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Oak Ridge National Laboratory

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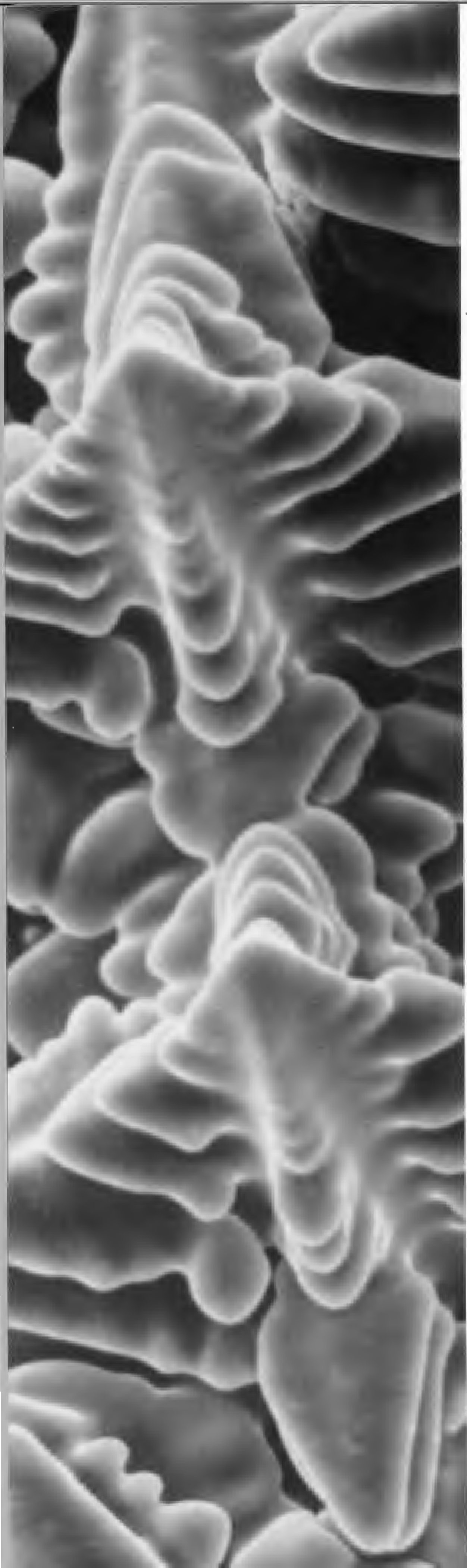
State of the Laboratory

ORNL-UT Partnership



ON THE COVER

The micrograph on the cover shows treelike crystallites called dendrites in a single-crystal weld. ORNL researchers Stan David and Lynn Boatner have found that making and studying single-crystal welds can provide insights into how to make stronger welds, as described in their article on p. 32.

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REVIEW

Volume 24
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FEATURES

DEPARTMENTS

Oak Ridge National Laboratory is a multiprogram, multipurpose laboratory that conducts research in the physical, chemical, and life sciences; in fusion, fission, and fossil energy; and in energy conservation and other energy-related technologies.

STATE OF THE LABORATORY 1990

By Alvin W. Trivelpiece

Editor's note: The following is an edited, updated version of the annual State of the Laboratory address presented by the Laboratory director. When ORNL Director Alvin Trivelpiece gave the State of the Laboratory–1990 address on February 12, 1991, he noted that the occasion of this address was more somber than usual because of the involvement of ORNL staff members and family members in the Persian Gulf War. So he asked the audience to join him in a moment of silence while reading the names of Laboratory people (shown on p. 4) who had been or were on active duty then as a result of the Middle East crisis.

This is a sober way to begin what is usually a somewhat lighthearted and optimistic event. But 1990 was a rather sobering year for the Laboratory and for much of the world. I know of no one, including the best of psychics, who successfully predicted the astonishing events of 1990, especially those in the Soviet Union, Eastern Europe, and the Persian Gulf. These events may seem remote from us, but they have had a profound influence on the activities at the Laboratory.

For instance, in early 1990 Congress spent considerable time debating how to spend the money no longer needed for defense because the Soviet threat in Europe had been reduced. While debating how best to spend the "peace dividend," Congress examined a long list of high-priority problems, such as the need to bail out the savings and loans industry, reduce the deficit, help the homeless, support AIDS and cancer research, and pay the increasing costs of health care through the Medicaid and Medicare programs. Unfortunately, basic and applied research of the sort we do at the Laboratory did not seem to be near the top of their list of high-priority items.

Even so, I believe that support for research and technology development should be near the top of their list. Our world has become technically complex and is becoming more so all the time. In the coverage of the Persian Gulf War, television showed the results of precision bombing using laser-guided "smart" bombs and of superior defense systems, such as the radar-guided Patriot air-defense missile used to intercept Scud missiles from Iraq. Only sophisticated technology development makes these smart weapons possible, saving the lives of civilians in time of war.

We need to sort out the effects on our future of smart munitions and many other technologies, such as nuclear power, nuclear waste disposal, conservation, fossil fuel combustion, asbestos, solar power, and fusion power. We need to determine the implications of their environmental effects, such as global warming and loss of biodiversity. Unfortunately, just at the time that Americans realize the need to better understand some of these complex technical issues, we find that international tests show that U. S. high school students are among the worst of the industrialized countries in math and science achievement. As an example of this problem, 47% of U. S. high school graduates do not know whether 87% of 10 is greater than, less than, or equal to 10. The United States is among the worst of the industrialized countries in terms of infant mortality and prenatal care, yet we spend enormous sums to reduce health risks that in some cases are more perception than reality. I believe we need to greatly improve our understanding of risk assessment and then allocate our resources accordingly to eliminate or protect people against the hazards that pose the highest risks. We aren't going to achieve such a goal unless we give a higher priority to education, particularly in math and science. We are not going to solve our technologically intensive problems by systematically knowing less about them. I believe institutions such as ORNL can play a vital role in developing the knowledge required to solve some of these complex problems. Unfortunately, not

Enjoying a humorous moment following the State of the Laboratory address are, from left, Herman Postma, ORNL Director Emeritus; Gordon Fee, Energy Systems senior vice president; Alvin Trivelpiece, ORNL director; ORNL Deputy Director Murray Rosenthal (facing Trivelpiece); and Alex Zucker, ORNL associate director for Nuclear Technologies.

The following Energy Systems employees who work at or for ORNL served in the U. S. armed forces during the Persian Gulf crisis.

Carl E. Allred, Plant and Equipment (P&E) Division

Bobby E. Argo, Fusion Energy Division

Betty A. Benton, Chemistry Division

J. E. Bridgett, Graphics Division

Carlos B. Brooks, Finance and Materials Division

Robert E. Carden, P&E Division

Jeffrey S. Delashmitt, Analytical Chemistry Division

Sharon Gottman, Office of Waste Management and Remedial Action

Howard E. Freeman, Quality Division

Hollis G. Hodge, Biology Division

J. P. Jones, Jr., Instrumentation and Controls (I&C) Division

R. T. Jubin, Robotics and Process Systems Division

C. T. Kring, Robotics and Process Systems Division

S. B. Lane, P&E Division

Gerald L. Martin, Laboratory Protection Division

Thomas J. McManamy, Engineering Division

J. B. Miles, P&E Division

R. J. Quinn, I&C Division

R. M. Reed, Laboratory Protection Division

Mark H. Robbins, Graphics Division

C. C. Roberts, P&E Division

Larry T. Shaw, Laboratory Protection Division

E. R. Simmons, P&E Division

J. A. Slice, Environmental and Health Protection Division

Frank Tauxe, Laboratory Protection Division

J. T. Trotter II, I&C Division

R. A. Vines, I&C Division

Joe L. Weaver, Environmental and Health Protection Division

Doyle Lee Whaley, P&E Division

C. F. Zamzow, Environmental and Health Protection Division

ORNL's Steam Plant, which was built in 1947 to produce steam for heating many of the Laboratory's buildings, has been selected as a model for the operating facilities in Energy Systems. The before-and-after photos show some of the aesthetic and safety improvements resulting from remodeling and the installation of machine guarding and soundproofing.

everyone agrees with me. Otherwise, adequate funding would be available to address many of these problems.

Tiger Team Audit

Although many might agree that these are important problems, it must be understood that the competition for resources is becoming keener. At the same time, the available resources are shrinking. Thus, the Laboratory must compete in a tougher and more competitive arena. This change requires us to do many things differently than we have in the past. One dimension of our ability to compete was our response to the Department of Energy Tiger Team audit of ORNL in 1990. This inspection was the defining activity of the Laboratory last year because we spent so much time preparing for it, undergoing it, and responding to it. In all these efforts, I believe that we did an outstanding job.

DOE Tiger Team audits are not easy. For more than six months before the Tiger Team arrived, everyone at the Laboratory was involved in some aspect of preparing for them. During the six weeks that the Tiger Team was on site, we made a major effort to escort team members to where they needed to be, fetch for them what they needed, and help them prepare their reports in a timely manner. After the Tiger Team left, we made a crash effort to prepare an action plan and get it approved and submitted to DOE. None of this was easy for anyone.

At the closeout meeting of the Tiger Team, I said, "You, the employees of Oak Ridge National Laboratory, have a justifiable right to be

The improvement of the interior of the Process Waste Treatment Plant (Building 3544) is obvious in these before-and-after photos. This facility was frequently used for training DOE Tiger Teams.

The Process Waste Treatment Plant was greatly improved in 1990. Leaks of nitric acid caused corrosion in the floors, walls, and ceiling. As the before-and-after photographs show, swimming pool liners serving as containment dikes were replaced by concrete dikes.

All ORNL employees, including members of the Central Management Division, were involved in preparations for the DOE Tiger Team in 1990. Shown here helping with housekeeping activities, such as cleaning and repair, are Alex Zucker, ORNL associate director for Nuclear Technologies, and Richard Montgomery of the Engineering Technology Division, which celebrated its 40th anniversary without a lost-time work accident.

proud of what you have accomplished. You have my appreciation, my admiration, and my respect." In an article that appeared in the January 15, 1991, issue of the *Knoxville News-Sentinel*, Martin Marietta Energy Systems President Clyde Hopkins said, "I am so proud of Oak Ridge National Laboratory and the way the employees worked together to prepare for the Tiger Team and the way they handled themselves while the Tiger Team was here. Considering what happened at the other national labs, we just have to be overjoyed." Thank you, Clyde, you said it better than I could have.

Because our objective was to make our house safe from tigers, we spent considerable time fixing up, cleaning up, and painting everything that we could before the Tiger Team arrived. One of the areas that received some special attention was the Steam Plant, which was built in 1947 to provide steam for heating our buildings. It had deteriorated over the years, but it is now in good shape, as shown in before-and-after photographs (on p. 5).

"Our objective was to make our house safe from tigers . . ."

Representatives of Sequoyah Fuel Services of Gore, Oklahoma, were interested in the implementation of "conduct of operations" at their facility and were referred to ORNL, and particularly the Steam Plant, by one of our recent Tiger Team visitors. He considered us an outstanding example of effective implementation of conduct of operations—operation of a facility to ensure its full compliance with the latest regulations.

Another facility that we improved to meet new standards was the Process Waste Treatment Plant (Building 3544), which has been in operation since 1976. The chemicals it uses to remove radioactive strontium from ORNL's process wastewater stream also "eat" metals and concrete and leak out. Over about 15 years, the concrete had eroded, making it look like the home for the creature from the Black Lagoon. The two sets of before-and-after photographs on p. 6 show the extent to which this facility was fixed up. Even the Tiger Team noticed the improvement. To help prepare for the audit, I spent a week earlier this year going through a training course offered for future Tiger Team members. The tigers used this building as one of their "classrooms" because it

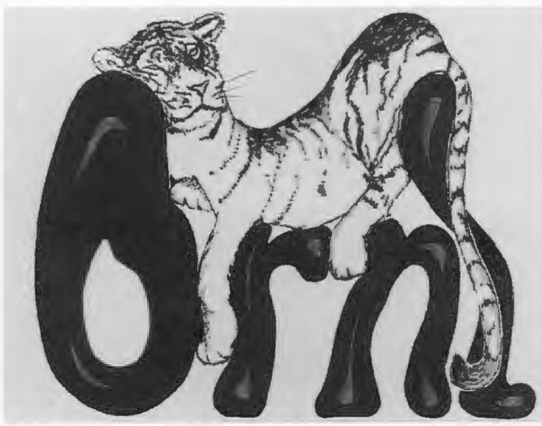
ORNL machinist Mickey Hall installs a guard on a machine in an ORNL fabrication shop to make the area safer for workers.

offered many examples for them to sharpen their claws on. For me it was an eye opener.

Employees at all levels rolled up their sleeves and went to work. The photograph on p. 7, for example, shows Alex Zucker, ORNL associate director for Nuclear Sciences, and Richard Montgomery attending to housekeeping chores in the Engineering Technology Division. This division passed a phenomenal milestone last year: it celebrated 40 years without a lost-time work accident.

One of the problems that quickly emerged after the Tiger Team arrived was the need to fix problems as quickly as possible after the Tiger Team members found them, and perhaps even more important, before they found them. A "swat" team of dedicated employees worked day and night to keep us ahead of the game. Some of the Tiger Team members found that, when they went back the next day to get a better look at some deficiency they had spotted, it wasn't there anymore. Much to their distress it had been fixed up—aw, too bad! This rapid response worked because our Tiger Team escorts would promptly communicate team concerns to Plant and Equipment Division managers, who asked the craft workers in the "swat" team to get the job done right away.

It is not possible to give credit to everyone who contributed in major ways to our efforts related to the Tiger Team audit. I am only going to mention a few. The support provided by the Information Services, Graphics, Publications, and Engineering divisions was outstanding. The escorts who kept their cool for longer than the law requires deserve hero medals.



This relaxed tiger—not asleep and ready to spring into action at ORNL if needed to stimulate compliance with government regulations—was drawn by Bob Eldridge of the Publications Division of Energy Systems. John Patterson, head of the DOE Tiger Team at ORNL, presented this "CAT-A-LYST" graphic as a souvenir to the Laboratory.

Until his gentle reminder from Mother Nature to slow down a bit, Tom Row played the key role in getting us organized for the Tiger Team. I am pleased to note that Tom Row is now back at work full time. Bill Fulkerson, Jerry Swanks, Frank Kornegay, and Tony Wright had key roles in organizing our efforts before, during, and after the Tiger Team audit. Others who played key roles include Bill Morgan, Dave Reichle, Jack Richard, John Sheffield, and Bill Simon. The effort to get the action plan completed and delivered to DOE after the Tiger Team left was led by Mike Kuliasha.

I would also like to reserve special recognition for one additional hero of the Tiger Team effort—Murray Rosenthal. He chaired the Environmental, Safety, and Health (ES&H) Coordinating Committee, which has been pivotal in our Tiger Team efforts. His attention to detail kept all areas of the Laboratory talking with each other and focused our efforts on what we needed to do. Besides deficiencies, the Tiger Team also identified some noteworthy practices at ORNL. The one example I will mention was the grassroots effort by the shops to assemble teams to design, develop, fabricate, and install appropriate machine guards on the equipment used in ten fabrication shops. This program began in the ORNL Fabrication Department in 1989 to assess compliance with machine safeguarding regulations enforced by the Occupational Safety and Health Adminstration (OSHA). To comply with regulations, we installed over 1500 guards on 574 different pieces of equipment (see the photograph on p. 8).

Our relations with the Tiger Team were generally good despite the many opportunities for friction and conflict. I believe one reason we had no serious conflicts is that the Laboratory staff did their best to be professional in working for and with the Tiger Team members. Another reason is the highly professional way that John Patterson, the Tiger Team leader, did his job. In many respects, it was no easier on him than it was on the rest of us. A symbol of our good working relations is the drawing above that Patterson presented to us at the end of the closeout briefing. In this so-called CAT-A-LYST, the tiger is relaxed, but not asleep. It could spring into action if we fail to continue meeting our ES&H responsibilities. But we hope to keep it tranquilized for a long time.

The term Total Quality Management, or TQM, has recently come into our lexicon. In many ways, the Laboratory's response to the Tiger Team challenge was an excellent example of TQM at work. No detail or problem that could be identified went unattended for long. This is TQM at its best. We need to continue what we have started and do as good a job in ES&H as we do in research.

One of the ironies of the Tiger Team visit was the criticism that we engage in what is sometimes called collegiate or consensus management. I don't believe that we would have done as well as we did without this approach. Our top managers met and agreed on a course of action by getting the best among us to work on particular problems.

"In 1990 five ORNL technologies were selected as being among the 100 most innovative technologies in the world."

In October 1990, Admiral Kenneth Carr, chairman of the Nuclear Regulatory Commission, was briefed at ORNL on its nuclear safety research. Here, John Merkle of the Engineering Technology Division shows Chairman Carr one of the Heavy-Section Steel Technology Program's vessels. Experiments with these vessels demonstrated that they could withstand pressures 3 times the design pressure.

There was no chair and whip to get people to do what we needed to be done. We did it because we came to a consensus that it had to be done. Our success was determined at least in part by our management style.

Excellence at ORNL

Our excellence as a staff was recognized once again in 1990. One way that a research and development (R&D) organization knows that it is performing well is through the recognition that others provide by bestowing honors and awards upon its individual scientists and engineers.

Our excellence has been recognized in many ways. For example, a number of researchers were elected fellows of professional societies in many different disciplines and a number of our secretaries were designated certified professional secretaries.

In 1990 five ORNL technologies were selected as being among the 100 most innovative technologies in the world (see "R&D Updates" in the *ORNL Review*, Vol. 23, No. 3, 1990, for details). They received R&D 100 awards from *Research & Development* magazine, giving ORNL a total of 62 such awards.

Assisted by John Allred, Prem Srivastava of the Health and Safety Research Division (HASRD) developed an agent for binding radioactive iodine more securely to monoclonal antibodies that go to specific sites in the body. Because it prevents the radioactive agent from being stripped off in the maelstrom of the bloodstream, this technology has the potential for improving the "magic bullet" approach to diagnosing and treating cancer.

Abu Ahmed, Rhonda Bogard, and Mark Buckner, all of HASRD, developed a superior radiation dosimetry system that permits badge reuse, speeds processing, and detects low doses. The system is now used for monitoring the radiation exposures of all Energy Systems employees.

Claudette McKamey, Vinod Sikka, and Chain T. Liu, all of the Metals and Ceramics (M&C) Division, developed a strong, ductile iron aluminide alloy that performs well in highly corrosive environments.

The "Z-contrast imaging" of Steve Pennycook of the Solid State Division has revolutionized electron microscopy by simultaneously producing high-resolution direct images of a material's atomic structure and composition.

Phil Maziasz and Robert Swindeman, both of the M&C Division, developed an inexpensive, crack-resistant stainless steel suitable for demanding, high-temperature environments.

In 1990 Martin Marietta Energy Systems elected a corporate fellow and a senior corporate fellow. Paul F. Becher of the M&C Division was elected corporate fellow "for basic studies in the fracture of and toughening mechanisms in ceramics and ceramic composites, in the establishment of the relationships between microstructure and composition and mechanical behavior, and in the development of advanced ceramic materials."

Rufus H. Ritchie of HASRD was elected senior corporate fellow "for fundamental studies in radiation physics, radiation dosimetry, and surface physics and for pioneering theoretical work on collective modes, surface electromagnetic waves in solids, and the elucidation of the interaction of charged particles with matter."

John Sheffield, director of the Fusion Energy Division, received the Outstanding Achievement Award of the American Nuclear Society's Fusion Energy Division for his exemplary individual achievement, requiring professional excellence and leadership of high caliber in the area of fusion science and engineering.

Deputy Director Murray Rosenthal joined a very select group of ORNL and Energy Systems staff members when he was elected a member of the National Academy of Engineering. Chuck Scott of the Chemical Technology Division is the only other ORNL employee who is a member of the Academy.

The grand prize in a major international competition in metallography has been awarded to three ORNL staff members. Honored with the International Metallographic Society's Pierre Jacquet Gold Medal and the Lucas Award of ASM International were Stan David and John Vitek of the M&C Division and Allison Baldwin of Energy Systems' Graphics Division at ORNL. This is the third time in the past four years this team has won this prestigious award—a feat never before accomplished by anyone in the history of the competition.

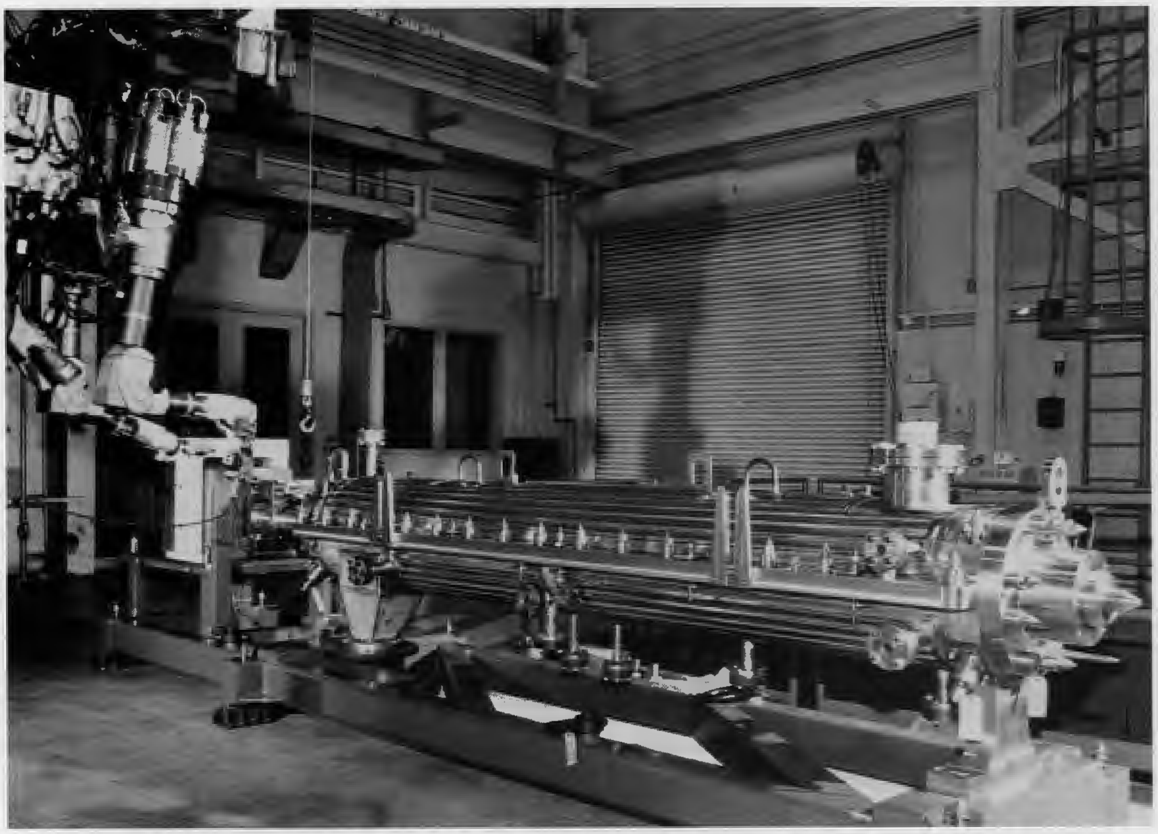
Energy Technology

To describe the research achievements of the Laboratory and the challenges it faces, I will use categories that my predecessor Herman Postma says will shape the agenda of the 1990s. These are the so-called "four E's"—energy, the environment, the economy, and education.

Energy will continue to be a problem in the 1990s. The role of energy in our nation's economy became apparent once again during the Persian Gulf crisis when the price of oil increased and decreased dramatically in response to the threat of an oil shortage. Cost-effective energy options are needed to stabilize these energy prices. In addition, energy production systems must be designed to minimize impacts on health and the environment so that they will be socially acceptable and to comply with the most recent regulations. Some selected highlights of ORNL's energy research achievements in 1990 follow.

"The grand prize in a major international competition in metallography has been awarded to three ORNL staff members."

Aging nuclear power plants. One important energy option is the conventional water-cooled nuclear power plant. Within the next 10 years, more than 100 nuclear power plant operators will submit applications to the U.S. Nuclear Regulatory Commission (NRC) for operating plant extensions. Yankee Atomic Electric Company was the first utility to request the relicensing of a nuclear power plant—its Yankee Rowe Plant. A key issue in relicensing aging power plants is the integrity of the pressure vessel and its ability to withstand a pressurized thermal shock (see photograph on p. 10). Because ORNL has managed the pressure vessel integrity program for the NRC for the past 25 years, the Laboratory has been asked to perform an independent evaluation of the Yankee Rowe Plant. Pressure vessels do fail, but ORNL tests in the Heavy-Section Steel Program have shown that pressure vessels can be subjected to pressures 3 times the design pressure and still not fail. Another NRC project at ORNL is the drafting of a generic environmental impact statement for relicensing power plants after their original licenses expire.



In its efforts to advance the technology of reprocessing breeder fuels, ORNL placed a new continuous rotary dissolver in the Integrated Process Demonstration Facility of the Robotics and Process Systems Division as part of a joint collaborative program between DOE and the Power Reactor and Nuclear Fuel Development Corporation (PNC) of Japan. The remotely maintainable continuous rotary dissolver is a full-scale prototype of the equipment that will be used by the PNC Recycle Equipment Test Facility in Japan.

Breeder technology. Another energy option is the breeder reactor. ORNL is participating in international research to advance breeder technology. We are working with Japan on the development of remote technologies for extracting usable nuclear fuel from material produced in breeder reactors for future fueling of breeders. A new continuous rotary dissolver was recently placed in the Integrated Process Demonstration Facility of ORNL's Robotics and Process Systems Division (formerly the Fuel Recycle Division) as part of a joint collaborative program between DOE and the Power Reactor and Nuclear Fuel Development Corporation of Japan (see photograph above). The continuous rotary dissolver, which is remotely maintainable, is a full-scale prototype of the equipment that will be used in the PNC Recycle Equipment Test Facility in Japan for the reprocessing of breeder reactor fuels.

Fusion energy. A long-range energy option is fusion energy. ORNL's flagship fusion research machine is the Advanced Toroidal Facility (ATF), shown in the photograph on p. 14. This stellarator has markedly extended the long-pulse capabilities of fusion research machines. The discharge duration has been extended to 20 seconds, an improvement of almost an order of magnitude over the past year. These improvements permit better studies of fundamental plasma physics. In a contribution from another part of the Fusion Energy Division, small frozen hydrogen pellets made by an ORNL injector were fired into the Joint European Torus, the world's largest tokamak, producing excellent results.

Biomass fuels. Renewable energy sources have a place in our nation's energy supply. They are valued because they delay the depletion of fossil fuels and they are cleaner to use. Biomass, such as trees and perennial and annual grasses, is burned by improved combustion technologies to produce steam for generating electricity, or it is processed into liquid fuel such as ethanol. Much of ORNL's biomass-related research, which is led by Jack Ranney of the Environmental Sciences Division (shown in photograph on p. 16), involves studying tree physiology to determine the most efficient and feasible species to use as fuels. The fast-growing hybrid poplar tree has been identified as one of the most promising biomass crops.

Environmental Research

Environmental and biological research is important to the national interest. The causes and impacts of global warming must be better understood to guide the development of improved technologies. Process systems must be designed to limit environmental impact. Quantitative risk assessment of energy technologies will allow intelligent, socially acceptable choices to be made. Remediation techniques must be evaluated and improvements made in waste handling and processing to remedy past actions and avoid future problems.

Isotope studies. Where does contaminated groundwater flow? How do forests respond to climate change or to the atmospheric deposition of nitrogen compounds discharged from automobiles and industry? Researchers in ORNL's Environmental Sciences Division have been studying these questions using stable isotopes of oxygen, carbon, and nitrogen and a new mass spectrometer at the Walker Branch Watershed Field Research Facility, shown in the top photograph on p. 17.

Waste site survey. Accurate characterization of waste sites is the first step in environmental restoration. An existing remotely operable vehicle (developed by the Department of Defense) has been modified and further developed by ORNL. Using the Ultrasonic Ranging and Data System (USRADS) developed by ORNL, this vehicle conducted a remote semiautonomous survey of a buried waste site (see photographs on p. 17). USRADS is also being used to survey parts of ORNL's X-10 site to measure and map contamination and identify suspect burial sites.

The Economy

ORNL can contribute significantly to national and regional economic growth in several ways. Technology transfer is one method; since 1985 Energy Systems has signed 54 licensing agreements involving mostly ORNL technologies. ORNL can help increase energy efficiency through improved materials, conservation strategies, and transportation research. DOE and its laboratories are catalysts for the R&D community, offering extended research opportunities through their user facilities, Superconductivity Pilot Centers, work-for-others programs, and the new cooperative research and development agreements (CRADAs) created by Congress.

ORNL was the first laboratory authorized by DOE to enter into CRADAs under the National Competitiveness Technology Transfer Act of 1989. The first CRADA was signed by Energy Systems with the Alternative Fluorocarbons Environmental Acceptability Study (AFAES), an industrial consortium of major chlorofluorocarbon (CFC) producers (see photograph on p. 19). CFCs are suspected of causing the ozone hole; the Montreal Protocol will eventually phase out their production. Alternatives to CFCs are being identified. They are less destructive to the ozone layer that protects us from harmful solar radiation, but tests must be done to determine if they are as energy efficient as the CFCs used for refrigeration

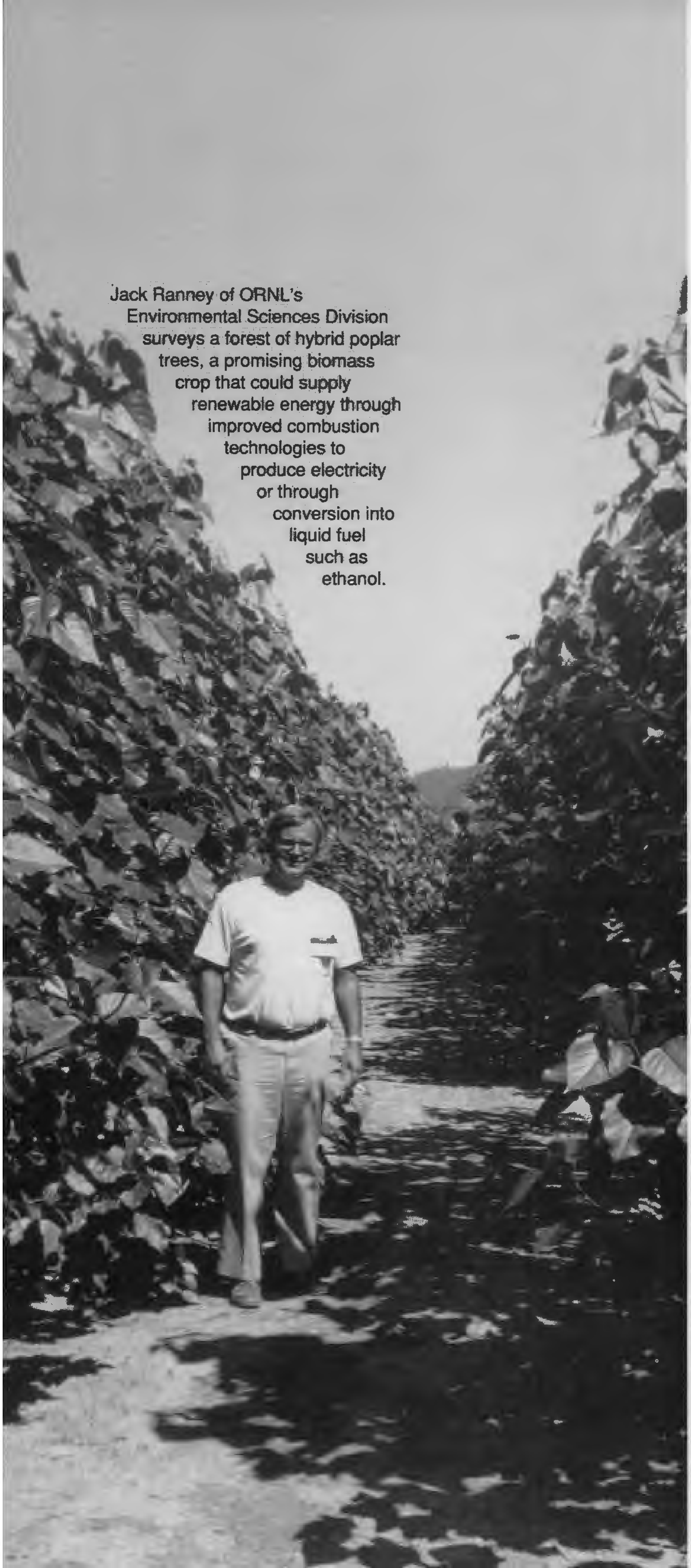
equipment, insulation, and commercial solvents and if they have some other ancillary environmental impact that has not been anticipated.

CRADAs provide a new flexible mechanism for helping government laboratories undertake joint research and technology development with industry. Cooperative research agreements developed and used by DOE's Superconductivity Pilot Centers served as the model for CRADAs. The ORNL pilot center is currently conducting research with outside companies and universities under 20 cooperative agreements.

ORNL's transportation research can help the economy by finding the most efficient ways to transport people and cargo from one point to another. ORNL's Energy Division developed computer software that was used and tested as part of the largest airlift operation in history (see photograph on p. 18). ORNL's Airlift Deployment Analysis System (ADANS) software was chosen to supplement pencils and yellow pads in scheduling the transport of troops and equipment for the missions of the Military Airlift Command (MAC) associated with Operation Desert Shield and later Desert Storm. This support included innovative mission scheduling algorithms and training of MAC mission schedulers in use of the software. ADANS is an integrated system for all MAC airlift planning and scheduling challenges. As of July 15, 1991, ADANS had been used to schedule more than 20,000 airlift missions, delivering more than 800,000 passengers and more than 650,000 tons of cargo to the Persian Gulf region. At the end of the hostilities, ADANS was used to schedule the return of troops and their equipment. ADANS received an honorable mention in the Franz Eldelman Competition for Management Science Achievement from The Institute of Management Sciences.

ORNL and SEMATECH are working together so the United States can be more competitive with Japan in making submicron computer chips for semiconductor devices. Building on expertise developed over the past two decades in the magnetic fusion program at ORNL, researchers Lee Berry of the Fusion Energy Division and

Progress in fundamental plasma physics studies has been made at the Advanced Toroidal Facility stellarator because of ORNL researchers' success in markedly extending its long-pulse capabilities and discharge duration by almost 10 times (to 20 s).



Jack Ranney of ORNL's Environmental Sciences Division surveys a forest of hybrid poplar trees, a promising biomass crop that could supply renewable energy through improved combustion technologies to produce electricity or through conversion into liquid fuel such as ethanol.

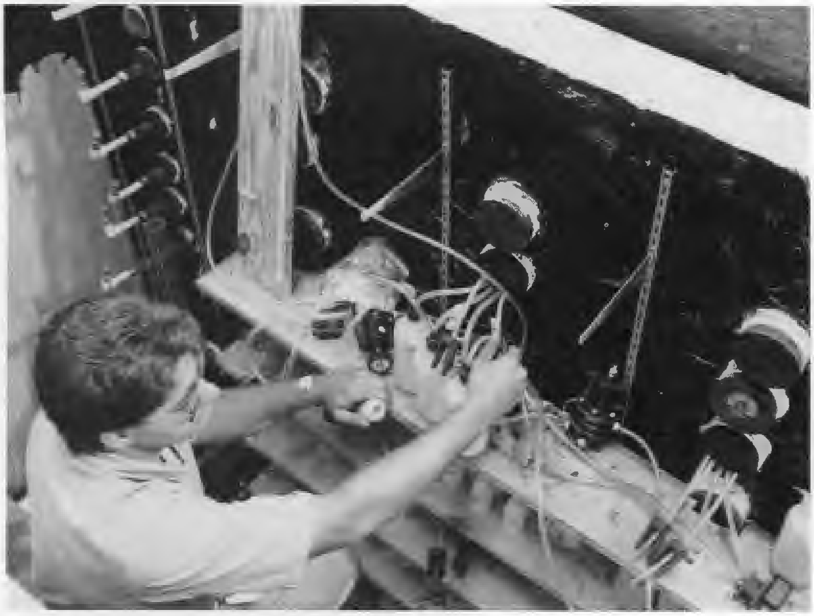
Steve Gorbatkin of the Solid State Division have made progress in developing a new etch technology for the next generation of submicron computer chips.

To reduce consumption of electricity by electric motors, ORNL is working on developing a superconducting motor. Members of the Applied Technology, Fusion Energy, Instrumentation and Controls, Engineering Technology, and Energy divisions have designed and fabricated an axial air gap superconducting magnet motor that ran the first time it was tested. By integrating the technologies of superconductivity, magnetics, power electronics, and composite materials, ORNL researchers produced an industrial-size, variable-speed, alternating-current motor and test facility that will provide a valuable resource for future studies.

Education

ORNL's efforts to improve science education are important to the nation's future. Many studies over the last several years have projected a shortage of American scientists and engineers. The Department of Energy is strongly influencing the development of this work force to meet its projected needs for scientific and technological expertise. For many years, DOE's national laboratories have collaborated closely with college and university faculties on research and education of students. In the past five years, DOE has asked the laboratories to increase their emphasis on science and mathematics education, particularly at the precollege level, and to incorporate education in their mission.

To respond to this increased role, ORNL's Office of Science Education Programs and External Relations was established in February 1990. During this past year, the Environmental Sciences Division hosted 58 students in the DOE High School Honors Workshop for the third consecutive year. Over 100 participants in national teacher training programs were hosted by ORNL. DOE's Science and Engineering Research Semester Program sponsored 57 participants at ORNL this past year; this program, in its third year, offers semester-length research



Using the Environmental Sciences Division's new mass spectrometer, researchers at the Walker Branch Watershed Field Research Facility have studied groundwater flow dynamics, forest response to climate change, and the effect of atmospheric deposition of anthropogenic nitrogen on forests. The use of stable isotopes of oxygen, carbon, and nitrogen is proving extremely useful in addressing these important environmental issues.

Accurate characterization of waste sites is needed to ensure a safer, faster, and less costly remediation. To better map and measure contamination at waste sites, ORNL researchers modified and further developed a remotely operable vehicle (developed by the Department of Defense). Using the Ultrasonic Ranging and Data System (USRADS) developed by ORNL, this vehicle conducted a remote semiautonomous survey of a buried waste site in 1990.

A computer display of an actual field survey of a contaminated site using USRADS technology developed at ORNL is shown to Raymond R. Miller (center), of Energy Systems' Office of Technology Transfer. Charles R. Flynn, president of Chemrad Tennessee Corporation, shows how the shades and peaks correspond to the level of contamination beneath the ground. Looking on is Lyndon Clevenger of Chemrad, which acquired commercial rights to USRADS through Energy Systems' technology transfer program.

These two C-5A cargo planes carried equipment from the United States to the Middle East that was later used in the Persian Gulf War. ORNL's Airlift Deployment Analysis System (ADANS) software helped plan and schedule the airlift of U. S. equipment and troops to Saudi Arabia.

Chris Bernabo of the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) industrial consortium signs the first cooperative research and development agreement (CRADA) involving ORNL. ORNL and AFEAS will jointly study the environmental impacts of alternatives to ozone-destroying chlorofluorocarbons.

opportunities to college juniors and seniors, as well as faculty, from across the country.

We have been making an effort to attract students into science from backgrounds that traditionally have not considered science. The Summer Education Experience for the Disadvantaged (SEED) Program is one such activity. ORNL, along with other Energy Systems facilities, is expanding its efforts with minority educational institutions. Several new internship programs are being developed to increase student and faculty internship support.

ORNL programs are not just focused on attracting the best and the brightest into science careers. Our activities include enhancing the science and technology literacy of today's students. Over 16,000 precollege students visited ORNL in 1990, many as part of the Ecological and Physical Sciences Study Center.

As part of Secretary of Energy Admiral Watkins' initiative to expand our support for precollege activities, ORNL adopted Vine Middle School in Knoxville and Roane County High School. In the fall of 1990, the first term of the Saturday Academy for Computing and

Fall 1990 was the first term of the Saturday Academy for Computing and Mathematics for selected high school students from East Tennessee. Many ORNL research staff members volunteer their time to acquaint students and their teachers with topics such as computer modeling at engineering workstations.

Principal Patricia Littlejohn and Knox County Adopt-A-School Coordinator Scott Bacon witness Chet Richmond's signature.

Mathematics (SACAM) was completed. This program continued this past winter for 47 students who attended the 8-week session. For this term, new participating high schools are Anderson County, Campbell County, Clinton, Lenoir City, Roane County, and West High School in Knoxville. Schools participating in the first session that will continue to send students to SACAM are Bearden, Farragut, Oak Ridge, Oliver Springs, and Webb. This educational project is largely a labor of love for many ORNL research staff members who volunteer their time to acquaint students and their teachers with topics

As a guest of the Environmental Sciences Division during the summer of 1990, Jessica Gaspar of Puerto Rico participated in the Summer Education Experience for the Disadvantaged (SEED) Program designed to attract students into science from backgrounds that traditionally have not considered careers in science.

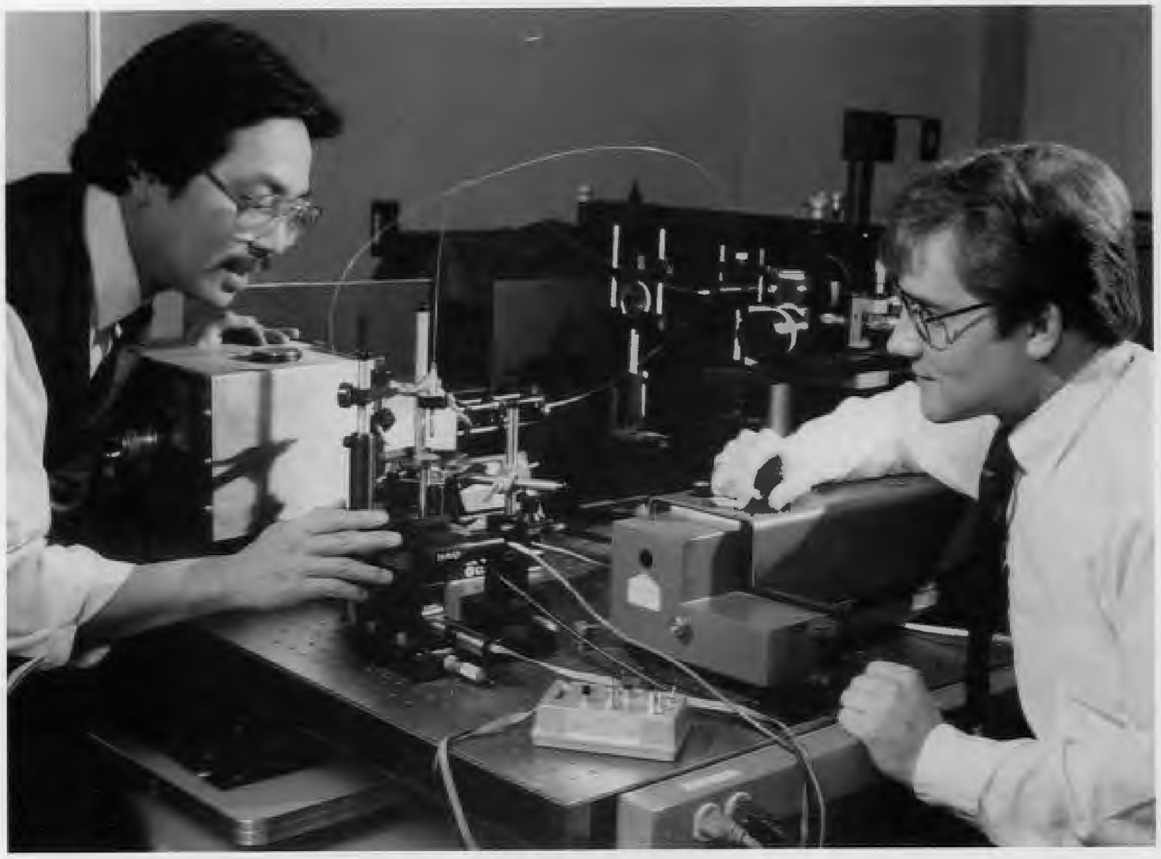
such as computer modeling on engineering workstations. (See education photographs here.)

Basic Research

The future economic development of the United States rests squarely on advances in many frontiers of science and technology. Our gross national product, our national security, and our economic competitiveness owe their existence to our nation's knowledge in the basic sciences. For the United States to have secure energy supplies and to remain among the world's leaders in economic development, DOE must do its part to ensure a strong national R&D effort. Basic research programs supported by DOE are an important first link in the chain of events from scientific discovery through technological innovation to economic growth.

Data storage. Tuan Vo-Dinh and David Stokes, both of HASRD, have built a prototype device (shown on p. 22) to test Vo-Dinh's exciting concept of surface-enhanced Raman optical data storage (SERODS). SERODS is a new technology for high-density optical disk data storage based on the surface-enhanced Raman effect. It is based on the principle that the enhanced light-emitting properties of certain molecules embedded in an optical medium can be altered at the molecular level to store information. The SERODS device has wide-ranging applications because of its tremendous storage capabilities. The SERODS technology makes possible the retention of each information bit by about 1000 to 10,000 molecules, providing a terabyte (10^{12} bytes) per 12-in. disk. This approach offers about 100 times as much storage density as current compact disk technology.

Electric polarization of the neutron. Our current understanding of the structure of the neutron is based on the quark model. Although the neutron has no net charge, it is made up of three quarks, each of which carries a fraction of a negative or positive charge. By directing a beam of neutrons into the powerful electric field of a target enriched in lead-208, two Austrian physicists working with ORNL researchers Jack Harvey and Nat Hill deformed some neutrons, separating their charges and inducing electric polarization. The result was a measurement of the tiny distance between the separated charges, providing new



Tuan Vo-Dinh and David Stokes work on a prototype of a surface-enhanced Raman optical data storage (SERODS) system. SERODS is a new technology invented by Vo-Dinh for high-density optical disk storage of data.

knowledge about the "strong force" holding the neutron together. This effect can best be deduced from the neutron energy dependence of the scattering of neutrons from the heavy lead nucleus. At least 10 earlier searches by various methods failed to verify an induced electric polarizability because the uncertainties on the measured values have been as large as the values. The success of the experiment was made possible by the low background noise of the Oak Ridge Electron Linear Accelerator's intense pulsed neutron source, the use of highly enriched samples of lead-208 supplied by ORNL's Chemical Technology Division, and the special electronics and detector system developed by Austrian physicists Jörg Schmiedmayer and Peter Riehs. (For details, see the sidebar on pp. 24–25.)

Computational studies of high-temperature superconductors. Malcolm Stocks of the M&C Division and Al Geist of the Engineering Physics and Mathematics Division have teamed with other researchers to use the new Intel iPSC/860 parallel processor at ORNL to calculate the electronic structure of a high-temperature superconducting material. Since the 1986 discovery of a new class of superconducting ceramic oxides, scientists around the world have been involved in intensive research efforts to understand and fabricate practical high-temperature superconductors. These efforts to model the structural, vibrational, and electronic properties of matter can be greatly assisted by parallel supercomputers and sophisticated algorithms written specifically for their use. Stocks and Geist efficiently made these complex computations using the Intel supercomputer and a network of IBM RS/6000 workstations linked together. As a result, they were co-winners of the 1990 Gordon Bell Prize for price/performance.

Budget Outlook

As of February 1991, we had no firm word on the status of the fiscal year 1992 budget requested by DOE nor did we know the view of Congress regarding national priorities. I do not anticipate great changes from last year. For the last decade, the House of Representatives has not succeeded in getting its views on authorization bills heard by the Senate. I believe that in 1991 the House Science, Space, and Technology Committee will have a prominent role in writing authorizing legislation for the national laboratories. None of DOE's nonweapons national laboratories, including ORNL, are doing exceptionally well; all must confront the problems of escalating overhead costs, aging facilities, ES&H concerns, and a lack of significant growth in the funding of their research. The weapons labs have had years of growth and recently participated in projects related to the revitalization of the defense complex. But they are feeling a pinch in their defense-related activities, and the layoff rate at the weapons facilities is expected to be higher than that at the nonweapons labs.

ORNL is positioning itself for future growth. I have asked Truman Anderson to lead an effort to assess R&D possibilities for us. I expect this study will lead to a strategic awareness of our future opportunities. For the near term, I see us focusing on several areas that take advantage of the diversity that makes ORNL the broadest based and most multidisciplinary of the DOE national laboratories.

Directions for the Future

Some of our long-term projects made important advances in 1990.

Advanced Neutron Source (ANS). During the past year, considerable technical progress has been made on the proposed new research reactor by the ANS Project Team at ORNL, Argonne National Laboratory, Idaho National Engineering Laboratory, Brookhaven National Laboratory, Babcock & Wilcox, and other organizations. A design concept offering many safety and performance advantages for the ANS reactor cooling system and fuel elements has been devised. This work forms the basis of the conceptual design for the ANS, now well under way. Gilbert-Commonwealth has been selected as the architect-engineering firm to participate in the conceptual design work. DOE has requested $24.6 million for the ANS in fiscal year 1992, putting it on schedule for going on-line by the end of the century.

Center for Excellence in Research Reactors. With the restart of the High Flux Isotope Reactor and the Tower Shielding Reactor, ORNL has made a commitment to pursue excellence in all aspects of reactor operations and associated science. It is most appropriate to tie this commitment with the need to promote future use of research reactors. This proposed center would provide a mechanism for matching users with research reactors, not only at ORNL, but throughout the country.

Energy Technologies for Developing Nations. The energy choices made by developing nations, including those in Eastern Europe, will have growing environmental and economic ramifications for the United States. Since 1982, ORNL has been involved in energy technology and policy assessments in 21 developing countries. ORNL's role will be focused on technology R&D—that is, ways to meet energy needs to increase economic growth in developing countries while reducing harmful impacts on the global environment and world oil market and improving the U.S. trade balance.

Education. In 1990 ORNL employees made plans for some exciting educational events in 1991. ORNL, along with Pellissippi State Technical Community College, Oak Ridge Associated Universities, and other partners, sponsored a regional science bowl in the spring of 1991 that led to a DOE-sponsored national competition during

"I see us focusing on several areas that take advantage of the diversity that makes ORNL the broadest based and most multidisciplinary of the DOE national laboratories."

FORCE HOLDING NEUTRON TOGETHER MEASURED AT ORNL

Austrian physicist Peter Riehs of the Institute of Nuclear Physics of the Technical University, Vienna, prepares for an experimental run on the Oak Ridge Electron Linear Accelerator to show that the positively and negatively charged quarks making up the neutron can be separated. In this landmark experiment at ORNL, scientists demonstrated the induced electric polarizability of the neutron, providing information on the structure of the neutron and the force holding it together.

The force holding together the neutron has been measured as a result of a very precise, low-energy physics experiment performed at ORNL.

A team of two Austrian physicists and two ORNL researchers, using low-energy neutrons at the Oak Ridge Electron Linear Accelerator (ORELA), have obtained information on basic constituents of matter. Such data can usually be gained only by using costlier high-energy physics accelerators.

The results of the research, published in the February 25, 1991, issue of *Physical Review Letters*, show that the positive and negative charges in the neutron, which has no net charge, can be separated by a distance of about 10^{-18} cm—one millionth of a billionth of a human hair—by the electric field just outside a lead nucleus. This measurement provides new knowledge about the "strong" force holding together the "quarks," believed to be the basic constituents of the neutron. More than 10 previous attempts by other research groups elsewhere failed to determine the size of this effect.

The landmark experiment was performed at ORNL by Jörg Schmiedmayer, an Austrian physicist now at Harvard University under the auspices of the Austrian Academy of Sciences; Peter Riehs, an Austrian physicist with the Institute of Nuclear Physics of the Technical University in Vienna; and ORNL researchers John Harvey, director of ORELA with the Engineering Physics and Mathematics Division, and Nat W. Hill, recently retired from the Instrumentation and Controls Division.

"Our experiment," said Schmiedmayer, "measured the electric polarizability, or specific charge separation in an electric field, of the neutron, providing information that could improve understanding of the structure of both the neutron and proton."

Neutrons and protons are the main constituents of the nucleus and have about the same mass. Not all neutrons are confined to a nucleus; some exist free as a result of nuclear reactions, as from fissioning nuclei in a nuclear reactor.

As a result of high-energy physics experiments, the neutron is known to have a detailed structure consisting of three quarks, which are bound together by gluons. One quark carries two-thirds of a positive charge, and the other two quarks each carry one-third of a negative charge, all adding up to make the neutron charge zero.

The researchers used lead-208 (^{208}Pb) atoms to apply an extremely

"The ORNL experiment gives the first numerical value of the neutron's electric polarizability, a fundamental property of one of the building blocks of all matter."

large electric field (up to 10^{21} V/m at the surface of the lead nucleus) to neutrons in a beam at ORELA. In this way, they deformed neutrons momentarily by forcing their opposite charges to be separated by a small distance, giving each neutron what physicists call an "induced electric dipole moment."

"The success of the experiment," said Harvey, "was due to the low background noise of ORELA's intense pulsed neutron source, the use of highly enriched lead-208 samples produced by ORNL's Isotopes Group, the use of a new detector, and the special electronics developed by the Austrian group. The detector and electronics enable the use of the full power of the neutron source and help to reduce errors from background corrections and detector instabilities."

Usually neutrons and other constituents of the nucleus are studied using high-energy physics accelerators to bombard the object of study—the sample—with a high-energy beam of charged particles, called the projectile beam. The sample's internal structure and interactions are studied by carefully detecting and identifying the scattered and created particles in the reaction.

In the ORNL experiment, however, low-energy beams of neutrons produced by ORELA serve as the object of study as well as the projectile, and the strong electric field of the lead nucleus provides a glimpse of the internal structure of the neutron.

This strong electric field gives rise to an additional interaction between the nucleus and the neutron that results from the forced separation of charges in the neutron. This interaction has a tiny but very characteristic influence on the scattering of the neutrons as their energy increases. Specifically, the fraction of neutrons that are scattered by the ^{208}Pb nuclei increases and the fraction that passes undeflected through the ^{208}Pb sample decreases.

In the ORNL experiment, short bursts of neutrons are produced by bombarding a tantalum target with short pulses of 140-MeV electrons from ORELA. The neutrons are slowed down by a water moderator to various energies in the keV energy range before they "fly" to the ^{208}Pb sample.

About 80% of the neutrons are scattered from the sample, and most of the remainder pass through the sample and are detected in a scintillation counter. The energy of each detected neutron is determined by measuring the time it takes to travel the 80-m flight path from the water moderator through the sample and into the detector. Knowing the number of neutrons reaching the detector with no sample in the beam allows the researchers to determine the change in the effective size of the neutron and the ^{208}Pb nucleus for each neutron energy measured.

The electric polarizability of the neutron was determined from its characteristic influence on the measured neutron scattering. At higher neutron energies, the researchers found that approximately 80.2% instead of about 80.0% of the neutrons were scattered by the lead nuclei—a measurable effect of the neutron's separated charges in the field of the Pb nuclei.

The electric polarizability of the neutron was determined to be $(1.20 \pm 0.15 \pm 0.20) \times 10^{-3}$ fm^3. The first error gives the statistical uncertainty, and the second is an estimate of the maximal systematic error.

"We obtained a very small quantity for the electric polarizability," said Schmiedmayer. "It is about a billion billion times smaller for the neutron than for the typical atom, which demonstrates nicely how small and how rigid the neutron is compared with the atom."

One of the most challenging problems of nuclear and particle physics is the calculation of the properties of neutrons and protons. The ORNL experiment gives the first numerical value of the neutron's electric polarizability, a fundamental property of one of the building blocks of all matter.—*Carolyn Krause*

National Science and Technology Week. A "Careers in Science and Technology for Women" conference was planned and staged. ORNL, in partnership with the state of Tennessee, the University of Tennessee, and the Oak Ridge School System, expressed an interest in the development of a 21st century classroom. A major goal of the project would be the development of reasonably priced equipment to serve as hands-on electronic teaching aids and student workstations.

Facilities Restoration. The capital plant facilities at ORNL have served for many years in support of productive research at ORNL. Because of insufficient capital improvement funding for modernization and adaptation to changing program needs over ORNL's nearly 50-year history, many of the buildings and utilities have deteriorated. Continued renovation and replacement of major facilities are needed to attract the highest quality staff to the Laboratory and to produce the finest results in science and technology.

Global Environmental Sciences. The Center for Global Environmental Studies completed its first year of operation in fiscal year 1990. ORNL is committed to supporting the development of a global scientific initiative for DOE and is helping to identify the unique scientific contribution that DOE can offer the Intergovernmental Panel on Climate Change and the Committee on Earth Sciences. ORNL is also developing interinstitutional mechanisms for coordinating DOE work with other federal agencies.

Grand Challenges in Computational Science. High-speed, large-scale computation has become the primary enabling technology for advanced research in many areas. The exploitation of massive parallelism in computer architecture and algorithms is expected to bring the next major increment in capacity needed to attack the grand challenges of computational science. ORNL and other regional institutions will

1990 was the year in which the "tigers" (members of the DOE Tiger Team) came to ORNL. But every year, in February when the State of the Laboratory address is delivered, migrating cedar waxwings stop at ORNL on their way north. Here they gather in large numbers in trees outside Building 4500-N, ORNL's administration building.

provide the expertise to solve potential grand challenges that include calculating physical properties of high-temperature superconductors, global climate modeling, and the design and analysis of particle detectors for the Superconducting Super Collider (SSC). We need better facilities to attract smarter people to work on this major DOE initiative.

High-Temperature Superconductivity. Recent discoveries of new superconducting materials that have high critical temperatures have generated interest in the scientific community. The primary goals of ORNL in this exciting field are to carry out a coordinated R&D effort to understand the new high-temperature superconducting oxides, to develop fabrication technologies for conductors that exhibit high critical currents in the presence of high magnetic fields, to identify viable commercial applications, and to work closely with U. S. industry to accelerate the commercial application of these discoveries. ORNL is making progress in these areas through its High-Temperature Superconductivity Pilot Center.

Holifield Heavy Ion Research Facility. An exciting new idea in nuclear structure physics is to develop the capability for accelerating radioactive beams of short-lived radioactive isotopes to produce and study nuclei in their final decay states. Because ORNL's Holifield Heavy Ion Research Facility has both a tandem accelerator and the Oak Ridge Isochronous Cyclotron, Holifield is better able to produce radioactive beams for research than are Argonne National Laboratory or Lawrence Berkeley Laboratory. This development, combined with the proposed construction of the Recoil Mass Spectrometer, the Heavy-Ion Storage Ring for Atomic Physics, and the Gammasphere, would give Holifield exceptional capabilities in heavy-ion physics.

Life Sciences Complex. The development of the Life Sciences Complex has long been a vision of the Biology, Environmental Sciences, and Health and Safety Research divisions. This complex will provide new, high-tech laboratories for expanding R&D needs in such areas as macromolecule mapping and bioprocessing research. It will provide superior research facilities to study mammalian genome and animal models for exploring human diseases.

Materials Science and Engineering Complex. This complex will include a new Solid State Sciences Building, a Center for Advanced Microstructure Analysis, a Center for Study of Advanced Materials, a Composite Materials Laboratory, and an Office of Guest and User Interactions. The plan of the complex addresses identified national, regional, and local needs for materials R&D, and it will support our rapidly expanding user programs and technology transfer activities.

Modular, High-Temperature, Gas-Cooled Reactor Technology. This DOE-supported design offers safety and investment protection features not available in any other fission reactor concept, but more research is needed to make this option economically attractive.

Oak Ridge Detector Center for High-Energy Physics Research. This center will serve as a focal point for all Laboratory divisions involved in SSC-related work. It will also provide an interface with outside collaborators in SSC detector R&D. The Center's goals include establishing the Southeast as a major force in high-energy physics and enhancing cooperation for joint detector R&D among ORNL, universities, and industry. We are involved in three collaborations and are in good shape as a participant in the design, development, construction, and testing of SSC detectors. Ultimately, this involvement will help us participate in the intellectual activities associated with the research for which these detectors will be used.

Waste R&D Initiatives. The magnitude of the work required for environmental restoration and waste management at DOE facilities poses large-scale problems never before experienced within the DOE complex. Vast resources will be devoted

to this issue. In many cases, our understanding of the complex systems associated with the remediation of disposal sites and the environmental behavior of wastes is either nonexistent or poorly developed. Because a large investment is required to remediate the environment at DOE facilities, a vigorous R&D program is needed to minimize cleanup costs, to quantitatively understand risks posed by the contaminated sites, and to help establish priorities for remediation. ORNL intends to research, develop, and demonstrate advanced technologies that will significantly reduce the costs of environmental restoration and waste management while meeting current and future requirements in a socially acceptable manner.

This year I decided to give two Director's Awards instead of one to a division of the year. One award recognizes the division that represents the operations activities during the Tiger Team audit. The other award recognizes scientific and technical excellence in one of the divisions. For outstanding accomplishments in support of the Laboratory's efforts to perform well on the Tiger Team audit, I present the Director's Award to the Plant and Equipment Division, directed by George Oliphant (shown at top left). For scientific accomplishments, educational support, external awards, publications, extramural interactions, cooperation, and key contributions to conservation and remedial action and environmental restoration programs, I present the Director's Award to the Environmental Sciences Division, directed by Bob Van Hook (shown at lower left).

"In conclusion, we will do whatever it takes to be the best at whatever we do. These words characterize what we need to do to be a world-class research institution." ornl

FAREWELL TO HERMAN POSTMA

"He was a visionary and sometimes a voice of dissent, and his irreverent humor usually aroused his fellow executives to laughter, if not action. Most ORNL employees remember him as an inspirational leader who interacted well with all kinds of people. Now, he is pondering a new career."

". . . outstanding leadership of and many contributions to the scientific research and development programs of DOE and its predecessor agencies."

On January 31, 1991, Herman Postma retired from Martin Marietta Energy Systems, Inc., as senior vice president. As director of ORNL from 1974 through 1988, he led the Laboratory as it became increasingly involved in nonnuclear energy research and in industrial subcontracting, work for state and federal government agencies other than DOE, collaboration in research with industry and universities through user facilities, and technology transfer.

During his State of the Laboratory address, ORNL Director Alvin W. Trivelpiece saluted Postma for his contributions to ORNL over the years. "Herman has been an outstanding director at the Laboratory for 14 years. He is now director emeritus, and we are pleased that he has this title." Other leaders in Oak Ridge saluted him through an article in the March 3, 1991, issue of the *Knoxville News-Sentinel*. Joe La Grone, manager of DOE's Oak Ridge Field Office, said, "Throughout his career, he has contributed to many important accomplishments in science and technology. Among his attributes, the one I admire the most is that he has always pushed the system with the proper irreverence to get something done."

Jack Reese, former chancellor of the University of Tennessee at Knoxville, said that Postma "was really a very substantial help to the university, enthusiastic about the Distinguished Scientists program, and very much aware of the interactions between the university and the lab."

Clyde Hopkins, president of Martin Marietta Energy Systems, said, "I've never seen anybody in my work experience who had more integrity. Second is Herman's unique talent to understand in-depth technical activities. And the thing we're going to miss dramatically is, he's the best visionary in our company—the person who has the ability to look forward and see what's coming and make plans."

The Department of Energy honored Postma this year by awarding him its Distinguished Associate Award. He was cited for his "outstanding leadership of and many contributions to the scientific research and development programs of DOE and its predecessor agencies."

Postma, the only child of Dutch parents, was raised on a farm in Wilmington, North Carolina. He graduated first from both his high school class and his class at Duke University. He obtained a Ph.D. degree in high-energy physics from Harvard University. He was a summer intern at ORNL during his junior year and, after earning his doctoral degree, he joined the staff of ORNL's Thermonuclear Division to conduct research in fusion energy. But when a vacuum in division leadership developed, his attention was soon diverted from the fast neutrons of fusion plasmas to the fast track of management. In his early 30s he was appointed director of the division now called the Fusion Energy Division. At the age of 40, he was elevated to ORNL director.

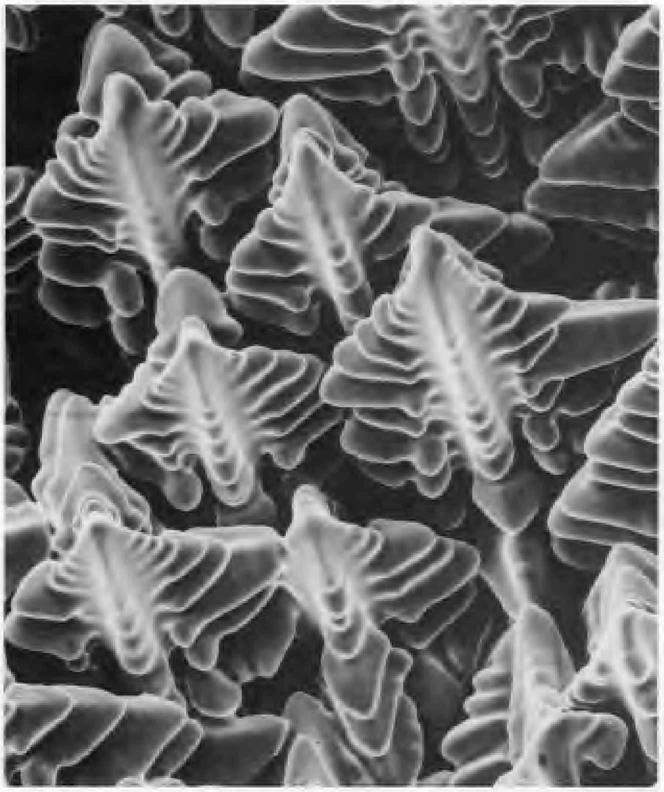
Single Crystals for Welding Research

By Stan A. David and Lynn A. Boatner

In June 1991, the Union of Concerned Scientists urged the shutdown of the Yankee Rowe nuclear power plant in Rowe, Massachusetts, because of its belief that a crucial weld in the plant had become so brittle from 31 years of radiation exposure that it was in danger of cracking. If the weld were to crack at the nation's oldest commercial nuclear reactor, the cooling water could drain out, causing the fuel to melt and release radioactive material into the reactor building. This was, in fact, one of the group's arguments against relicensing an aging nuclear power plant.

In the 1980s, a number of boilers in coal-fired power plants and other industrial systems were shut down frequently because of the failure of dissimilar metal welds (welds joining two different types of steel) in boiler tubes. The forced outages were often long and expensive because of the needed repairs and lost power production. According to the proceedings for the 1982 Dissimilar Metal Conference sponsored by the American Welding Society and the Electric Power Research Institute, it was estimated that if improved welds could make coal-fired power plants available for service for 1% more of the time, U.S electric utilities would save $1.2 billion.

In 1977 an interstate bridge near Pittsburgh, Pennsylvania, was closed because of a large crack in one of its main girders. An investigation indicated that the fracture ran through an "electroslag" weld. The discovery triggered an investigation of electroslag-welded bridges throughout Pennsylvania, and later the Federal Highway Administration banned the continued use of this type of weld in bridge construction on federally funded projects until questions were answered about the quality of these welds. This was not the first time that bridge welds presented a danger. In the 1940s the Hasselt bridge in Belgium collapsed because of weld failure. During World War II, some of the Liberty ships built earlier in the United States had failed structurally. The blame was placed in part on poor welding performance and materials.



This micrograph shows dendrites (treelike crystallites) in a weld made on a single-crystal PWA-1480 turbine blade alloy. ORNL researchers have found that making and studying welds in single crystals of stainless steel can provide new insights into how a weld's microstructure is formed.

Most welds last for many years, but a few fail after a relatively short time. Knowing the reasons why welds fail is important because cracks in welds can threaten the safety of people in buildings, airplanes, ships, automobiles, and power plants. Bad welds can lead to costly, extended shutdowns of industrial facilities such as petroleum refineries. Thus, research on this very important fabrication technology is critical to the multibillion-dollar welding industry.

Research at ORNL and elsewhere strives to determine the structural features that make some welds strong and others weak. The goals are to find cost-effective ways to characterize the

At left ORNL welder Dennis Swaney performs manual arc welding, which is used extensively in the construction industry.

Homer Harmon "pulls" a single crystal of stainless steel from a melt for use in ORNL welding experiments.

structure and strength of a new weld, correctly predict whether it will last a long time, and determine the welding conditions most likely to produce high-quality welds.

Welding may seem a simple process carried out by a person with a face mask intent on a welding instrument as the sparks fly. The welder brings together two different metal pieces to be joined, adds some filler metal if needed, and uses a suitable heat source to melt and fuse the metals together.

Actually, there is more to welding than meets the eye. The cracks that make welds fail result from the complexities of microstructures formed during welding. Thus, weld microstructure is linked to weld properties such as mechanical strength. As the hot weld material cools from a liquid into a solid, the crystalline grains grow at different speeds and in different directions, forming a new microstructure. By using single crystals rather than polycrystalline alloys to study different weld microstructures, scientists at ORNL have developed a way to predict more accurately the microstructures of various welds. The results could guide welders in providing the right conditions (correct welding speed, heat input, and weld thickness) for producing safer, higher-quality, and longer-lasting welds.

Multidisciplinary Approach

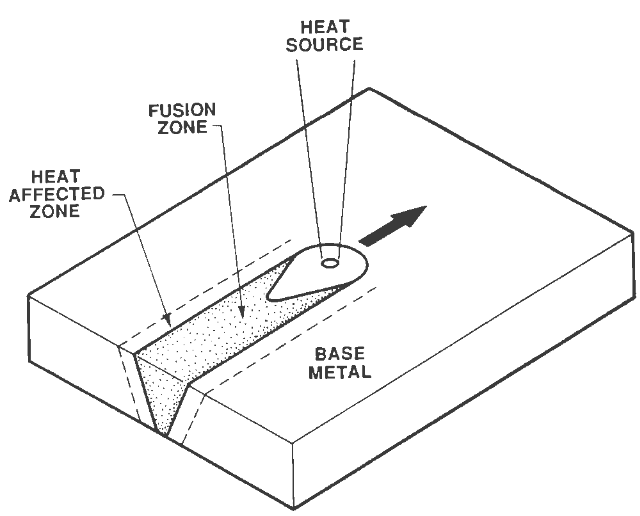
The ORNL results were made possible because of the Laboratory's multidisciplinary approach to scientific problems. Welding science, which seeks to understand the basic structure and mechanical properties of welds and to develop improved welding technologies, is a complex field requiring experts from both the basic and applied sciences. Modern welding science brings together diverse research disciplines such as arc and plasma physics; materials science; heat flow; fluid mechanics; mathematical modeling and computer science; robotics; economics; and mechanical, chemical, and electrical engineering. Thus, it is not surprising that ORNL's multidisciplinary approach to welding science has helped it play a leading role in advancing the basic understanding of welding.

In the spring of 1985, Alex Zucker, ORNL associate director for Physical Sciences, asked Stan David, a materials scientist and a specialist in welding science in the Metals and Ceramics (M&C) Division, and Lynn Boatner, a physicist in the Solid State Division with expertise in growing single crystals, to co-chair a special ORNL committee to review the Laboratory's research in composite materials. While working on this committee assignment, we began to discuss some of the outstanding problems in welding science and how they might be resolved by applying techniques used in solid-state physics. In time, these discussions led us to combine our resources, and we decided to attack some of the outstanding fundamental problems in the science of welding.

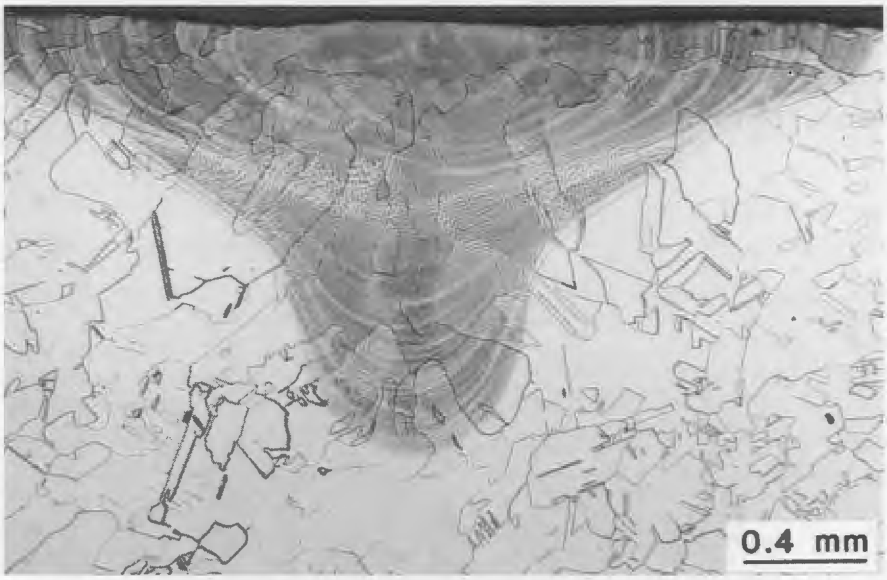
Most welds are made using metals that contain impurities and many small crystals (grains) having varying orientations, shapes, and sizes. As a result, traditional experimental studies of such polycrystalline welds yield results that are difficult to interpret. To overcome these experimental difficulties, in 1986 we developed the concept of using single crystals of metal alloys for studies of the microstructures that form as a molten weld pool solidifies. A weld pool is the liquid formed when the metals being joined together are melted. When the molten metal resolidifies, it takes on a microstructure different from its original solid structure. Our single-crystal approach has shown how this newly formed microstructure is determined by the shape of the weld pool (which, in turn, is affected by welding speed and other factors).

Fusion Welds in Polycrystalline Metals

There are a number of different types of welds, such as gas tungsten arc, shielded metal arc, submerged arc, and electroslag welds. Most joints made today are fusion welds in which two or more pieces of material are joined together by melting a common region between them, thereby forming molten weld pools that later cool to form a solid bond. For descriptive purposes (see figure below), fusion welds are often divided into three major regions: the base material; the "heat affected zone," the part of the weld that did not melt but became hot enough for its characteristics to change; and the fusion zone, the part of the weld that actually melted in the joining process. The fusion zone is the critical region in a fusion weld because its microstructural characteristics determine the mechanical properties of the weld. One such property can be a "hot cracking" tendency—the potential for the weld to crack as the fusion zone cools. The weld usually fails



A fusion weld structure has three principal zones, shown here.



This transverse-section photomicrograph at low magnification shows a polycrystalline Fe-15Ni-15Cr weld (dark area) made at a welding speed of 4.2 mm/s.

during the last stages of solidification when thermal stresses are superimposed.

Previous work on weld microstructure has shown that within the molten zone of a weld in a normal polycrystalline metal, the initial solidification occurs "epitaxially." In other words, the solid surface "seeds" and imposes a preferred growth orientation among some of the randomly oriented metal grains that lie along the solid-liquid boundary defining the weld pool. Those grains that have their "easy growth" directions aligned along the heat-flow direction will grow preferentially with respect to grains having other orientations. (For metals and alloys with cubic structures, the directions of "easy growth" are along the edges of a cube—the [100] directions, or cube axes.)

This early work demonstrated that the development of the fusion-zone microstructure in a weld is controlled by the grain structure of the base metal and by welding conditions. However, understanding and predicting weld-metal microstructures have traditionally been extremely difficult for a variety of reasons. These include (1) the dynamic nature of the welding process, (2) unknown weld pool shapes, (3) variations of the solidification parameters (e.g., growth rates and temperature gradients) in the weld pool, and (4) the epitaxial growth of treelike crystalline cells called dendrites among the randomly oriented grains in the normally polycrystalline base metal.

The complexity of an actual fusion-zone structure in a weld made using an iron-nickel-chromium (Fe-15Ni-15Cr) polycrystalline alloy—stainless steel—is clearly illustrated in the micrograph shown above. In this case, the multitude of grains in the polycrystalline material and their random orientations in the base metal have obscured the details of dendrite growth as well as the role played by the three-dimensional weld-pool shape in determining the microstructure of the weld. Thus, it is relatively difficult to understand the development of fusion-zone microstructures in welds using metallographic studies of stainless steel and other complex, polycrystalline specimens.

Single Crystals and Welding

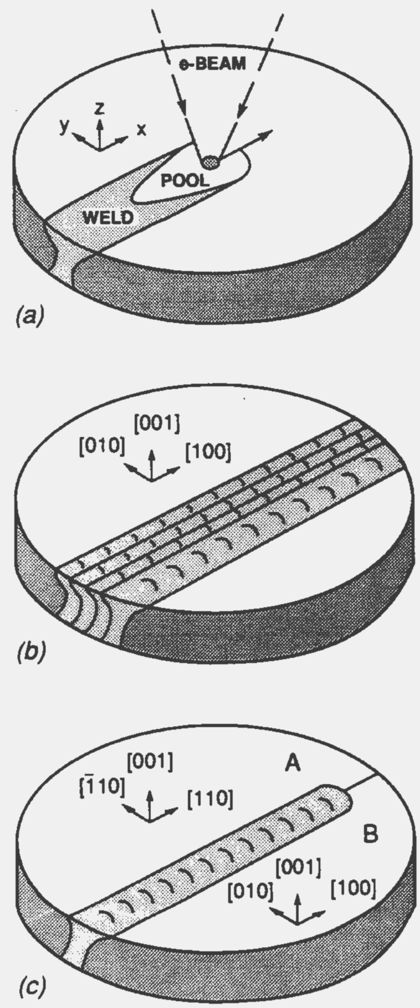
Our investigations using single crystals to characterize microstructural evolution in welds were expanded in our later collaborations with John Vitek, a scientist in the M&C Division at ORNL, and Michel Rappaz, a guest scientist from the Ecôle Polytechnique Federale de Lausanne in Switzerland. The four of us quickly discovered that by using single crystals of an alloy similar to a 300 series stainless steel, we could gain new insight

John Vitek (left) and Michel Rappaz apply newly developed analytical techniques to the prediction of the microstructural properties of single-crystal welds.

into the fundamental role played by crystal structure in the microstructural development of fusion welds.

One of the questions we sought to answer was whether the weld-pool shape affected the experimentally observed microstructure. If so, then the welding technique used could produce microstructures having desirable properties. Because weld-pool shape can be determined by factors such as welding speed (the rate at which the heat source moves during welding), we might be able to determine the welding conditions that produce extremely strong welds.

We replaced the polycrystalline alloy specimens normally used in welding studies with single crystals of an Fe-15Ni-15Cr alloy. Because the single crystals were relatively small, we used electron beams rather than arcs for the welding heat source. We made electron-beam welds along the principal crystallographic directions of each single crystal to simplify the interpretation of the resulting microstructure. The newly formed single-crystal weld microstructures were then characterized using optical microscopy and other conventional metallographic methods. We found that using alloy single crystals to study weld-



The welding configurations used in ORNL's single-crystal welding study include (a) an autogenous single-pass single-crystal weld, (b) an autogenous multipass single-crystal weld, and (c) an autogenous bicrystal weld joining two half disks at different orientations.

metal microstructures is a unique and powerful approach that helps us delineate the effects of the speed and direction of crystal growth on weld microstructure with unprecedented clarity and detail.

Single crystals of the Fe-15Ni-15Cr alloy used in our welding research were grown using the Czochralski technique in which an oriented "seed" crystal is used to "pull" a much larger single crystal from the melt. The principal crystallographic directions of the stainless steel crystals were determined using X-ray techniques. Single-crystal specimens were cut from the large single crystal using an electric-spark cutter to minimize damage to the crystal. Single-pass electron-beam welds were made along principal crystallographic directions lying in the different principal crystal planes. Eventually, we extended our studies to several other controlled conditions that relate to more realistic and practical welding configurations. For example, we examined overlapping, multipass, autogenous welds—the ones made without adding filler metal—and the "butt" welding of two single crystals in which different crystallographic orientations were joined together. The various experimental configurations used in these studies are illustrated schematically in the figure at left.

The figure on p. 39 shows a photomicrograph of the weld microstructure observed for a given welding condition in the case of single-pass electron beam welds. The microstructure shown here is simpler and more symmetrical than that shown on p. 36, indicating how the technique of using oriented single crystals and of making welds along well-defined principal axes has enabled us to measure the direction and degree of growth of dendrites in the weld zone.

Analyzing Single-Crystal Weld Microstructures

Based on the unambiguous microstructural information available from single-crystal electron-beam welds, we have developed a new, three-dimensional analytical method in which the directions and speed of dendrite growth for a given microstructure can be determined as a function of the shape of the weld pool. This new analytical approach is based on modern solidification theories, and the results specify the preferred direction and speed of dendrite growth as a function of the orientation relative to the solid-liquid interface in the weld pool. This analysis is the first of its kind to include the three-dimensional nature of the growth behavior, and the calculations have now been extended to the case of any given welding direction or crystal orientation.

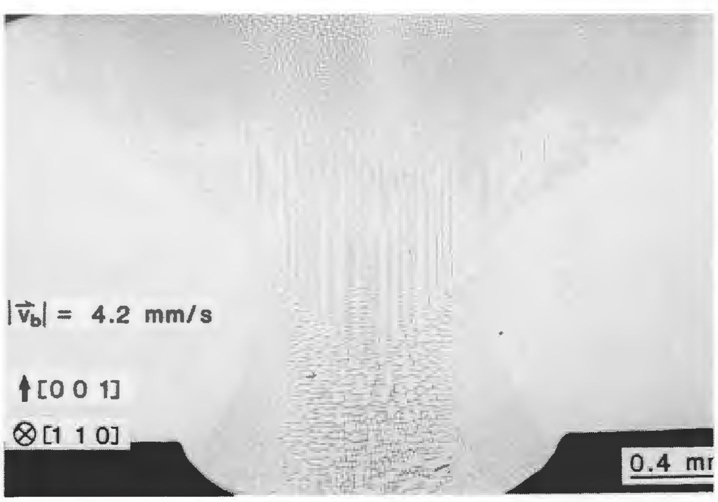
Experimental single-pass, multipass, and bicrystal welds have been made for various crystallographic orientations and at several welding speeds, and the evaluation of the weld microstructures agrees with the predictions of the theoretical calculations. In the case of overlapping multipass welds, transverse micrographs of the type shown on p. 40 reveal a remarkable reproducibility in the microstructure from pass to pass. This multipass microstructure, in fact, effectively represents a superimposition of the structural pattern found in a single-pass weld. The microstructures of butt welds of two single crystals with different relative orientations can also be explained by means of the new analytical approach. These bicrystal microstructures also remarkably resemble the patterns associated with each individual crystallographic orientation and simply represent a composite of two single-pass, single-crystal microstructures.

Microstructure and Weld-Pool Shape

The shape of the solidification front in the weld pool is instrumental in determining the growth direction and speed of the solidifying dendrites that ultimately make up the weld microstructures shown in the accompanying micrographs. Because the use of single crystals provides a fixed crystallographic reference system, the observed dendritic growth patterns can be directly related to the weld-pool shape that exists during the welding operation.

Because welding speed is one of the factors that determines the weld-pool shape, knowledge about weld-pool shapes that result in mechanically strong microstructures could indicate which welding speeds should produce safe, long-lasting welds. We have obtained different microstructures using different welding speeds. The relationship between the microstructure and the weld-pool shape has been used to determine the rate at which steady-state conditions in the weld can be achieved as a function of welding speed, heat input, weld thickness, and other parameters. This method is unique in that it predicts attainment of a steady state in a three-dimensional weld pool without perturbing the weld pool during solidification.

By making some reasonable assumptions, we can use the two-dimensional information available from transverse micrographs of the welds to reconstruct a three-dimensional weld-pool shape, such as that illustrated on p. 40. A reconstruction of this type provides information on the three-dimensional shape of the weld pool that would otherwise be unavailable and that would certainly be lost in the welding of a polycrystalline material. Nevertheless, because of uniform heat conduction in cubic metals, the results obtained from this type of analysis of weld-pool shapes as a function of the welding conditions are also applicable to welds in polycrystalline materials.

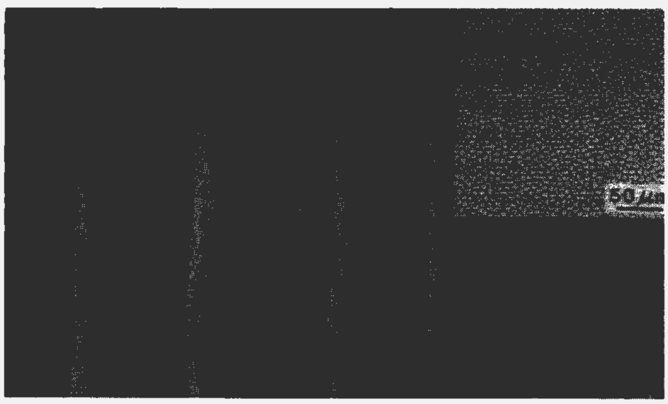


The photomicrograph shows the transverse macroscopic view of the microstructure of a single-crystal weld made at a welding speed of 4.2 mm/s along a <100> direction on a (001) surface.

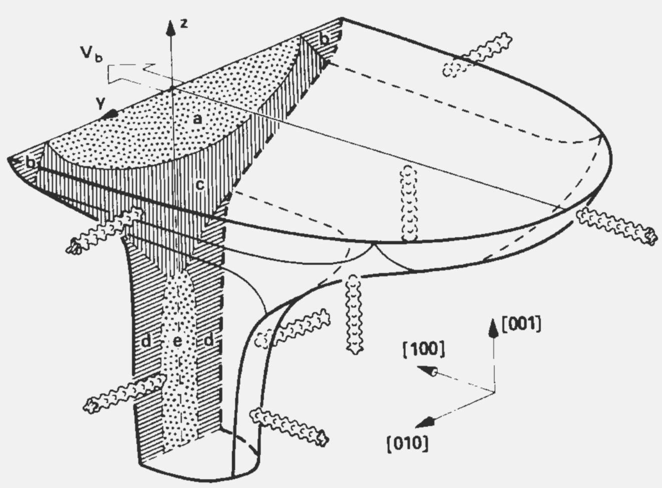
"Knowledge about weld-pool shapes that result in mechanically strong micro-structures could indicate which welding speeds should produce safe, long-lasting welds."

(a)

(b)



These two micrographs provide (a) a transverse section view and (b) a higher magnification view of an overlapping multipass weld on a stainless steel single crystal.



This three-dimensional weld-pool shape has been reconstructed by ORNL researchers from the single-crystal weld microstructural features (shown as dots and lines).

The geometrical analysis of the dendrite growth as a function of the shape of the weld pool allows a growth speed to be assigned to the observed dendritic structure in the weld. Accordingly, our approach can be used to evaluate quantitatively the current solidification theories that relate the sizes of dendrites to their growth speeds. Evaluations of this type have previously been possible only by using optically transparent, nonmetallic systems for which the growth velocity could be directly observed and measured. Our single-crystal approach now makes possible the evaluation of solidification theories about technologically important metallic systems such as stainless steel.

The single-crystal welding research project continues to thrive. We have been recognized for our work through the 1989 Jacquet-Lucas Award of ASM International and the International Metallographic Society, a feature article in *Microscope Technology and News*, and a number of technical articles published in key international journals. We plan to tackle the more challenging problem of finding ways to avert hot cracks in welds and to develop a more comprehensive theory that explains this technologically important phenomenon

Biographical Sketches

Stan David is group leader of the Materials Joining Group in ORNL's Metals and Ceramics Division. He holds an adjunct professorship at Ohio State University, the Colorado School of Mines, and the University of Pittsburgh, from which he received his Ph.D. degree in metallurgical engineering. In 1980, three years after joining the ORNL staff, he received the McKay-Helm award from the American Welding Society for a significant contribution in the field of welding. He is author of several award-winning International Metallographic Society exhibits. He was awarded the 1981 Lincoln Gold Medal by the American Welding Society for best technical contribution of the year. In 1984 he was elected a fellow of ASM International. He received a Martin Marietta Energy Systems Technical Achievement Award in 1987 and 1989 and a Publication Award in 1988. He is also the winner of the 1987, 1988, and 1990 IMS and ASM International Jacquet-Lucas Awards. In 1990 he was the recipient of the American Welding Society's Charles H. Jennings Memorial Award for the most valuable contribution to welding metallurgy.

Lynn A. Boatner is head of the Ceramics and Interfaces Section of ORNL's Solid State Division. In 1966 he received his Ph.D. degree in solid-state physics from Vanderbilt University. He joined the ORNL staff in 1977 after a two-year appointment at the Ecôle Polytechnique Federale de Lausanne in Switzerland. He is a fellow of the American Physical Society and the American Association for the Advancement of Science. His awards include recognition as one of *Science Digest's* 100 Top Innovators in 1985, I•R 100 Awards in 1982 (with M. M. Abraham) and in 1985 (with B. C. Sales), a U.S. Department of Energy Research Competition Award for "Significant Implications for Energy Technology in Solid State Physics" in 1984, The Francis F. Lucas Award of ASM International in 1988, The Pierre Jacquet Gold Medal Award of the International Metallographic Society in 1988, and a First in Class Award in the 1990 International Metallographic Contest. Boatner was named a Distinguished Alumnus in Physics by Texas Tech University in 1989.

Science Alliance: A Vital ORNL-UT Partnership

By C.R. Richmond, Lee Riedinger, and Tom Garritano

Partnerships between Department of Energy national laboratories and universities have long been keys to advancing scientific research and education in the United States. Perhaps the most enduring and closely knit of these relationships is the one between Oak Ridge National Laboratory and the University of Tennessee at Knoxville. Since its birth in the 1940s, ORNL has had a very special relationship with UT, and today the two institutions have closer ties than virtually any other university and national laboratory.

As adjunct faculty, ORNL staff members have long taught science and engineering courses at UT, while UT faculty have served as consultants and research participants at ORNL. Many ORNL staff members take advantage of the UT Resident Graduate Program in Oak Ridge, which offers evening courses to those pursuing advanced degrees in various science and engineering disciplines.

The first formal joint programs between the two institutions were two UT graduate schools located at ORNL, both of which are in their third decade of operation. The UT–Oak Ridge Graduate School of Biomedical Sciences, housed in the ORNL Biology Division, offers full-time graduate (M.S. and Ph.D.) and postdoctoral study for about 20 persons each year; during its 25 years of operation, 20 students have graduated with M.S. degrees and 127 students have graduated with Ph.D. degrees. The UT Graduate Program in Ecology annually instructs 15 graduate and postdoctoral participants hosted by ORNL's Environmental Sciences Division, which has

When President Bush visited UT in February 1990, the UT-ORNL connection was emphasized. Distinguished Scientist David Joy and Chancellor John Quinn watch as President Bush greets former Science Alliance Director Lee Riedinger.

directed the thesis research of about 100 graduate students over the past 20 years.

During his 1990 speech at the university's Knoxville campus, President George Bush hailed the school as a major research university and a pillar of the science-rich Oak Ridge corridor. The presidential visit was marked by the announcement of a new $3 million educational program for middle through high school teachers and students, who will be taught by scientists and mathematicians from UT and ORNL. The first cycle involving 73 teachers from Tennessee, Kentucky, North Carolina, and Florida, was held in July 1991.

To fund the program, $1 million from the state of Tennessee will be matched by another $1 million each from DOE and Martin Marietta Corporation. The resulting program, whose centerpiece is a new Academy for Teachers of Science and Mathematics, is yet another example of the partnership between UT and its "sister campus"—ORNL.

Science Alliance

Seven years ago, ORNL and UT began a new era of cooperation by creating the Science Alliance, a Center of Excellence at UT sponsored by the Tennessee Higher Education Commission. As the oldest and largest of these centers, the Science Alliance is the primary vehicle through which Tennessee promotes research and educational collaboration between UT and ORNL. By letting the two institutions pool their intellectual and financial resources, the alliance creates a more fertile scientific environment than either could achieve on its own.

Part of the UT College of Liberal Arts, the Science Alliance is composed of four divisions (Biological Sciences, Chemical Sciences, Physical Sciences, and Mathematics and Computer Science) that team 100 of the university's top faculty with their outstanding colleagues from ORNL. Its annual budget from the state of Tennessee is about $4 million, an investment that is doubled by matching money from DOE, other federal agencies, and private industry. The Science Alliance was directed during most of its first seven years by Lee Riedinger. Riedinger, who is also a professor of physics, is now

The Science Alliance is the focus of research and educational collaborations between UT and ORNL. Each of the four Science Alliance divisions is represented in the center's logo. Clockwise from the upper right, they are Physical Sciences (shown by an atomic nucleus), mathematics and computer science (an equation), life sciences (a DNA helix), and chemical sciences (the chemical formula for water, H_2O).

associate vice chancellor for research at UT. The new acting director is Tom Callcott, a professor of physics at UT.

The UT-ORNL partnership's cornerstone is the Distinguished Scientist Program, through which esteemed researchers are appointed to joint positions. Ten current Distinguished Scientists have brought excellent research groups and external funding that significantly enrich the local science community. More than 150 other faculty, students, and staff from UT's science departments regularly interact with colleagues at ORNL.

UT and ORNL also frequently purchase and share major pieces of equipment whose cost might otherwise be prohibitive. The Science Alliance often pledges substantial funding that attracts matching money from DOE, the National Science Foundation (NSF), or other sources. In this way, the state of Tennessee's investment is effectively doubled or even tripled.

Since 1984, the Science Alliance has administered the Joint Institute for Heavy Ion Research, a nuclear physics collaboration involving UT, ORNL, and Vanderbilt University. The JIHIR annually hosts several conferences and the visits of over 50 scientists from throughout the world. Three new Oak Ridge institutes patterned after the JIHIR will capitalize on emerging research strengths at UT and ORNL.

The Joint Institute for Applications of Computational Science will help to make widely available and usable the power of multiprocessor parallel computers, an exciting new technology that offers performance comparable to that of conventional supercomputers at a fraction of the cost. The Joint Institute for Energy and Environment will focus on the environmental impacts of all aspects of energy technologies. The Joint Institute for High Energy Physics will play a major role in developing particle detectors for the Superconducting Super Collider.

Each year 80 to 100 of the nation's most promising undergraduate science students come to East Tennessee through the Science Alliance Summer Fellows Program. They work closely with researchers at UT and ORNL for 10 weeks, after which a number of them return to UT for graduate study. The Science Alliance also supplements the university's graduate student stipends, making them competitive with those offered by other top schools.

As a result of a July 17, 1991, agreement between UT and Martin Marietta Energy Systems, Inc., the new Collaborating Scientist Program, based on the successful Distinguished Scientist model, will enable UT and ORNL to hire additional outstanding researchers at all faculty levels. UT and ORNL staff members are eligible for appointment. Collaborating Scientists have already been hired in computer science, physics, library science, and economics; and more joint hirings are planned. Because of these and other initiatives, the university and its "sister" campus at ORNL grow closer each day.

Distinguished Scientist Program

Since its inception in 1984, the Distinguished Scientist Program has attracted internationally prominent scientists to joint posts at UT and ORNL. The 10 current appointees enrich the Knoxville–Oak Ridge scientific community in many ways: by conducting excellent research, by leading and instructing students, by attracting external funds, and by drawing other outstanding scientists to East Tennessee.

Each Distinguished Scientist holds dual appointments as a full professor with tenure at UT and as a senior scientist at ORNL. Often their presence serves to cement longstanding linkages between the two institutions, such as those in physics and chemistry. But they can also act as catalysts that encourage entirely new collaborations to emerge, as has happened in computer science and electron microscopy.

Candidates are located and interviewed by a committee of senior scientists at UT and ORNL. The committee members work with the staff and management of both institutions to identify fields of mutual strength and interest, selecting researchers who ultimately benefit both the university and the national laboratory.

Via the Science Alliance, UT provides 50% of the program's budget; the other half comes from ORNL using DOE funds. Disciplines considered for Distinguished Scientist appointments include physics, chemistry, life sciences, geology, mathematics, computer science, and engineering. Current UT and ORNL staff members are not eligible for appointment.

ORNL-UT Joint Institutes

A principal goal of the Science Alliance is to create research institutes involving personnel from UT, ORNL, and other organizations, including private industry. These joint efforts strengthen existing ties between the two institutions while also creating new opportunities for collaboration and economic development in East Tennessee.

Established in 1984, the Joint Institute for Heavy Ion Research has helped lead UT and ORNL to international prominence in nuclear structure physics. Its success has inspired plans for at least two additional Oak Ridge institutes that offer new science and technology opportunities based on cooperation between state government (UT), federal government (ORNL), and private industry.

Hong Xie, a JIHIR-based graduate student in nuclear structure physics, is shown with the Spin Spectrometer at the Holifield accelerator. ORNL's facilities, used by 50 or more visiting scientists a year as well as by scientists from UT, ORNL, and Vanderbilt University, have given Tennessee a worldwide reputation for excellence in nuclear physics research.

Joint Institute for Heavy Ion Research

Housed in two buildings adjacent to ORNL's Holifield Heavy Ion Research Facility, the Joint Institute for Heavy Ion Research is popular with nuclear physicists from around the world. Each year scientists from UT, ORNL, or Vanderbilt University (the three members of this joint institute) are joined by 50 or more visiting scientists who come to make theoretical calculations or to perform experiments at the accelerator. The JIHIR also conducts conferences and workshops on topics relevant to heavy-ion physics, often emphasizing studies of how nuclei behave in exotic modes—for example, under rapid rotation or with an unstable number of neutrons or protons.

The institute is presided over by physicists-administrators: a three-member policy council of Carroll Bingham of UT, Russell Robinson of ORNL, and Joseph Hamilton of Vanderbult. To match the fine experimental facilities available, they have led the JIHIR in a direction that emphasizes nuclear structure theory; this emphasis is demonstrated by the visitors invited and the workshops sponsored. The institute currently has renowned theorists from Poland

Continued on p. 52

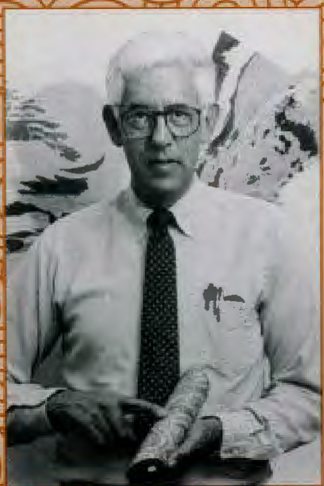
Profiles of Ten Distinguished Scientists

The Science Alliance has recruited one-third of the 30 world-class scientists it plans to attract to enrich the educational and research environment in East Tennessee. The 10 scientists now holding dual appointments at the University of Tennessee and Oak Ridge National Laboratory are profiled on the following pages. The date after each name indicates when he joined the Distinguished Scientist Program.

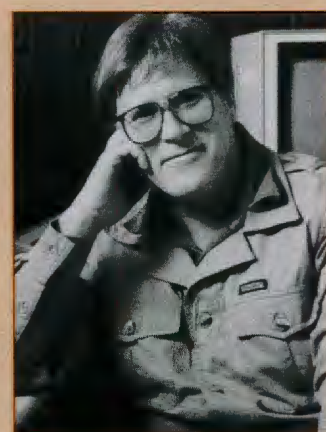
Jack Dongarra (September 1989) came to East Tennessee from Argonne National Laboratory. A computer scientist, he is based in the UT Computer Science Department and ORNL's Engineering Physics and Mathematics Division. He is an authority on parallel processing, a new technique in which thousands of processors work simultaneously rather than in sequential steps (as specified by conventional computer programs) to carry out complex calculations. These relatively inexpensive machines (costing $1 million to $3 million) are now surpassing the peak computational performance of costly "traditional" supercomputers (costing $10 million to $30 million). Dongarra's expertise is crucial to a planned Joint Institute for Applications of Computational Science, which will help scientists from UT, ORNL, and private industry use parallel computers in such fields as superconductivity, global climate, and the human genome. He is also the author of *Linpack*, a set of performance measurements for serial computers; he is now developing *Lapack* for parallel and vector computers. He received a Ph.D. degree in applied mathematics from the University of New Mexico.

Georges Guiochon (June 1987) is an expert in chemical separations. A native of France, he received a Ph.D. degree in chemistry from the University of Paris and spent much of his career at the University of Paris, where he directed the Laboratory for Physical-Analytical Chemistry. His gas and liquid chromatographic techniques have many uses, including analyses of high-temperature ceramic surfaces and studies of the effects of carcinogenic chemicals on DNA. His doctoral thesis on ammonium nitrate decomposition was the basis for French laws on handling nitrogen fertilizers. He came to East Tennessee from Georgetown University. He holds appointments in the UT Chemistry Department and ORNL's Analytical Chemistry Division. In 1991 he received the American Chemical Society's national Award for Separations Science and Technology.

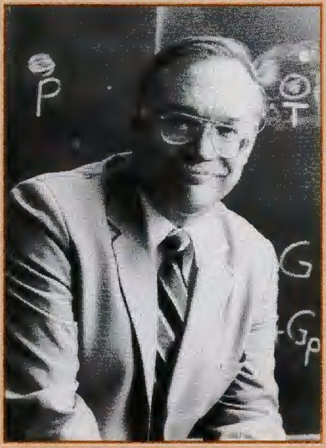
Bernhard Wunderlich (January 1988) is an expert on polymers and a former professor of chemistry at Rensselaer Polytechnic Institute, where he both founded and directed the Advanced Thermal Analysis Laboratory. He holds appointments in the UT Chemistry Department and ORNL's Chemistry Division. A native of Germany, he studies the solid state of polymers. He has written two books, entitled *Macromolecular Physics* and *Thermal Analysis*. Among his honors is the 1971 Mettler Award for pioneering work in thermal analysis and the 1987 Humboldt Prize from Germany's Alexander von Humboldt Foundation. He received a Ph.D. degree from Northwestern University.



Robert Hatcher (July 1986) came to East Tennessee from the University of South Carolina, where he was a professor of geology. He holds appointments in the UT Geological Sciences Department and ORNL's Environmental Sciences Division. He is a recognized authority on the structural geology and tectonics of mountain chains and on the structure and evolution of Earth's crust. Although most of his research has focused on the Appalachian Mountains, he also has made comparative studies of mountain chains in western North America, Europe, and North Africa. He recently published a textbook, *Structural Geology: Principles, Processes, and Problems*. In 1990 he published a color tectonic map of the Appalachians that chronicles the development of the mountains between 600 million and 250 million years ago. From 1981 through 1988, he was editor of the *Geological Society of America Bulletin*; the Geological Society of America honored him in 1988 as the first recipient of its Distinguished Service Award. Currently, he is a member of the National Academy of Sciences Board on Radioactive Waste Management. He received a Ph.D. degree from the University of Tennessee.



David Joy (April 1987) is one of the world's top specialists in electron and X-ray microanalysis. He has pioneered many analytical electron microscope techniques. In 1983–84 he was president of the Microbeam Analysis Society. Thanks largely to his expertise, the Hitachi Corporation of Japan has loaned at no cost to UT and ORNL an ultrahigh-performance scanning electron microscope and a powerful field emission microscope. Among the corporations that regularly send visiting researchers to his laboratory are 3M, Exxon, and Alcan. A native of England, Joy received his Ph.D. degree from Oxford University. He came to East Tennessee from AT&T Bell Laboratories in New Jersey. He holds appointments in the UT Zoology Department and ORNL's Metals and Ceramics Division.

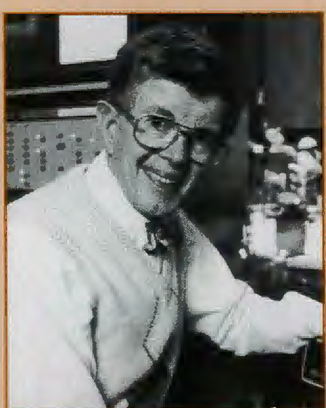


Joseph Macek (July 1988) is widely regarded as one of the leading atomic-collision theorists in the United States, making him an important addition to the atomic physics programs at UT and ORNL. He came to East Tennessee after holding a chair at the University of Nebraska and serving a year as a DFG Guest Professor at Freiburg University in West Germany. (DFG is the German equivalent of the National Science Foundation.) He holds dual appointments in the UT Physics Department and ORNL's Physics Division. He has been an editor of the German physics journal *Zeitschrift für Physik*, and he has served on the board of directors for the Harvard Atomic Theory Institute. He received a Ph.D. degree from Rensselaer Polytechnic Institute.

Gerald Mahan became the first UT-ORNL Distinguished Scientist in August 1984. Previously, he was the director of the Materials Research Laboratory at Indiana University. He holds appointments in the UT Physics Department and ORNL's Solid State Division. His accomplishments in the field of solid-state physics are widespread, including the development of theories to account for the optical and electrical behavior of semiconductors. His widely used graduate-level text, *Many-Particle Physics*, recently entered its second edition since its initial publication in 1981. He received the University of Chile's 1989 Centennial Medal in honor of his 20-year collaboration with Francisco Claro of that school. He is also chairman of the scientific committee for the International Center of Condensed Matter Physics at the University of Brasilia. He received a Ph.D. degree from the University of California at Berkeley.

Jack Weitsman (September 1989) is an expert on the mechanics of man-made composite materials. He came to East Tennessee from Texas A&M University, where he was a professor of civil engineering. He holds appointments in the UT Engineering Science and Mechanics Department and ORNL's Engineering Technology Division. He is known for his ability to combine materials science, applied mechanics, and mathematical modeling to address complex interdisciplinary issues in materials science. Because composites, such as graphite epoxy are durable and lightweight, they have many uses in spacecraft, submarine, and automobile construction as well as fine fishing rods. His recent research seeks methods to predict the behavior and durability of composites and their resistance to stresses resulting from mechanical loads, temperature, and moisture. He received a Ph.D. degree from Rensselaer Polytechnic Institute.

Robert Uhrig (January 1986) came to East Tennessee from the Florida Power and Light Company, where he was vice president for one of the country's most successful operators of nuclear power reactors. He holds appointments in the UT Nuclear Engineering Department and ORNL's Instrumentation and Controls Division. Much of his time is now spent developing neural network computers that might eventually help human operators manage power plants. Using artificial intelligence, these networks simulate the biological processes of the human brain so computers can "learn" to respond correctly to specific situations. The outcome of this research may be sophisticated computer programs that would rapidly evaluate complex power plant events, helping operators make decisions to better control nuclear reactors. He received a Ph.D. degree from Iowa State University.



David White (January 1986) is internationally recognized for his research on the biological monitoring of chemical contaminants in the environment, the environment's response to pollution, and the ecological consequences of introducing genetically manipulated organisms into the environment. White directs the Institute for Applied Microbiology, which is internationally recognized for research into microbially influenced corrosion and biofilm monitoring. His work has applications in the remediation of marine and medical biofouling and of pollutants in subsurface sediments. With UT microbiologist Gary Sayler, he is leading a four-year study for the Electric Power Research Institute using genetically engineered "bioluminescent" bacteria as sensors to define aspects of biofilm ecology important to assessing and remedying microbial corrosion. He came to East Tennessee from Florida State University, where he was co-director for biomedical and toxicological research. He holds appointments in the UT Microbiology Department and ORNL's Environmental Sciences Division. He received a Ph.D. degree from Rockefeller University and an M.D. degree from Tufts University.

It may look like a side-by-side refrigerator-freezer, but the new Intel iPSC/860 supercomputer at ORNL is one of the most powerful computers available. It will be used by UT students and faculty through JIACS.

and Sweden visiting for two-year periods, leading to lively exchanges of ideas and information between experimentalists and theorists and between resident physicists and guest researchers.

The Holifield's 25-million-volt electrostatic accelerator can generate a wide variety of particle beams used for producing nuclear reactions. Coupled with an excellent array of detection devices (e.g., the Spin Spectrometer), the Holifield facility forms one of the finest laboratories for nuclear structure experiments. The institute's low-cost dormitory is often used by scientists who might not otherwise be able to afford a visit to the Holifield facility. Because of its many visitors from the United Kingdom, France, Germany, Greece, China, and elsewhere, the JIHIR has helped to give Tennessee a worldwide reputation for excellence in nuclear physics research.

Joint Institute for Applications of Computational Science

The origins of computational science at UT and ORNL can be traced to Alston S. Householder, who chaired UT's Mathematics Department in the 1950s and 1960s. Householder attracted a number of excellent mathematical and computational scientists to UT and to ORNL's Mathematics Panel, which he formed in 1948. Cooperation and collaboration in computational science between UT and ORNL have continued through the years and are currently exemplified by the Advanced Computing Laboratory (ACL), which has been operated jointly by the two institutions for several years.

With help from UT through the ACL, ORNL has recently obtained a series of increasingly powerful parallel computers, including the 128-processor Intel iPSC/860 and a 64-processor iPSC/2. Parallel computers use hundreds or even thousands of individual processors that work simultaneously to perform the normally sequential tasks of a program, achieving speeds comparable to or even exceeding those of the fastest supercomputers.

The Joint Institute for Applications of Computational Science (JIACS) will be established to address important high-performance computing issues. The institute will bring together computing and scientific experts at the university for research, development, and educational purposes. UT-ORNL activities in this area will center on developing the science and technology base needed to make parallel computers widely useful, with particular emphasis on application to Grand Challenge problems currently being addressed by academic researchers. The mission of the JIACS will be

- to encourage the advancement of computationally intensive science by developing and promoting the use of computational tools on high-performance, massively parallel computers;

- to nourish interdisciplinary research by providing an environment in which researchers from a variety of disciplines can collaborate on Grand Challenge problems;

- to educate and train students and young investigators, as well as established researchers, in the effective use of advanced parallel computational systems;

- to attract students into scientific careers and to encourage educators to use high-performance computers for teaching scientific and mathematical principles;

- to strengthen American competitiveness in parallel architectures and parallel algorithms;

- to foster interaction among universities, government laboratories, and industry in computational science; and

- to work as a partner with the computer industry in achieving major advances in computing technology.

Working relationships with the Tennessee Valley Authority (TVA), the computer industry, and other universities in Tennessee will help the JIACS accomplish its mission. An important aspect of the institute's work will be the education of students in computational science. Activities of the JIACS will respond directly to the call for a National High-Performance Computing Program at the federal level.

Joint Institute for Energy and the Environment

The concept of a Joint Institute for Energy and the Environment (JIEE) emerged from discussions at meetings of the Consortium of Research Institutions (CRI)—an organization of senior planners from ORNL, UT, TVA, and DOE. A purpose of CRI is to use the collective resources and strengths of the member institutions in planning and implementing research and development programs.

Envisioned as an umbrella organization, JIEE will bring together existing ORNL, UT, and TVA programs that address problems in energy and the environment. JIEE will probably focus on the interface between environment and energy technologies. Programs that might work together through JIEE are ORNL's Center for Global Environmental Studies and UT's Energy, Environment and Resources Center. The organization of JIEE is being planned by a steering committee.

Through the many educational programs offered by UT and ORNL, students have access to Science Alliance equipment such as this peptide synthesizer in the Molecular Biology Resources Facility. ORNL staff scientists often direct student research and teach courses at UT, and many students use equipment and facilities at Oak Ridge.

Joint Institute for High Energy Physics

This institute, still in its early planning stages, would create opportunities for physicists at ORNL and UT to study high-energy physics issues related to the next generation of colliders, including the Superconducting Super Collider (SSC) and the Relativistic Heavy Ion Collider (RHIC). Through the JIHEP and ORNL's Oak Ridge Detector Center, scientists would assist in designing one or two of the massive, complex detectors planned for the SSC.

Educational Programs

In classrooms and laboratories alike, students enjoy access to the best UT and ORNL have to offer. Students in many departments are as likely to study under an ORNL scientist with a doctoral degree as under a UT professor; in 1989, Science Alliance–supported doctoral candidate Robin Reddick, directed by Bruce Warmack and Tom Ferrell, physicists in ORNL's Health and Safety Research Division and also UT instructors, helped to develop a photon scanning tunneling microscope later honored by *Research and Development* magazine as one of the year's top 100 innovations. Through the new Joint Institutes, opportunities for students to benefit from ORNL expertise continue to grow. The Science Alliance also operates several special programs that enhance education at UT.

Graduate Student Supplements account for over $500,000 of the annual Science Alliance budget, providing assistance to about 100 deserving students. These stipends are crucial because they allow UT science departments to compete with the nation's other top universities for outstanding graduate students; the quality of students attracted affects significantly both the success of UT research programs and the caliber of scientists the university is able to hire.

The **Summer Research Fellows Program** each year brings 80 to 100 exceptional undergraduates to East Tennessee for intensive study with Science Alliance personnel at the university and national laboratory. The program lasts for 10 weeks, during which each fellow completes a substantial research project devised by a UT or ORNL adviser. These superior young students sometimes return to UT for graduate school. Each summer fellow receives a stipend and a small travel allowance; most reside in an on-campus apartment building at UT, which encourages social and scientific interaction between the undergraduate visitors. This is for most their first exposure to a high-level research environment, and the experience is a strong inducement for them to pursue graduate study in the sciences.

The **Biotechnology Master's Degree Program** is an outgrowth of cooperation between the Science Alliance, ORNL, the UT College of Engineering, the UT Institute of Agriculture, and various biotechnology companies. Students gain skills needed for a wide range of careers based on the use of living cells and their components to produce practical materials that benefit society.

In an interdisciplinary atmosphere, students learn experimental approaches to biochemistry, microbiology, and industrial-scale bioprocesses. Students have access to special equipment at ORNL, including large bioreactors that few universities could afford. Faculty from the UT departments of sociology and philosophy also teach a required seminar on biotechnology ethics.

Equipment and Facilities

Science Alliance funds are often used to purchase equipment for UT and ORNL research programs, in most cases with matching money from external sources such as the NSF, DOE, and others. Sharing equipment expenses maximizes the state of Tennessee's return on its investment in the Science Alliance, effectively doubling or even tripling the state's outlay. The examples cited below are just a few of the many cost-sharing initiatives in this area.

The **Spin Spectrometer**, or Crystal Ball detector, at ORNL's Holifield accelerator is vital to UT-

ORNL nuclear physics research. It contains 72 sodium iodide gamma-ray detectors mounted on a spherical structure that surrounds the chamber in which gamma-ray–producing, heavy-ion collisions occur. To increase the instrument's sensitivity, UT, ORNL, and Vanderbilt have bought 21 high-resolution Compton-suppressed germanium detectors at a cost of $1.28 million, of which UT contributed $320,000 and Vanderbilt $65,000. These detectors can be mounted in the Spin Spectrometer or alone in the Compact Ball.

In 1987, the Science Alliance and ORNL equally shared the $80,000 expense of new high-speed electronics for the Spin Spectrometer, permitting more sensitive studies of gamma rays emitted from nuclear reactions. The Spin Spectrometer and the newer Compact Ball both can use the 21 high-resolution germanium gamma detectors purchased for the Holifield facility. This facility is crucial to the experiments of an active Holifield users' group of some 300 researchers from more than 100 universities and laboratories in the United States and abroad. Funds from the Science Alliance, the state of Tennessee, and Vanderbilt University have supported the imminent construction of a $2.3 million Recoil Mass Spectrometer for the Holifield facility; this instrument will foster new understanding of nuclear structure by revealing unstable atom nuclei never before identified.

The **Stable Isotope Facility** of UT's Geological Sciences Department lets researchers determine the history of rock samples through studies of fluids present at different time periods. Isotopes of nitrogen, carbon, and oxygen can be extracted from rock samples to offer clues about the movement and composition of fluids present millions of years ago. Startup and operating funds for the Stable Isotope Facility came from the Science Alliance; the UT departments of geological sciences, chemistry, ecology, and botany; and ORNL's Environmental Sciences Division. A special course gives students hands-on experience with the extraction equipment and mass spectrometer.

The **Electron Microscope Facility (EMF)** at UT has benefited greatly from the presence of Distinguished Scientist David Joy, who pioneered many analytical techniques in the field of electron microscopy. Largely because of his presence, the Hitachi Corporation of Japan has loaned at no cost to UT and ORNL a pair of ultrahigh-resolution microscopes whose combined value exceeds $2 million. With existing instrumentation, they have made the EMF one of the top facilities of its type at a U.S. university. Materials scientists and biologists from ORNL, UT, and private industry make frequent use of the EMF.

The **Molecular Biology Resources (MBR) Facility** at UT was built and equipped with the support of $1 million from the Science Alliance. A number of UT and ORNL scientists rely on the MBR to determine protein sequences for generating synthetic DNA and for confirming synthetic peptide sequences. Amino acids are peptides that form the basic building blocks of proteins (polypeptides). These biologically important sequences are useful tools for biochemists and molecular geneticists. This work is of particular relevance to the national Human Genome Project.

Future ORNL-UT Initiatives

The ORNL-UT partnership will continue to grow into the next century. Once the Advanced Neutron Source is successfully installed at ORNL in the late 1990s, this research reactor will open up many areas of study currently unavailable to most researchers at the two institutions. In hiring future faculty in physics, chemistry, and biology, the university plans to capitalize on the availability of this unique facility. The SSC era of high-energy physics also promises a number of opportunities for new collaborations, as does the advent of a federal computing initiative that will bring ORNL and UT scientists together to work on a wide range of new technologies for research and education. Finally, we can expect future recruitment of Distinguished Scientists and Collaborating Scientists for many UT departments and ORNL divisions. The expanding partnership will continue to enhance scientific research and education.

Biographical Sketches

Chet Richmond, an Associate Laboratory Director Emeritus, has directed ORNL's University and Educational programs since 1984. In 1990 he was named Director of Science Education and External Relations, making him liaison with several educational organizations, including UT, as well as for developing science education programs with Tennessee's community school systems and for expanding working agreements with R&D institutions here and abroad.

Richmond received his B.A. degree in biology from the New Jersey State College at Montclair and his M.S. and Ph.D. degrees in biology and physiology from the University of New Mexico in Albuquerque. A member of the U.S. National Council on Radiation Protection and Measurements since 1975, he has served on their board of directors since March 1988. He was resently appointed to the Advisory Council for Technical Education Association.

Lee Riedinger directed the Science Alliance during 1985–1987 and 1988–1991. He is now Associate Vice Chancellor for Research at UT. An experimental nuclear physicist, Riedinger until recently directed the Joint Institute for Heavy Ion Research that is adjacent to ORNL's Holifield accelerator facility. His received a B.A. degree in physics from Thomas More College in Kentucky and his doctorate in physics from Vanderbilt University. After postdoctoral appointments at the Niels Bohr Institute in Copenhagen and the University of Notre Dame, Riedinger joined the UT Physics Department in 1971. In 1990 he accepted a three-year appointment to the DOE-NSF Nuclear Science Advisory Committee and was named a fellow of the American Physics Society.

Tom Garritano is a technical writer for the Science Alliance, and among his responsibilities is a bimonthly newsletter called *Science Alliance News*. Since April 1991 he has hosted a weekly radio show featuring interviews with scientists at UT and ORNL. Garritano has worked in the publications office of ORNL's Engineering Technology Division and at the engineering firm JBF Associates. He also teaches non credit classes in desktop publishing and the use of other common personal computer software.

Eleanor Roosevelt watches Mary Sutliff of ORINS demonstrate a radiation counter in this 1955 photo.

The Partnership's Early Days

The partnership between Oak Ridge National Laboratory and the University of Tennessee at Knoxville began to blossom in the mid-1940s. Some UT faculty members took leaves of absence or left their positions to work for the Manhattan Project in Oak Ridge. The Oak Ridge government facilities requested that UT offer graduate-level courses to their employees in Oak Ridge, and UT first provided such instruction in the 1945–46 school year; thus was born the precursor to the UT Resident Graduate Program in Oak Ridge.

UT's first major outreach activity in Oak Ridge was the formation of the Oak Ridge Institute of Nuclear Studies (ORINS). In 1948 William G. Pollard and Kenneth L. Hertel, both of the UT Physics Department, established ORINS, which later became Oak Ridge Associated Universities (ORAU). For many years, Pollard was executive director of ORAU, a consortium of more than 50 universities that provides training and research opportunities in Oak Ridge for university faculty and students.

A clue to some of the early ORNL-UT interactions in the 1940s is provided by George K. Schweitzer's *Chemistry at UT, 1794–1987*. According to this history, "A demand for a graduate program in chemistry (and other areas) led to the establishment of a joint operation between UT and the Oak Ridge facilities. This program was to remain very active for over 25 years. Several chemistry courses were taught [in Oak Ridge] in 1945–49 by UT faculty supplemented by Oak Ridge personnel who were employed as part-time lecturers." These lecturers included Henri Levy, Ralph Overman, Herbert Clark, Alfred Eckert, Martin Kuna, and Lloyd Zumwalt. In 1948 Schweitzer joined the UT faculty to teach graduate inorganic chemistry and radiochemistry and to supervise the graduate chemistry program in Oak Ridge.

tudents: 'Resounding Success In Quality'–

Biology Graduate Director Hires 2, Tells Views

By ANN DIAMOND

Two fulltime professors have been named to the faculty of the University of Tennessee Oak Ridge Graduate School of Biomedical Sciences, which will begin operation in September.

Seven students have been accepted for the initial class.

R. Clinton Fuller, director of the school, announced the appointment of John Cook and Donald Olins as the first two fulltime faculty members. Eventually, a faculty staff of from four to six people will be fulltime U-T professors in the biomedical sciences school on the campus at the biology division in the Y-12 plant area, Fuller said in an interview Wednesday.

In addition, a number of biology division staffers will be "shared" members of the faculty.

Cook has been working in the biology division for the past year, on leave from his post as associate professor of physiology and assistant dean at New York University Medical School.

"We are very fortunate to have Mr. Cook because of his medical school background and his administrative experience with students. We are happy he de-

Fuller, left, and Young go over student applications in their office at the biology divisi at Y-12. On the board are some of the prospects.

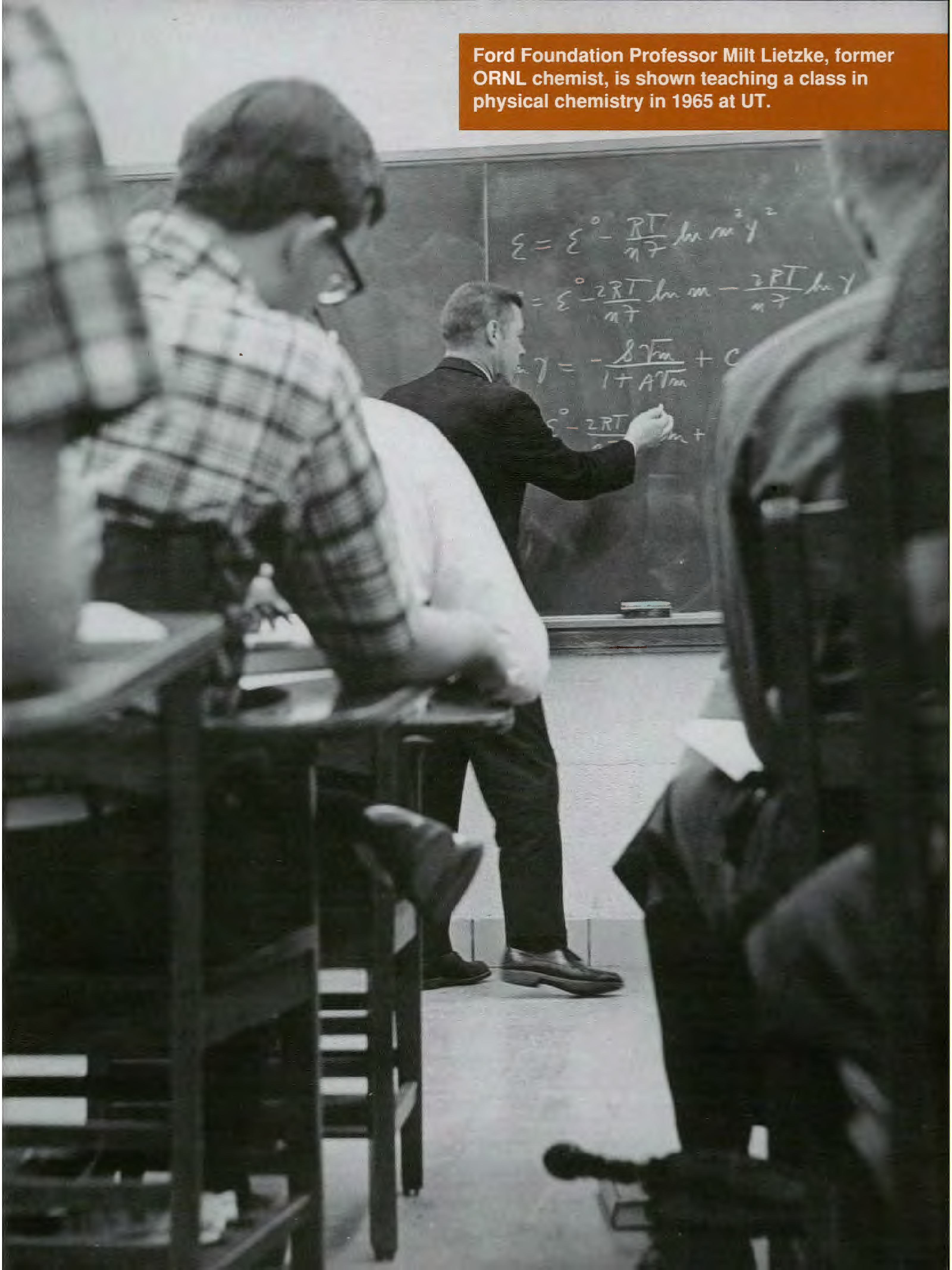
Schweitzer's history indicates that UT's Chemistry Department was affected by the needs of Oak Ridge chemistry students and the availability of Oak Ridge chemists who could teach. In 1945, he writes, "in response to demand from Oak Ridge students, a graduate sequence in inorganic chemistry was introduced" and "lecturers from the Oak Ridge staff [were] employed to teach it."

In the late 1940s and early 1950s, ORNL researchers Robert Birkhoff, Karl Z. Morgan, and others established Health Physics Education training programs for UT students.

In 1964 the Ford Foundation began providing UT with funding to appoint outstanding Oak Ridge researchers as part-time UT professors. The Ford Foundation professors taught part time on the Knoxville campus and directed graduate student research at Oak Ridge. The original Ford Foundation professors from ORNL who taught in the UT Chemistry Department were Clair Collins, Milt Lietzke, Ralph Livingston, G. Davis O'Kelley, and G. Pedro Smith. Other Ford Foundation professors from ORNL taught physics, mathematics, and metallurgical and chemical engineering. Among the original Ford Foundation professors still at ORNL today are Rufus Ritchie of the Health and Safety Research Division and Loucas Christophorou, chairman of ORNL's Corporate Fellow Council and first ORNL co-chairman of the Distinguished Scientist Program. After 5 years, the state of Tennessee provided funding to support the Ford Foundation professors. In 1964 19 ORNL researchers taught at UT; today 21 from ORNL are on the UT faculty.

By 1970 when Edward J. Boling replaced Andrew Holt as UT president, the university had changed significantly, partly as a result of ORNL's influence. According to Schweitzer, "The Holt period had seen the small campus centered around the Hill give way to a large university complex, served by a sizable staff and faculty, whose scholarly production had markedly expanded. UT was no longer an institution devoted exclusively to teaching; it had become a research center also. This development was strongly aided by the cooperative work done with the Oak Ridge laboratories."

In the decade of the 1980s, the ORNL-UT partnership was dominated by the Science Alliance, described in an accompanying article.



Ford Foundation Professor Milt Lietzke, former ORNL chemist, is shown teaching a class in physical chemistry in 1965 at UT.

The Science Alliance is one of three "centers of excellence" at the University of Tennessee. The other two "centers of excellence" sponsored by the state of Tennessee at UT are the **Center for Materials Processing** and the **Waste Management Research and Education Institute** (WMREI). ORNL researchers are involved in the activities of these centers and other UT institutes and programs.

ORNL-UT Interactions Outside the Science Alliance

The Center for Materials Processing in UT's School of Engineering is developing research and academic programs that address the specific needs of American industry in materials processing. These needs include development of materials having desirable properties and control of process variables to ensure economical and efficient reproduction of materials on an industrial scale. Participating industrial firms include Boeing Tennessee, Dow Chemical, E. I. du Pont de Nemours and Company, Commonwealth Edison, Steel Founders Society, and Martin Marietta. This center of excellence, headed by Joseph Danko, collaborates with the Science Alliance and other centers on the Knoxville campus.

ORNL scientists and engineers participate in joint research and teach highly specialized courses as adjunct professors with the Center for Materials Processing. Students, faculty, and industrial participants there have access to the specialized research facilities at ORNL, including the High Temperature Materials Laboratory, a DOE user facility.

WMREI was formed in 1985 to focus on resolving national, state, and societal issues and conflicts posed by the management of solid, chemical, low-level radioactive, and high-level radioactive waste. Headed by Gary Sayler, it is part of UT's Energy, Environment and Resources Center (EERC), which was created in 1972 as a multidisciplinary research center for exploring and resolving critical issues concerning energy, the environment, natural resources, and technology.

The Environmental Science and Biotechnology Division of WMREI has a collaborative relationship with three ORNL divisions. It is the base for David White, ORNL-UT Distinguished Scientist in applied microbiology. WMREI was instrumental in establishing a mixed waste management program with UT's Civil Engineering Department; students in this program carry out research projects at ORNL.

Researchers in the WMREI division are currently active in DOE's Integrated Trichloroethylene Bioremediation Demonstration Program; in this work, they are collaborating with ORNL researchers in the Chemical Technology and Environmental Sciences divisions and at UT's Pellissippi Laboratories.

Sayler and White, who are involved in this effort, are also principal investigators in the Deep Subsurface Microbiology Program of DOE's Office of Health and Environmental Research. They are collaborating directly with Steve Herbes and Anthony Palumbo of ORNL's Environmental Sciences Division and ORAU postdoctoral appointee Robert Burlage in the development of bioluminescent sensor technology for detecting light from genetically engineered bacteria as they metabolize toxic substances in soil.

EERC researchers carry out analyses for ORNL and its DOE contractor, Martin Marietta Energy Systems, Inc. A number of ORNL researchers have performed work for EERC, and EERC employees have done work for ORNL. Milton Russell, former assistant administrator at the Environmental Protection Agency, is a collaborating scientist at both EERC and ORNL's Energy Division.

This year ORNL joined EERC in publishing *Forum for Applied Research and Public Policy*, a quarterly journal that focuses on issues relating to energy, the environment, science and technology, and economic development. The publication has been guided by editor Daniel Schaffer since it was launched by the Tennessee Valley Authority in 1986. David Feldman of ORNL's Energy Division has joined *Forum*'s staff as senior editor. In addition, Chet Richmond, director of ORNL's Science Education Programs and External Relations, serves on the journal's advisory board. ORNL representatives on its editorial board are Bill Fulkerson, Eric Hirst, David Reichle, Tom Wilbanks, and board co-chairman Bob Van Hook.

Besides WMREI, EERC also operates

- the **Water Resources Research Center**, a federally designated state water research institute (whose acting director is Bruce Tschontz) designed to assist the state's academic institutions in carrying out water research programs, including groundwater monitoring and soil erosion control, and

- the new **Center for Environmental Biotechnology**, which conducts research (under Sayler's direction) to increase the effectiveness of environmental biotechnology in detoxifying or destroying pollutants and hazardous wastes and which teaches courses in the field (UT is now offering graduate degrees in environmental biotechnology).

EERC sponsors a Waste Management Internship Program, which gives undergraduate and graduate students work experience in fields directly related to waste management. The program is supported by Energy Systems' Hazardous Waste Remedial Action Program.

UT has several institutes that are not supported by the Science Alliance but foster interactions between ORNL and UT

"UT and ORNL have developed several centers for research and educational purposes in which industrial firms participate. . ."

personnel. An example is the **Institute for Resonance Ionization Spectroscopy** (IRIS), which grew from the pioneering work of Sam Hurst and his colleagues while he was an ORNL employee. The mission of IRIS is to exploit the ORNL development of single-atom detection using resonance ionization spectroscopy for solving basic and applied scientific problems. These problems range from detecting ultralow amounts of contaminants in materials to sequencing the human genome.

Another UT institute is the **Institute for Applied Microbiology**, headed by Distinguished Scientist David White; this institute has conducted research on using microorganisms to destroy polychlorinated biphenyls (PCBs) in soil. It also studies microbiologically influenced corrosion in collaboration with UT's Center for Materials Processing.

A third institute is the **Institute for Environmental Modeling**, which has been organized to undertake scientific research on theoretical and applied environmental problems requiring modeling and analysis. Its goal is to extend the boundaries of environmental studies through a multidisciplinary team approach using the expertise of researchers at UT, ORNL, and other local agencies. The institute's staff represent a range of disciplines, including environmental studies, ecology, mathematics, statistics, numerical analysis, and computer science. The ORNL coordinator for this institute is Donald DeAngelis.

UT and ORNL have developed several centers for research and educational purposes in which industrial firms participate, including the previously mentioned Center for Materials Processing. The first such center, which was formed in 1984, is the **Measurement and Control Engineering Center** Recognizing that no American university has a program for teaching measurement and control engineering and that the few skilled workers in the field have received their training on the job, ORNL collaborated with UT in setting up a university-industry cooperative research center for training graduate students in the area. Richard Anderson of ORNL's Instrumentation and Controls (I&C) Division spearheaded the Laboratory's effort in establishing the nation's first graduate program in this specialty.

Dan McDonald of the I&C Division and Charles Moore of UT, the center's co-technical directors, assist Bud Muly, the center director, in establishing its research direction. A number of manufacturers and users of measurement and control technologies provide funds and equipment for research and training. In July 1986 the center was named a National Science Foundation (NSF) University/Industry Cooperative Research Center, providing it the recognition needed to develop a national base of support for its programs. In addition to NSF and the Tennessee Valley Authority, 18 companies have joined the center as full or associate members. They are Alcoa, Allison Division of General Motors, Amoco, Anheuser-Busch, Bailey Controls, Dow Chemical Company, Duke Power, E. I. du Pont de Nemours, Eastman Kodak, Emerson Electric, Exxon Corporation, Martin Marietta, Perkin-Elmer, Rohm and Haas, Eastman Chemical Company, Texas Instruments, the 3M Company, and Union Carbide. Seven other companies have joined as contributing members to aid the center in developing several new sensor projects.

The center's research projects are proposed by researchers at UT, ORNL, and the member companies. The center has 15 funded research projects in process control, sensor development, and pattern recognition.

The **Composite Materials Science and Processing Laboratory** is a joint research and engineering venture between UT and ORNL that involves American industry. This

The 49-year partnership of ORNL and UT is making a valuable contribution to improving our economic well-being.

partnership was formed to accelerate the commercialization of advanced materials technologies to make the United States more competitive in world trade. The laboratory provides graduate courses in materials science and processing and the mechanics of composite structures, which include ceramics, metals, and polymers. Research projects at the UT laboratory or DOE facilities in Oak Ridge (such as the HTML and the K-25 polymer composites manufacturing facilities) range from design and synthesis of special alloys and polymeric matrices to exploring the theory of fracture mechanics. Principal ORNL divisions involved with the Composites Laboratory are the Applied Technology, Engineering Technology, and Metals and Ceramics divisions. The focal point for this laboratory at UT is the previously mentioned Center for Materials Processing.

Besides the Center for Materials Processing, Martin Marietta is one of several industrial participants in UT's new **Superior Engineering Design Program** headed by Clement Wilson. Established to reintegrate engineering and manufacturing to make U. S. industry more competitive, this program offers courses in design methodology and electro-mechanical systems integration. Other participating companies are the Alcoa Foundation, IBM, Northern Telecom, Saturn, and Westinghouse.

Several of the centers and institutes are located on the UT campus in Knoxville, and others are in the Tennessee Technology Corridor. The technology corridor is also the home of the Power Equipment Application Center (PEAC) and the Laser Technology Center, which are operated by the Tennessee Center for Research and Development (TCRD). TCRD is jointly funded by the Tennessee Valley Authority, Martin Marietta Energy Systems, UT, and the state of Tennessee.

PEAC is one of 12 test and application centers established by the Electric Power Research Institute to facilitate the development of electronic equipment to improve the efficiency and quality of power use for the benefit of utilities and their customers. The Laser Technology Center conducts research, trains laser technicians, and provides lasers and technical support services to small companies performing work under Small Business Innovation Research contracts.

TCRD, which works directly with DOE facilities in Oak Ridge, sponsored the Thermomechanical Model Software Development Consortium, which improved and commercialized software developed by the Massachusetts Institute of Technology and ORNL for analysis of the thermomechanical degradation of refractory materials in coal combustion environments. TCRD teamed up with Energy Systems and Battelle in proposing an advanced method for inspecting polymer composite structures in response to a request for proposals by the Department of Commerce Advanced Technology Program.

Energy Systems managers will be learning better management techniques for producing higher-quality products by attending seminars at UT's new Institutes for Productivity Through Quality. These institutes are part of the Management Development Center of the university's College of Business Administration. They include a Senior Executive Institute, an Administrative & Services Institute, a Design of Experiments Institute, and a Cost Management Institute.

The health of the nation's economy depends on an educated work force with technical know-how and on new products that often result from scientific research and technology development. The 49-year partnership of ORNL and UT is making a valuable contribution to improving our economic well-being.

RE: Awards & Appointments

Loucas G. Christophorou

Gerry J. Bunick

Ralph M. Moon, Jr.

Loucas G. Christophorou has been elevated to the rank of senior corporate fellow, and **Ralph M. Moon, Jr.**, and **Thomas E. Shannon** have been named corporate fellows of Martin Marietta Energy Systems, Inc.

Michael S. Bronzini has been named director of the recently formed Center for Transportation Analysis in ORNL's Energy Division.

Georges A. Guiochon, ORNL–University of Tennessee Distinguished Scientist, has received the American Chemical Society Award in Separations Science and Technology.

Richard F. Sincovec has been named head of the Mathematical Sciences Section of ORNL's Engineering Physics and Mathematics Division (EPMD), replacing **Robert C. Ward,** who is now the EPMD director.

Gerry J. Bunick has been appointed coordinator for structural biology, replacing **John Cook.**

Tony A. Gabriel has been elected a fellow of the American Physical Society.

Bennett C. Larson has been appointed head of the Thin Films and Microstructures Section of the Solid State Division.

Elias Greenbaum has been named Watkins Visiting Professor at Wichita State University.

Ben Myers received the 1990 Best Paper Award from the Nuclear Division of the American Ceramic Society for "Effect of Water Vapor on the Release of Fission Gases from UCO in HTGR Coated Fuel Particles."

Several researchers at ORNL's High Temperature Materials Laboratory received awards at the American Ceramic Society's 15th Annual Conference on Composites and Advanced Ceramics. **Ted Nolan, Larry Allard, Matt Ferber,** and **Dorothy Coffey** won a first-place award for their poster describing the phenomenon of long-term damage accumulation that can result in mechanical failure at high temperatures in high-performance ceramics. **Karren More** and **Cam Hubbard** were co-winners of a second-place poster award, and Hubbard was a co-winner of a third-place poster award.

Lynn A. Boatner has been named an associate editor of the new *Journal of Optical Materials.*

ORNL's Solid State Division entry, "Cavitation-Induced Fracture of Magnesium Oxide," by **Lynn A. Boatner, Janet Rankin, R. E. Boekenhauer,** and **D. L. Gilmore,** has received a second-place award in the Optical Microscopy category of the Ceramographic Competition of the American Ceramic Society.

Paul Rohwer has been named head of the new Assessment Technology Section in ORNL's Health and Safety Research Division.

Curtis Travis has been named director of ORNL's new Center for Risk Management. **Larry Barnthouse** has been named its deputy director.

Johnnie Cannon has been appointed an associate division director for ORNL's Energy Division. The other associate division director is Mike Kuliasha.

ORNL Biology Division Director **Fred C. Hartman** has been invited to speak at a Nobel Symposium sponsored by the Nobel Foundation. He will speak on "CO_2 Fixation in Photosynthesis" at the "CO_2 Fixation and CO_2 Reduction in Biological and Model Systems" meeting in December 1991 at the Royal Swedish Academy of Science in Stockholm, Sweden.

J. D. (Doug) Miller has been named coordinator of ORNL's Explosives Safety Program.

Thomas E. Shannon

Johnnie Cannon

Fred C. Hartman

Todd Anderson received a second-place award in the Graduate Student Paper Competition sponsored by the University of Tennessee Chapter of Sigma Xi.

Terry L. Lashley has been named project administrator of precollege programs for ORNL's Office of Science Education Programs and External Relations.

Webb Van Winkle has been appointed to the Scientific Advisory Committee for the Coastal Fisheries Ecosystems Program, which is part of the Coastal Ocean Program of the National Oceanic and Atmospheric Administration.

Susan Bly has been named ORNL Procedures Coordinator, replacing **Steve DeGangi,** who has been appointed coordinator for ORNL's Total Quality Management/ Performance Improvement Process.

James D. White has been appointed technical director of ORNL's Liquid-Metal Reactor and Light-Water Reactor Programs.

Jerry L. Hammontree has been appointed associate director of ORNL's Plant and Equipment Division.

Charles C. Baker has been named technology manager for the U. S. Home Team of the International Thermonuclear Experimental Reactor (ITER), and **Nermin A. Uckan** has been appointed program manager in connection with ORNL's work for the ITER.

John Hickey has been named associate director of ORNL's Finance and Materials Division.

Grant Stradley has been named technical assistant to Murray Rosenthal, deputy director at ORNL.

Ron Pope has been appointed to a newly created position as manager of the Office of Civilian Radioactive Waste Programs in the Office of Waste Research and Development Programs at ORNL.

Benjamin A. Carreras has been named head of the Transport Task Force of the U. S. Magnetic Fusion Program.

Lee A. Berry is chairing an international review of the Burning Plasma Experiment for DOE.

Robert A. Young has been certified as a diplomate by the American Board of Toxicology, Inc.

Monica G. Turner received the 11th annual Scientific Achievement Award of ORNL's Environmental Sciences Division.

Bill Laing has been named head of the newly formed Operations Section in ORNL's Analytical Chemistry Division.

Lee R. Shugart has been awarded funding by the North Atlantic Treaty Organization (NATO) Scientific Affairs Division to conduct a NATO workshop on advanced research in the assessment of environmental health issues.

Two ORNL entries received awards in the 1991 International Publications Competition of the Society for Technical Communication (STC). **Wanda G. Jackson, Walter S. Koncinski, Jr.,** and **Sandi C. Lyttle** received a distinguished technical communication award in the category of periodic activity reports for *ORNL '89*; and **Wilfred M. Post, Tsung-Hung Peng,** and **William R. Emanuel** won an award of excellence in scholarly/professional articles for "Global Carbon Cycle." In STC's International Art Competition,

Charles C. Baker

Nermin A. Uckan

Lee R. Shugart

Dami L. Rich, John E. Holbrook, and **Nelson T. Edwards** received an award of achievement in mechanical illustration, tone art, black and white, for *Root Respiration Measuring Device*; and **Vickie Conner, Carolyn Krause, Lynn Till,** and **Bill Norris** received an award of achievement in design graphics, covers, for the *ORNL Review*, Vol. 23, Number One, 1990.

The *ORNL Review* received the Francis E. McKinney Best-of-Show Award in the Technical Publications and Art Competition sponsored by STC's East Tennessee Chapter. The winners were **Carolyn Krause, Cindy Robinson,** and **Vickie Conner**. The Best of Show in Art Award went to **Sandra Schwartz** and **Jane Parrott** for their first-prize entry in "Design Graphics, Posters" entitled Top Cat *Gallon Giver Blood Drive Poster*. In this competition, 34 Energy Systems entries received awards.

In brochures, an award of achievement was given to the Carbon Dioxide Information Analysis Center and **Fred O'Hara;** in software user guides, a distinguished award, **Jane M. Kraemer, M. David Manes,** and **Cathy S. Fore;** in newsletters, award of achievement, **David Fields, Marilyn E. Langston,** and the Information Technology Group; in house organs, distinguished award, **Betty Mansfield, Judy M. Wyrick,** and **Anne E. Adamson;** distinguished award, **Judy M. Wyrick, Gloria M. Caton,** and Ceramic Technology for Advanced Heat Engines Program Staff; and **Carolyn Krause, Cindy Robinson, Luci Bell,** and **Vickie Conner;** award of merit, **Robert L. Wendt, Patricia M. Love,** and **Gail L. Anderson;** in promotional materials, distinguished award, **Donald W. Jared, Walter S. Koncinski, Jr.,** and **Vickie L. Conner;** award of excellence, **Gay Marie Logsdon** and **Vickie L. Conner;** award of merit, Carbon Dioxide Information Analysis Center, **Frederick M. O'Hara, Jr.,** and **Marvel D. Burtis;** in periodic activity reports, award of excellence, **Wanda G. Jackson, Walter S. Koncinski, Jr.,** and **Sandi C. Lyttle;** award of merit, **Judy M. Wyrick, Betty K. Mansfield,** and **Vicki L. Conner;** award of merit, **R. B. Shelton, R. H. Selden,** and **L. A. Daniel;** award of merit, **Allen Croff, Donna R. Reichle,** and **Cindy S. Robinson;** in whole periodicals, award of excellence, **Ernest Silver, Lisa Xiques,** and **Jean Smith;** award of merit, **Robert M. Cushman, Marvel Burtis,** and **Lydia S. Corrill.**

In scholarly/professional articles, distinguished award, **Wilfred M. Post, Tsung-Hung Peng,** and **William R. Emanuel;** distinguished award, **Frank Scheitlin, Brian H. Davison,** and **James E. Thompson;** award of excellence, **Jerome Dobson, Richard Rush,** and **Robert W. Peplies;** award of merit **R. B. Neal** et al., **Cynthia L. Mills,** and Publications Division Staff; award of merit, **Donna R. Reichle, Jonathan Woodward,** and **Norman E. Lee;** award of merit, **Frank M. Scheitlin, Brendlyn D. Faison,** and **Charlene A. Woodward;** award of merit, **Frances C. Godia, Brian H. Davison,** and **Vicki T. Hinkel;** in trade/news articles, award of excellence, **Luci Bell, Carolyn Krause,** and **Vickie Conner;** award of excellence, **Jon W. Jefferson;** award of excellence, **H. C. Thornton, Jr., Carolyn Krause,** and **Vickie Conner;** award of merit, **Carolyn Krause, Mike Aaron,** and **Vickie Conner;** award of merit, **Carolyn Krause, Lydia Corrill,** and **Vickie Conner;** and an award of

For their work on the *ORNL Review*, Carolyn Krause (left), Vickie Conner, Luci Bell, and Cindy Robinson received the Francis E. McKinney Best-of-Show Award in the Technical Publication Competition of the East Tennessee Chapter of the Society for Technical Communication.

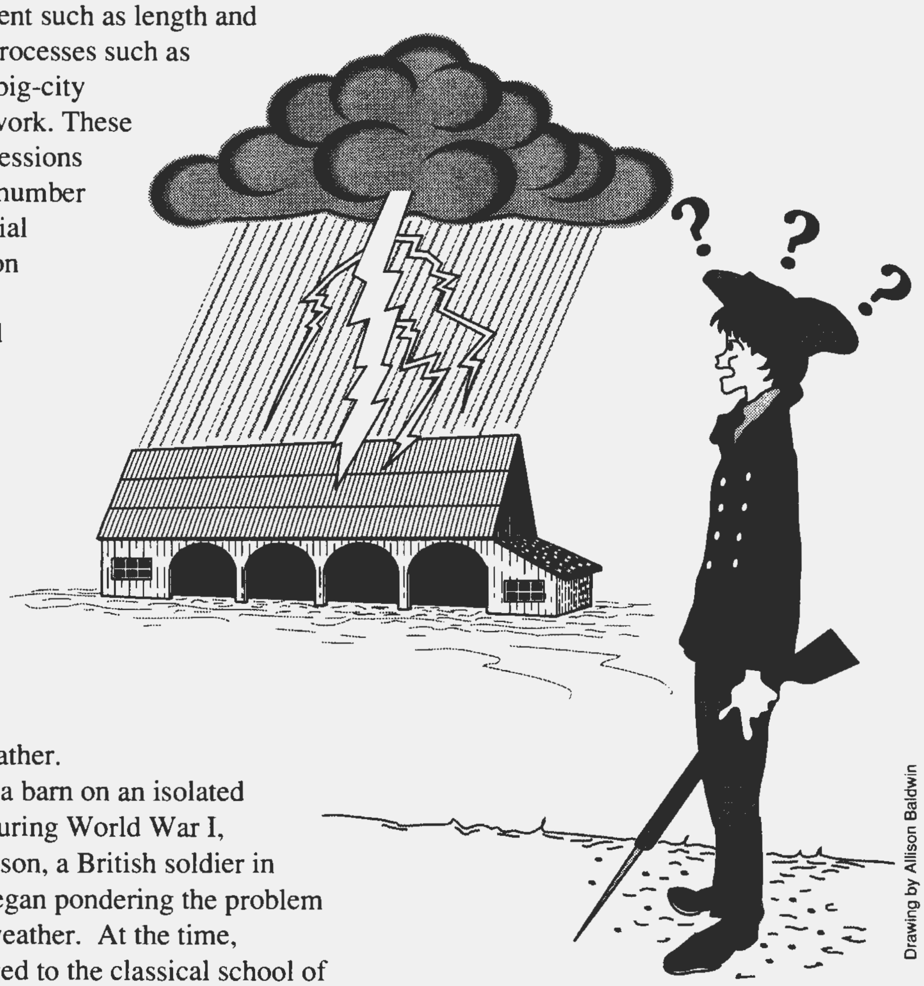
achievement, **Jon W. Jefferson;** in books, award of excellence, **Robert L. Jolley, Vivian A. Jacobs,** and Central Publications Office editorial staff; in technical reports, distinguished award, **Lawrence Dresner, Margaret Boone Nestor,** and **Brenda J. Smith;** distinguished award, **Sam A. Carnes;** award of excellence, **John T. Hogan, Margaret Boone Nestor,** and **Darcus Johnson;** award of excellence, **Kathryn Harris King, Mildred B. Sears,** and **John Keller;** and an award of achievement, **Jane M. Kraemer, Gail E. Powell,** and **Billy M. Gunter.**

In the STC Art Competition, 22 Energy Systems entries received awards. In the category of mechanical illustration, tone art, black and white, an award of excellence was given to **Dami L. Rich, John E. Holbrook,** and **Nelson T. Edwards;** in interpretive illustration, tone art, black and white, award of excellence, **Dami L. Rich** and **Brian P. Spalding;** in interpretive illustration, tone art, color, award of excellence, **Bobbie M. Lee** and **Harold Thornton, Jr.;** in design graphics, publications, award of merit, **Vickie Conner, A. Jane Morgan,** and **William W. Carpenter;** in design graphics, brochures, award of excellence, **Vickie Conner** and **Edward Aebischer;** award of achievement, **Vickie Conner, Katie Vandergriff,** and **Jim Hannah;** in design graphics, single sheets/mailers, award of distinction, **Sandra R. Schwartz;** award of excellence, **Sandra R. Schwartz;** in design graphics, covers, an award of distinction, **Vickie Conner, Carolyn Krause, Don Batchelor,** and **Johnny Tolliver;** award of excellence, **Vickie Conner, Carolyn Krause, Lynn Till,** and **Bill Norris;** award of merit, **Jane C. Parrott** and **Charles Baker**; award of merit, **Vickie Conner, Carolyn Krause,** and **John Hayter;** award of achievement, **Vickie Conner** and **Beverly Wilkes;** in design graphics, posters, an award of distinction, **Sandra Schwartz** and **Jane Parrott;** two awards of excellence, and an award of achievement, **Sandra R. Schwartz;** in design graphics, presentations, award of distinction, **Betty K. Mansfield, Eddie Barker, Judy M. Wyrick, Anne E. Adamson,** and **Laura N. Yust;** award of excellence, **J. J. Ferrada, I. W. Osborne-Lee,** and **Danny K. Cochran;** award of merit, **Terry L. Sams, Robin Taylor,** and **Danny K. Cochran;** and award of achievement, **Eddie Barker, J. B. Hayter, F. J. Peretz,** and ANS Project; and in design graphics, exhibits/displays, award of excellence, **Sandra Schwartz** and **Gail Anderson.**

Origins of Models for Weather Prediction

By Alan Solomon

Mathematical models represent concepts and processes in the language of mathematics. They may express geometric units of measurement such as length and area, or complex processes such as the operation of a big-city transportation network. These mathematical expressions may range from a number for length to a partial differential equation relating rates of change in time and space of entities such as heat and fluid velocity. Mathematical modeling is used today for a number of applications, the most familiar of which is probably forecasting the weather.



Drawing by Allison Baldwin

While guarding a barn on an isolated farm in Belgium during World War I, Lewis Fry Richardson, a British soldier in his early thirties began pondering the problem of predicting the weather. At the time, Richardson belonged to the classical school of British mathematicians and physicists, who

"Massive computing power linked to satellite observations and other information sources has improved the accuracy of weather prediction today."

had a keen interest in rigorously using the tools of mathematics to model complex physical and natural phenomena. Richardson's interests varied from human psychology to random motion and diffusion phenomena.

Weather is determined by the movement of heat and air masses (heat and mass transfer) in the atmosphere and their relation to Earth's rotation, solar radiation, and other factors. Richardson developed a set of equations representing these mechanisms, which, in principle, should enable the prediction of weather if we know such factors as wind speed and direction, humidity, time of day, and exposure to sunlight at any given moment. However, to actually forecast the weather, an enormous amount of computing must be done in a very short time. For example, a prediction of the weather 10 minutes from now must be carried out in less than that time to be of interest.

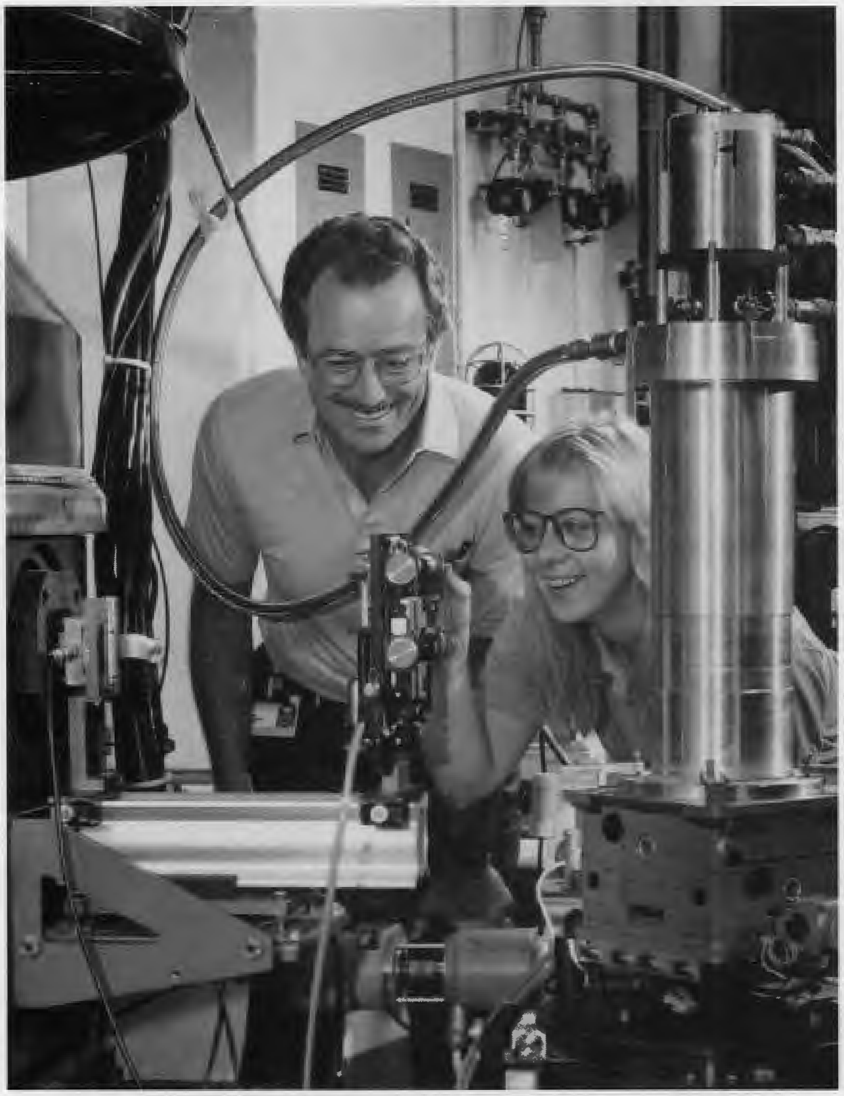
In Richardson's time, only pencil and paper and mechanical calculating machines were available to add, subtract, multiply, and divide pairs of numbers. With these tools, he developed the world's first weather prediction model. This crude model was designed to make predictions through discrete time steps of, say, 10 minutes, using only the four arithmetic operations.

In his classic book *Weather Prediction by Numerical Process*, published in 1922, he described a hypothetical building housing tens of thousands of people, each of whom would perform a single calculation based on pairs of numbers that each received via a pneumatic tube from two other persons and providing the result in the same fashion to someone else. In this way predictions of weather 10 minutes into the future could be made.

Richardson actually performed some calculations using his method and obtained incorrect results. The building he proposed was never built. However, the very failure of his method motivated others to develop stability of computing methods and to believe that computer-based numerical weather prediction was feasible. Subsequent prediction models have had a major and lasting impact on meteorology and other fields.

Massive computing power linked to satellite observations and other information sources has improved the accuracy of weather prediction today. So the next time you see your TV meteorologist forecasting rain, snow, or sunshine for tomorrow, think of a soldier guarding a barn in Belgium in World War I and dreaming of the day when accurate weather prediction would be possible.

A Chance to Scatter Neutrons



Bob Nicklow, who directs the Neutron Scattering Research Facility, and Marianne Holma, a graduate student in physics at the University of Illinois, adjust a spectrometer at the HFIR.The HFIR's two user facilities give students a chance to work with equipment that few universities can offer.

"Students earning degrees in solid-state physics study neutron scattering in textbooks, but they aren't always able to have a first-hand experience with it," says Bob Nicklow of ORNL's Solid State Division. "This user program is a way for them to come and do those experiments."

Nicklow and George Wignall manage the user facility program in neutron scattering at the High Flux Isotope Reactor (HFIR). Since the program began in 1980, more than 300 graduate students have used the facilities, and their work has appeared in over 600 research publications.

When the HFIR was shut down because of safety concerns in November 1986, the user facility program, which hosted about 150 users per year, was also suspended. The program began rebuilding when the HFIR was restarted May 16, 1990. Says Wignall, "I can't say that we're going at full speed, because the reactor was shut down for over three years. That's a whole class of graduate students who never came here and who have probably gone into another field of science."

In neutron scattering, neutrons are shot through a material to study its structure and internal dynamics. Neutrons that strike the atoms in the material are deflected, or scattered, producing a pattern that is a structural fingerprint of the material.

"Neutron scattering as a research tool provides a means of examining a wide variety of solid-state phenomena, from magnetism, superconductivity, and crystal structures to polymers, colloids, and biological materials," says Nicklow. "It's an extremely versatile technique, but it's available on very few university campuses."

Nicklow directs the user program at the Neutron Scattering Research Facility (NSRF), where intense neutron beams produced by the

HFIR are used with a variety of wide-angle scattering spectrometers for basic research. Wide-angle scattering is used primarily to study the locations and motions of individual atoms in solids and liquids. Currently, the research focuses on better understanding magnetic materials, superconductors, metal alloys, and phase transitions.

The neutron-scattering equipment at NSRF available for users includes several three-axis spectrometers for measuring magnetic energy levels and vibration frequencies of atoms, a polarized-beam spectrometer for investigations of magnetic materials, and a high-resolution powder diffractometer for studies of materials that cannot be obtained in crystalline form. The facilities also allow studies of materials in extreme environments, including low and high temperatures, high pressures, and strong magnetic fields.

Wignall directs the Center for Small-Angle Scattering Research, whose state-of-the-art equipment enables researchers to investigate the molecular structure of materials in biology, polymer science, chemistry, materials science, and solid-state physics. The two main instruments available to users are the 30-m small-angle neutron scattering (SANS) facility and the 10-m small-angle X ray scattering camera.

"The NSRF started off as an in-house research program that DOE wanted us to manage," says Nicklow. "Then, as the user concept grew, DOE still wanted us to do our own research, but they also wanted us to start a user community. It has not been established as an exclusive user research facility, because we still have our own research responsibility. In 1986 about two-thirds of the research was carried out by people from the outside. The remaining one-third was carried out strictly by people from ORNL." In the Center for Small-Angle Scattering Research, which was built with funding from the National Science Foundation, virtually all the research was done by outsiders.

The staff used the HFIR downtime in the late 1980s to improve the equipment; the spectrometers were modified so that the equipment would be safer and provide greater flexibility in optimizing resolution and intensity. Remote sample-handling and -orienting devices are now used so that the operator is further removed from the neutron-scattering beam, which is a source of some radiation. For the SANS facility, the software was completely rewritten, and new hardware was installed to provide virtually instantaneous on-line data analysis.

The HFIR's user facilities offer neutron scattering at an unbeatable price to the user—it's free unless the work is proprietary (proprietary work is not published in the open literature, so the public does not directly benefit from the research). A staff member works with the user to train him or her, but eventually the user is usually able to operate the equipment alone.

Currently, about five outside users work at the facilities in any given week. A particular user might come back several times a year, and an experiment might take two days or two weeks. Users come from all over the world; during a recent month they came from Germany, Japan, Canada, and, closer to home, Los Alamos and the University of Illinois. Although Nicklow and Wignall would like to see the programs rebuild to the former levels of use, their staffs have decreased since 1986. Therefore, they are rebuilding the programs carefully to avoid a deluge of users that will overwhelm the staff.

"I could book the small-angle neutron-scattering instrument 100% of the time," says Wignall, "if I had the staff to look after it. I've been turning a lot of people away because there's only me to look after the instrument. We were pleased when we had 150 users here, and we're trying to work our way back up to that. Not all of the experimental slots are filled with users, but it's getting to be a substantial fraction of the time already. Just a tiny bit of publicity is going to cause an explosion of users."

An explosion of users will put the facilities back where they belong—providing hundreds of students and other scientists a chance to broaden their horizons through the use of ORNL's world-class neutron scattering research tools.—*Cindy Robinson*

New Computer Science Research Facility Open

ORNL has a new Computer Science Research Facility, which is located among the physics buildings near the Swan Pond. Completed in the spring of 1991, the building houses the Mathematical Sciences Section of the Engineering Physics and Mathematics Division. This section, which was located at the Y-12 Plant, conducts basic research in computer science, mathematics, and statistics with an emphasis on research in parallel processing.

The 12,343-ft^2 building contains 38 offices, a student area, a library, a conference room, and a computer room. Among the division's computers is the Intel iPSC/860, which has set records in computation speed and brought much recognition to the division within the past year.

"This is a great move for our division," says Bob Ward, division director. "The move not only provides a new facility for the division's expanding computing research program, but it also enables stronger interactions among the division's multisection computing, mathematical, and statistical modeling and analysis activities. It also will benefit the many ORNL divisions that collaborate with the Mathematical Sciences Section."

This building for people who work with numbers has a number of its own, like all ORNL buildings. The Computer Science Research Facility is also known as Building 6012.

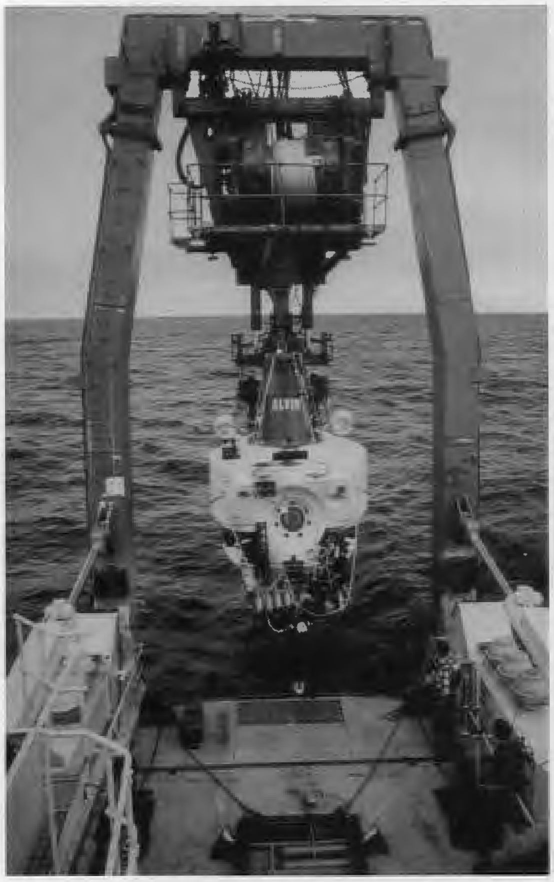
In the computer room of the Computer Science Research Facility is the Intel iPSC/860, which has set records in computation speed and brought much recognition to the Engineering Physics and Mathematics Division within the past year.

Underwater Lava Deposits Observed by ORNL Staff

In June 1991, when the world's attention was focused on the death and destruction from lava flows from the erupting Mount Pinatubo in the Philippines, two scientists at ORNL were telling news reporters about the new life they saw among fresh lava deposits from an underwater volcanic eruption. They had made these observations this past spring during a "voyage under the sea."

Karen Von Damm and Jackie Grebmeier, both of ORNL's Environmental Sciences Division, were among a group of scientists who discovered fresh lava deposits at the bottom of the ocean. Active eruptions on the deep seafloor have never been observed directly. However, the scientists found a spot that had been covered by lava flows within the past 15 months. For the ORNL scientists and their colleagues, the discovery provided an unprecedented opportunity to study the effects of underwater eruptions on the deep-sea biological community.

Two ORNL scientists spent a month at sea, using the submersible *Alvin* to dive to a hot-spring environment on the ocean floor.



In March the scientists sailed about 800 km (500 miles) southwest of Acapulco, Mexico, to study one of the most extensive areas of deep-sea hot springs known. The group included marine geologists, biologists, and chemists from many different universities and laboratories. The scientists spent a month at sea, diving a total of 25 times in the submersible *Alvin* to the bottom of the ocean—a depth of 2.4 km (1.5 miles).

The scientists visited the East Pacific Rise, a volcanic ridge at a site southwest of Mexico at a latitude of 9 to 10° N. These mid-ocean ridges form a global system representing the creation of new seafloor from molten rock (magma) in Earth's mantle. As the magma bubbles up from inside Earth, it cools on contact with the seawater and hardens into new oceanic crust. The heat of the magma pushes up a ridge on the seafloor from which the new rock spreads out. The underwater eruptions also create hot springs along parts of the ridges.

The researchers measured the temperatures of the hot springs; the maximum temperature (403°C) is one of the highest ever recorded in the sea. They also found that the hot springs (1) are the most acidic and the least salty of the hot springs known in the oceans and (2) contain concentrated metals and sulfides that darken the water so that the thermal vents seem to be emitting black smoke. The vents released carbon dioxide and other gases.

The fresh lava deposits also gave the group an unparalleled chance to study the growth of a new biological community around the hot springs. They found scorched bodies of tubeworms (jokingly called "tubeworm barbecue") that had been covered by lava flows. Another discovery was the white mats that had grown over the black lava, coating patchy areas for several kilometers. No one knows whether these mats are formed from minerals or bacteria.

Speaking to reporters, Von Damm described the mats as "not quite like cotton candy" but more like a peaceful winter snowscape. Water flowing from the hot springs, she said, occasionally rips the mats into pieces, creating a whirling "snowstorm." If bacterial in origin, she added, the mats indicate that a new biological community is growing up and replacing the one destroyed by the lava flow. The researchers expect to eventually find larger animals, such as mussels and clams, colonizing the area.

Von Damm and Grebmeier's research was funded by National Science Foundation (NSF) grants through their positions at the University of Tennessee, where Von Damm is a research associate professor in the geological sciences and Grebmeier is a research assistant professor in ecology.

The various scientists working with the expedition look for answers to a variety of questions. The geologists observed the beginnings of ore deposits forming from the metals and sulfides, obtaining information that may guide them in prospecting for minerals. The biologists were curious whether this chemosynthetically based ecosystem (with no light, photosynthesis cannot take place) could have been the environment for the origin of life. The chemists were interested in understanding the conditions controlling the chemistry of seawater.

Another goal of the expedition was to locate a site for the first drill hole of the International Program of Ocean Drilling. This project for studying the composition of various areas of the ocean floor will take the first core samples of the East Pacific Rise early in 1992. The scientists found a site having relatively thick and solid lava flows that is thought to meet the drilling requirements. No previous dives had been made in the area, so the group relied on mapping by remote sensing for guidance. Knowledge of the area's terrain is crucial because visibility from inside *Alvin* is only 15 to 20 m.

Alvin is a 26-year-old submersible owned by the U.S. Navy and operated by Woods Hole Oceanographic Institute. Three people can fit inside *Alvin*—a Navy-certified pilot and two scientific observers. Because the daily dive lasts from around 8 a.m. to 5 p.m., Von Damm warned, "You must have a strong bladder." During this expedition, she dived to the seafloor five times.

The NSF program manager, she said, was so excited by the results of the study that he has scheduled more dives at the site for January 1992. Specifically, the group will look for new biological growth at the springs and will study one unusual hot-water vent whose chemical composition was found to change every week.

The expedition has already proven its success from the first set of dives. But Von Damm, Grebmeier, and the others are eager to learn more about the impacts of volcanoes under the sea by exploring new depths.—*Alexandra Witze, ORNL* Review *summer intern and senior in geology at the Massachusetts Institute of Technology*

ORNL Has New Center for Risk Management

Toxic chemicals, radionuclides, acid deposition, and climate change can be hazardous to human health and the environment. What are the risks that exposure to any of these can result in illness, injury, or death or damage to natural resources? Do managerial actions and policies actually reduce environmental and health hazards? What are the negative environmental impacts of energy production and consumption? Which environmental problems should receive attention first?

These questions will be addressed by ORNL's newly established interdisciplinary Center for Risk Management. This research-and-development center will be based in ORNL's Health and Safety Research Division (HASRD). It will use ORNL's scientific resources and expertise to evaluate risks to human health and the environment and to determine the best methods for reducing them.

"Our goals are to integrate science into decision making and make Energy Systems a national leader in risk management and assessment," says Curtis Travis, director of the new center and head of HASRD's Risk Analysis Section. "We plan to do more than develop risk methodologies and perform risk assessments. For example, we will provide technical assistance to sponsors who manage societal risks or interpret risk assessments.

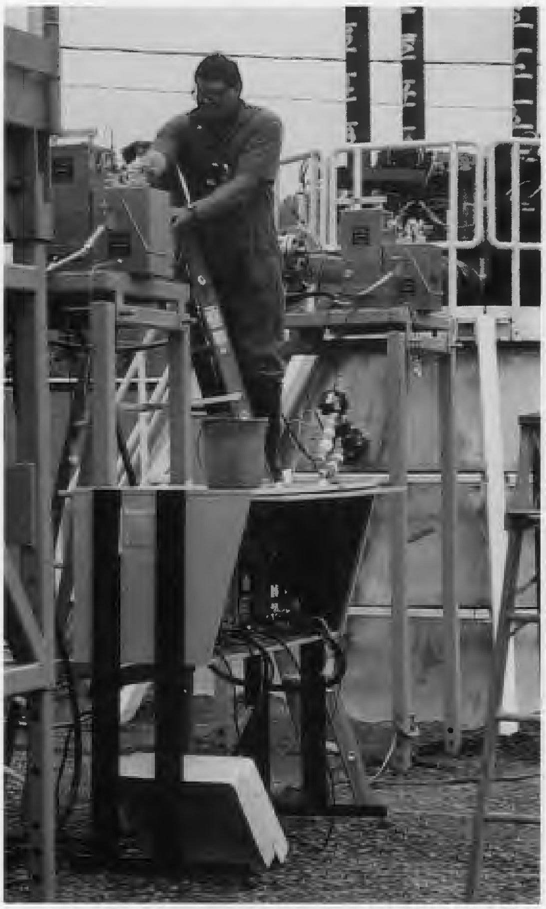
"In addition, we will look at the role of community relations in achieving public consensus on the most acceptable ways to manage environmental risks. We will conduct training for professionals and offer educational opportunies to the public to promote two-way communication between both groups on the management of environmental and health risks."

Travis will be assisted by the center's deputy director, Lawrence W. Barnthouse of ORNL's Environmental Sciences Division. Both will report to David E. Reichle, ORNL associate director for Environmental, Life, and Social Sciences.

The center's activities include human toxicology studies aimed at developing health-based standards, data-base development, environmental monitoring, applied ecology, engineering risk analysis, economic analysis, and policy analysis. ornl

"The fresh lava deposits also gave the group an unparalleled chance to study the growth of a new biological community around the hot springs."

Meltdown: A Solution to Radioactive Waste Disposal?



Reed D. Sharp, a Battelle technician, checks the equipment designed to melt radioactive sludge and surrounding soil in a trench into a block of glass, which seals the hazardous materials in place. Photo by Michael Patrick of the *Knoxville News-Sentinel.*

How do you contain radioactive sludge buried during the 1950s and 1960s, when the approach to waste disposal was explicitly to "dilute and disperse" in contrast to the present-day requirement of complete containment? How do you keep it from being released into the environment, contaminating the groundwater and the earth? ORNL recently demonstrated a possible solution: melting the sludge and surrounding soil into a block of glass, which seals the radioactive materials in place.

In May 1991 ORNL and Battelle Pacific Northwest Laboratories (PNL) performed a half-scale demonstration of "in situ vitrification" (ISV, or converting a material to glass right where it is) at Solid Waste Storage Area (SWSA) 6 on the Oak Ridge Reservation. Brian Spalding and Gary Jacobs, both of the Environmental Sciences Division, and Mary Peterson, project manager from PNL, organized the carefully controlled, well-publicized demonstration of ISV. Four separate tours gave employees and media representatives an opportunity to observe the technology in action and to learn about future plans.

According to Spalding, "During the 1950s and 1960s the preferred way of disposing of radioactive waste was to deposit it as a sludge in porous gravel. These disposal sites are now problems, of course; we must keep the waste from leaking into the environment. The in situ vitrification process is a perfect match for this type of problem; it allows us to convert the sludge into a monolith of glass."

For the demonstration, the researchers moved a sample of sludge containing 10 millicuries of radioactivity from an ORNL seepage pit to the SWSA site. The placement in the ground simulated burial in the old ORNL seepage pits that were last used in the 1960s. The radioactive isotopes present included cesium-137 and strontium-90, both of which have natural analogs in ordinary soil, and other transuranic (heavier-than-uranium) elements.

Several graphite electrodes planted in the ground transferred electrical power that, together with the earth's natural resistance to heat flow, melted the soil. The electrical power was gradually increased to as high as 300 kW. As the soil melted, the electrodes sank down into the molten soil.

The waste was well monitored: over 100 sensors, mostly thermocouples, were buried at various depths and distances from the waste. The scientists used them to monitor off-gases, heat flux, temperature, and pressure to learn how the waste and surrounding soil were reacting to the melting process.

A large hood capped off the site and collected any gases released by the 1500°C material. More than 97.3% of the radioactive material was retained in the ground, but the off-gases were nonetheless vented to a mobile unit for scrubbing and filtering, making the air clean enough to be returned to the environment. No traces of radioactivity could be found in the last stages of cleaning the gases.

When the desired depth was reached after about five days of heating, the power was switched off and the molten earth left to cool. A few weeks later, the treated area had solidified to a mixture of gray rock and dark green glass, which are very resistant to leaching. The waste was thus encapsulated in a monolithic glass, preventing it from threatening public health and the environment. On the surface, the blackened area looks like a big hole, about 1.5 m deep, with a chunk of glass at the bottom. The crater resulted from the loss of space between soil particles melted together during the experiment.

This black chunk of glass was formed by in situ vitrification.

In addition to the many sensors, the seismic imaging methods of Alan Witten of the Energy Division and Rick Williams of the University of Tennessee were applied to the melting soil and waste. For this application, a technician fired a shotgun slug into the ground at certain locations, creating sound waves that traveled through the soil. By tracking the waves, geophysicists can identify different subsurface conditions.

The soil and molten materials have very different mechanical properties that can be detected using the seismic measurements. The velocity of sound waves is quite different in the two materials, and this difference is what is used to image the two materials. Witten has been involved with other projects including searching for dinosaur bones, landfill contents, and perhaps even hidden narcotics. But for now, scientists hope it will give an accurate picture of the waste as it melts and cools, thus eliminating the need for more costly and invasive sensors.

The ISV process was developed more than a decade ago by James Buelt and William Bonner, both of PNL. They had been working on glassification projects for stabilizing samples of radioactive waste. They soon realized that, rather than exhuming the material and bringing it to the glass factory, which involved much risk, they should instead take the factory to the waste site. Researchers from both PNL and ORNL have been working together on ISV for a few years. The first ISV demonstration used nonradioactive materials.

Spalding is working on specific applications of ISV for waste site needs. The Oak Ridge Reservation has enough scattered waste sites for one to two busy years of continuous vitrification. The advantage of ISV, he says, is that "you make it and you're done with it." Converting the sludge into a massive chunk of glass permanently contains it.

In addition, ISV has no extra maintenance costs, as in repository disposal. Assuming an ISV unit that works for five years, the cost is estimated to be $400/m^3$ of glass. According to Spalding, this cost is at least a factor of 10 less than that of exhuming and repackaging (but not disposing of) the waste, which is "the ultimate alternative which no one wants to contemplate very long." Evidence so far indicates that ISV may provide a safer, simpler solution to the waste problem.—*Alexandra Witze, ORNL* Review *summer intern and senior at the Massachusetts Institute of Technology*

Technician Virginia Tevault focuses on a spinach leaf, which provides the membranes that, when coated with platinum, produce electricity. If platinum-coated spinach membranes could be used as electronic building blocks, smaller, faster computers could be built.

Green Power Plants

Spinach and platinum seem like an odd couple, but together they can make electricity flow. The secret is to use the platinum to give metal-like properties to the spinach's chloroplasts, which are the tiny, chlorophyll-packed sacs that green plants use to convert sunlight into usable energy.

By coating spinach thylakoids (the part of the chloroplast where the photochemical reactions of photosynthesis take place) with platinum and then irradiating them with a laser, Elias Greenbaum of ORNL's Chemical Technology Division has used the tools of photosynthesis to turn photons of light into electrical current. The process may be a key to developing very small and very fast optoelectronic switches for use in biomolecular electronic devices. The "electric eye" in burglar alarms is one example of such a switch.

"When laser light shines on these platinized chloroplasts, voltage is generated across the spinach membranes," explains Greenbaum. "The system converts light energy into electrical energy. The objective of our research is to try to extract and isolate the photosynthetic reaction centers that make a biological system convert light into electricity. Knowing their function in the biological system, we may be able to build our own assemblies that incorporate such photosynthetic centers." Greenbaum believes such assemblies could be used to construct biological optoelectronic logic devices, optic computers, or biocomputers. Such devices would be much smaller and faster than conventional computers.

"In such devices," Greenbaum says, "the presence or absence of light causes an optoelectronic switch to change its state from 'on' to 'off' or vice versa. Our research is intriguing because the optoelectronic reaction occurs in a molecular device, which is very small (about 1 nanometer) and has a switching time that is very fast (about 5 picoseconds). Of course, we're still doing basic research; we're a long way from using photosynthetic centers as parts of computers."

In all higher plants, including spinach, the thylakoid membranes contain photochemical reaction centers where electrons are transferred as photosynthesis takes place. The light captured by the chloroplasts transfers electrons across the photosynthetic membrane. When platinum is precipitated onto the surface of the membranes, the chloroplasts at least partially acquire metal-like properties, allowing them to conduct photoelectric current.

"The amount of platinum determines the degree of photoconductivity," says Greenbaum. Enough platinum must be present not only to make electrical contact between the photosynthetic membranes, but also to create a chloroplast-metal matrix. Thus, when the photosynthetic reaction centers generate their current, the electrons can flow between metal particles.

Other researchers have used thylakoids to conduct photoelectric current, but their membranes have been in direct contact with electrodes. Greenbaum's work is unique because the laser creates a flow of photocurrent in the plane of the entrapped platinized chloroplasts, allowing the current to flow from membrane to membrane.

To create the platinized chloroplasts, Greenbaum ruptures the chloroplast envelope and then precipitates platinum onto the exposed photosynthetic membrane. The platinized chloroplasts are trapped on filter paper and placed between two electrodes. This package is held together with lucite plates and compression screws. The laser creates a steady-state flow of current through the chloroplast-platinum composite matrix. The amount of precipitated platinum and the proximity of the laser source to a linear wire electrode determine the amount of current through the platinized chloroplasts.

This process does not harm the chloroplasts. The reaction will go on for days, and, when done in the absence of oxygen, the reaction has been measured for more than a week.

Greenbaum has been working with chloroplasts for several years. Much of his work has involved using photosynthesis to split water into hydrogen and oxygen. He first platinized chloroplasts in 1985 during a search for efficient photosynthetic methods for producing hydrogen fuel from water. His work with platinized chloroplasts has focused on the biomolecular electronic properties of this new composite material. Greenbaum uses these electrons to synthesize hydrogen (*Review*, Vol. 19, No. 3, 1986) and to create the sustained electrical current in the chloroplasts, which drive current through an external circuit.

"We stumbled into this field by looking at the photocatalytic properties of hydrogen and oxygen," says Greenbaum. "Once the platinum started going down into the chloroplasts, we decided to study its effects on the electronic properties of the chloroplasts. The platinum really did transform the electronic properties."—*Cindy Robinson*

Mysteries of Hollow Atoms Probed

Research at ORNL's Physics Division has provided insights about "hollow atoms," neutral atoms that are unusual because nearly all their electrons exist far from the nucleus and carry excess energy.

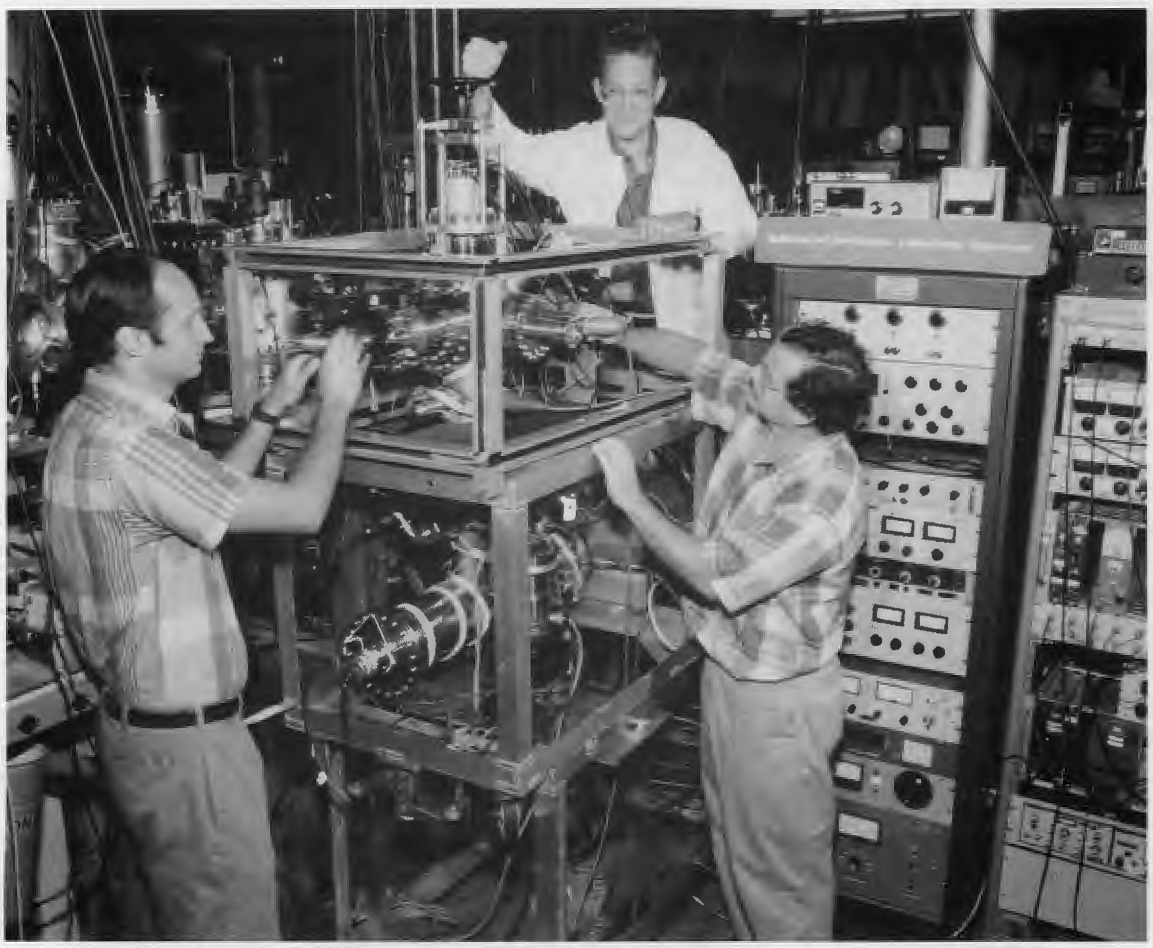
In a normal atom in the ground state, the electrons occupy orbitals (shells) so as to minimize their total energy. Shells are filled sequentially, starting with the lowest-energy, innermost shell closest to the nucleus, progressing to the second shell after the innermost one is filled and then to the third one, and so on. In a hollow atom, nearly all the electrons are located instead in outer shells, leaving a core of empty inner shells that make the atom hollow. Every electron in these outer shells carries excess energy in this exotic atomic state.

How are hollow atoms obtained? Visualize an atom of oxygen with eight electrons—two in the innermost shell and six in the next shell. Put the atom in ORNL's Electron Cyclotron Resonance (ECR) Ion Source and strip it of all but one of its electrons, giving it a net charge of +7. An ECR source has the capability of stripping atoms of nearly all their electrons without imparting high speeds to the resulting ions. A well-defined, low-energy beam of multiply charged oxygen-7+ ions is extracted from the source and directed toward a metallic crystal target so that it barely skims the surface. The ions travel almost parallel to the crystal plane before plunging into the surface.

Because they have a strong positive electric field, the highly charged ions can capture loosely bound electrons from the metal target as they skim over the surface. The ions pick up enough electrons to make them neutral but hollow atoms. These electrons are captured into highly excited levels called Rydberg states.

Hollow atoms do not stay hollow long, however. The excited electrons in the outer shells

Fred Meyer (right), Charlie Havener (left), and Pedro Zeijlmans van Emmichoven (background) make adjustments on the experimental apparatus used to study hollow atoms.



of hollow atoms eventually relax and drop down to the low-energy, innermost shells closest to the nucleus. In this process, they give up energy in the form of X rays or Auger electrons having characteristic energies. An Auger electron can be emitted when at least two electrons are in excited states. One of the electrons jumps to a lower-energy level, releasing energy that ejects another of the excited electrons from the atom. The ejected electron is an Auger electron.

An ORNL research team has obtained evidence of hollow atom formation above metal surfaces using beams of nitrogen-6+, oxygen-7+, and argon-9+ incident on single crystals of gold and copper. The team includes Fred Meyer, Charles Havener, and Pedro Zeijlmans van Emmichoven, all of the Physics Division; Steve Overbury of the Chemistry Division; and David Zehner of the Solid State Division.

By analyzing the energies of Auger electrons emitted by these multicharged ions, the researchers found a characteristic signature of hollow atoms that distinguishes them from ions that have captured electrons directly to inner shells after penetrating the metal bulk. They determined that a hollow atom survives only tens to hundreds of femtoseconds (10^{-15} s) before its electrons revert to their minimum energy states by jumping into inner shells.

Description of such hollow atom decay poses a large challenge to theorists. One difficulty arises from the simultaneous participation of many, mutually repelling electrons, both in the hollow atoms and in the metal target they penetrate. These electron interactions (also called correlations) play a large role not only in the initial formation of the hollow atom state but also in determining the speed of its subsequent decay. Another complication is the proximity of the metal surface during the hollow atom's decay, which may affect the nature of the transient hollow atom states formed during the atom's lifetime.

The research on producing hollow atoms near metal surfaces raises fundamental questions about atomic physicists' understanding of atom decay and the properties of atoms in multiply excited states. The results of the research may also have practical applications because the excited electrons in the outer shells of hollow atoms might be used for new types of lasers.—*Carolyn Krause*

Energy Systems and Tennessee Enter into CRADAs

To increase the federal government's commitment to transfer its technologies to private industry, to improve U. S. competitiveness in world markets, and to help Tennessee companies improve their manufacturing processes and environmental practices in metal-working and machining, three agreements were signed in Oak Ridge this past summer.

On June 24, 1991, officials of Martin Marietta Energy Systems, Inc., and the state of Tennessee signed two agreements for assisting Tennessee's private firms through the transfer of technologies developed at DOE facilities in Oak Ridge.

The agreements—known as Cooperative Research and Development Agreements (CRADAs)—were signed during a ceremony attended by Joe La Grone, manager of DOE's Field Office in Oak Ridge, and Rockwell Schnabel, deputy secretary of the Department of Commerce. The two officials also signed a letter of agreement for continued cooperation between the two federal agencies in technology transfer.

The two new CRADAs will help Tennessee firms implement environmentally sound manufacturing processes and improved metal-working and machining operations. The agreements pledging regional technical assistance and cooperative research and development (R&D) were signed by Clyde C. Hopkins, president of Energy Systems, and Carl Johnson, Tennessee Commissioner for Economic and Community Development.

Under the conditions of the CRADA for regional technical assistance, Tennessee will provide an industrial assistance program to identify the technological needs of small private manufacturers and to match them with Energy Systems' resources. The National Institute of Standards and Technology, which is part of the Department of Commerce, will also participate in this program through the Boehert-Rockefeller program, which financially supports industrial assistance and networking in Tennessee.

Funding from DOE's Defense Program makes possible the participation of Energy Systems through the Y-12 Plant, which provides technological assistance to meet the needs of smaller companies using machining and metal-working processes. The ultimate goal of the CRADA is to improve manufacturing practices by creating development partnerships among the cooperating smaller private manufacturers. In this way, advanced technologies that could improve U. S. competitiveness in global markets could be developed and deployed.

The CRADA calling for cooperative R&D for environmentally sound manufacturing will use the capabilities of Tennessee's Center for Industrial Services and technical experts within Energy Systems. Waste minimization experts from the Y-12 Plant are expected to be used, along with ORNL experts in waste processing from the Chemical Technology Division, characterization and monitoring technologies from the Instrumentation and Controls and Health and Safety Research divisions, and risk assessment from the Environmental Sciences Division. They will initiate needed cooperative R&D with Tennessee manufacturers for the development and use of manufacturing technologies that minimize waste production and damage to the environment and comply with increasingly rigorous environmental requirements.

The project is co-funded by DOE's Defense and Environmental Management programs. The cooperative R&D will focus initially on finding less environmentally threatening substitutes for solvents and other standard process chemicals currently used in production. Both CRADAs with the state of Tennessee will use Tennessee's Center for Industrial Services, which has a network of industry extension agents who will provide technical assistance to the companies of Tennessee. Energy Systems will provide the technical experts needed by these agents.

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Radiation Monitoring Software Licensed

A computer program that can collect and interpret information simultaneously from more than 100 radiation detectors has been licensed by Energy Systems. The company granted exclusive rights to the Integrated Alpha Spectroscopy Software to Canberra Industries.

The software was developed by Larry Burchfield of the Oak Ridge Y-12 Plant. Copies of it will be produced and marketed by the Canberra Industries' Nuclear Products Group in Schaumburg, Illinois.

The software was originally developed for use with monitors of alpha radiation, the most difficult type of radiation to detect because it can be easily absorbed by any material, including air. The software package sorts out data from the detectors and makes calculations to determine the presence of radioactive material and its level of radioactivity. The program can be used with instruments for personnel monitoring and environmental analyses.

Alpha spectrometers are used to detect radioactive isotopes that emit alpha radiation (an alpha particle is a helium nucleus—two protons and two neutrons). Each alpha-emitting isotope has a characteristic decay energy, or "fingerprint," making possible identification of specific isotopes.

Current regulations require the detection and measurement of very low levels of alpha radiation at nuclear facilities such as the Y-12 Plant. To meet this requirement for each large batch of samples processed daily in large-scale monitoring programs, long count times and 50 to 100 individual alpha detectors acquiring data simultaneously are needed. The new software sorts the data and does calculations at least 20 times faster than other currently used methods.

Respirator Software Licensed to Local Firm

An Energy Systems computer program that monitors the safety of respirators and the qualifications of workers using them in hazardous areas has been licensed to an Oak Ridge company.

Sigma Science, Engineering and Technology Applications Corporation has been awarded a commercial license for RespFit 2.0, a program that stores and analyzes information taken from tests of form-fitting respirators.

About 2900 employees at the Oak Ridge Y-12 Plant are trained to use protective face masks when working in areas that sometimes expose them to increased concentrations of airborne hazardous substances. The new program gives supervisors a record of employees having the proper training and those lacking it.

In addition, the program provides a methodology for testing whether a worker wearing a respirator and performing specific tasks meets the safety guidelines established by the American National Standards Institute. The testing procedure asks the worker to make movements similar to those made on the job and determines whether these movements increase the worker's risk of exposure to hazardous substances.

The computer program was developed by Joseph Sherrill, an industrial hygienist at the Y-12 Plant. This is the fourth Energy Systems license involving a Y-12 technology. ornl

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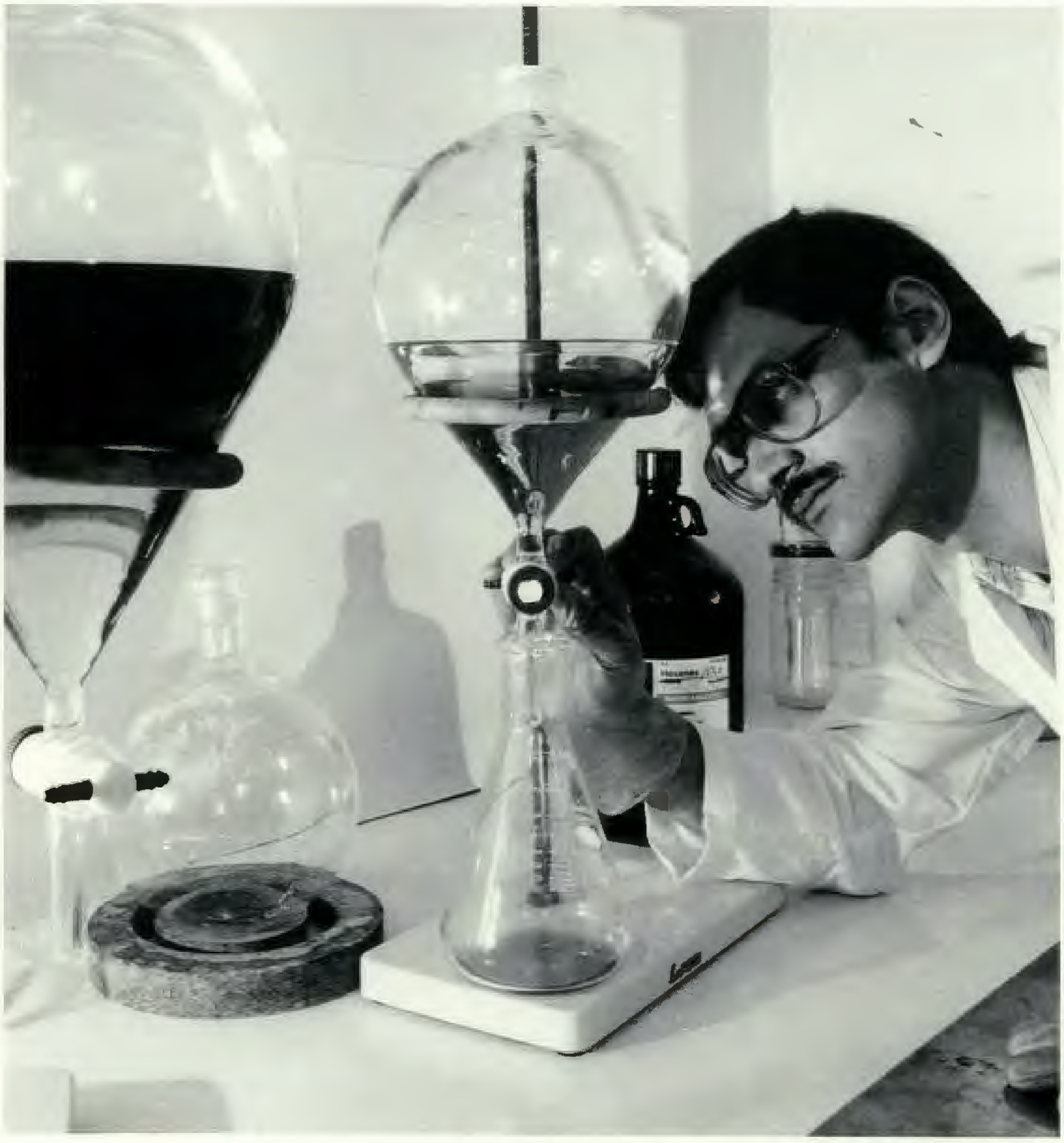

Next Issue

ORNL chemists are synthesizing new compounds for extracting metals from solution.

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