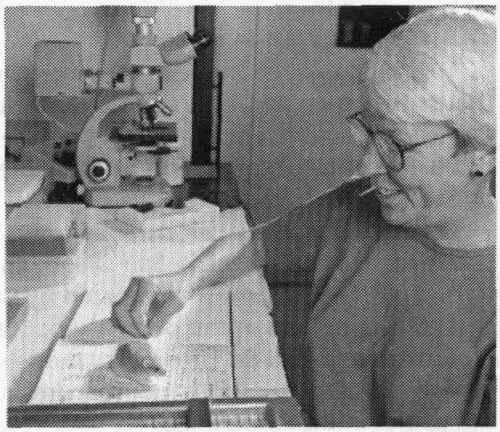
Fully developed turbulence (L) at the plasma edge in the DIII-D tokamak amplifies shear flows in the plasma, which, in turn, suppress the turbulence (R).

Biological sciences and biomedicine

ORNL has been engaged in biomedical research since the early days of the Manhattan Project. Researchers today develop fundamental biological information and explore the health and environmental effects of energy-related agents and processes, working to understand the complex relationships between genetics and health and to develop new techniques and processes for understanding and characterizing biological processes.

Breakthrough discoveries in the biological sciences are occurring at a rapid rate and are expected to continue as advances in other disciplines are leveraged to address significant biological and biomedical problems. ORNL is uniquely positioned to contribute to these developments because of its multidisciplinary strengths in biology, information and computational science, analytical methodologies, biochemistry and biophysics, biotechnology, nuclear medicine, and toxicology and health risk analysis. The integration of biomedical R&D and related efforts affords opportunities to form project teams that are centered in biology but link expertise in several fields.

Studying mice to improve human health. The genetic similarity of mice and humans is used to good advantage by researchers in ORNL's Laboratory for Comparative and Functional Genomics, which houses a unique collection of mice with pedigrees dating back to the 1940s.



Dabney Johnson examines a mouse that carries a single-gene obesity mutation.

Agouti, a gene known to regulate coat color in mammals, may also play a physiological role in the development of obesity in humans. Consistent with its role in the pigmentation of fur, the mouse agouti gene product is primarily found in the skin. The human version of the agouti protein, however, appears in fat tissue and has been shown to regulate lipid metabolism in cultured fat cells. ORNL researchers found that an excess supply of insulin in combination with the presence of agouti in fat cells triggers weight gain in transgenic mice. This result suggests that human agouti expressed in fat cells may play an important role in fat cell metabolism and obesity in humans.

Human Chediak-Higashi syndrome (CHS), a disorder that causes clinical symptoms such as partial albinism (light hair and skin), an increased susceptibility to infections, and a predisposition to malignant lymphoma, has a mouse counterpart called "beige," and beige mice have the same clinical symptoms as human CHS patients. This similarity in diseases, along with comparative mapping studies, led ORNL researchers and collaborators at the University of Utah and Millennium Pharmaceuticals to hunt down the mouse gene in the hopes of using it to discover the cause of the human disease. This team of researchers succeeded in identifying the disease gene in mice and used the mouse gene to identify the human gene. Identifying the human gene made it possible to determine the cause of the clinical symptoms in humans, and the mouse model will be used to examine more effective treatments of the disease.

Developing new instruments for detecting and diagnosing disease. During the last two years, ORNL biologists have worked with physicists and chemists in an interdisciplinary physical biosciences program to produce new instruments for greatly improved measurements of biological molecules and processes. These interactions represent a new paradigm for advancing the "century of biology." The new instruments

are providing new methods for detecting and sequencing DNA samples. A variety of sensitive and specific biosensors and body function sensors have been developed.

- Detecting DNA fragments in an infectious pathogen is a first step in disease diagnosis and drug development. ORNL scientists have developed a new type of DNA gene probe based on surface-enhanced Raman scattering. This SERGen technology can rapidly and simply detect DNA biotargets (e.g., bacteria or viral DNA fragments) without radioactive labels. It should be useful for diagnosing certain types of cancer and other diseases; for monitoring human exposure to infectious agents such as the human immunodeficiency virus (HIV) or hepatitis; for screening blood supplies for the presence of pathogens or vaccines for contaminants; and for cancer research. It also has applications in forensics, agriculture, and environmental bioremediation.
- ORNL's "DNA biochip" incorporates bioreceptor probes, other techniques for optical detection, and an electro-optic integrated circuit system on a single chip to provide rapid and inexpensive analysis of blood samples. The DNA biochip requires much less blood than conventional techniques, and it uses no radioactive substances, so it does not depend on materials with a short shelf life (this characteristic also eliminates a potential source of health effects on persons who handle samples and reduces disposal costs). ORNL researchers have shown that the concept works on a synthetic HIV, a synthetic tuberculosis virus, and certain cancer genes. The DNA biochip should be available to physicians in about three years. It is also expected to have environmental applications.

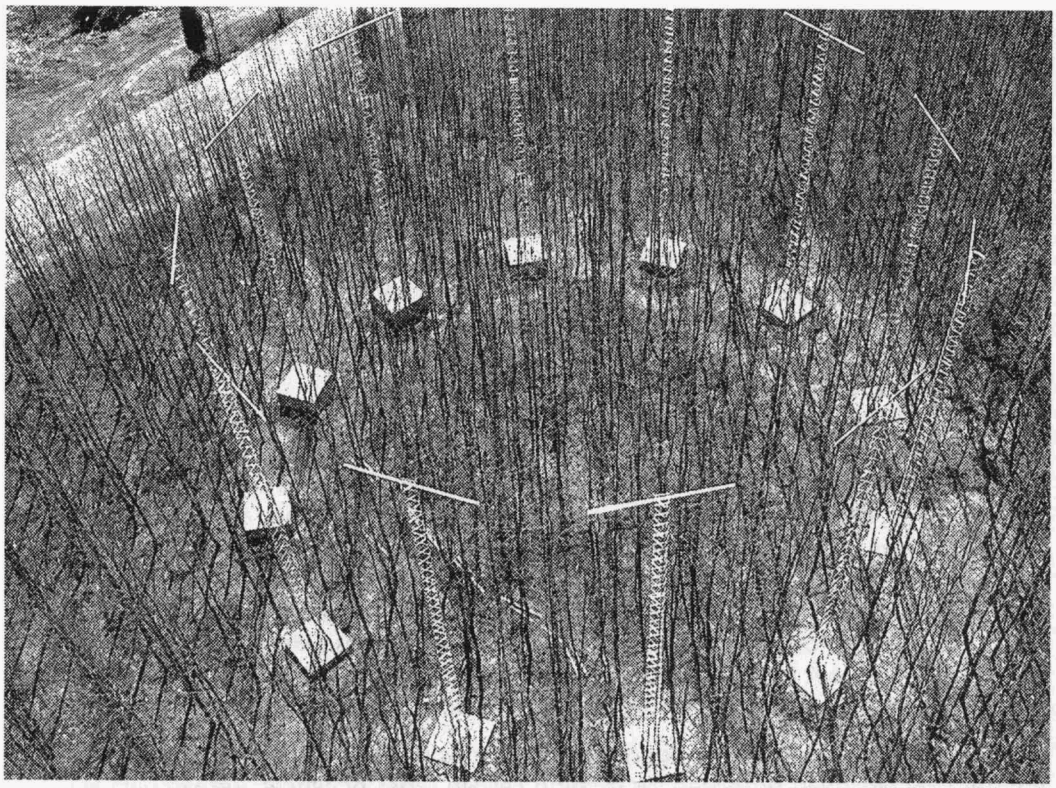
Separating therapeutic agents from surplus nuclear materials. The alpha emitter ^{213}Bi has been proposed for treating certain types of cancer. Researchers at ORNL have developed methods for recovery and purification of ^{229}Th from ^{233}U and for generating ^{213}Bi from ^{229}Th. This work takes advantage of ORNL's expertise in nuclear medicine and its role as a national repository for surplus ^{233}U. In collaboration with the National Institutes of Health, researchers developed methods for attaching ^{213}Bi to monoclonal antibodies (MAbs) and demonstrated that the MAbs with ^{213}Bi were effective in selectively destroying tumor cells in mice. In addition, ^{213}Bi has promise as a leukemia treatment. Clinical trials are being conducted at the Memorial Sloane-Kettering Cancer Center in New York, with encouraging preliminary results.

If God has a golden book and writes down what it is that Oak Ridge National Laboratory did that had the biggest influence on science, I would guess that it was the production and distribution of radioisotopes.
—Dr. Alvin M. Weinberg, Director Emeritus, ORNL

Environmental science

ORNL's environmental science research covers biogeochemistry, environmental biotechnology, global environmental chemistry, ecosystem studies, geosciences, hydrology, and environmental assessment.

Discovering new organisms. Bacteria that thrive at high temperatures (45–75°C) in geologic formations far below the earth's surface were discovered by researchers from ORNL and other institutions through DOE's Subsurface Science Program. These unusual microorganisms, recovered from 2.3 km deep in the Taylorsville Basin of Virginia and from Piceance Basin in Colorado, produce 10- to 500-nm crystals of magnetic oxides as a result of iron reduction–based respiration. Besides expanding the knowledge of bioprocesses in the biosphere, these thermophilic microorganisms may improve the understanding of the evolution of respiratory systems or serve as surrogates for early bioprocesses on other planets, such as Mars. Bacterial products such as magnetite could enter the Earth's atmosphere via meteorites, potentially providing biomarkers for life on other planets. These nanoscale magnets may also have biotechnological applications in data storage, energy deflection, medicine, and environmental remediation.



ORNL's free-air CO_2 enrichment system introduces additional CO_2 to a stand of trees to study its effects on their biological processes.

Examining the impacts of climate change. ORNL scientists are conducting large-scale experiments in the Oak Ridge National Environmental Research Park to study the impacts of climate change. A one-of-a-kind experiment manipulates rainfall in a 20,000-m^2 area of deciduous forest. Results suggest that seasonal differences in rainfall have greater impacts on forest productivity than equivalent rainfall increases or decreases distributed evenly over a year. Additional experiments suggest that changes in precipitation in the eastern United States are likely to be less important to the forest than the direct impacts of warming and elevated concentrations of CO_2.

Seeking genetic information in plants. There are no known DNA sequences that control the expression of gender in any plant species. However, if gender-determining genes were known, they would provide a fundamental understanding of the physiological or genetic basis of flower induction that could be used to manipulate floral development for energy production, forestry, or agriculture. As a first step toward this goal, ORNL has identified two DNA markers associated with female willow plants. Willow is an ideal subject because its members contain solely male or solely female plants. A library of willow DNA is being constructed in an effort to use these DNA markers to find genes that control gender.

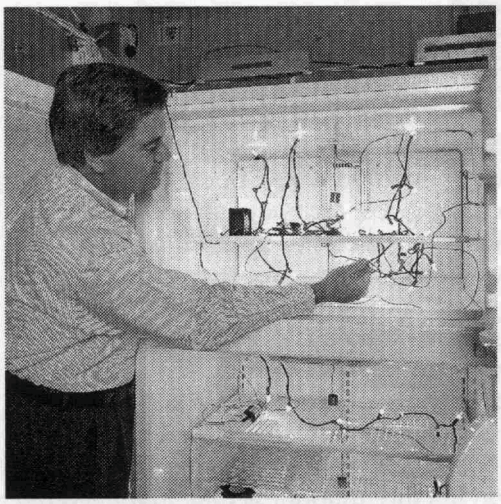
Computational science

High-speed, large-scale computation has become the primary technology enabling advanced research in many areas of science and engineering. For some problems, computer simulations provide the only feasible method of scientific investigation. ORNL's computational sciences program integrates advanced mathematical and computational techniques, data management and analysis methods, software tools, communications technologies, and high-performance computing systems.

Predicting the performance of high-temperature lubricants. Molecular simulation calculations on ORNL's Intel Paragon supercomputers have been used to predict the performance of advanced lubricants designed to stand up to the higher temperatures and engine speeds expected in highly efficient vehicles under development through the Partnership for a New Generation of Vehicles.

Supplying the tools for modeling materials. ORNL researchers have developed a deformation modeling method for predicting the strain hardening and grain orientation changes in metals during forming and shaping operations. Conventional methods lack the ability to model orientation changes, which play a major role in the deformation processing of metals. The new method makes it possible to model the material behavior in greater detail at the microscopic level.

Linking powerful computers to solve difficult problems. Massive computational problems are being addressed by linking the Intel Paragons at ORNL and Sandia National Laboratories. An atmospheric code running on Sandia's computer and an ocean code running on ORNL's computer work together to produce more accurate predictions of climate change than either code can give alone. Research on a high-strength nickel-iron alloy, Invar, a structural material with diverse applications, is combining innovative computational methods and the availability of massively parallel computers to enhance the understanding of metallic magnetism. In addition to solving problems that are too complex for any of the individual computers to handle alone, this collaboration has led the way in establishing systems and procedures for distributed computing.



Eddie Vineyard of ORNL checks instruments in the highly efficient refrigerator.

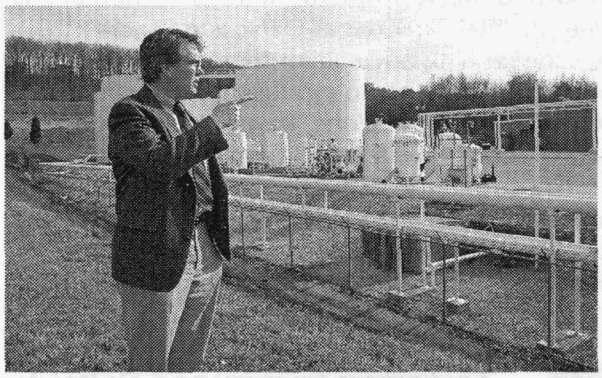
Fostering Secure and Reliable Energy

ORNL conducts extensive R&D on the production, distribution, and use of energy and on the effects of energy technologies and decisions on society. The products of these R&D programs range from new technologies for conserving energy to information that will support rational decisions about energy choices for the future.

Building a more efficient refrigerator. ORNL led an industry/government team in developing a 20-ft^3, top-freezer refrigerator that uses available technology and consumes less energy than a 40-W light bulb. Special features include vacuum insulation around the freezer section, thicker door insulation, a low-wattage condenser fan, a high-efficiency compressor, and adaptive defrost control that senses when the unit needs to be defrosted. The improved unit uses 650 fewer kilowatt-hours per year than vintage models and exceeds the goal of government standards for 2001. It should save the average consumer about $55 in annual operating costs, representing a potential energy cost savings of $6.5 billion annually to consumers and a significant decrease in greenhouse gas emissions through decreased electricity demand (72 MWh per year). A production unit is being designed in cooperation with Frigidaire and is scheduled to be introduced on the market by the year 2000.

Developing new systems for power distribution. ORNL is engaged in a partnership with Waukesha Electric Systems, Intermagnetics General Corporation, and

Rochester Gas & Electric Corporation to demonstrate a single-phase, 1-MVA high-temperature superconducting (HTS) transformer. Such transformers are smaller and lighter than conventional systems and, because they contain no oil, are more environmentally friendly and do not create a fire hazard. A further advantage to electric utilities is the HTS transformer's inherent capability for overcapacity operation. In contrast to standard oil-filled transformers, in which overloads rapidly degrade the electrical insulation system, HTS transformers can operate at twice their rated power for indefinite periods without any loss of operating life. Researchers carried out experiments to establish concepts and obtain experimental design data, developed and tested system components, and designed and built a demonstration transformer.



An ORNL oil market analysis led by David Greene revealed that the United States is vulnerable to an oil price shock.

Predicting the impact of rising oil prices. An ORNL analysis of the outlook for U.S. oil dependence revealed that the United States is increasingly vulnerable to an oil price shock similar to those that occurred in the 1970s and 1980s. The analysis revealed that the Organization of Petroleum Exporting Countries (OPEC) market share is projected to exceed 50% by 2000. With this increase, world oil markets are likely to be as vulnerable to monopoly influence as they were 20 years ago, and the U.S. economy appears to be as exposed as it was in the early 1970s to losses from monopoly oil pricing. A supply reduction in 2005 and 2006 would boost OPEC revenues by roughly half a trillion dollars and cost the U.S. economy an approximately equal amount. While the Strategic Petroleum Reserve appears to be of little benefit in reducing OPEC revenues or in protecting the U.S. economy against such a supply curtailment, increasing the price elasticity of oil demand and supply in the United States and the rest of the world would be an effective strategy.

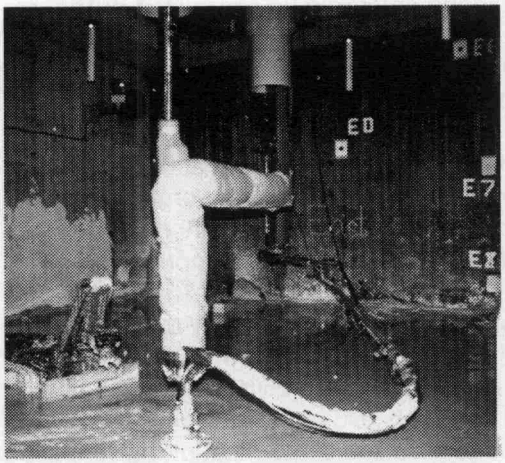
Improving the integrity of nuclear reactor pressure vessels. A new method of conducting fracture toughness tests developed at ORNL produces more accurate assessments of the integrity of the pressure vessels in nuclear reactors, which are prone to develop shallow flaws over time. The traditional approach to evaluating the integrity of pressure vessels containing flaws uses data on fracture toughness that are generated under conditions of uniaxial loading—that is, with stresses in only one direction. Pressure vessels operate in conditions that generate biaxial stress fields. ORNL researchers developed a cruciform test specimen that can generate shallow-flaw fracture toughness data under biaxial loading conditions. It is leading to much better integrity assessments for pressure vessels subjected to a condition known as pressurized thermal shock loading and contributing to improved nuclear reactor safety.

Supporting policy decisions on global climate change. ORNL played a leading role in multilaboratory studies that supplied information for the December 1997 United Nations Framework Conference on Climate Change in Kyoto. An 11-laboratory study co-led by ORNL cataloged technology pathways with significant potential for reducing greenhouse gas emissions. ORNL also co-led a study by five DOE national laboratories, *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond*, that assessed opportunities for reducing greenhouse gas emissions in major sectors of the U.S. economy (buildings, industry, transportation, and electric utilities);

this study's conclusion was that a national investment in energy efficiency and clean energy technologies could reduce U.S. emissions of global warming gases and produce energy savings that roughly equal or exceed the direct technology and program implementation costs. The report was cited by the Secretary of Energy at the October 6, 1997, White House Conference on Climate Change, and it is mentioned in the press package accompanying the Climate Change Proposal announced by the President on October 22, 1997.

Restoring and Protecting the Environment

ORNL develops and implements tools for cleaning up contaminated sites, minimizing the toxicity and volume of waste, managing unavoidable waste efficiently and safely, and safely disposing of waste in accordance with regulatory guidelines.



The remotely operated Radioactive Tank Cleaning System is shown at work in one of ORNL's waste storage tanks.

Cleaning up underground storage tanks

Radioactive wastes are stored in underground tanks at several DOE sites, presenting a major disposal problem. ORNL has been a significant contributor to efforts to dispose of these wastes.

Robotics technology for waste removal. Oak Ridge leads the DOE effort to develop, test, and demonstrate robotics technology for characterizing and remediating underground storage tanks. Tank waste retrieval technologies and modeling tools developed by ORNL, in collaboration with other DOE laboratories and industry partners, are being used in the cleanup of World War II–era waste storage tanks at the Laboratory. These tanks were built in the 1940s and are high on ORNL's list of remediation priorities because of their age and the contaminants they contain. The Radioactive Tank Cleaning System is being used to remove radioactive liquids and sludges from the tanks. Its operation marks the first full-scale use of a remotely operated system in the United States to remove radioactive wastes from underground storage tanks. The system was designed and fabricated by ORNL, Pacific Northwest National Laboratory, SPAR Aerospace, Redzone Robotics, Inc., Water Jet Technology, Inc., and Tennessee Tool and Engineering.

System for removing cesium from tank waste. Treatment and disposal options for wastes in underground storage tanks at several DOE sites are limited by the high gamma radiation fields produced by cesium in the wastes. ORNL has demonstrated a system for removing cesium that is based on an ion exchange material, crystalline silicotitanate (CST), developed in cooperation with private industry. The system offers several advantages over current organic ion exchange technologies: its ability to remove cesium in the presence of high concentrations of potassium, its high affinity for cesium across a range of alkaline and acidic conditions, its stability in chemical and radioactive environments, and its elimination of large volumes of secondary waste required for regeneration of organic ion exchangers. Deploying this technology at the Hanford and Oak Ridge sites should produce significant cost savings. The CST-based ion exchange process also provides DOE's Savannah River Site with a potential alternative to its baseline in-tank precipitation process.

Detecting and removing environmental contamination

Working with the University of Tennessee through the Center for Environmental Biotechnology, ORNL researchers have developed and tested innovative ways of using genetically engineered microorganisms to clean up hazardous waste. These bioluminescent bacteria, *Pseudomonas fluorescens* HK44, consume naphthalene, a common industrial solvent, and emit blue-green light as they do so.

Demonstration of naphthalene removal. The first U.S. field tests of genetically engineered microorganisms to clean up hazardous waste were conducted in 1996 at an ORNL site that had been experimentally contaminated with naphthalene. Because the HK44 bacteria contain genetic elements from three different types of bacteria, the environmental application required regulatory review and approval from the Environmental Protection Agency before the experiment could be conducted outdoors, and the bacteria were confined in steel-lined containers and monitored to keep them from leaking from the experiment site. The microbes remove pollution from the soil much more efficiently than conventional methods such as burning the contaminated soil.

Novel technology for detection of contamination. A novel ORNL technology informally called "critters on a chip" shows how genetically engineered organisms can be combined with microelectronics to detect and report the presence of contaminants. In a recently demonstrated prototype device, HK44 were placed on an optical application-specific integrated circuit (OASIC) chip developed at ORNL. The light emitted by the bacteria in the presence of naphthalene was absorbed by the chip, creating electrical charges that were measured by the OASIC. The prototype device produced a measurable electrical signal when exposed to moth balls, which contain naphthalene. Because the amount of electrical current is related to the concentration of the contaminant, the technology could be used to map soil contamination by sprinkling a suspect area with the tiny chips. Specialized applications could be developed by combining the OASIC chip with bacteria engineered for sensitivity to a specific biological or chemical agent, such as toluene, mercury, or TNT. The chip may also be useful for detecting hydrocarbons that indicate the presence of nearby oil or gas deposits.

Contributing to National Security

Robotics for munitions handling. A robot designed by ORNL researchers is expected to save the U.S. Air Force and Navy about $40 million a year. The Next Generation Munitions Handler, a metal arm-like robot sometimes called the "air arm" because of its Air Force applications, has the strength, speed, and precision needed for safely loading weapons weighing up to 2.5 tons. The robot requires only one person for assistance (compared with three for today's equipment) and incorporates half a dozen novel technologies. It should also have applications in areas such as construction, warehouse and waste management operations, forestry, and mining.

Acoustic signature analysis. Technologies and systems developed by ORNL have been used in acoustic qualification tests for the nation's latest attack-class submarine, the SSN-21 Seawolf. ORNL research staff participated in these tests, which were conducted at sea by the U.S. Navy as part of a series of certification tests for this submarine. ORNL provided expertise in the analysis of acoustic signatures radiated by the submarine and supported and operated the $26 million system that it developed for qualification of the entire submarine fleet.

Nuclear stockpile reduction. Reduction of the number of nuclear weapons in the world is one of President Clinton's main foreign affairs goals. A key program for achieving this goal is the $12 billion purchase from Russia of low-enriched uranium produced by blending weapons-grade highly enriched uranium with natural uranium. An ORNL team was responsible for conceiving of, developing, and implementing a

prototype system for verifying the dilution of weapons-grade uranium; testing the concept; and demonstrating this system to DOE, the Department of State, and representatives of the Russian Ministry of Atomic Energy. This system was written into the verification portion of the treaty as the confirmation measurement method.

Operating National User Facilities

The advanced scientific facilities at ORNL provide unique capabilities not only to ORNL researchers, but also to users from industry, universities, other national laboratories, and other research institutions. In the last two years, four ORNL research facilities have been designated national user facilities: the Californium User Facility for Neutron Science, the Metals Processing Laboratory User Center, the Metrology R&D Laboratory, and the Laboratory for Comparative and Functional Genomics. ORNL now has 16 designated user facilities, more than any other national laboratory. These facilities play an important role in ORNL's creation and delivery of knowledge.

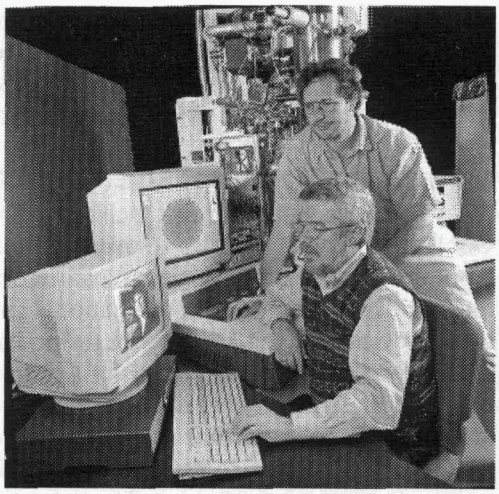
Nuclear structure physics. The Holifield Radioactive Ion Beam Facility (HRIBF) is a unique tool for research in nuclear astrophysics and nuclear structure physics. The HRIBF's first radioactive ion beam experiment, the Coulomb excitation of radioactive 69As, was completed in June 1997. This experiment was conducted by experimenters from Clark University, Yale University, and Brookhaven National Laboratory, who are exploring the structure and dynamical behavior of nuclear matter under extreme conditions.

Storage system for high-performance computing. ORNL is working with Sandia National Laboratories and the Pittsburgh Supercomputing Center to develop the high-performance computing environment needed to address complex scientific problems. This collaboration takes advantage of ORNL's Center for Computational Sciences and its Intel Paragon computers. For many high-performance computing applications, dealing with massive amounts of data is a challenging problem that causes long delays. The High-Performance Storage System (HPSS)—developed by researchers from ORNL, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Sandia National Laboratories, and IBM Global Government Industry—allows users to increase the performance and capacity of storage systems for large-scale computer applications. The HPSS, which was a 1997 R&D 100 award winner, is faster and has more storage capacity than any other storage system, allowing users to efficiently manage huge amounts of data.

Residual strain distribution in aluminum welds. ORNL's High Temperature Materials Laboratory is a collection of six user centers focused on solving materials problems that limit the efficiency and reliability of advanced systems for energy conversion. One of these user centers, the Residual Stress User Center, brings together the Laboratory's materials R&D expertise and neutrons from the HFIR, with support from DOE's Office of Energy Research and Office of Energy Efficiency and Renewable Energy. Researchers from the Edison Welding Institute (EWI) used these capabilities to investigate the residual strain distribution in an aluminum weld. Data from these experiments provided guidance for improving a finite-element method model that predicts distortion and residual stress. Neutron diffraction strain measurements confirmed the qualitative characteristics of the strain distributions predicted by EWI's finite-element calculations.

Virtual facilities. ORNL resources are increasingly available to users beyond the Laboratory through "virtual facilities"—capabilities that facilitate collaboration among geographically separated researchers. Remote operation of a field emission transmission electron microscope was demonstrated to then–Secretary of Energy Hazel O'Leary in March 1996; this and three other ORNL electron microscopes are part of DOE's Materials MicroCharacterization Collaboratory. A medium-resolution double-crystal small-angle spectrometer called DIXIE at the HFIR is the first neutron scattering

instrument with a World Wide Web–based interface for remote control, monitoring, and scientific collaboration. More than 50 groups in the United States are using "Electronic Notebook" software developed at ORNL to share information; users include the Materials MicroCharacterization Collaboratory, the virtual laboratory centered on the DIXIE instrument, and the seamless computing group that is developing software for the high-performance computing centers at Sandia National Laboratories, ORNL, and other sites.



Larry Allard (L) and Edgar Voelkl demonstrate remote operation of an electron microscope.

2.1.2 Initiatives for Science and Technology

ORNL is focusing its Laboratory-level strategic planning on a limited number of science and technology investments, with increased emphasis on programs that make connections between basic science and technology application for public benefit. This emphasis reflects one of the distinctive characteristics of the multiprogram national laboratories: the multidisciplinary style that Dr. Alvin Weinberg, ORNL's director from 1955 to 1972, characterized in terms of "their coherence, their close contact with basic science, their flair for getting after very big and difficult matters." These initiatives build on the Laboratory's capabilities and offer the opportunity for sustaining and extending these capabilities in key areas of science and technology.

Neutron Science Initiative

Neutrons play a vital role in many areas of science and technology. They provide an ideal probe of the structure and dynamics of condensed matter; they are useful in the study of magnetic structure and dynamics; and, because they are highly penetrating, they can be used for nondestructive studies of bulk materials, an application of obvious interest for industry.

ORNL's strengths in neutron-based science and technology include

- designing and operating neutron sources (reactors and accelerators);
- conducting research on the interaction of neutrons with atomic nuclei and all forms of condensed matter, drawing on capabilities in neutron scattering, neutron activation analysis, materials irradiation, and molecular structure determination;
- developing and applying techniques for producing neutron-rich radioisotopes; and
- calculating neutron transport in complex systems.

Facilities at ORNL provide the world's highest thermal neutron flux, the only domestic source of heavy transuranic isotopes, and specialized neutron activation analysis for sensitive measurements of trace elements. Capabilities in this area support fundamental nuclear physics research, studies of material properties, nuclear materials management, development of materials for nuclear fusion and fission, isotope production for industrial and medical applications, and environmental protection.

ORNL is applying its strengths in this area to national needs through modernization of the HFIR to maintain and extend its unique capabilities, through leadership of DOE's Spallation Neutron Source (SNS) project, and through collaboration with the University of Tennessee and the state of Tennessee in

establishing a Joint Institute for Neutron Sciences (see Sect. 2.5.1). This initiative will enable ORNL to continue its pioneering work in neutron scattering, neutron activation analysis, isotope production, and materials development. ORNL has elected to focus part of its LDRD investment in this area, committing a total of $2 million during FY 1998 and FY 1999 to projects aimed at developing instrumentation that will take advantage of the new thermal neutron beam lines at the HFIR and the capabilities of the SNS.

Progress on the HFIR modernization and the SNS project is discussed in Sect. 2.4, "Scientific Facilities."

Functional Genomics Initiative

The Human Genome Project is approaching its goal of analyzing the structure of human DNA and determining the location of the estimated 100,000 human genes. The next phase of this national program will move beyond mapping and sequencing to linking the location and structure of genes to the functions that they control.

ORNL is combining its long-standing expertise in mammalian genetics with its capabilities in structural biology, computational science, robotics, and instrumentation to accelerate the exploration of gene function on a genome-wide basis. Integration of the expertise of molecular biologists, computer scientists, mathematicians, analytical chemists, and engineers should provide highly productive experimental capabilities and technological breakthroughs for research in functional genomics. ORNL has focused part of its LDRD investment in this area; 12 projects, representing about 20% of the Laboratory's LDRD resources, are aimed at developing innovative strategies for functional genomics research.

Efforts to secure a new building for the Laboratory for Comparative and Functional Genomics, an important resource for this initiative, are described in Sect. 4.1.4.

Teraflops Computing Initiative

Computational tools that enable the creation of realistic models of physical situations are vital to most fields of science and engineering. As computing speed and memory capacity increase, new insights into a host of scientific problems are being attained. Computers operating in the trillions of floating point operations (teraflops) range are now a reality. Scientific problems of interest to DOE that will require computational power in the range of 5 to 10 teraflops have been identified, and needs in some areas already extend beyond this range.

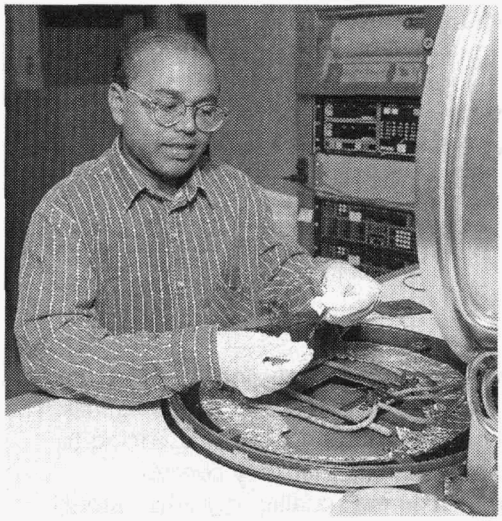
Distributed computing—the linking of several computers, often in different locations—multiplies the power available from any individual system. It also imposes a number of challenging requirements: massively parallel processing computers; "seamless" operation; high-speed, secure networks; software and applications to support user needs; and data storage systems that provide ready access to users.

ORNL is pursuing the development of the multiple-teraflops computing environment needed to address major scientific challenges by working to acquire a new high-performance machine and incorporate it into the Laboratory's collaboration with Sandia National Laboratories on the networking of widely distributed, heterogeneous high-performance computers.

2.1.3 Mechanisms for Effectively Meeting Mission Needs

Integrated R&D

One of ORNL's strengths as an institution is R&D integration. This term covers both the Laboratory's ability to link basic and applied R&D and its facility for collaborating across disciplinary, programmatic, organizational, and institutional



Mariappan Paranthaman shows a nickel substrate that will be coated using electron-beam evaporation to make superconducting wire.

boundaries. Integrated R&D makes it possible for ORNL to leverage its resources and create value for sponsors within and beyond DOE, expediting the transfer of knowledge and technology.

Superconducting wire development. The rolling-assisted, biaxially textured substrates (RABiTS) process developed at ORNL shows great promise for the production of practical high-temperature superconducting wire. This development, co-sponsored by DOE's Office of Energy Research and Office of Energy Efficiency and Renewable Energy, involved a diverse group of physicists, materials scientists, and chemists. Their work ranged from studying the mechanism for current flow in high-temperature superconductors, through the development of a working model for the microstructure of practical polycrystalline wires, to the demonstration of an innovative method for wire production.

Transportation R&D. ORNL's transportation program serves, and is supported by, the Department of Defense, the Department of Transportation, the Environmental Protection Agency, the Department of Commerce, the Bureau of the Census, and several offices within DOE. In a key element of this program, ORNL participates in DOE's Partnership for a New Generation of Vehicles, which is aimed at designing and producing, by 2004, a car with a fuel efficiency of 80 miles per gallon that emits little or no pollution. A diesel engine has been chosen to meet the fuel economy objective, so DOE national laboratories, including ORNL, are working with Detroit Diesel Corporation and other companies to cut NOx emissions in half. ORNL applies its broad analytical capabilities to evaluating new catalysts. Materials scientists at ORNL use electron microscopes to characterize the microstructures of these catalysts (e.g., the spatial distribution of platinum atoms and the movements of rhodium atoms) to better understand their performance. Engineers, chemists, and physicists at ORNL's Advanced Propulsion Technology Center identify and measure the constituents of diesel engine exhaust before and after catalytic aftertreatment. ORNL researchers and their partners from other DOE laboratories and industrial firms received a Presidential Award for technical accomplishment and teaming for lean-burn NOx catalyst research conducted as part of the Partnership for a New Generation of Vehicles.

System of Labs Materials Initiative. ORNL, Sandia National Laboratories, and Idaho National Engineering and Environmental Laboratory are working together on welding science and the direct fabrication of structural components using rapid manufacturing technology. The three-laboratory welding group has demonstrated that, when laser and arc welding are combined, the laser penetrates aluminum alloys better because of the presence of the arc plasma. Laser-arc welding also achieves a desirable speed for melting the material. The welding collaboration, which also involves the Oak Ridge Y-12 Plant, was initially funded through the laboratories' LDRD programs. Early successes led to funding from DOE's Office of Industrial Technologies to develop a process combining laser welding and arc welding for steels for automotive applications. Additional support is being provided by the steel industry.

Innovative R&D

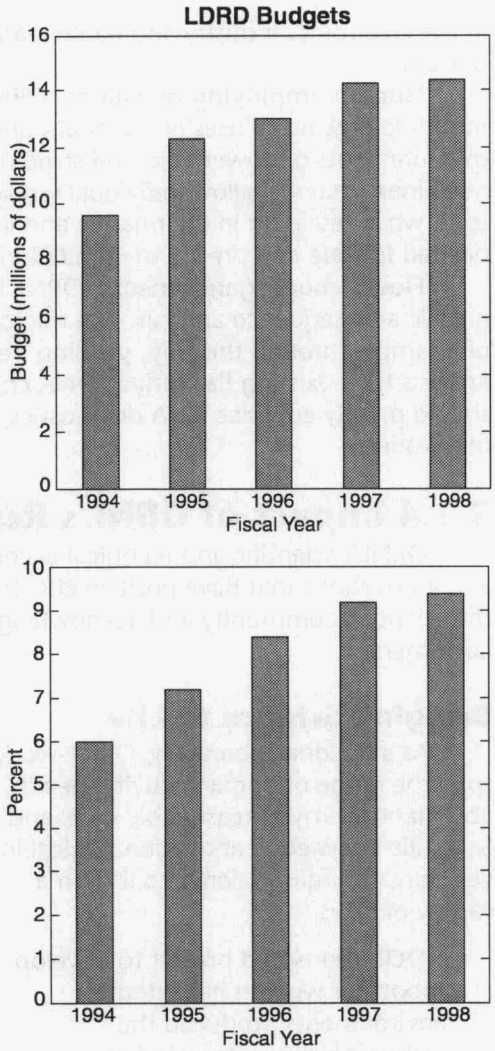
ORNL's LDRD program is a major resource for fostering innovation and creativity. The program's productivity is demonstrated by the inventions, follow-on funding, and awards generated by the projects that it supports.

ORNL has increased its investment in the LDRD program and is strategically focusing its LDRD investments in two areas—functional genomics and neutron science and technology—for maximum effectiveness. The Laboratory has also streamlined its processes for awarding LDRD funds and overseeing LDRD projects.

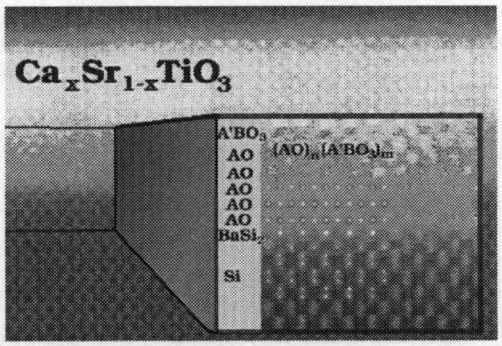
The annual budget for LDRD has grown from $9.6 million in FY 1994 to more than $14 million in FY 1998. This 50% increase has come about even as the Laboratory's overhead budget is being reduced. As a result, LDRD's share of Laboratory overhead has grown from 6% in FY 1994 to 9.4% in FY 1998. This growth is indicative of ORNL's strong commitment to the program.

LDRD annually supports about 120 projects that range from small demonstration efforts (about a month of effort) to multiyear, interdivisional activities involving several scientific and technical staff members. The diversity and innovative nature of the program are reflected in the following descriptions of recent projects.

Silicon-integrated ferroelectrics. In the process of studying the physics associated with length-scale phenomena in ferroelectricity, ORNL researchers discovered a way to grow highly perfect, crystalline oxides on silicon. This new method produces a crystalline silicon/oxide interface with a monolithic, commensurate transition that is free of the amorphous structure found in interfaces made with conventional processes. These crystalline oxides on silicon may bring about the first practical development of a fully integrated transistor memory circuit, a ferroelectric field effect transistor (FFET). A successful FFET device would have wide application



Funding for Laboratory Directed R&D. Top: Total budgets. Bottom: Budgets as a percentage of laboratory overhead.



A new method of growing crystalline oxides on silicon could lead to new types of high-density data storage devices.

in the electronics industry and could lead to new types of high-density data storage devices.

Human-amplifying machines. ORNL researchers are combining a new controls methodology, novel uses of materials, and new microsensors for real-time measurements of power fluid and structural properties to build "human-amplifying machines" that will allow individual workers to lift and handle objects weighing several tons, while retaining in their hands and limbs all the tactile and force perception needed for safe and precise manipulation of the large payloads.

Flowthrough genosensors. ORNL is developing an advanced technology for nucleic acid sequence analysis. The microchannel hybridization wafer enables the flow of a sample through the chip, yielding better speed, sensitivity, and dynamic range of analysis than existing flat-surface DNA chips. The flowthrough genosensor system should greatly enhance DNA diagnostics, gene expression profiling, and environmental monitoring.

2.1.4 Impact of ORNL's R&D

What I mean by missions, laying aside the DOE missions, is the mission of knowledge and what it involves: generating new knowledge, exchanging knowledge—whether you're talking about exchanging it between generations or between people in different parts of our lives, between our neighbors and ourselves, between industry scientists and lab scientists—and, finally, knowledge applied to public benefit.

—Dr. Martha A. Krebs, January 11, 1996

ORNL's scientific and technical accomplishments are translated into knowledge and innovations that have positive effects on the nation and the world, recognized by the scientific community and acknowledged by the Laboratory's sponsors and customers.

Bringing Science to Life

As a national laboratory, ORNL works to meet national needs and concerns that span the range of human activity: health, safety and security, clean air and water, abundant energy at reasonable cost, and better ways of accomplishing daily tasks. Scientific knowledge and technological innovations generated at ORNL in the last two years are "bringing science to life" in a variety of ways:

Robotics technologies developed at ORNL are used in the highly maneuverable TransRovr wheelchair.

- A DOE-sponsored project to develop robots for work in hazardous environments produced the technologies incorporated in a revolutionary wheelchair that turns by simply rotating on its platform base, eliminating the wide turning radius needed for conventional wheelchairs.
- Radioisotopes developed at ORNL provide ways to diagnose heart disease and treat several forms of cancer.
- A security system developed by researchers from ORNL and the Oak Ridge Y-12 Plant provides a fast and efficient means for identifying hidden occupants in vehicles by detecting the tiny motions of a beating heart.
- ORNL is part of a multilaboratory partnership with industry to manufacture chemical feedstocks from corn and other renewable farm crops. The process costs significantly less than conventional petroleum-based methods and eliminates gypsum, an undesirable by-product that must be hauled to landfills. It was a 1997 R&D 100 award winner.

- Nickel aluminide alloys created by ORNL are used for dies and tools, for transfer rollers in steel mills, and for "furnace furniture"—assemblies that hold automobile parts during heat treatment—because of their durability and resistance to wear and deformation. These alloys are licensed to manufacturers; in 1997, commercial sales made by the 11 active licensees exceeded 100 tons.

The breadth of ORNL's R&D programs and its strengths in R&D integration and partnerships are keys to its ability to bridge the gap between ideas and products.

Recognition and Awards

The Laboratory's contributions are also recognized with significant numbers of honors and awards. ORNL leads the national laboratories in R&D 100 awards, with 6 awards in 1996, 9 in 1997, and a total of 94 since the program was established in 1963. In each of the last two years, two ORNL researchers have received Presidential Early Career Awards for Scientists and Engineers, which recognize demonstrated excellence and promise of future success. The Junior Chamber of Commerce Outstanding Young American Award is presented to only ten persons each year; in each of the last two years, one of these awards has gone to an ORNL researcher. The

MAJOR AWARDS TO ORNL RESEARCHERS 1996–1997

Presidential Early Career Awards,
1996 (two winners) and 1997 (two winners)
Presidential Green Chemistry Challenge Award, 1997
American Crystallographic Association Buerger Award, 1997
American Powder Metals Institute Powder Metallurgy Metallography Competition Grand Prize, 1996
American Society for Mass Spectrometry Biemann Medal, 1997
American Welding Society William Irrgang Memorial Award, 1996
Christopher Columbus Fellowship Foundation Award, 1997
Council of the Institute of Materials (London) Elegant Work Prize, 1997
Discover magazine Technology Award, 1996 and 1997
Federal Laboratory Consortium Awards for Excellence in Technology Transfer, 1996 (two winners)
Inventors Clubs of America, Inc., Inventor of the Year, 1996
Inventors Clubs of America, Inc., Hall of Fame Award, 1996 (nine winners)
Junior Chamber of Commerce Outstanding Young American Award, 1996 and 1997
R&D 100 Awards: 1996 (six winning entries) and 1997 (nine winning entries)
Supercomputing '96 Heterogeneous Computing Challenge:
Gold Medal for Concurrency and Silver Medal for Innovation

DOE Awards

Sadi Carnot Award in Energy Conservation, 1996
Young Independent Scientist Awards, 1996 (three winners) and 1997 (two winners)
Office of Biological and Environmental Research Program Recognition Award, 1997 (three winners)
Office of Basic Energy Sciences Materials Sciences Award, 1996 (three winners) and 1997 (one winner)
National Energy Efficiency and Renewable Energy Award, 1996

There are certainly a number of exciting activities under way especially within the Solid State Division. The recruitment of several really good new scientists is a very positive development.... The development of many close interactions with the University of Tennessee over the past three years has exceeded expectations and bodes well for the future of both institutions.... Keep it up!
— DOE Office of Basic Energy Sciences, Division of Materials Sciences, Site Review of the ORNL Solid State Physics and Materials Chemistry Programs, September 1996

Christopher Columbus Fellowship Foundation award, presented to "an individual American whose innovative thinking has led to a creative work, process, product or other discovery that has made a significant and beneficial impact on society," also went to an ORNL researcher in 1997.

Publication in the scientific literature is a major means of disseminating the results of R&D and an important indicator of the health of the research effort. The Laboratory's scientific and technical staff members published 1,149 articles in 1996 and 1,176 in 1997, continuing a trend of modest growth during the past few years (974 articles in 1993; 1,031 in 1994; and 1,048 in 1995). Among these were 7 articles in *Nature*, 12 in *Science*, and more than 70 in *Physical Review Letters*, to name 3 of the most prestigious journals. Examples of ORNL's work have appeared on the covers of about 25 journals during the past 2 years, often accompanying articles that describe leading-edge research; and 6 papers by ORNL authors have been recognized with "Best Paper" awards in fields from intelligent systems to materials research. A large number of ORNL researchers also serve as reviewers, board members, editors, and associate editors of technical journals.

Customer Satisfaction

ORNL's performance in the last two years has received positive comments from DOE and from other sponsors. In 1996 and again in 1997, an ORNL project received the highest rating in DOE reviews of high-temperature superconducting wire technology projects. The ORNL intermetallic alloy development program was favorably reviewed by a topical panel, assembled at DOE's request, from the National Materials Advisory Board. ORNL support to SEMATECH, the manufacturing research consortium of leading U.S. semiconductor companies, was praised in letters from the chief executive officer and from member companies; and SEMATECH elected to locate its Radio Frequency Benchmark Center in Oak Ridge to take advantage of the capabilities available through ORNL and the Oak Ridge Centers for Manufacturing Technology.

Ratings provided by customers of ORNL's Work for Others program average about 4 on a scale of 1 (unsatisfactory) to 5 (excellent). Surveys conducted at ORNL's user facilities, which gauge overall satisfaction with the research and technical assistance provided, also reflect a high level of satisfaction; the average rating during the past two years has been about 4.6 on a scale of 1 (fails to meet requirements) to 5 (among the very best).

In securing knowledge about the world and beyond, scientists rely on the veracity, competency, and credibility of other researchers. And society's confidence in and support for science rests on public trust in the integrity and objectivity of individual researchers and their supporting institutions. To ensure scientific progress and to sustain public support for research, it is incumbent upon scientists and their institutions to maintain the quality and integrity of scientific research.
—Mark S. Frankel, Director, Scientific Freedom, Responsibility, and Law Program, American Association for the Advancement of Science

2.2 Scientific Integrity

In carrying out its R&D, ORNL recognizes the absolute necessity of scientific integrity. The Laboratory is committed to enhancing the awareness of scientific integrity among its staff members and ensuring a quality product for its customers.

This commitment was made visible across Lockheed Martin Corporation when "The Importance of Being Trustworthy," a guest column by ORNL Director and LMER President Al Trivelpiece, was featured in the March 1997 issue of the corporation's employee newsletter, *Lockheed Martin Today*. In response to input from ORNL, the Lockheed Martin glossary of ethics allegations was expanded to include scientific integrity issues.

ORNL distributes the National Academy of Sciences publication *On Being a Scientist—Ensuring Integrity in Research* to all new research staff members and postdoctoral appointees. The Laboratory's Ethics Office also has outreach activities to the community, professional societies, and participants in the Science and Engineering Research Semester for undergraduates. The Ethics Office home page, at [http://www-internal.ornl.gov/ethics/] (accessible only within ORNL), provides employees with direct links to extensive online information on scientific ethics and with information on additional resources.

Guidelines for the conduct of research at ORNL are under development. A procedure for handling allegations of scientific misconduct is being prepared.

ORNL's proactive efforts in this area are unique within Lockheed Martin and have attracted attention from DOE and the Laboratory's other customers.

2.3 Intellectual Resources

Much of ORNL's funding is linked to proposals prepared by principal investigators and submitted to DOE and other sponsors. ORNL depends on its principal investigators to bring in funds and is committed to attracting and supporting staff members who create and deliver excellent science and technology. The Laboratory is only as good and as productive—and in the longer term as strong—as its best R&D staff.

In 1994, more than 400 staff members took advantage of a Special Retirement Incentive Program. Many were senior researchers with considerable stature in the scientific community. As resources have permitted, ORNL has made a concerted effort to rebuild expertise in key programs and to expand its intellectual resources by recruiting "top talent" as positions become available. The departure in 1996 of two staff members associated with the functional genomics initiative was a disappointment; however, the Laboratory has recently hired a senior research scientist in this area and is continuing its search for a new director for the functional genomics program. Several key positions for the Spallation Neutron Source project, including scientific director, have been filled.

New staff members are frequently found among young scientists who come to ORNL to participate in the Laboratory's Postdoctoral Research Associates Program, which is jointly administered by ORNL's Office of University and Science Education and the Oak Ridge Institute for Science and Education. The program was established in 1992 and currently has about 175 participants. A steering committee composed of ORNL scientists, engineers, and managers guides the program.

Another source for attracting the best and brightest young scientific talent to ORNL is the Laboratory's Eugene P. Wigner Postdoctoral Fellowship Program. Many of these "Wigner fellows" accept permanent positions at ORNL and make significant, sustained contributions. During the last two years, ORNL has increased its investment in this program to support seven fellows. In 1997, two former Wigner fellows on ORNL's staff received Presidential Early Career Awards, presented by the U.S. government to outstanding scientists and engineers at the outset of their independent research careers.

ORNL is also an employer member of the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (the GEM Consortium). GEM fellows who work at ORNL represent a pool of highly qualified minority scientists and engineers.

The LMER Corporate Fellows Program recognizes sustained contributions by ORNL staff members. Corporate fellowships are awarded to those individuals whose contributions have been both significant and continually high over a number of years. Their contributions are acknowledged by their peers throughout the world. In 1996, two ORNL staff members were recognized as corporate fellows; in 1997, one researcher was named a senior corporate fellow and two others were named corporate fellows.

The Laboratory also participates in a Distinguished Scientist Program with the University of Tennessee, which attracts internationally prominent scientists to joint posts at the university and ORNL. Twelve appointees currently enrich the local scientific community by conducting excellent research, leading and instructing students, attracting equipment and external funds, and drawing other outstanding scientists to East Tennessee. A separate program supports Visiting Distinguished Scientists from other research institutions.

A special role accepted by the Department of Energy is to provide large-scale leading-edge facilities at the national laboratories for public and private research and development.

—Department of Energy Laboratory Operations Board,* Strategic Laboratory Missions Plan, Phase I, *p. 47, July 1996

2.4 Scientific Facilities

ORNL is enhancing its capabilities for conducting R&D by developing new facilities, by upgrading existing facilities, and by developing innovative ways of making its facilities available to users outside the Laboratory.

2.4.1 Spallation Neutron Source

ORNL leads a collaborative project with Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos national laboratories to design and build the proposed Spallation Neutron Source (SNS), a 1-MW source of neutrons that can be upgraded to 5 MW. The SNS will significantly improve the nation's capabilities for conducting high-quality, innovative research, thus supporting DOE's strategic goal in science and technology.

Vice-President Al Gore visited ORNL to announce the FY 1999 budget request for the SNS.

The extensive collaboration established for the SNS project represents a relatively new approach to designing and constructing a major DOE facility. Although ORNL has responsibility for coordinating the design and construction and will ultimately operate the SNS, the other participating laboratories are totally responsible for designing and constructing the components that they will contribute and integrating these components into the facility. This approach was taken to make use of the best technical expertise and most current technologies available, to support a design and construction process that makes the most efficient use of DOE resources, to incorporate results of previous feasibility studies conducted by the collaborating laboratories, to involve the most active neutron user programs in DOE, and to provide a means for the scientific user community to participate in the planning and ultimate operation of the SNS. This approach also facilitates ORNL's transition at the end of the construction project to a staff that is expert in operating the SNS for the user community instead of one whose expertise is limited to accelerator construction. The SNS collaboration has also established collaborations with the international community that will further leverage the SNS project.

Oak Ridge National Laboratory has been one of the world's leading institutions in science and technology—the key to our nation's prosperity in the past, and our competitiveness in the future. As part of this future, I look forward to the time when the Spallation Neutron Source will begin operations in Oak Ridge, expanding the frontiers of science and materials research.

— Secretary of Energy Federico Peña, Knoxville, Tennessee, May 30, 1997

The conceptual design report for the SNS underwent review and validation by DOE in June 1997. The review committee consisted of about 60 scientists, engineers, and business leaders from the United States and Europe. The SNS Steering Committee and an independent cost estimating team from DOE also attended the review. After performing an in-depth assessment of the technical feasibility, scope, cost, schedule, and management of the SNS, the review team strongly endorsed the SNS project.

A grassroots citizens' organization, Tennesseans for the Spallation Neutron Source, has produced endorsements for the construction of the SNS at ORNL from more than 25 city and county government and labor organizations throughout the state.

The total estimated cost for the SNS is $1.3 billion. For FY 1998, $23 million has been budgeted for preparation of a line item request for SNS in the FY 1999 budget. ORNL has provided DOE with cost and schedule profiles to support a construction line item request for FY 1999, and in January 1998 Vice President Al Gore visited ORNL to announce that the President's budget for FY 1999 would include a $157 million construction line item request for the SNS.

2.4.2 High Flux Isotope Reactor

The HFIR is one of the world's most powerful research reactor facilities. At its current operating power of 85 MW, it has a peak thermal neutron flux of 2.6×10^{15} neutrons per square centimeter per second, highest in the Western world. This gives the HFIR unique capabilities for producing important radioisotopes and providing facilities for materials irradiation, neutron activation analysis, and neutron beam scattering studies. The reactor was originally designed primarily for isotope production. Over time, however, its neutron scattering mssion has grown in scientific and economic importance, providing, for example, much of today's knowledge about the molecular and magnetic structure and behavior of high-temperature superconductors.

The proposed SNS will serve many of the needs of the neutron scattering research community and provide significant improvements over existing beam scattering facilities worldwide for many experiments. However, the HFIR will remain the facility of choice for some classes of scattering experiments requiring steady-state beams and for radioisotope production, materials irradiation, and neutron activation analysis.

Upgrades now under way at HFIR will increase the reactor's power level, modernize its 30-year-old instruments and components, enhance its capabilities, extend its operating life, and maintain or improve the availability of neutrons to researchers.

- A return to the design power level of 100 MW from the 85-MW level in use since 1989 will benefit all activities by increasing the neutron production rate, which is proportional to reactor power, by nearly 20%.
- Modernizing instrumentation and electrical equipment and replacing some components will reduce maintenance downtime, making more operating time, and hence more neutrons, available for all users. ORNL initiated the cost-effective replacement of components of HFIR subsystems, providing support for extending the reactor's operating life by an additional 30 years.
- A cold neutron source now being added to the HFIR will provide capabilities comparable to those of the best cold sources in the world.
- Upgrades to HFIR's thermal neutron guides will result in beams that are two to three times brighter than those at any other facility.
- Funding has been allocated for a Neutron Science Support Building near the HFIR to support the planned changeout of the beryllium reflector and HFIR operations, and plans have been developed for a modular user facility to provide space for HFIR users and the HFIR upgrades team.

With these improvements, the HFIR can continue to operate for 30 years or more and will provide a unique resource for neutron-based science.

ORNL's Chang-Hong Yu inspects the Recoil Mass Spectrometer in the HRIBF.

2.4.3 Holifield Radioactive Ion Beam Facility

ORNL's development of the Holifield Radioactive Ion Beam Facility (HRIBF) represents a creative and cost-effective approach to acquiring unique capabilities. The HRIBF, a major modification of ORNL's former Holifield Heavy Ion Research Facility, is the first isotope separation on-line facility capable of addressing both nuclear structure physics and nuclear astrophysics topics.

These capabilities were secured for a modest investment. Upgrades to the existing 25-MV tandem accelerator and the Oak Ridge Isochronous Cyclotron improved their reliability and maintainability. The Daresbury Recoil Separator was acquired from the Daresbury Laboratory in England, and the Recoil Mass Spectrometer was funded by DOE, ORNL, Oak Ridge Associated Universities, the state of Tennessee, and several universities.

The HRIBF was dedicated in December 1996, and user operations commenced in March 1997, serving an international research community. Highlights since the HRIBF was commissioned include progress on the development of ^{17}F beams, successful experiments on the Recoil Mass Spectrometer, and commissioning of the Daresbury Recoil Separator.

2.4.4 Laboratory for Comparative and Functional Genomics

ORNL's Laboratory for Comparative and Functional Genomics represents a key resource for the major initiative in functional genomics (see Sect. 2.1.2). It was designated a national user facility in June 1997. ORNL is seeking innovative means of providing a new home for this resource, which is currently housed in an aging building at the Oak Ridge Y-12 Plant. This near-term challenge is discussed in Sect. 4.1.4.

2.4.5 Virtual Laboratories and Remote Operations

ORNL is increasing the availability of its resources to users beyond the Laboratory through "virtual facilities"—capabilities that facilitate collaboration among geographically separated researchers, supporting the delivery of leading-edge science and technology at reduced costs.

ORNL is participating in the DOE2000 initiative to develop and explore new computational tools and libraries that advance the concept of "national collaboratories" and advanced computational testing and simulation (ACTS). Activities include the Materials MicroCharacterization Collaboratory; the neutron scattering virtual laboratory based on the DIXIE instrument at the HFIR; the ACTS Scientific Template Library; and the Electronic Logbooks project, which builds on "Electronic Notebook" software developed at ORNL for remote experimentation and collaboration.

2.5 R&D Partnerships

ORNL uses partnerships as a means of conducting collaborative R&D and performing work for non-DOE customers; of transferring technology to industry and assisting in its commercialization; and of supporting the education of the next generation of scientists and engineers. These partnerships provide ways for ORNL to leverage its resources and increase its scientific productivity.

Half our economic growth in the last half-century has come from technological innovation and the science that supports it.... Firms that use advanced technologies are more productive and profitable than those which do not.

—President Bill Clinton, December 16, 1997

They also provide an avenue for directing ORNL's resources toward the regional economy. People and technology from ORNL have contributed to the creation of more than 70 companies that currently employ more than 2,000 people. The formation of 48 of these companies (60% of the total) since 1984 attests to the emphasis on and support of entrepreneurial activities by Lockheed Martin since it became ORNL's management and operating contractor (as Martin Marietta Energy Systems, Inc.).

2.5.1 Support for Collaborative R&D

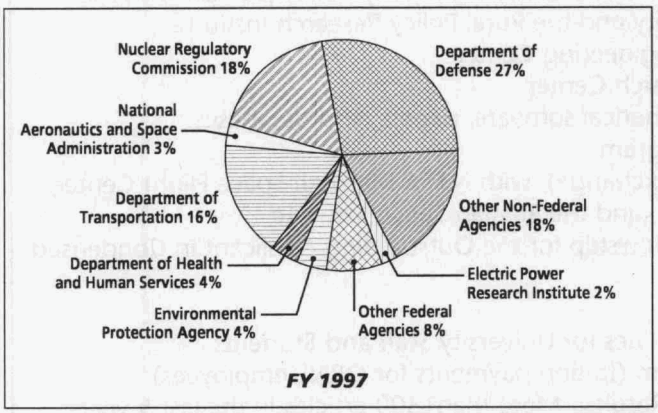
As one of DOE's most diversified research organizations, ORNL believes that it is imperative to provide for its scientists and engineers a climate that is conducive to interaction with their colleagues from industry, academia, and other organizations, on both a national and an international basis. Almost 75% of ORNL's journal publications are co-authored with colleagues from other institutions, up from about 55% ten years ago.

Guest assignments, which range from two weeks to two years, broaden the Laboratory's base of expertise and support its goals in scientific cooperation and technology transfer. The large number of guests effectively doubles the intellectual resources at ORNL. In FY 1997, more than 3,500 guest scientists and engineers came to ORNL, with about 25% from industry. The number of industrial participants dropped 30% from the previous year, primarily because of declining DOE support for cooperative efforts and downsizing at some assigning organizations. On a positive note, the maximum length of short-term consulting agreements has been extended from 10 to 30 days, making these agreements more useful and less expensive to administer.

Although it is formally a national laboratory, ORNL has a strong role as an *international* laboratory. In FY 1997, the Laboratory hosted 983 guest researchers from 74 countries, and 1,846 scientists and engineers from 92 countries visited ORNL. These kinds of partnerships facilitate access to facilities in other nations by U.S. scientists and encourage the globalization of science.

Many of these researchers conduct experiments on ORNL's 16 "national user facilities," which received this designation because of policies that make them accessible to researchers from other institutions. Capabilities for remote operation of some facilities are further broadening access to researchers at other institutions, as described in Sect. 2.4.5.

ORNL is committed to simplifying the procedures for accessing its facilities. The Laboratory has worked with DOE to make the advance payment requirement at its user facilities less burdensome by reducing the requirement from 90 to 30 days. An account containing corporate funds was set up to provide a means for early payment coverage, thus expediting work starts and ensuring that DOE funds would not be used for this purpose. An expedited billing account process was also put in place to speed access to the facilities by outside users. Work is under way to provide a single point of contact for guests and visitors, with the aim of making the Laboratory more user-friendly.



ORNL's Work for Others sponsors.

Access to ORNL's capabilities is also available through Work for Others (WFO), the reimbursable work that ORNL performs for other federal agencies and for other sponsors, including the private sector. In the last two years, ORNL has increased its emphasis on program development for non-DOE customers and expanded the use of offsite assignments to create new opportunities and partnerships. In addition, WFO cycle times have been reduced 30%, and more blanket WFO agreements are now in place. New WFO funding for FY 1997 increased by 36% from FY 1996 levels. Efforts are under way to develop a "paperless" system for processing WFO documents, which should further reduce cycle times.

As the only national laboratory in the southeastern United States, ORNL emphasizes the building of collaborative relationships in this region. The Laboratory's strongest research partner is the University of Tennessee. The two institutions are partners in the Science Alliance, the state's oldest and largest academic Center of Excellence. The Science Alliance sponsors the Distinguished Scientist Program, which provides joint appointments to tenured positions at the University of Tennessee–Knoxville and research positions at ORNL. ORNL and the University also combine their resources through joint institutes and graduate programs.

I cannot imagine having a better partner than ORNL to help us intensify our increased investment in high-technology products and services.
—Pete DeBusk, President and CEO, DeRoyal Industries, Knoxville, Tennessee

I found the facilities to be excellent and well maintained. All of the HTML contacts, including those in the Program Office, were very friendly, helpful, and knowledgeable. I would be pleased to return to ORNL's HTML in the future.
— High Temperature Materials Laboratory user survey response

Our use of your facilities enabled us to do testing which we are not currently able to perform, leading to the immediate purpose of satisfying customer requirements. However, what we learned will help us meet requirements in foreign markets and thus have significant potential for additional sales overseas. We gained valuable information for both current and future needs, and your staff expertise helped immensely.
— Work for Others sponsor survey comment

Interactions between ORNL and the University of Tennessee, Knoxville

Joint Institutes:

- Joint Institute for Biological Sciences
- Joint Institute for Computational Science
- Joint Institute for Energy and Environment, with the Tennessee Valley Authority; home of the National Center for Environmental Decision-Making Research
- Joint Institute for Heavy Ion Research
- Joint Institute for Molecular-Based Engineering and Science
- Joint Institute for Neutron Sciences

Science Alliance, a Tennessee Accomplished Center of Excellence:

- Distinguished Scientist Program (12 participants)
- Collaborating Scientist Program (9 participants)
- Research fellowships for upper-level physics students

University Graduate Programs that Draw on ORNL Resources:

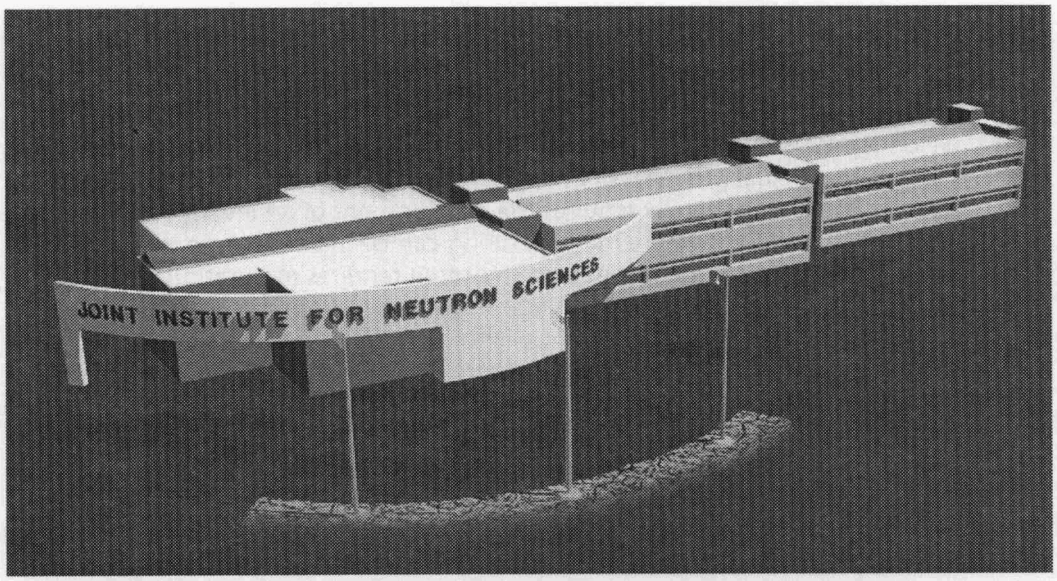
- Graduate School of Biomedical Sciences (based at ORNL)
- Graduate Program in Ecology
- Joint Program in Mixed-Signal VLSI and Monolithic Sensors

Academy for Teachers of Science and Mathematics
Center for Environmental Biotechnology
Composite Materials Science and Processing Laboratory
Forum for Applied Research and Public Policy, a quarterly policy journal, with the Tennessee Valley Authority and the Rural Policy Research Institute
Measurement and Control Engineering Center
National Transportation Research Center
Netlib, a collection of mathematical software, papers, and databases
Nuclear Structure Theory Program
Project SEE (Satellite Energy Exchange), with NASA Marshall Space Flight Center, the University of Virginia, and the Russian Space Institute
UT-ORNL Select Graduate Fellowship for the Outstanding Applicant in Condensed Matter Physics

Access to ORNL Research Facilities for University Staff and Students
Educational Assistance Program (tuition payments for ORNL employees)
Joint Publication of Research Results: More than1300 articles in the last 5 years
Participation of ORNL Staff as Adjunct Faculty
Subcontracts to University Employees ($15 million annually)

ORNL, the University of Tennessee, and the state of Tennessee are combining their resources to support the major Laboratory initiative in neutron science. Continuing the tradition established by the Joint Institute for Heavy Ion Research, the Joint Institute for Neutron Sciences was created to enhance the utility of ORNL's neutron science facilities by providing meeting facilities, offices, laboratories, a communication center, and housing for scientists and engineers from universities, industries, and the international community. The state of Tennessee has budgeted $8 million for the Joint Institute for Neutron Sciences, and planning for the facility is under way.

ORNL and the University of Tennessee have also joined forces through a new Joint Institute for Biological Sciences. Its mission is to promote and develop support for collaborative R&D in this area, which is experiencing dramatic advances in knowledge and in the pace, frequency, and significance of breakthrough discoveries.



The Joint Institute for Neutron Sciences will serve as an interface and economic development gateway for access to ORNL's neutron science facilities.

The National Transportation Research Center recently established by ORNL and the University, a partnership of federal, state, and local entities, affords opportunities for leveraging work for sponsors with mutual interests in a cooperative working environment. Another new endeavor, the National Safe Skies Alliance, combines ORNL, University of Tennessee, and other public and private resources to address aviation safety and security needs for the Federal Aviation Administration. The alliance focuses the R&D, technology, and systems engineering capabilities of industry, universities, and national laboratories on the task of creating, demonstrating, and evaluating next-generation solutions that will enhance aviation safety and security.

ORNL works with other national laboratories and other institutions to leverage capabilities and address challenging scientific and technical problems. The SNS project (see Sect. 2.4.1) integrates the expertise of five DOE national laboratories and has been described by ORNL Director Al Trivelpiece as "the best example of a collaborative project involving several DOE laboratories I have ever seen." ORNL also participates in multilaboratory projects such as the American Textile Partnership and the Partnership for a New Generation of Vehicles and in the development of collaboratories and virtual laboratories. The White House Initiative on Climate Change announced in October 1997 drew on two reports prepared by multilaboratory teams led by ORNL. The ORNL–Sandia National Laboratories collaboration on distributed computing has produced new methods for attacking complex scientific problems and innovative ways of combining geographically separate computational resources. ORNL and Sandia also organized an Interlaboratory Task Force on Unexploded Ordnance to coordinate capabilities of DOE's laboratories and facilities that can be applied to the detection and removal of unexploded ordnance; 11 DOE laboratories and facilities now participate in this group.

2.5.2 Management of Intellectual Property

ORNL transfers the knowledge and technology that are the products of its R&D to its sponsors and customers through a variety of mechanisms: publications, presentations, lectures, personnel exchanges, and WFO. One key mechanism is the transfer of licensable intellectual property to the private sector. The successful commercialization of the intellectual property creates economic and technological benefits for the nation. In the last 2 years, 65 licenses of ORNL technologies were issued, up 20% from the previous 2-year period.

The key priorities driving this budget request [include] leveraging science and technology to advance fundamental knowledge and our country's economic competitiveness with a stronger partnership with the private sector.

— Secretary Federico Peña, on the Department of Energy FY 1998 Budget Request, before the House Committee on Appropriations, Subcommittee on Energy and Water Development, March 19, 1997

Commercial sales based on licensed intellectual property represent a major indicator of success in technology transfer (with the caveat that technology maturation to commercialization usually takes four to six years, and sales also depend on the state of the economy). Commercial sales have shown a healthy increase; the total of $43.2 million for 1996 and 1997 represents 30% of the total commercial sales based on licensed ORNL intellectual property since 1985.

Commercialization generally requires the development of an invention beyond the prototype stage to the point where manufacturing can be initiated or an idea related to a manufacturing process can be put to use. This often requires maturation of an innovation from the concept to the prototype stage or development and/or optimization of a manufacturing process. Collaborative R&D agreements (CRADAs) tied to licenses are important to this maturation. There has been a significant increase in the percentage of new CRADAs tied to background intellectual property or licenses, and the total amount of funds provided by industry to the Laboratory for maturation increased by 73% (from $2.6 million to $4.5 million) in the past two years.

A close working relationship between the inventor and the licensee is also important to successful technology transfer. Mechanisms that support such relationships include user agreements, arrangements for inventors to consult with licensees, and an Entrepreneurial Leave of Absence Program for ORNL employees. Established in 1996, this program is now giving four employees the opportunity for principal involvement in the creation of companies that deploy Oak Ridge technologies.

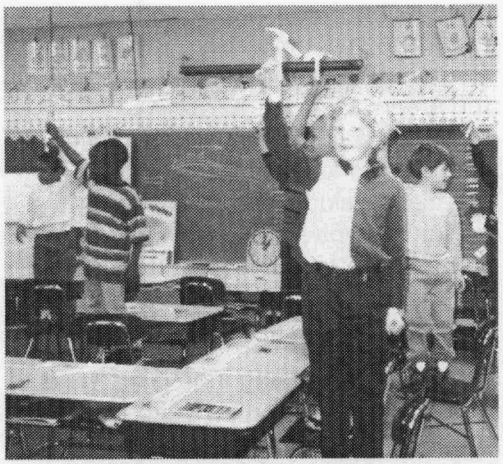
During the past 5 years, more than 240 disclosures of intellectual property have been made annually. The number and quality of these disclosures have increased as more principal investigators and divisions have become aware of the importance of intellectual property to ORNL and DOE. The level of investment in the intellectual property portfolio has been maintained, and the quality of the portfolio is improving; 85 patents were issued during the last 2 years, matching the number issued during the previous 2-year period. Since January 1996, ORNL's Executive Committee has twice made special allocations to support the filing of patent applications that may have significant long-term value to the Laboratory, supplementing the resources focused on patents with the highest near-term potential.

Industry interest and investment in licensing ORNL-developed technology are increasing, as indicated both by collaborative research in areas where there is ORNL background intellectual property and by funds-in CRADAs that help to mature technologies for commercialization. A metric reflecting this increased industrial focus is that 59 of the 87 new user agreements for participation in the ORNL user program have come from industry. A number of industrial users either visit the laboratory to perform collaborative research or execute user agreements to work at one of ORNL's 16 designated user facilities. Overall growth in industrial interest in ORNL's technology is illustrated by the steady annual growth of about 6% in the number of licenses for the past 4 years, with 34 licenses granted in 1997.

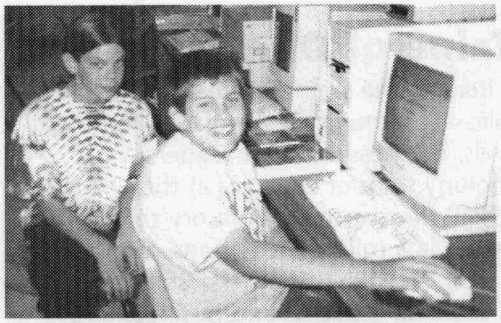
Currently, 62% of ORNL's licenses are with small businesses or startup companies. The overall success rate of 83% in new businesses based on intellectual property licensed from ORNL is notable; generally, more than 50% of new businesses fail within their first two years.

2.5.3 Education

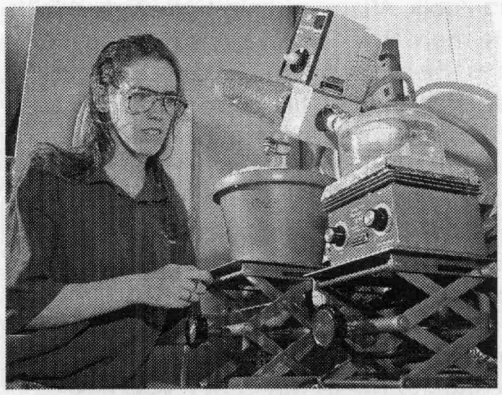
The nation's need for scientifically literate citizens will continue to grow, and the DOE national laboratories have the capability to enhance the science education of students and faculty. ORNL has a long tradition of service as a national and international science education resource, with emphasis on the southeastern United States. The Laboratory's Office of University and Science Education coordinates more than



These students from Dogwood Elementary School in East Tennessee are participating in Flight, one of the study units provided by ORNL's Ecological and Physical Sciences Study Center.



Students like these are introduced to power computing through ORNL's Adventures in Supercomputing program, which serves 24 Tennessee schools.



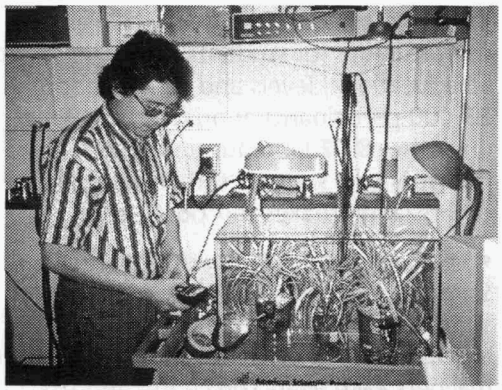
Heather Bullen, a student at Albion College, conducts an experiment in an ORNL laboratory as part of the Science and Engineering Research Semester.

40 programs, providing unparalleled opportunities for students and teachers at all educational levels and serving about 23,000 participants annually, more than any other DOE laboratory. Strong management support throughout the organization makes this possible.

- The Ecological and Physical Sciences Study Center offers a variety of hands-on study units and serves more than 15,000 elementary and secondary students and teachers each year. The center and the Tennessee Space Grant Consortium offer reduced-fee classes to area schools with a significant enrollment of economically disadvantaged students.
- The Adventures in Supercomputing program introduces students from more than 100 schools in 9 states to the excitement of working with powerful computational tools.
- As a sponsor of the Southeastern Consortium for Minorities in Engineering and Science, which introduces precollege students to an environment that might enhance their interest in science, mathematics, and engineering careers, ORNL provides opportunities for minority high school students to work at the Laboratory.
- ORNL has two undergraduate science semester research participation programs: the Oak Ridge Science Semester offered through the Great Lakes Colleges Association/Associated Colleges of the Midwest (GLCA/ACM) Consortium and the DOE-sponsored Science and Engineering Research Semester program.
- Postdoctoral researchers are an important component of the ORNL education effort. More than 250 postdoctoral fellows annually advance their understanding of the research process while making significant contributions to ORNL's R&D activities.
- ORNL is an active participant in the Consorcio Educativo para la Proteccion Ambiental (CEPA), a consortium involving three national laboratories, DOE, and selected universities in Texas, Puerto Rico, Mexico, and Chile. CEPA was created to

I want the Department of Energy to open its doors of knowledge and make them available to the next generaton of scientists.

— Secretary of Energy Federico Peña, December 4, 1997



Franz Muñoz Ibañez, a CEPA participant, monitors a phytoremediation experiment.

meet recognized needs for effective environmental protection, environmental training, and education in the Americas.

- ORNL is a partner in the Appalachian Rural Systemic Initiative, providing teacher development programs for the six states involved, and sponsors a Summer Math/Science Institute in collaboration with the Appalachian Regional Commission.

ORNL is seeking innovative ways to expand its education activities beyond those currently supported by DOE and to increase the availability of the Laboratory's resources to more faculty, students, and the general population. For example, ORNL recently supported a Laboratory staff member who assisted Tech Corps, a national initiative to match volunteers from the technology community with local schools to promote the use of new education technologies in the K–12 education system.

Scientists are powerful players in contemporary society, but what we are discovering is that the exercise of that power to do research and create new abilities from new knowledge carries with it responsibilities far beyond our laboratories. We must help the public understand the nature and the value of science.

— Dr. Neal Lane, Director, National Science Foundation, July 14, 1997

2.6 Communicating the Value of ORNL's R&D

In addition to publishing the results of its R&D in the scientific literature, ORNL works to communicate effectively with the public—community residents; government officials at local, state, regional and national levels; business and civic leaders; employees; and visitors—about R&D and technology transfer activities at the Laboratory. Communication tools include the *ORNL Review*, the Laboratory's R&D magazine; audio news updates available on line or via a toll-free telephone number; a home page on the World Wide Web; news releases; the ORNL Speakers' Bureau; lectures; special events; customized Laboratory tours for students and business and technical visitors, serving about 2,000 people each year; and a more general public tour program (see Sect. 3.9).

An effective and comprehensive media relations program is providing information about ORNL R&D activities and their significance to media representatives, resulting in significant coverage in local, national, international, and trade media. During 1996 and 1997, writers in the ORNL Communications and Public Affairs organization worked with Laboratory researchers to produce and distribute more than 75 news releases about ORNL's R&D. These stories covered such topics as the use of natural organisms to remove pollutants from the environment, the development of a laser/drug method for destroying breast tumors without surgery, and the creation of a computer model to simulate crash tests and help ensure that future vehicles meet safety requirements. They shared a common theme—how science and technology can improve the quality of life.

The ORNL Speakers' Bureau supplies speakers on various scientific topics to civic, educational, business, and professional groups throughout the East Tennessee area. During the past two years, the bureau has scheduled and coordinated nearly 100 such presentations.

The Laboratory's "Showcase Lecture" series provides further opportunities for ORNL staff to explain how science works for the public. The lecture series, which is open to the public and to media representatives, features presentations on current Laboratory programs and their impacts. Since January 1996, some 25 presentations have been made, on topics ranging from global climate change to environmental tobacco smoke exposure to U.S. dependence on imported oil. Other special

Charles Townes, winner of the 1964 Nobel Prize in physics, delivered the 1997 Weinberg lecture.

Nature walks on the Oak Ridge Reservation provide visitors with information about the ecology of the area.

presentations, such as the Weinberg and Distinguished Lecture Series, are also open to the public and are promoted in area news media.

Information on the value of science and technology is also presented to the public through special events and visits sponsored or supported by ORNL. The Laboratory hosts thousands of visitors at its Community Days, which offer tours and festivities celebrating science and its importance to East Tennessee. ORNL also has supported a Black History Celebration featuring the contributions of African-American scientists, inventors, and engineers; an interactive scientific exhibit at the state capitol in Nashville; and nature walks on the Oak Ridge Reservation that enable the public to view and learn more about area plant and animal life and ORNL's research programs in environmental and ecological research.

The public tour program and customized tours allow thousands of visitors each year to learn more about science and how it affects their lives, and special Leadership Breakfasts and other visits also provide government and civic leaders a close-up look at successful research and technology efforts in Oak Ridge.

3 Operational Support

The ability of the Oak Ridge National Laboratory (ORNL) to serve the needs of the Department of Energy (DOE) and other customers rests in no small part on functions that support ORNL's operation as a science and technology laboratory. Expectations established when Lockheed Martin Energy Research Corporation (LMER) undertook the management and operation of ORNL addressed the operation of the Laboratory in a safe and environmentally responsible manner, the management of its business functions to provide the maximum return on the taxpayers' investment, the fostering of communication and trust among stakeholders, and ORNL's role as a good neighbor in the community. In working to meet these expectations, ORNL has begun a systematic integration of safety into its work at all levels; reengineered several key activities; and focused attention on business ethics, business partnerships, and communications and community relations.

3.1 Integrated Safety Management

Both DOE policy and the contract between DOE and LMER require the use of safety management systems to systematically integrate safety into management and work practices at all levels so that missions are accomplished while the public, the worker, and the environment are protected. [In this context, the term "safety" specifically includes all aspects of environment, safety, and health (ES&H).]

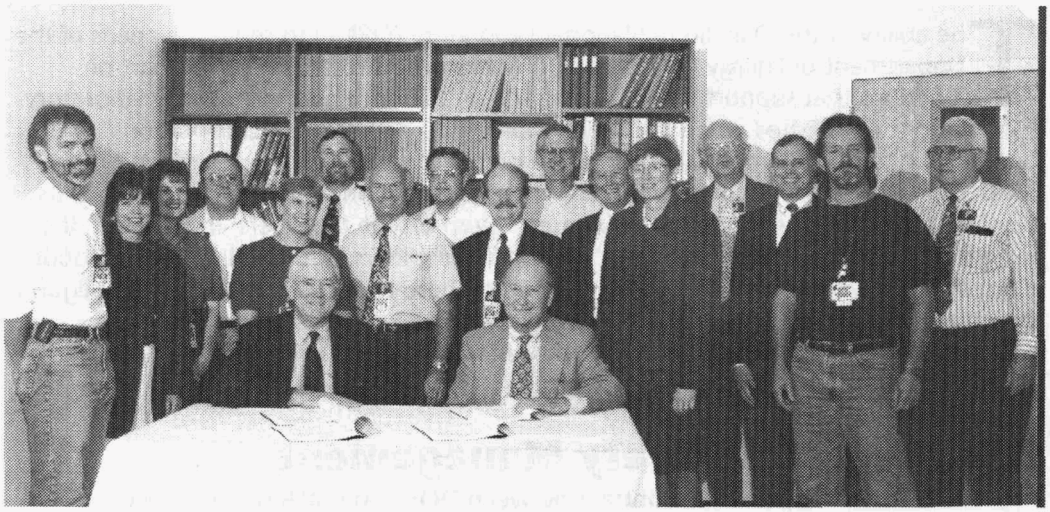
Development and implementation of an integrated safety management system are under way. A key to this effort is the principle that excellence in research is inseparable from excellence in ES&H performance; the most effective and efficient ES&H programs are "owned" by the employees conducting the work, and responsibility and accountability for ES&H are clearly understood by everyone involved.

In its efforts to address ES&H issues with an integrated approach to safety management, ORNL is working to improve performance while significantly reducing costs and negative impacts on research. The Laboratory's leadership in a number of initiatives for DOE's Office of Energy Research (DOE-ER)—such as sitewide Work Smart standards, oversight reduction, and participation in industrial research organizations—has resulted in opportunities for improvement at all DOE facilities.

3.1.1 Developing Work Smart Standards

ORNL, working in partnership with DOE's Oak Ridge Operations Office (DOE-ORO), was the first multiprogram DOE laboratory to develop Work Smart standards on a sitewide basis. ORNL's senior management recognized the importance of this opportunity and assigned key managers and staff from research divisions, supported by bargaining unit employees and ES&H and quality (ESH&Q) professionals from both ORNL and DOE, to lead the effort. Staff familiar with the work were involved throughout the process, ensuring that standards would be appropriate for ORNL activities and accepted by staff performing work at ORNL. The central focus of the effort was to identify standards that were most applicable to the research conducted and support services required at ORNL. To provide an external perspective, an experienced ES&H manager from an industrial research and development (R&D) organization reviewed the entire process and the standards that were proposed, ensuring that ORNL now follows ES&H requirements similar to those followed by best-in-class industrial R&D organizations.

Throughout this effort, close communication was maintained with staff from ORNL, DOE-ORO, DOE-ER, and DOE's Office of Environment, Safety, and Health. For non-nuclear activities at ORNL, standards were identified, tested, confirmed, approved, and placed in the DOE-LMER contract in 73 days. Standards for nuclear activities and facilities were then developed, focusing on the work and associated hazards that are unique to those activities. This approach, which was unique in the DOE complex at the time, builds on existing standards, thereby capitalizing on prior efforts, minimizing the



Al Trivelpiece, ORNL, and Jim Hall, DOE-ORO, sign the Work Smart standards for ORNL.

cost associated with developing standards, and maximizing the benefits of the Work Smart standards process.

To ensure that any further changes in the standards by which ORNL works will receive the same level of scrutiny and staff involvement as did the development of the Work Smart standards, a "gatekeeper" with extensive knowledge of the Work Smart standards process was appointed to review any suggested changes in the approved standards. This formal review ensures that the requirements included in the DOE-LMER contract remain meaningful and ensures that staff involved in activities at ORNL are fully aware of the standards that apply to their efforts.

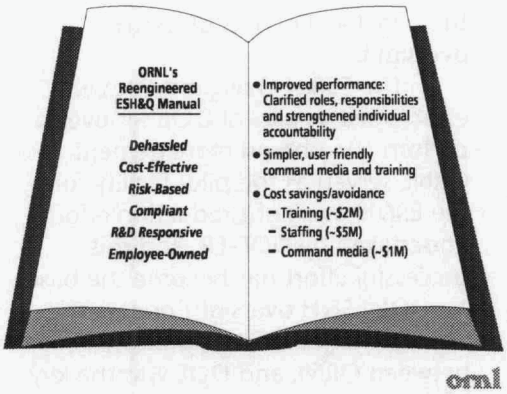
Developing appropriate ES&H standards was the critical first step toward implementing a truly integrated approach to ES&H issues at ORNL. Effective implementation of the approved standards as part of an integrated safety management system is the challenge that now faces ORNL (see Sect. 4.2.1).

3.1.2 Reengineering ES&H

ORNL's ESH&Q functions were evaluated as part of the overall Laboratory reengineering effort. This ESH&Q reengineering effort was co-chaired by R&D and support management to foster a feeling of ownership by staff members in both groups. Following an in-depth analysis of the existing ORNL programs and interaction with best-in-class industrial R&D programs, four major initiatives were identified:

- Define and maintain a complete set of Work Smart standards that is well understood and used as a framework for all ESH&Q programs.
- Develop and maintain operating procedures used throughout the Laboratory to promulgate the Work Smart standards and ensure effective ESH&Q operations.
- Develop and implement training programs necessary to support ESH&Q work and compliance.
- Define and operate compliance assurance programs to ensure that ORNL is meeting the requirements of the Work Smart standards and procedures.

Responsibility for each initiative was assigned, and progress toward full implementation is tracked. The first initiative is now substantially complete, with sets of Work Smart standards developed and approved for all ORNL operations and facilities except the High Flux Isotope Reactor, as described in Sect. 3.1.1. Progress in the other three initiatives is described in the remainder of this section.



ESH&Q reengineering goals and outcomes.

Operating Procedures

An evaluation of ORNL's ES&H procedure system was conducted by teams consisting of R&D staff, ES&H support staff, and members of the bargaining unit. This evaluation revealed that the system contained many requirements not driven by the approved Work Smart standards. The teams then turned to the task of modifying the procedures to align them with the Work Smart standards, with the goal of creating procedures that clearly communicate expectations and work requirements. Every requirement contained in the procedures was to be explicitly linked to regulatory drivers or best management practices that clearly enhance protection of employees, the public, and the environment in a cost-effective manner.

Procedures incorporating these directions were developed and distributed to ES&H experts from industry, former DOE managers, and Lockheed Martin Corporation to ensure the validity of the concept. Results of these reviews were extremely positive, and the comments received have been incorporated in the procedures. The ES&H procedures are currently undergoing an ORNL-wide review and will be distributed by May 1998.

As a result of these efforts, the number of ORNL ES&H procedures has been significantly reduced (from more than 120 to fewer than 80), and reviews indicate that the new procedures are much improved and more useful. This change obviously represents a bold step, but one that clearly was needed to maximize the benefits of the Work Smart standards process.

Training Programs

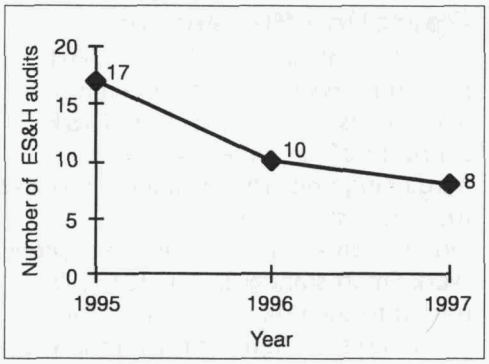
Shortcomings in compliance training were identified as a significant issue by ORNL staff. An evaluation of training requirements revealed that many requirements were inappropriate for ORNL activities. An ORNL ES&H compliance training office was established to assist divisions in identifying required training and determining the most effective method of delivering the information to staff.

Non-value-added training is being eliminated, resulting in identified cost avoidances of more than $1.5 million per year. Appropriate, cost-effective training will be provided to ORNL staff by subject matter experts from ORNL organizations; external training materials will be used to supplement in-house expertise as needed. As the new ES&H procedures are distributed, staff will be provided with the training necessary to implement the requirements, and further savings will be realized.

Compliance Assurance Programs

ORNL is subject to a variety of regulatory and contractual obligations, many of which are related to ES&H. Its compliance with these obligations is monitored by DOE. The Laboratory's compliance assurance programs assist the line organizations in meeting their compliance responsibilities.

ES&H oversight improvements. Actions to restore clear lines of personal and organizational responsibility and accountability, which had become blurred over time, have been under way throughout the DOE complex for several years. In 1995, as a result of discussions between the directors of the national laboratories and then–Secretary of Energy Hazel O'Leary, DOE began an intensive effort to improve the quality and reduce



ES&H audit score card.

the negative impacts of ES&H oversight.

The ES&H Oversight Pilot was established as part of DOE's move to performance-based management. ORNL served as the pilot facility for the ES&H oversight reduction effort undertaken by DOE-ER, and this successful effort has become the basis for DOE ES&H oversight policy. The development of a strong partnership between ORNL and DOE was the key to this success.

The approach, which was developed, tested, and proved at ORNL, comprised strong self-assessment by all Laboratory organizations, operational awareness by local DOE staff, meaningful measures of performance mutually developed and agreed to by ORNL and DOE, and a focused, value-added review by DOE. DOE-ORO served as a gatekeeper, ensuring that all ES&H oversight by DOE was conducted in the approved 2-week review period and preventing duplicative reviews. This approach resulted in measurable savings to both DOE and ORNL, as well as a significantly reduced burden of oversight on ORNL's staff and activities.

Line organization responsibility and accountability. Pilot programs to clearly define responsibility and accountability for ES&H issues are under way in two of ORNL's R&D divisions, involving all ES&H support organizations. ES&H tasks have been identified, and services associated with these tasks and paid for with overhead funds are being reviewed to give the divisions a basis for deciding whether to continue purchasing services or to perform the tasks themselves. As these pilot programs mature, the lessons learned will be transmitted throughout ORNL. Employee involvement at every level is the guiding principle for this effort.

3.1.3 Maintaining ES&H Performance

ORNL is committed to continuous improvement in its ES&H performance, including reductions in the cost of ES&H support and in the burden that ES&H requirements impose on R&D activities. During the past two years, as reengineering of ES&H has proceeded, ORNL management has taken steps to ensure that changes made to improve the Laboratory's ES&H performance do not adversely affect that performance.

In FY 1997, following a DOE evaluation of ES&H performance at Brookhaven National Laboratory, senior management at ORNL created a team of R&D and ES&H support staff, teamed with personnel from the DOE ORNL Site Office, to critically evaluate ORNL activities using the criteria from the Brookhaven review. This review indicated that some of the shortcomings identified at Brookhaven were present at ORNL; it also indicated that the efforts under way to reengineer the processes for integrating ES&H issues into R&D and support activities would effectively address these shortcomings. The ORNL review team identified a number of activities that would further enhance the rigor of hazardous operations, and ORNL senior management has made a commitment to aggressive implementation of these improvements.

Representatives from ORNL and DOE-ORO were invited to describe ORNL's ES&H initiatives to managers at Brookhaven in July 1997. On that occasion, a senior DOE-ER manager identified ORNL's approach as the standard for integration of ES&H issues into the mission of a DOE-ER laboratory. Guidance from Lockheed Martin Corporation also indicated that ORNL's reengineered ES&H programs, in their design and early

implementation, were performing to the ES&H expectations associated with best-in-class initiatives. Sustaining this performance will require a strong continuing effort.

To ensure that ES&H issues receive appropriate attention and consistent funding consideration, an ORNL Risk Ranking Board has been established. This board will use consistent criteria to promote the effective use of resources through risk-knowledgeable operations management. At present, multiple prioritization processes exist, and these processes are often in conflict with established funding mechanisms. The ORNL Risk Ranking Board will ensure that needs are identified and balanced. The ORNL integrated planning process (see Sect. 3.3.3) will use the board results, thereby ensuring that ES&H considerations are a part of every ORNL project and activity and that consistently prioritized needs are integrated into all decisions.

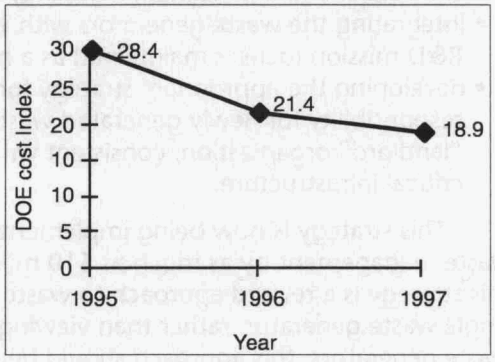
ORNL has established and is maturing, in partnership with DOE-ORO, a program that addresses the Laboratory's nuclear safety responsibilities under the Price-Anderson Amendments Act. A series of reviews by the Defense Nuclear Facility Safety Board at selected ORNL nuclear facilities has resulted in generally positive findings.

The Laboratory's commitment to reducing the risks of operations at ORNL is demonstrated in a number of activities. ORNL staff provide significant support to DOE's Office of Environmental Management, addressing major issues associated with waste management and legacy facilities. The technical expertise of many ORNL R&D and support organizations was brought to bear on the Molten Salt Reactor Experiment facility, and the risk posed by that facility was reduced. ORNL staff were also directly involved in developing and demonstrating innovative processes and systems for use on underground storage tanks at ORNL; this task has moved from a demonstration project to an effective cleanup campaign in the center of ORNL's campus. Eliminating excess conservatism in operations requirement documents for waste management facilities at ORNL, as recommended by the waste management reengineering team, will allow more work to be done in the face of declining budgets.

In finding innovative solutions to ES&H issues, ORNL uses the best examples from industry, coupled with input from staff in all Laboratory organizations. For example, ORNL developed a new technique for the removal of laboratory hoods that have operated with perchloric acid. This approach saved ORNL more than $3.5 million compared with conventional techniques and is now the model for handling this problem at other DOE facilities.

Effective involvement of all ORNL employees has been the cornerstone of these improvements. As a public recognition of this important facet of ES&H improvement, ORNL, in concert with the Atomic Trades and Labor Council, is moving toward participation in DOE's Voluntary Protection Program.

Through Lockheed Martin Corporation's membership in the Industrial Research Institute, ORNL has access to the best practices of industry. The Industrial Research Institute provides a forum for the ES&H managers from the nation's largest and most successful R&D firms to discuss issues and share solutions to common problems. ORNL has been an active participant in this organization, and information gained from these best-in-class organizations has been of great value to ORNL.



DOE Safety and Health Cost Index for ORNL. This index rates ORNL's safety performance by assigning values to safety indicators. Lower values indicate better performance.

Excellence in R&D is inseparable from excellent ES&H performance. ORNL is committed to aggressively implementing the improvements that have been identified over the past few years and to continuing to lead the way in ES&H performance for DOE-ER.

3.2 Reengineering Waste Management

Waste management is a critical component of the infrastructure that supports ORNL's R&D. The availability of waste facilities that operate in compliance with regulations and can handle all types of waste (radioactive, hazardous, or mixed) supports ORNL's R&D divisions both in executing their present mission assignments and in obtaining new work.

The cost of waste management has been increasing because of complex regulatory requirements and the continuing lack of disposal facilities for DOE's radioactive and mixed waste. The ORNL Waste Management and Remedial Action Division (WMRAD) spends more than $40 million annually in managing ORNL's wastes. The ten R&D divisions that generate significant quantities of waste spend at least $15 million on waste characterization and packaging activities. Reducing these costs is essential to ORNL's ability to compete successfully with other R&D institutions.

In addition, DOE's approach to waste management on the Oak Ridge Reservation is undergoing significant changes, which are expected to have a major impact on ORNL's ability to carry out its mission assignments. DOE has elected to establish a management and integration (M&I) contract for the execution of its environmental management (EM) work in Oak Ridge. The M&I contractor, Bechtel Jacobs Company LLC, is assuming the overall control of waste management operations from the Lockheed Martin business units in Oak Ridge. This change will intensify the focus on lowering the cost of waste management. It also tends to diminish the supporting role of waste management in the execution of R&D, because Bechtel Jacobs is expected to focus primarily on eliminating the legacy waste problems rather than on ensuring full support for programs that deal with newly generated wastes.

To address this situation, the Laboratory is engaged in a comprehensive reengineering of its waste management operations, involving both the ten R&D divisions that generate significant amounts of waste and WMRAD, which is the Laboratory's primary waste services organization. The reengineering strategy has three major thrusts:

- determining the optimum changes in waste management processes for minimizing the cost of characterization, handling, treatment, storage, and disposal of waste;
- integrating the waste generators with waste management operations to ensure that R&D mission focus is maintained as a high priority; and
- developing the appropriate strategy for dealing with the proposed transfer of responsibility for newly generated waste from the EM program to DOE-ER, ORNL's "landlord" organization, consistent with the long-term vision of landlord control of critical infrastructure.

This strategy is now being implemented and is expected to reduce the cost of waste management by as much as $10 million per year starting in FY 1999. Included in this strategy is a revised approach to waste certification that considers ORNL to be a single waste generator, rather than viewing the 1,500 R&D staff members as individual waste generators; this approach should help in building a strong, integrated ORNL waste management team.

Issues associated with the proposed transfer of responsibility for newly generated waste are discussed in Sect. 4.1.2.

3.3 Reengineering Business Practices

ORNL's management has taken aggressive steps to tailor the Laboratory's business practices to best support its primary R&D role. Following the creation of LMER, an extensive review, conducted with assistance from an outside management consultant (Ernst & Young), revealed numerous processes that, far from being "best in class," fell short of industry standards. In response, the Laboratory chartered a reengineering effort aimed at process improvements and increased efficiency in several business-related areas.

It is the DOE's intent to have its facilities and laboratories operated in the most efficient and effective manner possible. To this end the Contractor shall, in the performance of this contract, assess its operations and identify ways to make them more cost effective. . .

—Lockheed Martin Energy Research Corporation Contract with the United States Department of Energy, Contract No. DE-AC05-96OR22464

3.3.1 Business Systems

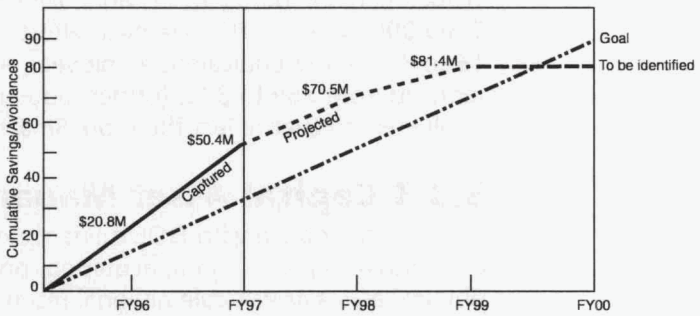
When ORNL reviewed its processes in 1996, reengineering of business systems was identified as a priority. In partnership with Lockheed Martin Energy Systems, Inc. (LMES), ORNL is engaged in an ambitious reengineering task, the Delta Project, that includes installing a commercial software package, SAP R/3, to replace a number of existing finance, project management, acquisition, and human resources systems and introduce a number of recognized "best business practices" in these areas. SAP R/3 is a highly integrated information system that will eliminate the need to maintain and update multiple databases and, over the long term, will reduce the costs required to maintain multiple nonintegrated business systems. It will begin operating in October 1998.

In parallel with the installation of SAP R/3, new or enhanced automated systems are being used to plan and control cost, reduce redundant systems, and increase efficiency. Examples include the PRISM property management system, which allows equipment custodians and employees to complete most property actions on line, and the Program Management Tracking System, which provides personal computer and workstation users with easy access to programmatic and overhead budget data. These efforts reflect an expansion of ORNL's use of computer networks as a tool for managing and distributing information.

3.3.2 Cost Efficiencies

In each of the last two years, cost efficiencies arising from reengineering efforts, combined with the work of ORNL's Fix-It Committee and individual division efforts, have exceeded the $18 million annual target established in connection with DOE's Strategic Alignment Initiative.

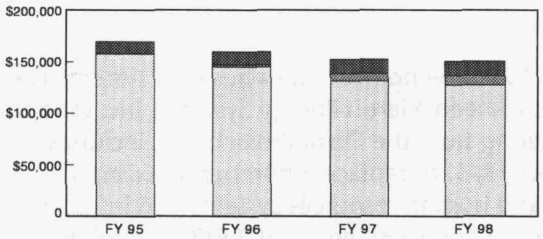
ORNL has significantly reduced overhead while sustaining investments in programs that create future opportunities.



Cost efficiencies at ORNL. The goal is ORNL's commitment to DOE's Strategic Alignment Initiative.

- Overhead has been reduced from $170.6 million in FY 1995 to a projected $152.5 million in FY 1998, a decrease of approximately $18 million.
- ORNL has also reduced burden costs and transferred funds to institutional investment areas, increasing its investments in Laboratory Directed R&D, reengineering, program development, technology transfer, and Wigner postdoctoral programs by approximately $14.5 million during the past two years.
- The ORNL overhead budget, less investments, has decreased from $153.3 million in FY 1995 to $120.7 million in FY 1998, a 21.3% reduction. If a 3% cost of living increase is factored into this calculation, the overhead budget less investments shows a reduction of approximately 30%.

- The ORNL overhead rate remained essentially constant from FY 1995 through FY 1997 despite increases in funding for investments that represent an increase of 5.2 percentage points in the rate. The investment increases were offset by reductions in nonessential support services and other cost reduction efforts. This has been accomplished during a time when the overhead base has dropped significantly.
- As calculated by DOE-ER, the cost per full-time equivalent R&D employee at ORNL is lower than at most other national laboratories.



	Actual FY 95	Actual FY 96	Actual FY 97	Budgeted FY 98
LDRD	12,262	13,291	14,325	14,505
Reengineering	0	2,027	7,870	9,800
Net Overhead	158,373	145,103	132,854	128,238
Total Overhead	170,635	160,421	155,049	152,543

Expenditures in $1000s of Dollars

ORNL overhead expenditures, showing LDRD, reengineering, and net overhead for FY 1995–1998.

ORNL's work with DOE to implement changes in oversight requirements has led both to reductions in the cost and burden associated with compliance, and to process improvements. A key example is ORNL's service as a pilot institution for the Business Management Review process, which focuses on performance improvement and reduces cost by minimizing DOE's need to conduct on-site reviews and assessments. ORNL played a similar role in DOE's Environment, Safety, and Health Oversight Pilot and in the "necessary and sufficient" process that led to the implementation of Work Smart standards, as described in Sect. 3.1.

With the establishment of LMER, ORNL was able to create its own procedures organization for dealing with directives. In conjunction with the implementation of Work Smart standards, this change allowed ORNL to reduce overhead costs by $505,000 per year. The overhead effort devoted to procedures has been reduced from 16 to 3 full-time-equivalent employees, and the number of procedures has been reduced from 769 to 323; further reductions are expected as procedures are implemented that reflect the Work Smart standards and are tailored to ORNL's needs.

3.3.3 Capital Asset Management

In accordance with DOE guidance on life cycle asset management, ORNL is committed to planning for, acquiring, operating, maintaining, and disposing of DOE's physical assets as valuable national resources, and managing them cost-effectively. Maintaining existing facilities and obtaining new facilities to support R&D activities are key objectives of the life cycle asset management process. These tasks are of special importance at ORNL, which has one of the oldest physical plants in the DOE laboratory system.

ORNL occupies 1,100 acres in the Bethel and Melton Valley areas, with 531 buildings and other major facilities totaling approximately 3.1 million ft^2. The site infrastructure includes 37 miles of paved roads, 280 miles of unpaved roads, 115 acres of mowed grounds, and a number of utility systems (electrical, steam, sewer, water, and waste). The estimated replacement value of these facilities is more than $3.5 billion.

Efficient use of available resources is essential, especially during times of constrained federal budgets. Since the formation of LMER, ORNL has made a number of improvements to its processes for various aspects of life cycle asset management. Many of these improvements draw on recommendations made by reengineering teams established to review ORNL's research support services and its engineering design and construction practices, as discussed in Sect. 3.4.

Infrastructure Planning

In 1996, with funding support from DOE, the ORNL Capital Assets Management group developed an Infrastructure Management Planning Process to provide a comprehensive listing of proposed infrastructure upgrades at ORNL. In 1997, this system was integrated with the existing ES&H management planning system to support equitable prioritization of projects and activities and efficient allocation of resources consistent with DOE's initiative to implement an integrated safety management process. In addition, a Risk Ranking Board has been established, consolidating three separate prioritization processes into one and promoting more consistent, uniform development of priorities.

Also being implemented is a more systematic approach to infrastructure planning based on a business risk analysis approach. This approach was used to develop a detailed plan for upgrades to the ORNL steam generation and distribution system, which is now being implemented and should result in lower life-cycle costs and greatly reduced environmental liabilities while extending the service life of the system by 25 to 30 years. Similar, more limited assessments have been performed on elements of the potable water and electrical distribution systems, and plans are to expand the use of this tool to enhance the prioritization and allocation of infrastructure resources.

A Space Allocation and Management System developed in 1997 promotes better management of Laboratory space and supports the implementation of a space charge system in 1998. Since 1996, ORNL has vacated 31,000 ft^2 of leased space, for an annual cost savings of $438,000.

Project Execution

A number of key infrastructure projects have been very effectively managed. An upgrade of the sanitary sewer system was completed in September 1996, ahead of schedule and significantly below budget. An aggressive project for underground storage tank remediation is nearing completion about a year ahead of the regulatory compliance date. Replacement of heating, ventilation, and air-conditioning chillers and units that use chlorofluorocarbon coolants is continuing with no anticipated operational or environmental issues. A prioritized roof replacement program supported by line item funding is progressing well.

Timely and effective costing of general plant project (GPP) funding is a key measure of project management effectiveness. The overall goal for the GPP program is to cost at least 50% of available GPP funding in any fiscal year. In FY 1997, ORNL costed 61% of available GPP funding. Overall, the uncosted carryover in the GPP program decreased from $19.4 million in FY 1994 to $4.5 million in FY 1997.

Executing individual projects in a timely manner is essential to improving costing performance. Two significant projects were completed in FY 1997 on constrained schedules: replacement of the Building 4510 cooling tower without negative impacts to the critical research facilities that it serves, and rehabilitation of the steam plant stack, which was moved up a year because of significant structural deterioration found in late FY 1996 and was completed without adversely affecting steam plant operations.

Performance Measures

To promote continued improvement, a number of life cycle asset management performance measures were jointly developed with DOE personnel and implemented in FY 1997. These performance measures will be evaluated and updated annually to ensure that appropriate objectives are being pursued in maintaining and developing ORNL's infrastructure.

3.4 Reengineering Research Support Services and Engineering

3.4.1 Research Support Services

Research support services at ORNL are provided by the Plant and Equipment Division. Reengineering of these services was undertaken with the goal of providing best-in-class services for ORNL. An intensive 12-week effort that included surveys of Plant and Equipment Division customers and staff, small group discussions, and analyses of processes and costs led to the conclusion that low productivity (not the cost of services, the organizational structure, or the level of skills) was the biggest hindrance to best-in-class research support services.

Commitments made as part of the reengineering of ORNL's research support services are commemorated with a plaque displayed here by Al Trivelpiece; Dan McDonald, leader of the Research Support Services Reengineering Team; Martha Krebs, director of DOE's Office of Energy Research; Ed Mee, bargaining unit representative; and Jerry Hammontree, director of ORNL's Plant and Equipment Division.

Several steps have been taken to improve this situation. A joint labor/management steering team was established to oversee the implementation of reengineering; this included a personal partnership agreement between the director of the Plant and Equipment Division and the bargaining unit representative. In addition, more than 650 people signed a personal commitment to improve the organizational culture. Measures have also been taken to remove barriers to productivity by improving work planning and coordination, procuring newer tools, and ensuring reliable sources of needed materials. Examples include the following actions.

- A carpenter shop in Building 7009 was reopened.
- A power shear was installed in Building 3044, substantially reducing travel time for personnel at the west end of the ORNL site who need sheet metal work.
- Changes were made in the taxi service schedule to increase the availability of transportation to craft workers. Division vehicles were redistributed for more effective support, and a small rental pool of vehicles is available to meet short-term needs. A west-end transport service team was established.
- To make available a reliable source of needed supplies, a pilot bench stock area was opened in Building 3023. This area was stocked with equipment and material acquired at no cost from the East Tennessee Technology Park.
- A customer service team continues to identify better ways to achieve and measure customer satisfaction. Customer service training is being provided to division staff. A reorganization of the heating, ventilation, and air conditioning work group is providing more focused and cost-effective customer support.

- Cultural change activities are gaining momentum. Consultants from the University of Alabama at Huntsville and the Saturn car company continue to provide advice on tapping the strength of an effective union-management partnership to achieve customer enthusiasm. As joint teams experience this strength through successful completion of projects, support for cultural change grows.

3.4.2 Engineering Design and Construction

Reengineering of engineering design and construction was undertaken with the aim of providing ORNL with cost-effective "industrial standard" engineering and construction support services. The recommendations of the reengineering team are documented in *ORNL Engineering Design and Construction Reengineering Report*, ORNL/TM-13558.

In January 1997, the ORNL Engineering Division was established from selected elements of the LMES engineering organization. The ORNL Engineering Division has been configured to meet the Laboratory's projected needs in the present austere budget climate; organizational costs have already been reduced by 17% compared with 1996.

As recommended by the reengineering team, ORNL has assumed direct responsibility for design contracting and construction management. This move eliminates several layers of interfaces with the construction management organization, the LMES engineering organization, and DOE. This approach, which is just being implemented, is expected to save 20 to 30% for a typical construction project.

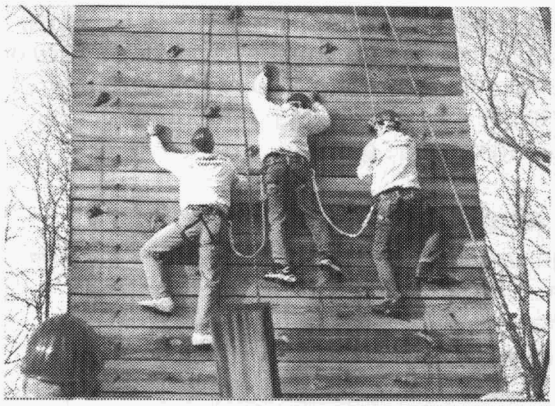
ORNL has also implemented contracting reforms based on commercial contracting requirements, prequalification criteria for construction contractors, and a graded approach to contract specifications using Work Smart standards. These reforms, combined with revisions to ES&H and waste management requirements for roofing projects, have contributed to a 50% reduction in the cost of roof replacement. (This reduction was demonstrated before the change in construction management responsibility.)

3.5 Reengineering Human Resources

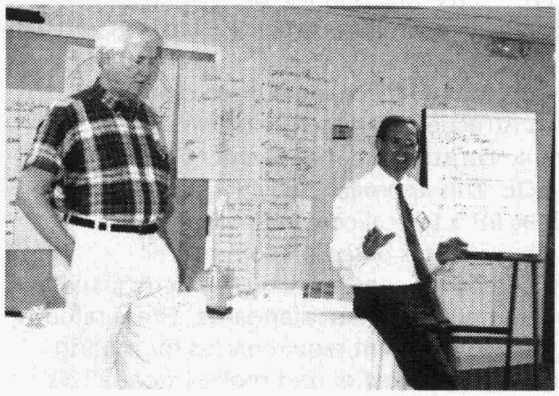
ORNL's Human Resources organization provides consultation and support service to line organizations in several areas: staffing, compensation, personnel relations, employee and organizational development, work force diversity, and consulting and staff support.

Human Resources is reengineering its programs, systems, and processes to support ORNL's overall reengineering efforts and the culture change necessary for these efforts to be successful. Primary goals for Human Resources reengineering are to (1) assign individual and organizational responsibility and accountability for human resources transactions, thus giving line organizations the authority to make most human resources decisions; (2) let each division or office choose the criteria to best establish and maintain excellence in what it does (one size does not fit all); (3) embrace the role of Human Resources in providing consultation and support to the line organizations; and (4) develop innovative solutions that support the culture change necessary for ORNL to be more effective in performing its assignments and conducting its work "faster, cheaper, and better."

A new Human Resources information system, being developed as part of the SAP R/3 implementation, will put information and transaction capabilities on the desktop. Revision of human resources policies and procedures to support the desired culture change is under way. Initiatives aimed at supporting the "work force of the future," such as increased flexibility in work schedules and a flexible workplace program to allow "telecommuting" by selected employees, are being implemented. Other key actions are being taken in employee development and rewards and in work force diversity.



Participants in the Leadership Challenge take on a ropes course.



Laboratory Director Al Trivelpiece (L) and Deputy Director Richard Genung are among the session leaders of ORNL's Leadership Development Program.

3.5.1 Employee Development and Rewards

ORNL works to provide its employees with opportunities to develop and optimize their unique talents and skills and to be rewarded in accordance with their contributions to the success of the business. The new "Leadership Alive" program, developed as part of ORNL's reengineering effort, is aimed at ensuring the viability of the Laboratory through the development of its future leaders. The Variable Pay Program enables managers to reward those employees who are making the most significant contributions. A new competency-based compensation and job worth system is being developed, drawing on seven underlying job competencies that have been identified, defined, and aligned with ORNL strategies. The performance management process has been streamlined as an initial step toward a reengineered performance management system. Line managers are being given new tools to assist them in managing performance.

3.5.2 Diversity

ORNL is committed to achieving its strategic business objectives by capitalizing on the diversity of its work force. The Diversity Plan, implemented in March 1996, outlines means for promoting a high-performance, diverse, and inclusive organization. The Diversity Leadership Team, led by the Laboratory deputy director, meets quarterly to monitor progress toward the objectives outlined in the plan.

The ORNL Office of Workforce Diversity conducts an annual assessment of organizational performance in addressing diversity objectives and reports the results to the Laboratory director. This office also manages an annual awards program that recognizes outstanding efforts toward meeting diversity goals. It has established both internal and external web pages to enhance communications and external benchmarking.

During a period of limited hiring and continuing reductions in the work force, ORNL has continued to emphasize its diversity program. ORNL's reduction-in-force review process was recognized as a best industry practice by the Nashville office of the Office of Federal Contract Compliance Programs. During the past two years, the overall representation of women and minorities at ORNL has increased, and the number of women in the Officials and Managers category has increased significantly (from 8.8% to 11.8%). ORNL is committed to increasing the number of minorities in senior Officials and Managers and individual contributor positions.

The Office of Workforce Diversity also manages ORNL's Employee Concerns/ Response Program, which is part of an effort to ensure that all employees know that their concerns and suggestions will be taken seriously and feel free to voice them. Key aspects of the Employee Concerns/Response Program are a simple process for submitting suggestions and concerns, a time frame in which the employee's concern should be addressed, and a two-level appeal process. A significant increase in employee concerns activity during the past two years suggests that employees feel free to present issues and concerns to be managed within the system.

3.6 Business Ethics

ORNL is committed to fulfilling DOE and Lockheed Martin Corporation expectations of the highest ethical conduct in all aspects of its operations. LMER has an Ethics Office with a full-time director to ensure an appropriate focus on ethics, and ORNL has an Audit and Ethics Committee.

The Ethics Office works to resolve ethical issues raised at ORNL. Several cases that might have resulted in litigation against ORNL have been resolved; the actions of the Ethics Office appear to have contributed to their resolution. The ORNL Ethics Office also has outreach activities to the community, professional societies, and students participating in the Science and Engineering Research Semester at ORNL.

Annual ethics training for all employees is a corporate requirement. Dr. Martha Krebs, director of DOE-ER, requested and received a review of the 1996 ethics training package. A 100% completion rate was attained for the 1997 training, which was well received. Evaluation forms showed that 85% of respondents considered the training "useful" to "very useful."

In late 1997, Lockheed Martin Corporation conducted a survey to assess views on ethical conduct at each of the corporation's companies and collect information on job satisfaction and work environments. The results of the survey are now being analyzed and their relevance to the ORNL environment is being assessed. Near-term actions in this area are discussed in Sect. 4.1.5.

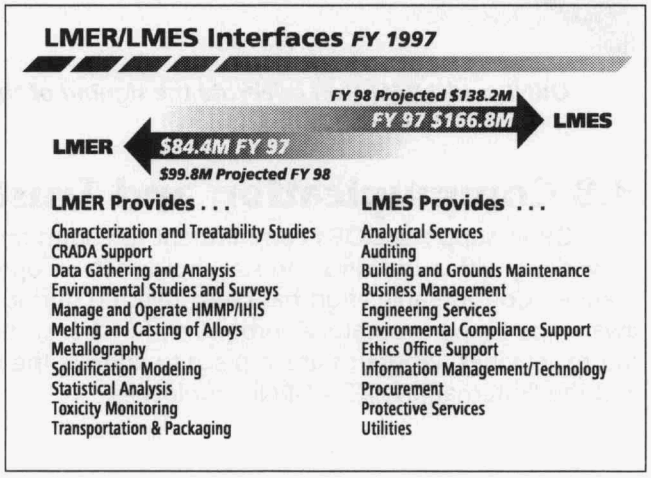
Lockheed Martin aims to "set the standard"for ethical business conduct. We will achieve this through six virtues: Honesty, Integrity, Respect, Trust, Responsibility, and Citizenship.

—Setting the Standard: Code of Ethics and Business Conduct, Lockheed Martin Corporation, August 1997

3.7 Business Partnerships

3.7.1 Partnerships with Other DOE Contractors

ORNL interactions with other DOE contractors in the Oak Ridge area are efficient and cost-effective. LMER and LMES provide each other with services in accordance with memoranda of understanding; for example, ORNL purchases procurement services from LMES. By working with LMES to improve procurement practices, ORNL has secured significant improvements. The move of dedicated staff to ORNL's main location has improved support and significantly reduced cycle times, and the implementation of purchase cards and improvement in just-in-time delivery represent a major improvement in operations with a corresponding decrease in cost per transaction.



An LMER/LMES/DOE procurement team streamlined basic procurement contract terms and reduced the number of clauses in this contract from 80 to 24. The team also effected a shift to electronic commerce and improved customer satisfaction by 49% with a positive response rate of 72%.

ORNL has also provided significant support to LMES for DOE's EM operations in Oak Ridge. It is expected that similar agreements will be established with Bechtel Jacobs Company, which was recently awarded an M&I contract for these operations.

The Oak Ridge Centers for Manufacturing Technology, a joint venture of ORNL and the Oak Ridge Y-12 Plant, provides industry with ready access to the capabilities of both institutions.

Master agreements with Sandia National Laboratories and Idaho National Engineering and Environmental Laboratory under the "System of Labs" approach have improved support and produced savings of more than $1.6 million.

3.7.2 Partnerships with Minority Businesses and Institutions

Vision of the Oak Ridge Complex
An integrated science, technology, and education complex operated in partnership with the private sector—supporting a dynamic regional and national economy.
—James C. Hall, Manager, DOE Operations Office

ORNL is the first national laboratory to establish a mentor-protégé program to assist energy-related small, small disadvantaged, 8(a), and women-owned businesses in enhancing their business and technical capabilities. LMER corporate funding was provided to support this program.

During 1997, DOE awarded ORNL an "outstanding" rating in its efforts in subcontracting with small and small disadvantaged businesses and an "excellent" rating in its efforts in subcontracting with women-owned businesses. Subcontracting with historically black colleges and universities and other minority educational institutions is increasing and will be the focus of strengthened efforts in FY 1998.

ORNL and AIMSI staff celebrate the signing of the mentor-protégé agreement.

3.8 Communication and Trust

ORNL supports DOE's commitment to communication and trust and its objective of working with customers and stakeholders in an open, frank, and constructive manner. Considerable effort has been invested during the past two years to increase awareness of the Laboratory's programs, functions, successes, lessons learned, and future activities. Programs are in place to address the needs of both the general public and the "internal public"—ORNL employees.

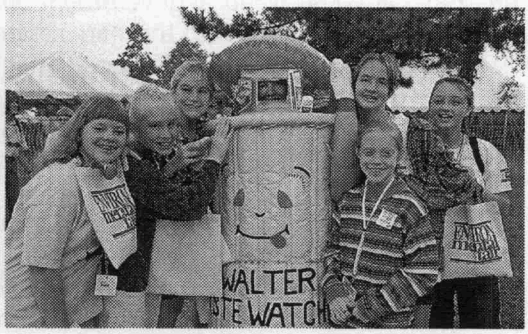
Employee communication vehicles—such as *Ridgelines*, a newsletter for employees and retirees; the "ORNL Today" feature on the internal web server; all-hands meetings on reengineering and other issues; and a system of Laboratory-wide electronic mail—have been developed or updated to support frequent communication to employees of in-depth information about ORNL programs, projects, policies, and issues.

An effective and comprehensive media relations program provides information about ORNL activities and their significance to a wide variety of media representatives through the distribution of some 150 news releases per year, telephone and face-to-face interaction with ORNL Communications and Public Affairs staff, and regular updates of the Laboratory's World Wide Web home page and a special "Newsroom" page. More than 90 examples of positive coverage of ORNL developments or programs in the national or international press were tracked in 1997. Stories about ORNL appeared, for example, in *Business Week*, the *Christian Science Monitor, Discover* magazine, the London Sunday *Times*, the *New York Times, Popular Science, USA Today*, and the *Wall Street Journal*, and on CNN, NBC Nightly News, and TBS.

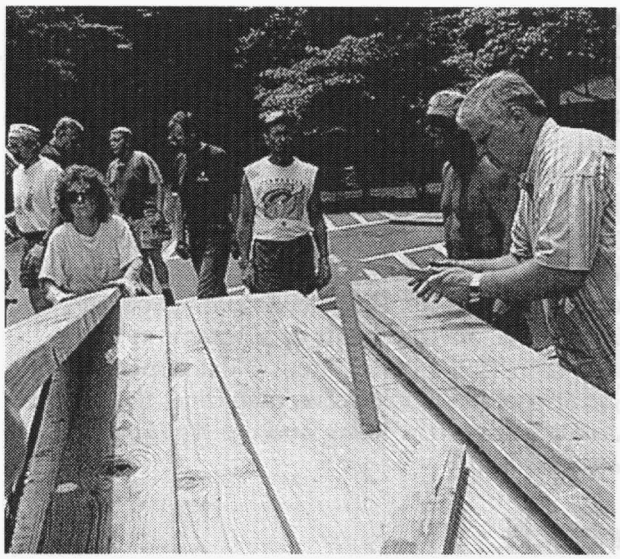
3.9 Community Outreach

Community outreach and community service programs provide a means for ORNL to demonstrate its commitment to being a good neighbor and a public partner. Corporate support provided by LMER underpins many of these activities.

- LMER supports an annual United Way campaign through which ORNL employees contribute hundreds of thousand of dollars to area agencies each year. Lockheed Martin Corporation makes a direct corporate contribution to the campaign. Many employees also volunteer their time to assist with United Way programs, and employees serve as "loaned executives" in county-level drives. The 1997 ORNL campaign generated nearly $600,000.
- Corporate contributions to cultural, educational, and economic development programs in East Tennessee exceeded $200,000 for 1997. Recipients of corporate grants through LMER included the American Society of Mechanical Engineers; the Challenger Center at the University of Tennessee in Chattanooga; the Nature Conservancy, Tennessee Chapter; Maryville College; and the 20th Symposium on Biotechnology for Fuels.
- Lockheed Martin Corporation is a patron—with the National Park Service, the city of Knoxville, and the Tennessee Valley Authority—of the Southern Highlands Nature and Technology Visitor Center, designed to be a highlight of Knoxville's Riverfront Development Project. Lockheed Martin is contributing $100,000 and assisting with project development and technical support and resources. The center will showcase the uniqueness of the region as a place "where nature and technology meet."



The EnvironMENTAL fair increases students' awareness and understanding of local and global environmental issues by showcasing environmental work in the Oak Ridge area.



ORNL employees volunteer to restore the Metcalf Bottoms picnic area in the Great Smoky Mountains National Park.

- ORNL employees and LMER have actively participated in the Friends of the Smokies' grassroots effort to preserve the Great Smoky Mountains National Park. Employees have volunteered their time to restore picnic areas in Metcalf Bottoms, and the corporation has contributed thousands of dollars to assist with this and other projects in the park.
- ORNL employees and LMER have also helped to support the Oak Ridge EnvironMENTAL Fair, which has provided entertaining introductions to scientific and technological careers for thousands of East Tennessee elementary school students. More than 7,500 area sixth graders participated in the 2-day event in 1997.
- ORNL employees and LMER are staunch supporters of educational programs and activities in the community through efforts such as the corporate matching gifts program, which generated more than $170,000 for Tennessee colleges and universities in 1997; Adopt-a-School projects; the Academy for Teachers of Science and Mathematics, a joint effort with the University of Tennessee at Knoxville; the Southern Appalachian Science and Engineering Fair; and the corporate scholarship program.

ORNL staff are working to promote and implement successful community partnerships. Significant support has been provided to the East Tennessee Summits and the Clean Cities initiative, and several successful partnerships have been forged with the city of Oak Ridge and other area communities. New business development is also an important community focus. By participating in business development programs such as the mentor-protégé program and small business partnerships, ORNL staff are sharing important information to help entrepreneurs start successful companies.

ORNL has also created new opportunities for interacting with government leaders and providing them with information about Laboratory activities. Initiatives include breakfasts at ORNL for local government officials, tours for members of area "leadership" classes, visits to the state capitol by ORNL leaders, and the provision of news materials to the offices of elected officials. ORNL's director, Al Trivelpiece, chairs the State of Tennessee's Science and Technology Advisory Council, which advises the governor, the General Assembly, and the commissioner of economic and community development on the full range of science and technology issues confronting state government.

ORNL regularly opens its doors to thousands of area residents for Community Day, a full day of tours and festivities celebrating science and its importance to life in East Tennessee. The inaugural event was held in 1995; and some 2,000 people participated in 1997, when ORNL teamed with the city of Oak Ridge, the American Museum of Science and Energy, LMES, and other organizations to sponsor "Oak Ridge Community Day." ORNL also hosts Family Days and Take Your Child to Work Days.

Visitors to ORNL may participate in prearranged general orientation tours, customized group tours, self-guided driving tours, or public bus tours originating at the American Museum of Science and Energy in the city of Oak Ridge. The public bus tours, introduced as a pilot program in 1995, have reached more than 6,000 people. Through the customized tours, some 2,000 students, business people, and technical people visit the Laboratory annually. These tours serve to educate local, regional, and national groups about DOE activities in the Oak Ridge area. They are also expected to help increase science literacy and to serve as a means of obtaining feedback on how ORNL is perceived by the public.

Public bus tours introduce more than 3,000 people each year to ORNL.

4 The Path Forward

The actions and activities of the past two years have brought the Oak Ridge National Laboratory (ORNL) to a threshold of opportunity. Notable accomplishments in science and technology have strengthened ORNL's reputation as a primary provider of research and development (R&D) addressing national priorities. Resources have been secured to support initiatives that will sustain and extend ORNL's distinctive capabilities. Operational improvements are making it easier to get things done in an environment that treats safety as an integral part of mission accomplishment.

As a result, ORNL is in an enviable position to address new challenges in science and technology.

- With the construction of the Spallation Neutron Source (SNS) and the completion of upgrades to the High Flux Isotope Reactor (HFIR) at ORNL, the United States will possess broad new capabilities for neutron science.
- ORNL's long-standing expertise in genetics is being combined with its fundamental understanding of biological and environmental systems and its computational and technological resources to give the Laboratory a matchless set of tools for improving human health and advancing sustainable development.
- The linking of powerful computers at ORNL to those at other institutions across high-performance networks creates a new paradigm for the solution of challenging scientific and technical problems.
- The Holifield Radioactive Ion Beam Facility gives the world's physicists unique capabilities for exploring nuclear structure and nuclear astrophysics.
- ORNL's comprehensive capabilities for addressing energy issues will play a leading role in the emerging effort to create the knowledge and technologies needed to meet the world's energy needs.

To take advantage of these and other opportunities, however, ORNL must maintain its focus on continual improvements in its ability to execute its mission assignments, operate safely and efficiently at reasonable cost, and sustain and enhance its unique strengths. Both near-term actions and long-term efforts are needed to ensure progress on the path forward to a bright future for ORNL.

The Department has a simple and clear vision for its laboratories in the 21st century. The laboratories will
• maintain the highest standards of excellence in science and technology;
• have well-defined roles in achieving the Department's missions and outcomes;
• be well integrated with the nation's R&D enterprise; and
• be recognized as highly efficient and cost-effective research institutions.

—Department of Energy Laboratory Operations Board,* Strategic Laboratory Missions Plan, Phase I, *p. 6, July 1996

4.1 Near-Term Actions

4.1.1 Issue Resolution

Steps are being taken to address several issues that are affecting ORNL's ability to perform its work safely and effectively.

Management

Efficient and effective management is an issue of prime importance if ORNL is to achieve its goals for improvement across all areas—science and technology; environment, safety, and health; and business operations. In addition to the specific actions that will be taken as part of ORNL's path forward, a change in the Laboratory's culture is needed to ensure success. A variety of activities are under way to build teamwork within the management levels.

Resolution of Employee Concerns

The ORNL Employee Concerns/Response Program provides a process for individuals to report environmental, health, safety and other concerns to appropriate management. A perception that reporting such concerns will lead to retribution or retaliation is being addressed by reissuing ORNL's health and safety policy, benchmarking other companies to identify how they address this issue, and reviewing

"lessons learned." Also planned is enhanced management communication to employees, encouraging them to voice their concerns and reiterating that any form of retribution for doing so will not be tolerated.

Safe Operations at ORNL

All employees at ORNL are expected to be totally committed to their own health and safety and to the health and safety of others in the workplace. ORNL's continuing implementation of integrated safety management (ISM) and of the Department of Energy (DOE) Voluntary Protection Program, which promotes excellence in occupational safety and health protection through cooperative efforts, will focus on supporting and strengthening this commitment.

While ORNL's current accident rate is about average for DOE research facilities, it has been increasing, especially for employees in the Plant and Equipment Division. Safety staff and division management are working to increase employee awareness of potential safety hazards and reduce accidents.

ORNL is in the process of transferring "ownership" of environment, safety, health, and quality (ESH&Q) to line organizations through a number of ongoing and new initiatives. Division directors will be assigned greater responsibility and accountability for ESH&Q. Processes for this transfer include provisions to give division directors greater flexibility in implementing safety and health requirements that are commensurate with the hazards presented by the division's activities. The development and implementation of ISM provide a platform for each division to tailor hazard identification and control, as well as employee training, to the work that it performs.

The implementation of Work Smart standards, as described in Sect. 3.1, includes the replacement of about 120 ESH&Q procedures with fewer than 80 new procedures that are clearer and easier to understand. Completion of this effort will eliminate burdensome and expensive requirements and result in a superior directives system that supports ISM at ORNL. Full implementation and acceptance of ISM is a continuing challenge, as discussed in Sect. 4.2.1.

Environmental Compliance

A National Pollutant Discharge Elimination System (NPDES) permit from the state of Tennessee defines effluent limits and water quality criteria for surface waters within ORNL. A number of NPDES violations have occurred at ORNL since a revised permit was issued in February 1997, leading to a concern that the state of Tennessee may issue a Notice of Violation. Many of these violations result from operator error; others have been associated with high chlorine levels when potable water was discharged from once-through cooling systems. All outfalls are being reviewed to ensure that dechlorination equipment has been installed and is operating correctly, and all once-through cooling systems are being examined to determine whether closed cycles can be installed.

A high-level examination of noncompliances with environmental regulations revealed that, in many cases, noncompliances resulted from an incomplete understanding of the obligations associated with operating a facility in compliance with a particular permit or agreement. In other cases, noncompliances resulted from a miscommunication between those involved in acquiring a permit and those responsible for operating facilities in compliance with the permit.

To address these issues, ORNL's environmental compliance organizations are meeting with the Laboratory's divisions to highlight the environmental considerations associated with the mission of each organization and to clarify actions required for compliance with environmental requirements. To date, meetings have been held with two research divisions. Both divisions now have a fuller understanding of the environmental requirements associated with their operations, a clearer understanding

of the actions necessary for compliance with the requirements, and a sense of ownership of the requirements. The meetings have also created a teaming relationship among the research organizations and the support organizations with responsibilities in the environmental area.

Property Accountability

In 1997, the Laboratory was alerted to a significant theft of government property by a call to the Ethics Hotline. Lockheed Martin Energy Research Corporation (LMER) and DOE's Oak Ridge Operations Office (DOE-ORO) chartered a team to develop an approach to deter further thefts. The ORNL Executive Committee strongly endorsed the team's efforts and directed the immediate implementation of the following recommendations:

- Revise the procedures to address team findings and to clarify confusing direction.
- Formalize a project start and completion process for subcontractor personnel to establish firm responsibility.
- Conduct random vehicle checks.
- Revise the property disposal and excess property process to provide more positive control and accountability.
- Continue the ongoing education and awareness campaign on appropriate property management and accountability.
- Make property management an element of the annual employee performance review process.

Most of these recommendations have been implemented by functional managers. The status of ongoing and future actions will be reviewed at regular meetings of LMER and DOE-ORO property management staff.

Safety Documentation

A joint DOE-contractor Safety Analysis Report Update Program (SARUP) was initiated in 1989 to ensure that safety analysis reports (SARs) and accompanying operational safety requirement (OSR) documents were in place for ORNL nuclear facilities and other hazardous facilities. The SARUP was expected to be complete in early FY 1999.

In 1992, DOE issued new orders for the development of SARs and technical safety requirements (TSRs), which replaced OSRs. An implementation plan to address these new orders was submitted in 1993. The schedule for completing these documents was contingent on funding; shortfalls in the funding provided and changing priorities driven by other events resulted in revised schedules for SAR and TSR development for some ORNL nuclear facilities. Revisions were documented in annual updates to the implementation plan.

In response to a DOE concern about the proposed completion schedules for some ORNL SARs and TSRs, ORNL and DOE senior managers evaluated the existing schedules. Where necessary, schedules were revised to allow submittal to DOE for approval by December 1999. Progress toward meeting these schedules will be reviewed quarterly by the Laboratory Facility Authorization Basis Board.

HFIR Operations

Over the past year, a series of events has reduced the availability of the HFIR. These events, taken individually, were not of a serious nature, but their number and increasing frequency and their overall impact on the reactor operating schedule have caused significant concern. Early in 1998, in consultation with its DOE sponsors, the Laboratory imposed a 30-day management stand-down at the HFIR to allow a self-

assessment of factors leading to missed customer expectations and of barriers to improved performance. A team chaired by Harold Denton, formerly Director of Reactor Regulation for the Nuclear Regulatory Commission, was appointed to perform this assessment. DOE conducted a parallel assessment of its HFIR-related management. Recommendations made by these assessment teams provided the basis for a number of actions being taken to improve HFIR operations. The management stand-down was followed by a scheduled 10-year in-service inspection that is required to ensure continued integrity of the reactor pressure vessel and associated systems. The in-service inspection has shown all tested systems to be in excellent condition, and the reactor is now being prepared to return to operation.

4.1.2 Completion of Reengineering Activities

The large-scale reengineering effort launched in March 1996 involves a cultural change that emphasizes individual and organizational accountability. Cultural change of this sort normally takes years to effect. The principal near-term challenge in reengineering ORNL is to sustain the effort long enough to complete the change; actions to meet this challenge are required in several areas.

Environment, Safety, and Health

The emphasis on individual accountability will manifest itself most strongly in ESH&Q activities, where ORNL is moving from ensuring compliance through audits and inspections to building compliance into all functions as part of the way the Laboratory does business. This approach is based on the belief that the line organizations are in the best position to define the criteria and the approaches that allow them not only to maintain compliance, but also to achieve excellence in all that they do. The new approach will require that all staff members understand fully what is expected of them and that they have an increased awareness of their legal and ethical responsibilities and of the resources available to support them.

The current ESH&Q pilot program will define expectations, provide the basis for an understanding of authority and accountability, construct division-specific approaches, and finally validate and document changes to current practices. After completion of the pilot, the approaches, techniques, and processes will be transferred to all of the divisions at the Laboratory. Many challenges must be met if this approach is to succeed, ranging from understanding and acceptance of accountability by individual staff members to a management posture that consistently holds individuals accountable for their actions and deals decisively with inappropriate behavior.

Business Management

Cost-effective management of business functions requires a number of changes in how ORNL does its work.

With its Delta Project, ORNL is taking an aggressive approach to implementing SAP R/3 and reengineering business processes, including areas such as travel and inventory control. Strong and continuing management attention will be required to ensure that resources are available both to meet the schedule and to realize the benefits of reengineering. ORNL and Lockheed Martin Energy Systems, Inc. (LMES) are fully committed to providing the necessary support. Resources from other parts of Lockheed Martin Corporation that have already implemented SAP R/3 will also be used.

In addition, cost reductions in all areas of operations are essential if ORNL is to (1) secure a competitive position for its researchers; (2) position its organizations to compete successfully for work from Bechtel Jacobs Company LLC, the new management and integration (M&I) contractor for DOE's Oak Ridge environmental management (EM) programs (see Sect. 4.1.6); and (3) offset the effects of reduced funding in some program areas. Achieving the needed cost reductions demands

innovative thinking in analyzing ORNL's processes, involvement of the entire staff in finding improved approaches, and strong leadership to overcome resistance to change. All parts of the Laboratory have already made contributions to this effort; in the near term, ORNL must remain committed to continued actions aimed at reducing the cost of doing business.

A perception exists that central overhead costs are imposed on the Laboratory's R&D organizations with the attitude that these organizations should not question either the amount involved or the need for the services provided. An effort to improve staff understanding of these costs is needed to address this perception. Continued and increased involvement of ORNL researchers in assessment of overhead functions is needed to validate overhead investments.

Human Resources

The cultural change required for successful reengineering also embraces a change from control of behavior to motivation for performance. This requires the development of new tools for assessing and rewarding performance. A new competency-based performance management system will be completed in FY 1998 and piloted and implemented in FY 1999, and a new and simplified job worth/job evaluation system will be developed in FY 1999. An integrated employee development module will also be provided. The line organizations will be responsible for most decision making about human relations. Information, tools, and guidelines to support line managers are under development, as are analyses, summary overviews, and reporting of results for senior management review. Challenges remain in developing these tools and in demonstrating to DOE that ORNL can responsibly manage its operations using this approach.

Research Support Services

A key aspect of the overall cultural change is the development of a customer focus in ORNL's service and support organizations, many of which have operated in a near-monopoly environment. Developing this focus requires continuous emphasis on the need for change, development of appropriate tools and training, and positive recognition of changes when they occur. ORNL must build on the foundations established by its development of a strong partnership with the bargaining unit, removal of barriers to productivity, and implementation of specialized training to reinforce the cultural change. Continuing support for these activities is needed to ensure success. In addition, ORNL's Plant and Equipment Division will be challenged to position itself to support its traditional R&D customer base while also responding to the craft-related needs of M&I-generated work.

Engineering Design and Construction

Progress in the reengineering of ORNL's engineering design and construction practices is described in Sect. 3.4.2. ORNL is also working to obtain contracting authority for construction and architect/engineer design services. Several contracts for design are already in place for use, and corresponding construction agreements should be available by mid-1998. On most jobs, ORNL will act as its own construction manager; hiring construction managers on a project-by-project basis will also be an option.

Other near-term challenges include working within the Construction Labor Agreement between the Knoxville Building and Construction Trades Council and MK-Ferguson of Oak Ridge and the associated challenge of attracting highly qualified and committed firms to do business at the ORNL site. Another key to achieving cost-effectiveness is adoption of industrial paradigms. The implementation of Work Smart standards is a significant advance toward this end. Further modification of the

ultraconservative, risk-averse culture remains an opportunity. Efforts are also being made to improve the understanding of the various relationships between costs and requirements and to work with the accounting systems to highlight anomalous practices.

Waste Management

As discussed in Sect. 3.2, the proposed transfer of responsibility for newly generated wastes from the DOE Office of Environmental Management (DOE-EM) to the Office of Energy Research (DOE-ER) in its capacity as ORNL's "landlord" raises a number of issues. A decision on this proposal is expected from DOE Headquarters during FY 1998. Depending on the outcome of this decision, ORNL will either

- begin the logical process of separating its newly generated waste operations from its legacy waste operations, while implementing an appropriate chargeback to the divisions that generate significant quantities of waste, or
- prepare for the transfer of all waste management operations to Bechtel Jacobs control, with the expectation that these operations will later be outsourced under the M&I contracting approach.

The latter case appears to represent an unfortunate loss of control over a critical aspect of R&D infrastructure support. ORNL will work with DOE Headquarters staff to provide information that supports the decision-making process.

General Issues

ORNL must maintain the momentum of the entire reengineering effort. ORNL management must work to keep reengineering highly visible and clearly demonstrate its successes to all staff members to address the continuing perception that the problem belongs to someone else and that, while reengineering "sounds good," the net real impact has been small so far. Certainly, reengineering has been a real learning experience for the Laboratory in terms of the complexity of making changes.

4.1.3 Achievement of DOE-ORO Goals

Performance measures for the evaluation of LMER have been developed by DOE-ORO with input from ORNL management. These measures, collected as "Critical Outcomes, Objectives, and Performance Indicators," represent a departure from past practices. They reflect a combination of longer-term expectations for ORNL and specific accomplishments within this fiscal year. Focus areas include Laboratory sponsorship, preparation for the SNS project line item start; environment, safety, and health integration; leadership and management (which includes progress on reengineering goals); and ORNL as a diverse institution (including socioeconomic procurement goals).

4.1.4 New Building for Laboratory for Comparative and Functional Genomics

The Laboratory for Comparative and Functional Genomics, now located in Building 9210 at the Oak Ridge Y-12 Plant, houses ORNL's mouse colony and is a key resource for the functional genomics initiative (see Sect. 2.1.2). This initiative supports the objectives of DOE's Office of Biological and Environmental Research and provides opportunities for significant collaborations with the commercial sector. (A workshop with R&D executives from pharmaceutical companies to discuss technical areas and business models for cooperation was held in April 1998.) ORNL has invested significant discretionary resources to build a comprehensive R&D program, leveraging the Laboratory for Comparative and Functional Genomics and special competencies in genetics, molecular biology, and computational and engineering sciences.

The physical infrastructure of the Laboratory for Comparative and Functional Genomics is no longer sustainable. Building 9210, which was constructed during World War II, long ago exceeded its design life and has serious structural problems. Repairs, if they can be performed at all, are very expensive because the building contains asbestos and radiological contamination, dating back to the immediate post-war era, and because many building parts and structures are unique. Heating, ventilation, and air conditioning systems are obsolete and need constant upkeep to remain marginally functional. Projected repair and maintenance costs for the next 3 years amount to $15 million. Building 9210 is simply no longer fit to house one of ORNL's premier research facilities.

A plan is being developed to construct a Gene Function Research Complex within the Marilyn Lloyd Environmental and Life Sciences Complex at ORNL. The Gene Function Research Complex is a modular campus of buildings that includes a new Laboratory for Comparative and Functional Genomics, a state-of-the-art facility to house the ORNL mouse colony. The estimated cost for this initial phase of the Gene Function Research Complex is $18 million. The Office of Biological and Environmental Research has indicated its intent to request $12 million for this project in the FY 2000 budget. It is critical for the survival of the research program that preconstruction activities begin in FY 1998 and construction begin in FY 1999. With an investment of $6 million in FY 1999, the new facility could be occupied by the end of FY 2000. This would allow ORNL to maintain its competitive advantage in this highly competitive and rapidly developing field.

4.1.5 Response to Ethics Survey Results

In late 1997, Lockheed Martin Corporation conducted a survey to assess views on ethical conduct at its companies and to collect information on job satisfaction and work environment. The results of the survey and its relevance to the ORNL environment are being assessed.

In comparing results from LMER employees with those from the corporation as a whole, it is evident that more attention must be given to increasing the morale of ORNL staff, creating a more positive feeling toward the company as an employer, and enhancing management communication with staff. Focus groups are being identified to reach a clearer understanding of the exact meaning of many of the survey questions and to investigate the underlying causes for areas needing attention. Information gained from these groups will be used to identify actions (both near- and long-term) that can be implemented to address the issues.

4.1.6 Interface with Bechtel Jacobs

Responsibility for EM-funded work on the Oak Ridge Reservation (including the ORNL site) is being transferred from LMES to Bechtel Jacobs Company LLC in April 1998. ORNL plays a major role in the Oak Ridge EM program; the equivalent of 1,300 ORNL staff members carry out projects that represent direct funding of $130 million and $35 million in overhead support.

The fiscal effects of this transfer for ORNL are not yet clear, but it appears that they will be substantial. The transfer of the responsibility for this program to Bechtel Jacobs under a management and integration (M&I) contract will also impose new ways of doing business and new expectations on those who carry out the work. Significant shifts in project execution will occur: a non–Lockheed Martin company will direct work at the ORNL site, much of the work now being done by LMER and LMES could be outsourced, work will be done under performance-based or fixed-price contracts, and certain ESH&Q responsibilities for EM work will belong to the M&I contractor, with much less ORNL control in this area.

ORNL must develop a high-level understanding and agreements with Bechtel Jacobs to facilitate a smooth transition to the new arrangement. Mobilizing to support M&I-sponsored work will be a challenge, but this endeavor can give the Laboratory a broader customer base and the potential for increased flexibility that will ultimately be beneficial to the research mission. In particular, ORNL's Plant and Equipment Division will be challenged to position itself to support its traditional R&D customer base while also responding to the craft-related needs of M&I-generated work.

Maintaining ORNL's good ESH&Q record as Bechtel Jacobs and its contractors begin work on the ORNL site represents a major near-term challenge, in part because the reduction in ORNL overhead funds associated with the transfer will significantly reduce the funds available for ESH&Q activities. Experience with multiple contractors, both at ORNL and at other DOE sites such as Hanford and Rocky Flats, shows that ESH&Q problems tend to occur at the "seams" or "interfaces" among multiple organizations—that is, where confusion, misunderstanding, uncertainty, and company pride can act to the detriment of safety.

The framework for M&I contractor operations is established in the M&I contract. Bechtel Jacobs assumes responsibility and accountability for ensuring that ES&H considerations are incorporated in all work that it performs on the ORNL site, and requirements for work performed by Bechtel Jacobs or its contractors are to be incorporated in the contractor's Work Smart standards. Because ORNL operates under its own Work Smart standards, the M&I contractor project manager is responsible for comparing the contractor's Work Smart standards with the ORNL Work Smart standards and for resolving any differences between the two sets of standards. The M&I contractor will follow ORNL procedures in some cases; in other cases, ORNL activities—such as those in the waste management area—will have to comply with appropriate M&I contractor criteria to ensure an effective interface. Potential nuclear safety issues governed by the Price-Anderson Amendments Act (PAAA) are the responsibility of the M&I contractor for the work that it performs. The M&I contractor and ORNL PAAA coordinators will work together to resolve any questions of responsibility for noncompliances or corrective actions. Ultimately, any ORNL or M&I contractor employee has the responsibility to stop work that is deemed to pose an imminent danger to personnel or a threat to the environment or the public.

ISM principles on incorporation of ES&H considerations into work planning will provide the critical interface between ORNL and the M&I contractor. A signed memorandum of agreement between ORNL and the M&I contractor will address all activities carried out on the ORNL site. This agreement will allow for full review of activities and resolution of any differences before work begins.

The Department and Contractors must systematically integrate safety into management and work practices at all levels so that missions are accomplished while protecting the public, the worker, and the environment. This is to be accomplished through effective integration of safety management into all facets of work planning and execution. In other words, the overall management of safety functions and activities becomes an integral part of mission accomplishment.

—DOE P 450.4, "Safety Management Systems," October 15, 1996

4.2 Continuing Challenges

4.2.1 Implementation of Integrated Safety Management System

ORNL is implementing an ISM system (ISMS) to ensure that safety considerations are integrated into the planning and execution of research and support activities. A written policy documents ORNL's commitment to ISM and to accomplishing mission assignments in a safe and effective manner. ORNL is finalizing an ISMS program description and will initiate a series of applications of ISM principles to selected projects and activities.

Full implementation and acceptance of ISM will require a change in ORNL's existing safety culture. The challenge is to ensure that ORNL staff understand that safety is an integral part of each work activity. The ISMS will integrate the work definition and an analysis of hazards to provide for the safe performance of work. Line management responsibility and accountability will be achieved by weaving safety management into

the fundamental fabric of mission accomplishment. Acceptance of ISMS by line management and the individual worker is expected to significantly improve safety performance and reduce worker injuries.

4.2.2 Strategic Planning and Program Development

To address the challenge of implementing strategic change in a more disciplined manner, ORNL has adopted a strategic management model that calls for (1) developing and implementing a strategic plan dedicated to change; (2) managing discretionary resources for strategic change consistent with the plan; (3) measuring performance and acting on results; and (4) conducting continual environmental scanning to keep up to date on potential threats and opportunities.

Consistent with this model, ORNL has established a set of challenging scientific goals that are documented in the Laboratory's strategic plan (which is incorporated in the *Oak Ridge National Laboratory Institutional Plan: FY 1998–FY 2002*, ORNL/PPA-97/2, and available on ORNL's public web server). Senior managers have taken responsibility for strategic objectives designed to move ORNL toward accomplishment of these goals; and allocations of program development, Laboratory Directed R&D (LDRD), and general plant project/general-purpose equipment funds will be reviewed to establish their consistency with the scientific goals. The goals will be periodically examined to assess progress and ensure alignment with DOE goals and missions.

We need a plan that defines a challenging future, one that stretches us to perform in a manner consistent with our heritage and traditions . . . The problem is that in our environment, such plans cannot be more than a near-term guideline. This doesn't mean that we should stop planning but, rather, that we have to have realistic expectations about what strategic plans can accomplish as tools.

—Dr. Alvin W. Trivelpiece, State of the Laboratory address, June 12, 1997

Achieving these goals will impose challenges in attracting and retaining key staff, maintaining and building unique facilities, and developing innovative research programs. The initiatives in neutron science, functional genomics, and distributed computing establish a focus for these challenges. For example, the SNS can serve as the basis for new research programs that span organizations and enhance progress in functional genomics and computational science.

A related challenge is the structuring of program development to effectively market and develop key areas. This will require both financial resources and a commitment to focusing attention on emerging opportunities such as DOE's Climate Change Technology Initiative. A new Office of Program and Partnerships Development is planned to help ORNL R&D staff members find opportunities to market new ideas and develop new research areas.

A complicating factor in this challenge is the nature of the process for funding ORNL's R&D. Principal investigators prepare and submit proposals to DOE and other sponsors; funding is perceived to result largely from direct interaction between principal investigators and their sponsors, and principal investigators' interest in Laboratory-wide strategic planning and program development tends to be inversely proportional to the availability of funds through traditional sponsors. ORNL's senior managers need to foster a broad awareness of the strategic goals to encourage the development of programs that are aligned with these goals. Also needed are efforts to increase the effective integration of ORNL's capabilities, focusing on improving the visibility of these capabilities and on developing new mechanisms for teaming.

Program development activities present additional challenges. The mechanics of the Work for Others process have been improved through reengineering at ORNL and cooperation with DOE-ORO, but challenges remain in handling legal issues and working with other federal agencies. ORNL, other DOE laboratories, and senior DOE officials will continue high-level discussions with key agencies to facilitate the application of national laboratory capabilities to their needs. ORNL will also continue its emphasis on offsite assignments of staff members, which provide opportunities for integration of ORNL staff into other government agencies and for learning more about the private sector.

Given the need to reduce Laboratory overhead, ORNL expects to face a continuing challenge in sustaining its investments in program development and LDRD. Because these programs represent investments in the future and a tool for growing the base, they will be monitored to ensure that ORNL is using them as wisely and as effectively as possible.

4.2.3 Building the Work Force of the Future

To succeed in the rapidly changing scientific, business, and political environment that lies ahead, ORNL will need a diverse and talented staff of scientists, engineers, and support personnel to carry out its mission assignments. The Laboratory is committed to being an employer of choice for the staff members that it needs to realize its strategic goals.

To meet this commitment, ORNL is focusing attention on three areas: restructuring compensation and performance management systems, fostering diversity in the "workplace of the future," and improving employee development. Efforts in these areas that began with the reengineering of human resources (see Sect. 3.5) will be sustained.

In the first area, the emphasis is on developing flexible job structures that are aligned with current organizational strategies and allow appropriate salary growth. Salaries, benefits, and incentives will be market competitive. A mechanism will be developed to support the collection of feedback from several sources (peers, direct reports, and managers) in assessing competencies.

In recognizing and promoting the competitive advantage of diversity in the workplace of the future, ORNL will continue working to recruit, retain, and develop a diverse work force; to promote understanding and valuing of differences; and to create an environment that accommodates this future work force. Proposed strategies include the development of more flexible work schedules, an onsite child care facility and fitness center, and a cafeteria-style benefits package.

In its efforts to improve employee development, ORNL will create a process that provides mentoring, training, educational assistance, and challenging job assignments for employees to enhance their potential and to support the Laboratory's business strategy. Employees will have primary responsibility for their development; supervisors will be responsible for providing guidance and appropriate opportunities and resources. Enhanced succession planning will allow ORNL management to identify employees with the potential to become leaders in the Laboratory and facilitate their development.

4.2.4 Maintaining and Improving Facilities and Infrastructure

The condition of ORNL's facilities and infrastructure directly affects its ability to do quality research. Palatial surroundings are not expected, but the facilities must be adequate to support the work to be performed. Appearance also makes an impression on potential customers; poor conditions can cause research dollars to flow to other institutions in the belief that a shabby facility means shabby science.

Infrastructure Maintenance

ORNL has one of the oldest physical plants in the DOE laboratory complex. Requirements for maintenance and infrastructure improvements, which already exceed the available resources, will continue to grow as the facilities age. At the same time, the current emphasis on reducing the federal budget has constrained funding for meeting these needs. Therefore, setting appropriate priorities for infrastructure projects is—and will continue to be—extremely important in order to optimize the utility of available funds. Risk scores developed by the recently established Risk Ranking Board, which consists of senior Laboratory personnel, will facilitate a consistent, integrated ranking of Laboratory requirements, as will the planned expansion of a business risk methodology to assess requirements for sitewide utility systems. The development of this integrated process will support the most effective allocation of scarce resources.

Facility Modernization and Replacement

Facility modernization is closely linked to ORNL's major initiatives. In addition to the near-term efforts to secure a new building for the Laboratory for Comparative and Functional Genomics, as discussed in Sect. 4.1.4, ORNL will address challenges in upgrading its capabilities in neutron science and high-performance computing.

High Flux Isotope Reactor. The HFIR is a key facility for the Laboratory's initiative in neutron science; it is also a major source for radioisotopes. Past funding reductions for the HFIR have reduced the reactor's availability; further reductions could jeopardize continued operation. ORNL plans the following actions:

- internal and external reviews of HFIR operations and budget, aimed at identifying areas of possible improvement and cost reductions;
- careful prioritization of needs; and
- projection of future needs to upgrade, replace, or repair plant equipment for use as input to the prioritization process.

Improvements in HFIR operations are needed to improve reliability in research use and radioisotope production, thus increasing customer satisfaction in these important areas.

Teraflops computing. In support of its major initiative in distributed computing, ORNL is working to acquire a new high-performance machine that can operate in the trillions of floating point operations per second (teraflops) range. A building in which to house this and future high-performance computers should be part of ORNL's planning for the longer term.

4.2.5 Management of the Oak Ridge Reservation

The Oak Ridge Reservation is a valuable natural resource for the nation. Its 14,000 hectares (35,000 acres) contain relatively undisturbed ecosystems that are important habitats for many species uncommon or absent in surrounding areas, and it has experienced minimal impact from human land use for the past 50 years, providing an invaluable reference point for determining the effects of human development on natural resources. An extensive collection of data about the reservation has been accumulated over the past few decades, including information on geophysical properties, biogeochemical dynamics, landscape patterns, meteorology, and atmospheric dynamics.

Public use of the reservation includes bird walks, wildflower hikes, and trips to field research sites. Work is in progress to expand these activities.

The reservation provides a buffer for ORNL operations and space for future facilities. ORNL will continue to play a leadership role in Oak Ridge Reservation land use decisions and management. Laboratory managers will work to ensure that a comprehensive integrated management plan, which considers the input of all stakeholders, is maintained and that the reservation remains available for activities that support key DOE missions, both known and not yet known.

4.2.6 Management of Intellectual Property

Technology transfer and collaborative relationships are expected to remain an important part of ORNL's activities as a national laboratory. ORNL has been quite successful in terms of the widely used technology transfer metrics of numbers of cooperative R&D agreements (CRADAs) and licenses. A review of the broader area of science and technology partnerships, conducted as part of the reengineering effort, indicated that this area comprises a much larger and more important set of activities. The partnerships reengineering team concluded that ORNL could improve its effectiveness in working with industry, academia, and other federal laboratories and

made recommendations for improvement. Among these were recommendations for improving the management of intellectual property.

A diversity of legal mechanisms govern technology transfer. Different types of contracts may be executed by different organizations; they may involve potential effects on intellectual property and difficult legal problems that can lead to the compromise or loss of rights. Many of the forms of agreement are relatively mature and the processes to handle them are stable, for both the contractor and DOE. However, the current management framework is overly bureaucratic and controlling compared with the other contractual mechanisms used with the private sector. The time is right to structure a comprehensive, streamlined system for managing technology transfer, consistent with the risks and objectives associated with this activity. The system should address intellectual property such as licenses and CRADAs, user agreements, Work for Others agreements, short-term and long-term consulting agreements, and personal services contracts.

One objective of technology transfer is private-sector commercialization of ORNL innovations. The Laboratory's achievements in this area are indicated by the fact that it is now possible to begin thinking about measuring success in terms of number of jobs generated, rather than in terms of patents granted or CRADAs completed. Financial benefits from the successful commercialization of innovations are increasing. Royalties from sales of licensed technologies can be used to promote more research and could eventually yield enough income to make up a significant portion of the Laboratory's budget.

Successfully partnering with industry requires researchers to be familiar with the needs of the private sector. Efforts to increase the number of ORNL researchers with a good understanding of these needs will be part of creating a climate that encourages more ORNL staff members to seek out research opportunities with the private sector. The local economy can also be stimulated through interactions with the private sector, and ORNL is committed to working with the city of Oak Ridge on economic development issues.

4.2.7 Strengthening Support for ORNL's Activities

ORNL wants and needs the support of its employees, its customers, and its neighbors. Areas of special emphasis include expanding the communications activities related to the SNS, focusing on community outreach, and improving the flow of information about reengineering to ORNL employees.

In an ideal world, our Showcase Lectures and Distinguished Lecture series should provide some thought-provoking challenges for you to consider and Ridgelines should keep you up to date. Our Web pages contain a great deal of information. But this is not an ideal world. I know as well as you that these sources of information don't provide the depth of communication that we should have.

— Dr. Al Trivelpiece, State of the Laboratory address, June 12, 1997

The success of the SNS depends on acceptance by the local and scientific communities. ORNL plans to

- develop a series of op-ed media pieces discussing the SNS, its importance, and how it fits into DOE's "System of Labs" approach;
- include SNS updates on ORNL's NewsLine, the new toll-free phone line for area and regional broadcast media;
- provide information about the SNS to industry and university leaders;
- include SNS updates in a proposed new outreach newsletter to be distributed to community leaders; and
- work closely with Tennesseans for the Spallation Neutron Source to ensure continuity of message.

In the area of community outreach, ORNL plans to establish a formal volunteer program involving company employees and retirees. Other activities include benchmarking practices at Sandia National Laboratories and other facilities; increasing communication about the Laboratory's public tours and breakfasts for community leaders; and expanding efforts to communicate with local and regional communities to heighten their awareness of Lockheed Martin and ORNL as good corporate citizens,

supported by information about monetary and community service contributions. ORNL will also expand its efforts to report on operations, health issues, and other activities. The East and Middle Tennessee media markets will be targeted with these stories.

Success in reengineering depends to a large extent on employee support for these efforts. ORNL will continue to hold Lab-wide employee meetings to inform employees about progress in reengineering, scheduling these meetings on a more regular basis. Reengineering updates will continue to be featured on "ORNL Today," the Laboratory's internal Web news page, focusing on activities, progress, and concerns in various ORNL divisions and offices. A link to the reengineering home page will be added to "ORNL Today," and employees will be reminded that they can submit questions about reengineering through "ORNL Today" or through *Ridgelines*, as well as through the reengineering home page. Prompt answers to such questions will be provided.

4.2.8 Site Access

ORNL will continue to press for improvements in access to its facilities and in the freedom for employees and visitors to come and go, including improvement in areas such as paperwork, access, schedules, and fences. Procedures that are friendly to the outside world will be developed. The approach will be to work for the elimination of existing constraints, where possible, and to strictly and thoroughly justify any addition of rules and constraints that may interfere with increasing access.

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