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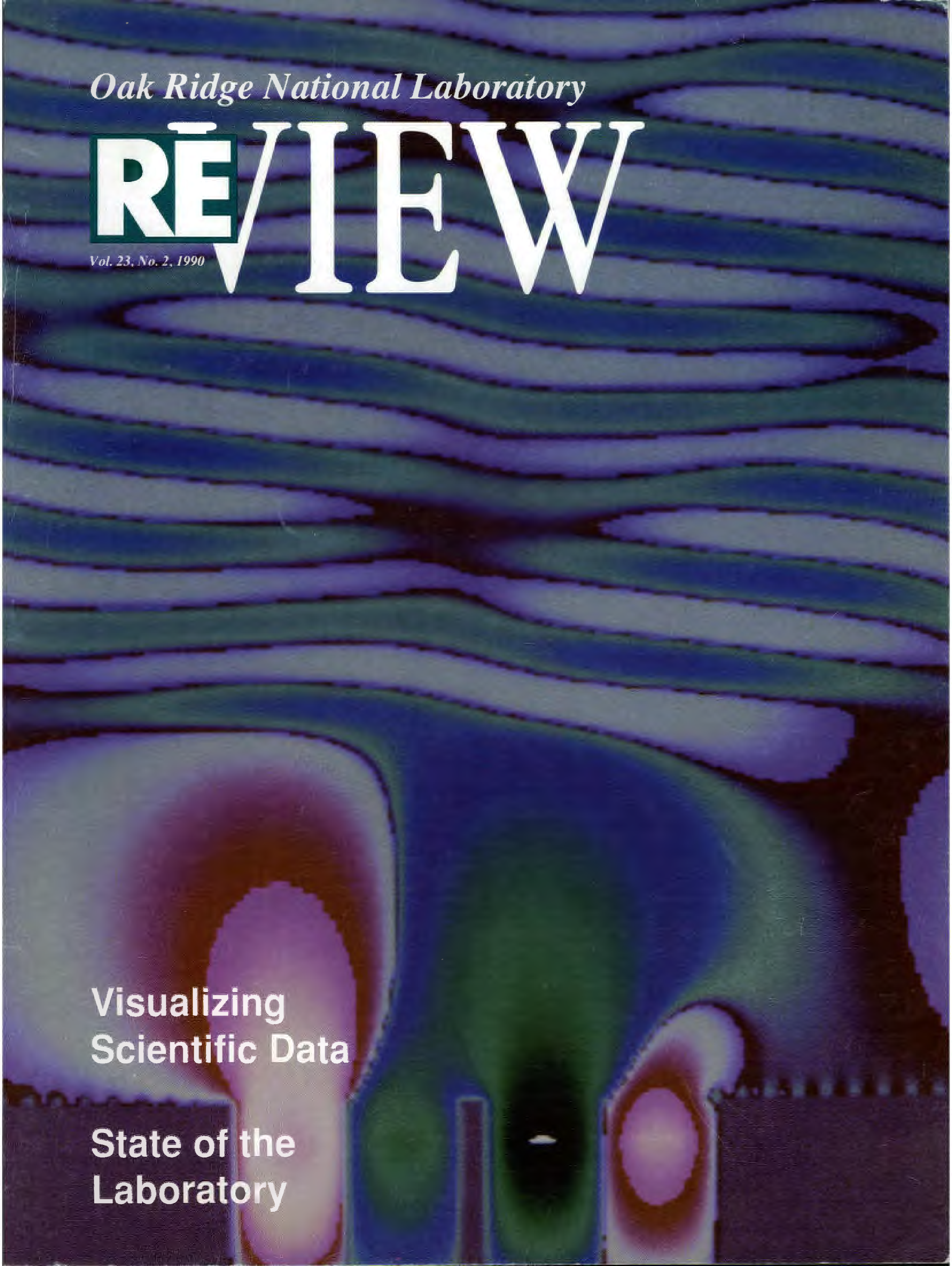

Visualizing Scientific Data

State of the Laboratory

REVIEW

Volume 23 *Number Two, 1990*

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.

ON THE COVER

This image of electromagnetic plasma waves propagating from an ORNL-designed phased array antenna in a tokamak is an example of the visualization of scientific data. The waves, which drive an electron current through the plasma, are shown here propagating preferentially to one side, thus pushing plasma current in this direction. The different hues in this animation image represent the varying intensities of the plama waves and the strengths of the electrical field throughout the plasma. The colors allow scientists to quickly visualize a three-dimensional phenomenon and obtain more meaningful information than is available in conventionally used contour plots. See the article on p. 29.

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Views of Oak Ridge National Laboratory on a winter day.

State of the Laboratory–1989

By Alvin W. Trivelpiece

To outsiders, Oak Ridge National Laboratory appears to be a large, complex facility. But, really, the Laboratory is people, and all our people are needed to get things done. Everybody's job is important. Our product is new knowledge, which results from doing basic and applied research and development in various areas. Research is done well if every element in the system is optimized. Scientists cannot do good research without technicians, other support personnel, and the right kind of work environment. So everybody counts in this kind of activity.

Joe La Grone, manager of the Department of Energy's Oak Ridge Operations Office, asked Clyde Hopkins, president of Martin Marietta Energy Systems, Inc., to ask me to reiterate my commitment as ORNL director to improving environmental, health, and safety conditions at the Laboratory. I'm glad to do so, and I would have done so anyway without such urging. I want to illustrate my commitment by mentioning the circumstances I encountered when I first assumed the position as director of the Office of Energy Research at DOE.


ORNL Director Alvin Trivelpiece delivers an upbeat message.

Old and New Commitments

When I arrived at the department in 1981, one of the first things I did was to read the Crawford report, which addressed the problems of managing DOE's nuclear reactors and concerns about some reactors' safety. (The report, published in 1981 and prepared by a DOE committee headed by John W. Crawford, Jr., is entitled "A Safety Assessment of DOE Nuclear Reactors," and its number is DOE/US 0005.) Few people read the report, and fewer still responded to it. Among those responding were Ken Davis, then DOE Deputy Secretary, and me. We became concerned that poor operation of or an incident or accident at a DOE reactor could have a serious negative impact on the civilian reactor economy in the United States. Davis and I met several times with Bill Vaughn, then DOE Assistant Secretary for Environment, Health, and Safety, and urged him to commit more resources from his programs into monitoring DOE's reactors. Such an action was not a very popular thing to do at that time, and one

"The Laboratory is people, and all our people are needed to get things done."

"We must work as a team and try not to play into the hands of people who seek to shut us down."

Trivelpiece was the first ORNL employee to go through the radiation monitor in the Flagpole Lobby of Building 4500 North. All employees at the X-10 site were checked recently in the walk-through monitor to obtain baseline data on the amount of radioactivity carried by each person.

of the problems was getting people to run a monitoring program. When I joined DOE, the Reagan administration was new, and a move was afoot to abolish the Department of Energy. A more immediate problem was that several thousand DOE staff members had been removed, and replacing them was very difficult. Nevertheless, in spite of the needs for additional programmatic staff in the department, I hired somebody to focus on the operation and safety of the reactors associated with the Office of Energy Research programs. Although expensive, I thought this action was an absolutely essential step to take at that time. Interestingly, five years later, an accident at a Russian reactor, not a U.S. reactor, prompted shutdowns of DOE reactors and revived negative perceptions about nuclear power in the United States.

In 1982, it was disclosed that, in the mid-1950s, large amounts of mercury had been discharged to the Oak Ridge environment from the DOE plants. I was well aware of the Minamata incident in which a number of Japanese died from eating fish contaminated with methylmercury, so I was very responsive to the request for funding to begin removing the mercury from the soil and water in which it was found. As I recall, we had to scrounge up $20 million for the first year. It was tempting to deflect that request because it occurred at an awkward time in the budget cycle and required diverting money from other programmatic areas. I think many people wanted me to ignore the mercury cleanup request, but I believe that preserving the environment and having a safe and healthy workplace are paramount. We simply have to do what is needed to ensure good environmental, health, and safety conditions for employees and the public.

I was also a member of DOE's Budget Review Committee, which looks over all the department's budgets. Quite frequently we debated whether funds should be directed toward supporting particular sequences of weapons tests or toward cleaning up the weapons plants. This debate was usually acrimonious and, after much analysis and discussion, we always agreed to establish some reasonable balance between meeting the needs to clean up the environment by properly disposing of DOE's legacy wastes and meeting the department's mission requirements to ensure a strong national defense.

In an article in *The Oak Ridger* in 1989, I was quoted as saying that ORNL is still a scientific laboratory. Some people took my statement to mean that I was unalterably opposed to using money and personnel for environmental, health, and safety activities. Some have implied that I was thumbing my nose at the Department of Energy. This is absolute rubbish. Remember, I was committed to improving the environment and employee health and safety at DOE facilities when, in fact, it was somewhat unpopular to do so. So I find this misunderstanding a bit distressing, and I hope my statements about my past commitment will clear it up.

We must work as a team and try not to play into the hands of people who seek to shut us down. We cannot afford to have incidents that violate mandated procedures and endanger other employees—for example, leaving a bottle of a hazardous chemical in somebody else's lab. Such incidents put everybody's jobs— and the work of this fine laboratory—in jeopardy. I hope all ORNL employees understand that it is important that we comply with regulations. You don't have to like them, and, in fact, you have a right to seek to change those you believe to be unreasonable. But, remember, I am committed to making ORNL the best in environment, safety, and health, and I expect division directors, line managers, and all Laboratory employees to support these efforts. One indication of our growing commitment in this area is that the number of ORNL's environmental and health protection personnel has increased from 240 in June 1988 to 390 in September 1990.

During a recent visit to Washington, D.C., I watched President Bush give his State of the Union Address. At the time, I was with ten Soviet scientists and ten other guests at the home of Frank Press, president of the National Academy of Sciences. This gathering followed a reception at the Soviet Embassy to commemorate the 30th anniversary of the beginning of relations between the U.S. Academy of Sciences and the Soviet Academy of Sciences. At this Embassy reception, Gurey Marchuk, who is the president of the Soviet Academy of Sciences, inducted Press into the Soviet Academy of Sciences as a foreign member. This well-deserved honor calls attention to a point I want to make: frequently scientists serve as the ambassadors who play leading roles in stimulating dialogue among nations even during periods of strained diplomatic relations. I have seen this phenomenon firsthand in Washington several times, so it was with some interest that we sat there with Soviet scientists watching them watch President Bush discuss the decline of communism in Eastern Europe and the Soviet Union and wondering what was going on in their minds. A few years ago none of us would have thought to ask them to express their feelings about communism because we suspected we wouldn't have gotten a straight answer. This time some of us asked them about their reaction to President Bush's speech, and most agreed that it was accurate and appropriate. However, they were also understandably apprehensive because events over which they have little control are unfolding around them with blinding speed. Still, they are optimistic about the future activities in their country.

I'm optimistic about the future of this laboratory, but I am also concerned, given all the changes that confront us in areas ranging from budgets to maintenance to issues involved in improving environmental, health, and safety conditions. Despite these problems, I remain optimistic in part because of the commitment of Secretary of Energy Admiral James Watkins to making improvements. The following statement made by the Secretary of Energy during his nomination hearing emphasizes the important role of national laboratories in this country's future: "I know that the Department of Energy's national laboratories are home to some of the world's brightest, most innovative scientists and engineers. These creative minds are a precious national asset and will be encouraged not only to continue their basic research but also to improve

"We cannot afford to have incidents that violate mandated procedures and endanger other employees."

Secretary of Energy Watkins (right) admires the HFIR's renovated control room. Photo by Frank Hoffman.

"... the Department of Energy's national laboratories are home to some of the world's brightest, most innovative scientists and engineers."

the process by which new technologies are transferred to American industries, small businesses, and universities. The laboratories will also have a growing role in helping high schools and universities motivate young people to seek vocations in science and mathematics and engineering of tomorrow. We're simply not doing enough in our nation to encourage young people, particularly the growing number from minority backgrounds, to pursue careers in science and engineering."

At a recent DOE Laboratory Directors' meeting, Secretary Watkins reiterated this commitment and indicated that new funding would be available for many of these educational activities. This new direction was really brought home forcefully on February 2, 1990, when President Bush visited the University of Tennessee at Knoxville. While he was at UT, it was announced that contributions of $1 million each will come from the state of Tennessee, Martin Marietta Corporation, and the Department of Energy to establish a Summer School of the South for Science and Mathematics for precollege students and an Academy for Teachers of Science and Mathematics, an advanced training ground for 200 of the region's most outstanding teachers. These activities have been carried out on a marginal level, but given the growing importance of increasing science literacy in the United States, I believe it is necessary to give even greater visibility to these efforts. Thus, I'm really pleased that Chet Richmond agreed to become ORNL director of Science Education Programs and External Relations. For 15 years Chet served with distinction as the associate director for Biomedical and Environmental Sciences.

Administrative Changes

A number of administrative changes took place last year. First, I decided that I needed a deputy director to carry out much of the administrative work of the director's office, especially the

Trivelpiece's job as ORNL director includes the opportunity to meet visitors such as Dr. Rosalyn Yalow. Here, he inspects the Nobel Prize she received in 1977 in Physiology and Medicine for the development of the radioimmunoassay technique. She spoke at ORNL recently on "Radiation and Society" at the invitation of P.C. Srivastava (right). At left is David Reichle, who was recently appointed ORNL associate director for Biomedical and Environmental Sciences by Trivelpiece.

"I'm optimistic about the future of this laboratory, but I am also concerned."

responsibility for the Environmental, Safety, and Health Upgrade efforts, which includes weekly meetings of an advisory committee. I am pleased that Murray Rosenthal accepted this position and that he is doing the job well. I created an Office of Planning and Management and appointed Truman Anderson as its director. After a number of off-site meetings and a reexamination of the organization achieved by Herman Postma during his 14-year tenure as ORNL director, we decided to make several changes at the associate director and division director levels. In recent months it has been announced that Bill Appleton is associate director for Physical Sciences and Advanced Materials (previously called Physical Sciences); Fred Young is director of the Solid State Division, replacing Appleton; Dave Reichle is the new associate director for Biomedical and Environmental Sciences, replacing Richmond; Bob Van Hook has been named director of the Environmental Sciences Division, replacing Reichle; Fred Hartman is director of the Biology Division; Bill Fulkerson is the associate director for Advanced Energy Systems; Bob Shelton is director of the Energy Division, replacing Fulkerson; Alex Zucker is associate director for Nuclear Technologies (formerly Engineering and Nuclear Technologies); John Jones is the new director of the Engineering Technology Division; Frank Homan is director of the Research Reactors Program; Claude Pugh is director of the Nuclear Regulatory Commission Programs, and Joe Herndon is director of the Robotics and Intelligent Systems Program. Under Zucker, the focus is strictly on nuclear technologies; thus, we added to his programmatic area the Advanced Neutron Source and sections of the Instrumentation and Controls (I&C) Division and removed from his domain the Chemical Technology and Applied Technology divisions.

Because Jack Richard has been given full responsibilities for research reactors, we abolished the associate directorship for Research Reactor Systems (first held by Fred Mynatt) and appointed Hal Glovier director of the Research Reactors Division. We created a Center for Global Environmental Studies, an Office of Guest User Interactions, and an Oak Ridge Detector Center to respond to research opportunities presented by the proposed Superconducting Super Collider (SSC), which I will discuss later. We created a new but short-lived associate directorship for the Chemical, Environmental, and Health Protection Technologies. Fred Mynatt was appointed associate director for this new organization, which focused attention on some of ORNL's most critical issues. He then was promoted to Energy Systems vice president for Compliance, Evaluations, and Policy and replaced by Tom Row, now director of Environmental, Safety, and Health Compliance; reporting to Row are the directors of the Analytical Chemistry and Chemical Technology divisions, the Office of Environmental and Health Protection (of which Jerry Swanks is director), and Tony Malinauskas, manager of the new Waste R&D Program.

In operations, we shifted some of the responsibilities of Bill Morgan's office to other folks. Morgan is associate director for Operations, previously called Support and Services. He is responsible for the Plant and Equipment, Finance and Materials, Quality, and Human Resources divisions, as well as the Office of Operational Readiness and Safety; in addition, his office interfaces with the Energy Systems Engineering and Information Resources and Administration

AWARDS AND RECOGNITION

One way to measure how well this institution is performing is to keep track of the awards and other forms of recognition given by outsiders to ORNL staff members.

organizations at ORNL. Jim Bryson is the new director of the Human Resources Division.

One of my first concerns shortly after becoming Laboratory director was that ORNL did not seem well positioned to use large-scale computing to respond to complex scientific problems. I persuaded Ed Oliver, formerly with the Air Force Weapons Laboratory, to join the staff and head a newly created Office of Laboratory Computing to (1) determine the computing resources used by ORNL researchers and compare them with other installations' resources, (2) develop strategies to offer the ORNL research staff first-class computing resources, (3) coordinate activities with the Computing and Telecommunication Division, such as implementing the recently issued *Strategic Plan on Computing at ORNL*, and (4) interface with organizations outside of ORNL. He reports directly to me so that we can decide how best to integrate our existing computing capability with equipment we plan to purchase to provide large-scale digital computers, such as supercomputers and parallel computers, for scientific programs.

Our next step in improving the administration of the Laboratory is to look at the activities now grouped under the various associate directors and at the individual divisions to see what changes are needed. We are deciding which activities should be merged and which should be separate and whether we have too many—or too few—divisions. Effectiveness of operation is our goal.

Based on this measure, we had a rather interesting and important year in 1989. ORNL received four out of a possible nine awards in the DOE Materials Science Research Competition. Malcolm Stocks of ORNL's Metals and Ceramics Division received the Sustained Outstanding Research in Metallurgy and Ceramics Award for "First Principles Theory of the Physical and Metallurgical Properties of Alloys"; Warren Oliver of the Metals and Ceramics Division, the Significant Implication for DOE-Related Technologies in Metallurgy and Ceramics Award for "The Development of Use of the Mechanical Properties Microprobe for Characterizing Energy-Related Materials"; Steve Pennycook, the Outstanding Scientific Accomplishment in Solid State Physics Award for "Atomic Resolution Imaging of Materials Structure and Chemistry Using Localized Electron Scattering in a Scanning Transmission Electron Microscope"; and Carlos Bamberger, Significant Implications for DOE-Related Technologies in Materials Chemistry Award for "Synthesis of Ceramic Whiskers." Eight ORNL researchers were advanced to the rank of fellow in various professional societies (see "Awards and Appointments" in the 1989 issues of the *Review*).

I find it interesting that the Laboratory has a relatively high number of Certified Professional

Here are two views of the $18-million Nonradiological Wastewater Treatment Facility at ORNL, which is almost complete after nine years of effort.

This project, which received the Tennessee Association of Business Excellence Award for Water Quality, will reduce the number of ORNL's major waste streams from six to three.

Secretaries; last year the results of two tests showed that, outside the state of Texas, Tennessee led in the number of Certified Professional Secretaries, and 10 secretaries from ORNL were certified—quite a remarkable accomplishment.

ORNL had three developments that received 1989 R&D 100 Awards from *Research & Development* magazine (for details, see "Technical Highlights" in the *Review*, Vol. 22, No. 4, 1989). One award was given for the scanning tunneling photon microscope developed by Tom Ferrell and Bruce Warmack of the Health and Safety Research Division and Robin Reddick, a graduate student at the University of Tennessee. It is similar to the scanning tunneling electron microscope (STM), in which a small electrode moves back and forth close to a surface, and, by drawing current at a constant level, reveals characteristics of surfaces down to the resolution of single atoms. When photons of light from a laser travel through a prism,

Tommy McKamey checks the status of the process storage tanks (shown in photo at left) on a monitor in the control room of the Nonradiological Wastewater Treatment Facility.

This STM image of a piece of bacterial DNA was obtained in 1989 at ORNL.

an evanescent field is produced that can be used to image microscopic surface features. This development may well replace conventional optical microscopes.

Speaking of the STM, I think one of the most interesting pictures I have seen this past year is the STM image of a piece of bacterial DNA obtained at ORNL. Because it clearly shows the structure of the double helix to be the same as that determined by X-ray diffraction and reveals the separation between pitches of the helix, which is about 40 Å, the blown-up ORNL image is remarkable.

Another R&D 100 Award winner is the gasless atomization nozzle developed by Dave Hobson and Vinod Sikka, both of the Metals and Ceramics Division, and Igor Alexeff, an ORNL consultant from the University of Tennessee. Sheet used for automotive bodies and office furniture is produced by casting large ingots, followed by

"ORNL also received the National Safety Council Award for working without a lost workday from October 14, 1988, through August 18, 1989—another remarkable achievement."

expensive processing steps. The gasless atomization nozzle offers an economical method of sheetmaking by direct spraying of atomized liquid metal droplets on a substrate followed by minimum processing requirements.

ORNL's third R&D 100 Award was received by John Hayter and Herb Mook, both of the Solid State Division, for developing a polarizer that permits neutrons having one polarization to pass through while reflecting neutrons having the opposite polarization. The result is a polarized neutron beam that allows some experiments to be carried out that would otherwise be difficult to do.

In addition, the Martin Marietta Corporation recognizes many ORNL staff accomplishments during Awards Night every May, and several award winners are selected to attend an awards ceremony in Bethesda, Maryland, to receive the corporation's Jefferson Cup. Our Jefferson Cup winners in 1989 were Claudette McKamey (Metals and Ceramics Division), for her work in developing corrosion-resistant iron aluminides (see the article on her work in the *Review*, Vol. 23, No. 1, 1990); Salil Niyogi (Biology Division), for developing structural changes in epidermal growth factor to better understand how it works and whether an altered form could have potential for treatment of tumors; and Toby Mitchell

An ORNL welder makes a tungsten inert gas weld on a stainless steel pressure vessel built by the Fabrication Department of ORNL's Plant and Equipment Division.

(Engineering Physics and Mathematics Division), for "Bayesian Variable Selection in Linear Regression," a statistical study that has been recognized in several ways by people in the field. In addition, two of our people—Fred Hartman of the Biology Division and Sam Liu of the Solid State Division—were made Corporate Fellows.

ORNL also received the National Safety Council Award for working without a lost workday from October 14, 1988, through August 18, 1989—another remarkable achievement.

The $18-million Nonradiological Wastewater Treatment Facility is almost complete, after nine years of effort. This project, which received the Tennessee Association of Business Excellence Award for Water Quality, will reduce the number of ORNL's major waste streams from six to three (for more details, see p. 64 of the *Review*, Vol. 21, No. 4, 1988).

In 1989 the American Society of Mechanical Engineers (ASME) audited the Laboratory to determine its ability to fabricate unfired pressure vessels that meet ASME safety criteria. ORNL, through the Plant and Equipment Division's Fabrication Department, is one of only two DOE facilities that have been recertified by ASME for three years to construct pressure vessels for testing. The ORNL department recently built two pressure vessels for use as prefilter tanks for the HFIR.

In 1989 ORNL was one of only two DOE facilities certified by the American Society of Mechanical Engineers to construct pressure vessels for testing.

Rep. Lloyd, Secretary of Energy Watkins, and former Sen. Baker (right) listen to Sam Hurt of ORNL's Research Reactors Division describe the internals of the HFIR.

Secretary of Energy Watkins announces that the HFIR will resume operations shortly. His audience includes Rep. Lloyd, former Sen. Baker, and ORNL's Jackson Richard.

Technical Highlights

Reactor restarts. Last year was a good time for ORNL to be visited by the Secretary of Energy, Admiral Watkins. We were glad that he came, and it was a pleasant experience talking with him and his friends—Howard Baker, former White House chief of staff and Tennessee senator; Marilyn Lloyd, U.S. representative from Tennessee's Third District, Leo Duffy of DOE Headquarters, and Polly Gault, the Secretary of Energy's chief of staff who has a great deal to say about what goes on in DOE. When he was here last November, Admiral Watkins addressed personnel at the High Flux Isotope Reactor (HFIR) and announced that the reactor, which had been idle three years, would be operating soon. He was right—on January 29, 1990, operation of the HFIR was resumed. [On May 18, 1990, its power level was raised from 11 MW to 85 MW.] The Tower Shielding Reactor, which resumed operation on December 8, 1989, reached full power on January 15 and, on January 16, the Japanese-American program on developing shielding for liquid metal reactors was again under way.

Steam line upgrade. In 1989 the $6.8-million steam line upgrade project, started in the fall of 1988, was completed. The project involved improving a 30-year-old system for heating the Laboratory's buildings that began to fail when outer pipes protecting the steam lines became corroded, resulting in large energy losses. About half the steam lines have been reinsulated and placed in concrete trenches, which have been covered with removable concrete lids to provide easy access for repairs and adjustments. The 30 steam pits where control valves are located have also been upgraded. The new system is easier to maintain and uses 15% less energy to meet building heating requirements.

Motor monitor. Each of us has felt vibrations by putting a hand on the hood of a car whose engine is running. Electric motors also vibrate. The operation of a motor can be monitored by measuring its acoustic and mechanical vibrations; a variation in the vibration signature can indicate the need for maintenance. It turns out the same phenomenon causing motor vibrations also affects the electrical current flowing into it. This discovery by Howard Haynes and David Eissenberg of the Engineering Technology Divison led to the development of a method for determining whether a motor is operating normally or abnormally by measuring the motor's current. This clever piece of work can be used for nonintrusive monitoring of nuclear plants, and the method has been licensed to three private companies.

On December 8, 1989, the Tower Shielding Reactor was restarted after being idle for almost three years. Since January 16, 1990, it has been used for Japanese-American experiments to develop shielding for advanced liquid metal reactors.

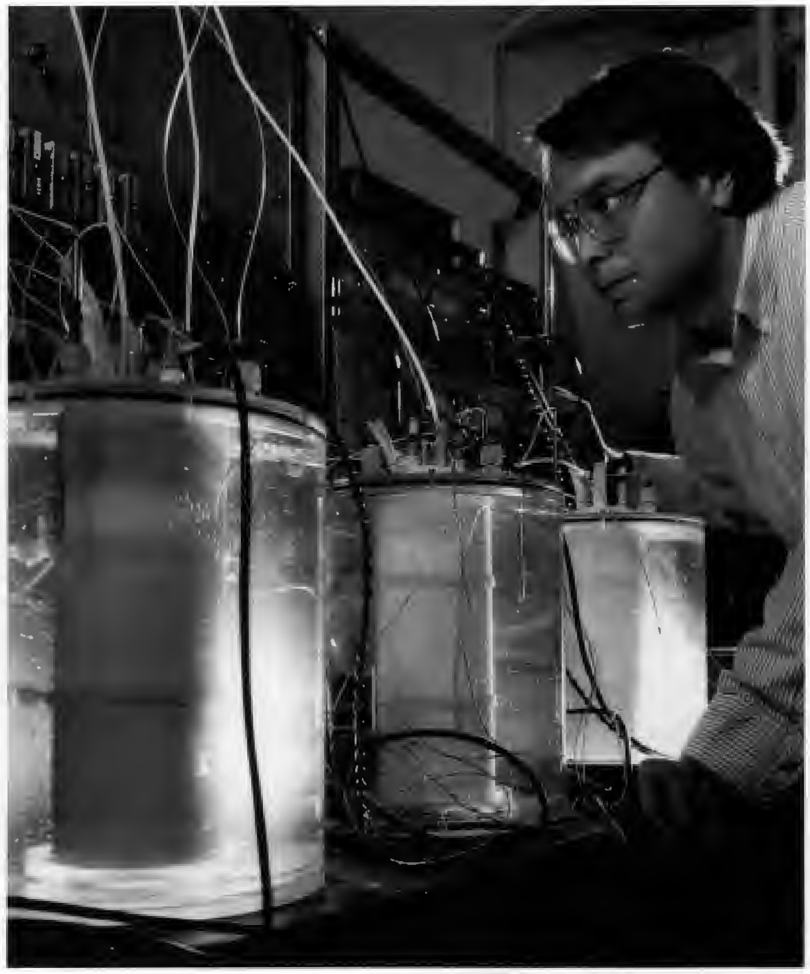
Taking a turbine blades's temperature. ORNL researchers recently found a way to measure the temperature of a rotating jet turbine blade using phosphor thermography, a method of determining the temperature of a surface by measuring the intensity and persistence of the light emitted from a fluorescent material coating the surface. The researchers caused the phosphors that were coating test turbine blades and vanes to fluoresce by passing pulsed laser light through optical fibers entering the engine; then they measured the fluorescence signals leaving the engine through the optical fibers to determine the temperatures of the spinning blades and vanes. This remarkable application of an important technique by Mike Cates, Steve Allison, David Beshears, Gary Capps, Jeffrey Muhs, and Kenneth Tobin, all of ORNL's Applied Technology Division, reveals whether the spinning components of jet turbines are too hot or too cold for proper engine performance.

Cold fusion research. A major scientific story in 1989 was the report that cold fusion had been achieved. Like most of you I read about the University of Utah experiments in the *Wall Street Journal*. As a new director, I didn't know where the appropriate equipment for cold fusion experiments might be and, because the report surfaced over a holiday weekend, I couldn't find anybody at the Laboratory who might know who could work on cold fusion experiments. I used the only scientific tool available to me that weekend—a push-button telephone. I called everyone I know who might be able to help me and I tried to find out as much as I could. Then on Monday or Tuesday, a group of us began talking about whether this effect is real or not real. I think we concluded that the chance that cold fusion is real is small. However, we also agreed that ORNL should make a reasonable effort to try to understand whether cold fusion or some other new effect exists. This event suggests that ORNL needs a "scientific swat team" that responds to possible new discoveries by quickly contacting the appropriate researchers and organizing group meetings to determine research needs and exchange results. We let a few days go by before we started the experiments, while researchers at other labs had already started fairly large experiments by Sunday afternoon; I was somewhat distressed that we weren't among

Howard Haynes (left) and David Eissenberg have developed a method for detecting mechanical and electrical abnormalities in a motor and the equipment it is driving. Here, Haynes attaches a clamp to wiring in a motor-operated valve as he and Eissenberg watch the signal conditioner current probe of a mobile motor current signature analysis device. The sounds are stored on a cassette tape for later analysis by the recorder Haynes is carrying on his shoulder.

In 1989 ORNL's $6.8-million steam line upgrade project, started in the fall of 1988, was completed. The new system is easier to maintain and uses 15% less energy than the old system to meet building heating requirements.

them. However, I congratulate our "cold fusion" researchers at the Laboratory because of the sane and civilized way in which this whole problem was approached. We did not get caught up in activities that resulted in some rather adverse publicity for certain institutions. One group, for example, discovered an age-old phenomenon known to many physics graduate students: a neutron-measuring apparatus is temperature-sensitive and, if it gets warm, it indicates an increase in neutrons, which could be interpreted as evidence of cold fusion. Some people embarrassed themselves by announcing that this result showed that cold fusion exists and almost rushed to publish their findings. We were careful in our experiments, and I think Mike Saltmarsh of the Fusion Energy Division deserves a great deal of credit for orchestrating our efforts and providing a well-reasoned assessment of our results to Congress. His carefully presented testimony served to mediate the circus atmosphere of the congressional hearing on cold fusion during

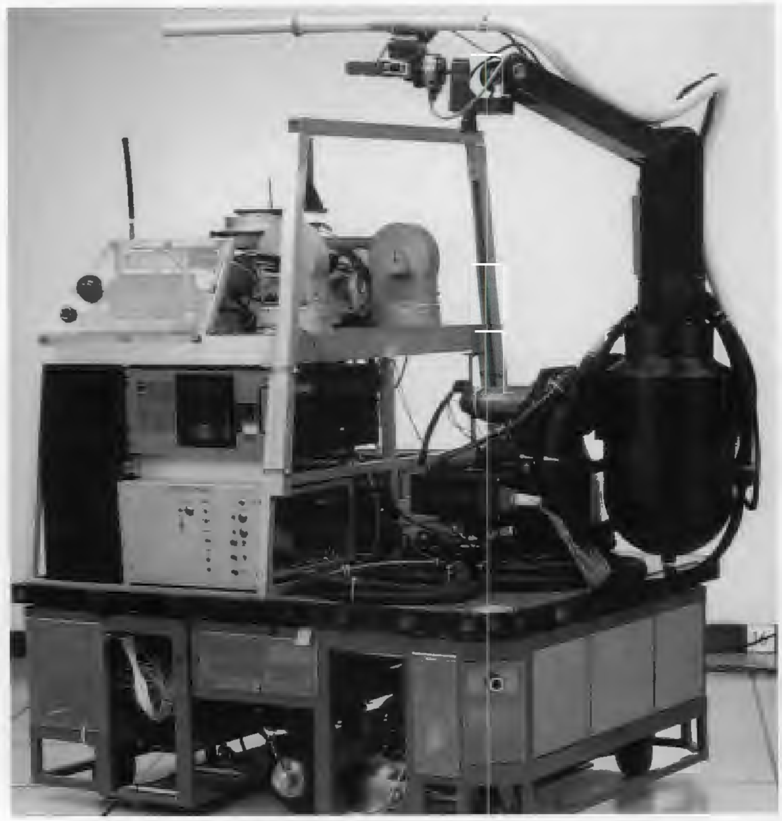


Charles A. Bennett, visiting professor from the University of North Carolina at Asheville, examines the operation of three "cold fusion" cells at ORNL for testing the claims of Utah researchers.

which federal funds were sought to support University of Utah cold fusion research. This testimony, I think, really helped turn the tide to prevent what would have been a mistake at that time, given the information then available. So I congratulate him on his service to science and the public.

Spill-cleaning robot. In December 1989, our newest robot, HERMIES-III, performed its first major task—vacuum cleaning of a mock chemical spill. The robot was given the approximate location of a simulated chemical spill and the instruction to clean it up. Using its on-board computer power, the robot planned its path and moved close to the spill after avoiding obstacles along the way. HERMIES-III determined the extent of the spill and then cleaned it up using its dexterous on-board manipulator, or robot arm, to which a vacuum hose was attached.

Transgenic mouse research. Rick Woychik and his group in the Biology Division



In December 1989, ORNL's newest robot, HERMIES-III, performed its first major task. The robot was given the approximate location of a simulated chemical spill and the instruction to clean it up. Using its on-board computer power, the robot planned its path, moved close to the spill after avoiding obstacles, and cleaned it up with a vacuum hose.

are using a technique for transferring foreign, well-characterized DNA into fertilized mouse eggs to determine whether disruptions in specific genes by the transplanted genetic material directly affect mouse development. When the foreign DNA integrates into or near a vital gene, the gene may become inactive or altered in its expression, leading to abnormalities in the mouse's offspring. Findings from this project could help determine which genes, or which DNA structures of individual genes, are responsible for normal mouse functions. [For details, see "Technical Highlights" in the *Review*, Vol. 22, No. 4, 1989.]

Gel casting. In technology transfer, one of the success stories at the Laboratory is the development of "gel-casting" technology by O. O. Omatete and Mark Janney, both of the Metals and Ceramics Division. Gel casting is superior to current ceramic molding because it minimizes the final machining needed after the part has been hardened by heating. In other developments showing that Oak Ridge is becoming a national center of ceramics research, Coors Ceramics announced it would relocate here to take advantage of ORNL talents and know-how in ceramics and to interact with our scientists in research on whisker-reinforced ceramics, which were developed here. This exciting material has motivated Cercom and Hertel Cutting Technologies Service to locate here. [See "Technology Transfer" in the *Review*, Vol. 22, No. 4, 1989.]

Ductile iron aluminides. Iron aluminides based on the Fe_3Al and FeAl alloys are difficult materials to work with because they crack easily at room temperature and are not easily shaped into useful components. But despite this low fracture toughness and poor ductility, they are being considered for structural materials in high-temperature environments because of their hot fabricability, low cost, and excellent oxidation and

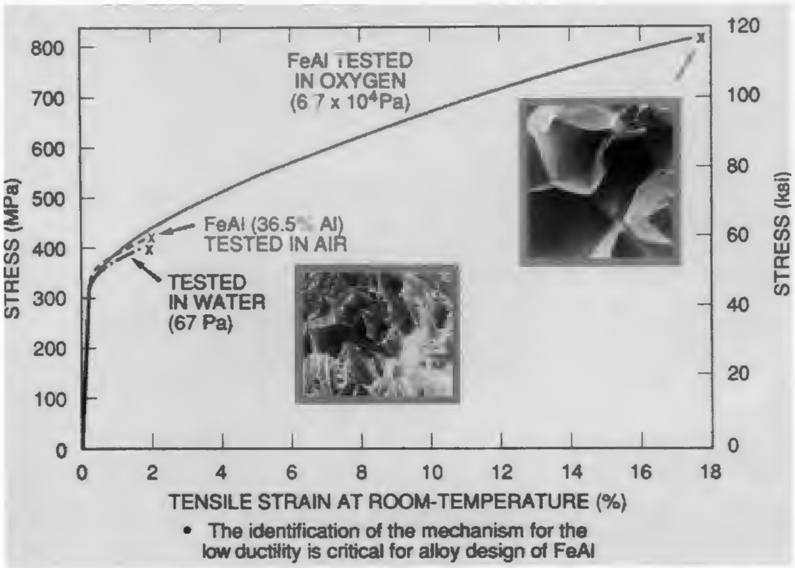
Rick Woychik and his ORNL colleagues are using a technique for transferring foreign, well-characterized DNA into fertilized mouse eggs to determine whether disruptions in specific genes by the transplanted genetic material directly affect mouse development. The foreign DNA could cause a vital gene to become inactive or altered in its expression, leading to abnormalities in the mouse's offspring. The results could help determine which genes are responsible for normal mouse functions.

O. O. Omatete (left) and Mark Janney demonstrate the "gel casting" process they invented. Omatete pours a slurry of ceramic powder and pre-gel solution into a warm mold designed to make a rotor for a gas turbine engine. The slurry sets into a firm gel body that can be dried in the rack behind the researchers. On the table are some ceramic pieces formed by the process.

corrosion resistance. Since these brittle materials do not corrode very rapidly when exposed to sulfur gases at a temperature as high as 800°C (see graph on p. 20), they are promising structural materials for high-temperature power-generating and gasification facilities using fossil fuels. To understand how to make these iron aluminides more ductile, C. T. Liu, McKamey, and others in the Metals and Ceramics Division have tried to understand the process by which embrittlement occurs. They have found that the embrittlement is extrinsic, not intrinsic. They attribute this "environmental embrittlement" to the reaction of moisture in the air with aluminum atoms at crack tips, resulting in the formation of atomic hydrogen that drives into the metal and causes crack propagation and loss in ductility. By controlling the test environments at room temperature, they have increased the tensile ductility for FeAl from 2% to 18%—that is, the material can be stretched to 18% of its original length without breaking. Our identification of this embrittlement mechanism provides critical information for alloy design of ductile iron aluminides that can be used for structural materials in high-temperature environments.

Photoconductivity of bioelectronic materials. In 1989, Eli Greenbaum of the Chemical Technology Division was the first to measure the intrinsic photoconductivity of a composite bioelectronic material. The material consists of spinach chloroplasts coated with platinum. A helium-neon laser was used to irradiate the platinized chloroplasts, and the laser light stimulated the flow of electric current, which Greenbaum measured. This research provides information on the electrical properties of biological materials.

CFC substitutes. ORNL researchers Jim Sand and Ed Vineyard are concerned about



ORNL researchers have found that, at room temperature, iron aluminide (FeAl) can become severely embrittled by water vapor in air. Identification of this mechanism has aided in the design of the FeAl alloy to make it more ductile.

Tennessee Governor Ned McWherter and Tony Schaffhauser, director of ORNL's High Temperature Superconductivity Pilot Center, watch a magnet suspended in midair by a high-temperature superconducting material that has been chilled by liquid nitrogen.

chlorofluorocarbons (CFCs), which are used in heat pumps, because they help destroy the ozone layer that shields the Earth from unwelcome solar radiation, causing ecological damage and cancer. The Laboratory has been playing a lead role in trying to find appropriate substitutes for CFCs; in this effort, we are collaborating with DuPont.

Superconductivity collaborations. Last year our High Temperature Superconductivity Pilot Center, managed by Tony Schaffhauser, signed cooperative agreements with several private companies, including General Electric Company, Westinghouse Electric Corporation, Corning Inc., and American Magnetics. These unusual cooperative activities bode well for future laboratory-industry collaborations to hasten the introduction of high-temperature superconducting technologies into the marketplace.

Housekeeping Activities

This past year we have accomplished a considerable amount in the environmental, safety, and health areas. We made use of information obtained from audits of other DOE facilities. We established an Environmental, Safety, and Health Upgrade Team, composed of representatives from all ORNL divisions, to coordinate our cleanup efforts. We organized a spring cleanup, conducted extensive walk-through inspections, updated or developed hundreds of new procedures for critical activities, and improved the training of thousands of staff members in these areas. We removed many artifacts left over from an earlier era from our reactor areas, stopped leaks, and installed new filter covers to improve the quality of the air flowing in and out of our buildings. Because of our efforts, we received fairly good grades as a result of DOE's Technical Safety Appraisal (TSA). We are now busy correcting the deficiencies uncovered by the TSA.

In 1990 we are addressing such problems as removing asbestos from areas where it is a hazard, improving fire safety, and changing the workplace to better comply with the regulations of the U.S. Occupational Safety and Health Administration (OSHA). To improve radiation protection, many new portable radiation detection instruments will be placed in the field to monitor radiation levels, and the training program and safety analysis documents will be upgraded. The corporate culture is changing, and all employees are responsible for carrying out these changes to improve protection of our health and environment.

Because of problems in finding space for our employees to work, we had to buy some trailers and place them in the back of the new parking lot, which once again exacerbates the parking problem. I am assured that the trailers are comfortable and safe and that they will be loved by the new occupants.

To solve some of our organizational problems, we call upon employees to work together in Process Improvement Project (PIP) groups to focus on a specific problem and recommend possible solutions. Recently, at an ORNL vice president's caucus, the question was raised: What should ORNL do with the recommendations of some of the PIP teams? I turned the question around, asking how ORNL can better achieve its missions. As a result, we have identified five PIP projects for priority action:

- improve ORNL's means of controlling business costs
- improve operations and research interface,
- improve ORNL's image,
- improve Laboratory operations in a regulatory environment, and
- improve retention and vitality of the ORNL research staff.

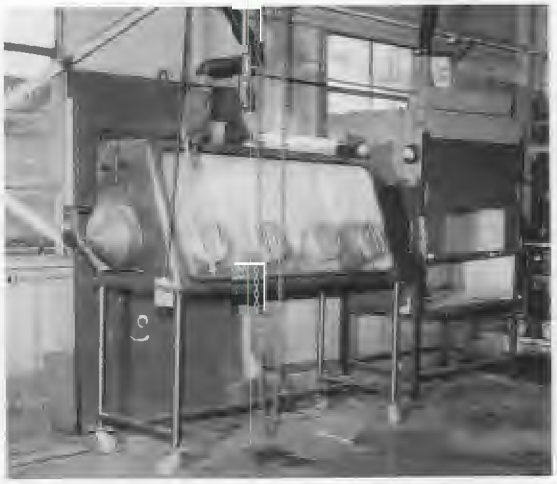
Our goals are to persuade ORNL employees to work together as a team and to eliminate the causes of friction between various groups that should be cooperating for the good of the Laboratory. To make ORNL a better place to work, I also have established a Values Committee.

The Future

As ORNL's new director, I am troubled by certain things that could affect the future of the Laboratory. For example, I am not happy about the Laboratory's shortage of adequate office space that meets OSHA requirements, the high cost of new buildings, the decrease in DOE's Basic Energy Sciences budget, the high overhead rate (the tax that research divisions must pay for services), and the lack of funds for capital equipment.

Yet, despite the obstacles, I am excited about ORNL's future. One exciting development will be the work of the new Oak Ridge Detector Center, which will provide support for the SSC planned by DOE. The SSC will be about 53 miles in circumference and will be buried a few hundred feet underground in Texas. The accelerator will cause protons to collide with protons at an energy of 20 billion electron volts. When the protons collide, they will produce a shower of other subatomic particles; the object is to try to understand whether quarks, believed to be the fundamental constituents of protons, are the most basic units of matter or can be further

Caps are placed on leaking plugs in the roof of the filter house for ORNL's Graphite Reactor as part of ORNL's effort to upgrade facilities for health and environmental protection.



The high bay area of ORNL's Homogeneous Reactor Experiment building is shown here before and after cleanup. The cleanup was done in preparation for DOE's Technical Safety Appraisal of ORNL facilities and activities.

subdivided. Ironically, the smaller the sizes of and the shorter the distances between the particles of interest, the larger the scientific apparatus must be to study them. To understand the difficulty of the quest of the SSC physicists, think of a couple of reckless mechanics who decide to try to figure out how an internal combustion engine works by driving two automobiles together at a hundred miles an hour and then examining the scattered parts. Even if they find the normally expected parts, such as pistons and a carburetor, they would still have a hard time figuring out how the engine works. But imagine their dilemma if, instead of the expected parts, they find two Mack trucks, a bulldozer, and a bunch of tricycles all nicely assembled and working.

Members of the Computing and Telecommunications Division have offices in the new trailers in the parking lot between the Physics Division buildings and main administration building.

Although this example seems odd in our ordinary experience, manipulations of nature also will provide surprising, logic-defying results. People normally think of $E = mc^2$ in terms of mass being converted to energy, as in nuclear weapons or nuclear power, but, in fact, it works in reverse. If enough energy is confined in a small enough space, new matter is condensed out somewhat like rain out of a fog. Newly formed matter can be more massive than any of the constituents in the collisions that produced it. A few years ago, the Italian physicist and Nobel Laureate Carlo Rubbia and his colleagues collided protons together at high enough energies to produce a new particle called the W Plus Minus; remarkably, this particle has 80 times the mass of a proton.

To create particles of greater mass, an accelerator that can propel particles at much greater energies is required. The SSC will be designed to produce particles having a thousand times the proton mass. To measure the characteristics of these collision events, large particle detectors will be required. The SSC will cost about $8 billion and the detectors themselves will cost $600 million each. We hope to become heavily involved in detector design.

In January 1990, Professor Samuel Ting, who is leading an international effort to design the L-Star Detector for the SSC, was a keynote speaker at an international detector design meeting held by the Oak Ridge Detector Center. Ting shared the 1976 Nobel Prize in Physics with Burton Richter for their 1974 discovery of the J/psi particle, which provided conclusive evidence that quarks really exist. In what I think is a remarkable international tour de force, Ting has for ten years coordinated the efforts of 450 physicists from the Soviet Union, China, France, Italy, Switzerland, and about 12 other nations in providing the materials and building the components to make a detector that is a one-half-scale version of what will be needed for the SSC. They have carried out unusual activities such as shipping germanium oxide from the Soviet Union through Switzerland to Shanghai, where it was processed into bismuth-germanide crystals (which have the clarity of diamonds). Because of irregularities in Shanghai's electrical supply, Ting personally flew to Shanghai and persuaded the mayor to set up a secure system to ensure that the crystal-pulling apparatus would not be deprived of electricity under any circumstances. As a result of all these efforts, a large detector, called the L-3 detector, has been built and put into operation at the newly operating Large Electron Positron (LEP) Collider at the European Center for

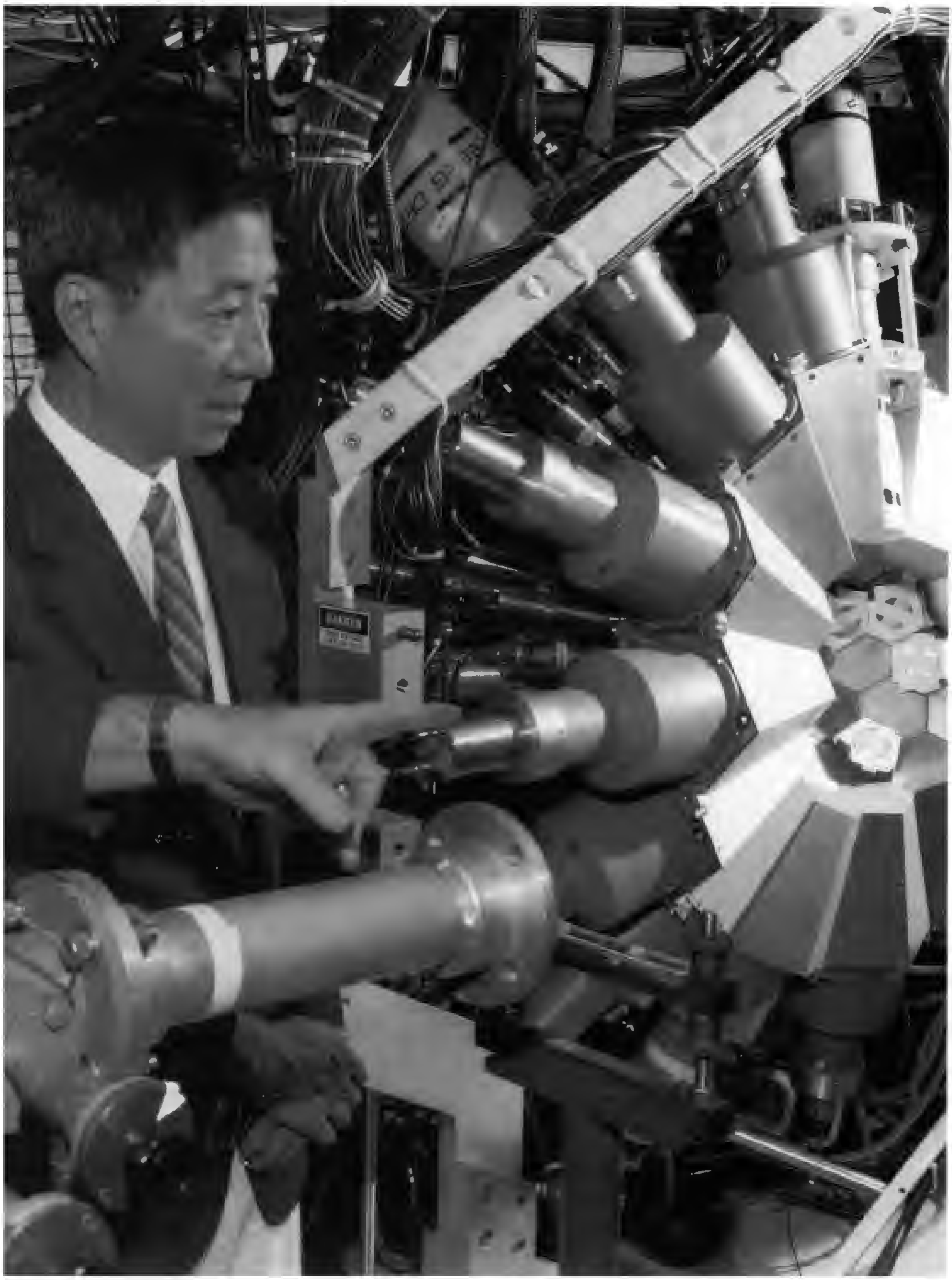
"People normally think of E= mc² *in terms of mass being converted to energy, as in nuclear weapons or nuclear power, but, in fact, it works in reverse."*

Nuclear Research (CERN) in Geneva, Switzerland, where Ting has conducted some of his high-energy physics research. He would like to continue working at CERN, but he is also interested in the physics results that will be possible from the SSC if it has good detectors. He would like to take advantage of the new scientific information that may become available as a result of the efforts he has put into developing the L-Star Detector. He also would like the SSC to have the kind of detectors that he and his colleagues are capable of putting together.

Ting's desires may work to our advantage. Recently, Chuck Hall, an Energy Systems vice president, Bill Bugg, head of the UT Department of Physics, and Bill Appleton, ORNL associate director for Physical Sciences and Advanced Materials, met with Ting and some of his colleagues to talk about the prospects for Oak Ridge as a possible site for some of the design and construction work required to make a full-scale detector for the SSC. This effort would be carried out cooperatively with a number of academic institutions in the South. I am fairly optimistic that ORNL has a good chance to be involved in this effort, which would eventually make us a new force in high-energy physics. [For more details, see "R&D Updates" in the *Review*, Vol. 23, No. 1, 1990.]

Speaking of detectors, ORNL will be the site for a world-class high-resolution gamma-ray detection facility for the study of the structures of atomic nuclei having high angular momentum after high-speed collisions with target nuclei in an accelerator. Called the Gammasphere, this close-packed array of 110 large germanium gamma-ray detectors will be constructed at ORNL's Holifield Heavy Ion Research Facility. Like Ting's detector, the $18-million project is the result of considerable cooperation. Governor Ned McWherter of Tennessee offered $800,000 in cost-sharing funds, and Vanderbilt University and the University of Tennessee at Knoxville will help support the facility in exchange for making it available to their physics students and faculty.

Nobel Laureate Samuel Ting (right) and Trivelpiece are shown features for the spin spectrometer by Tony Gabriel (left). The device is a detector that measures gamma rays produced when heavy ions collide with target nuclei at ORNL's Heavy Ion Research Facility. Ting and about 75 other scientists from several countries were at ORNL in April 1990 to develop a proposal for a much larger detector, to be constructed for the Superconducting Super Collider.



This device, which will increase U.S. gamma-ray detection efficiency by 100 to 1000 times, is in the President's proposed budget. However, its location—Oak Ridge—was not determined until after a site selection committee meeting in 1989. This decision is a shot in the arm for our fine efforts in nuclear physics, one of the hallmarks of the Laboratory. The new facility should help physicists determine whether superdeformed nuclei are formed in heavy-ion collisions and provide answers to certain astrophysics questions. The addition of the Gammasphere and the newly funded Recoil Mass Spectrometer Facility will make the Holifield Heavy Ion Research Facility a world center for nuclear structure research.

When the HFIR reaches the end of its useful life, we will need a new reactor to enable U.S. scientists to conduct neutron-scattering studies to make progress in certain key fields. The proposed reactor to replace the HFIR is the Advanced Neutron Source (ANS). This reactor is essential, and this Laboratory should be the place where the ANS is designed, constructed, and operated. I think we need to make a full court press, and I regard this project as the highest priority technical facility pursued by the Laboratory.

In June 1990, the U.S. House of Representatives appropriated $12 million for the ANS. [For more details, see Colin West's article in the *Review*, Vol. 22, No. 4, 1989.]

One of the high points during the past year at the Laboratory was the visit by Senator Albert Gore of Tennessee. He came here to announce an important future activity for the Laboratory—our research agreement with SEMATECH to work on developing an advanced etching technology, using electron cyclotron resonance plasmas—for the production of improved semiconductors. SEMATECH is an industrial consortium formed to help the United States regain its leadership in semiconductor manufacturing. During the ceremony, Bob Noyce, president of SEMATECH, gave Senator Gore one of the first silicon wafers produced by SEMATECH. ORNL's involvement should help improve U.S. competitiveness in the vital area of electronics.

"I regard [the Advanced Neutron Source] as the highest priority technical facility pursued by the Laboratory."

In general, I think the future for ORNL and the other national laboratories will be bright even as our missions shift in emphasis. Secretary Watkins has expressed a strong interest in ensuring the health and well-being of the DOE laboratories. When he met with us recently, he stressed once again his desire that DOE take care of the laboratories and stated that changes are planned to increase the ability of the DOE labs to transfer their technologies to the commercial sector. He also announced that he will abolish DOE's Energy Research Advisory Board and replace it with something better—a broadly based, high-level committee of about 30 individuals chosen from around the nation to give the group a range of desired characteristics. The new committee will examine the management of DOE and the management of the laboratories. My past experience with advisory committees has been that some members initially are concerned about or hostile toward DOE and its laboratories but, after becoming familiar with the agency and the labs, they very quickly become converts and do what they can to help preserve, protect, and promote the activities of each DOE laboratory.

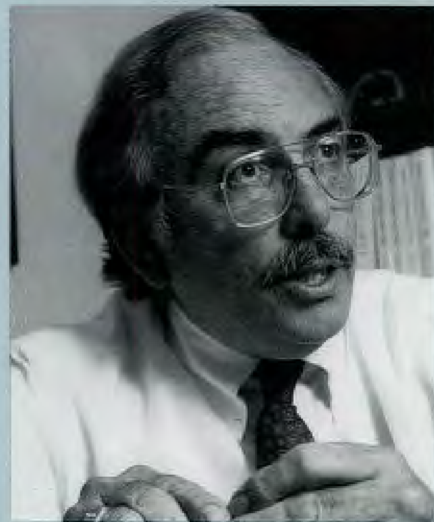
I am also optimistic about the future of the Laboratory because of the role we can play in encouraging more students to become scientists, engineers, and mathematicians, helping to reduce the projected shortage of personnel for the U.S. labs of the future. The Admiral, who is a natural with children, has long been very interested in improving math and science education in the nation; in fact, he appeared before a committee that I was chairing a few years ago and talked about his commitment to improving the teaching of mathematics and science in grammar schools. I strongly support his efforts to involve ORNL and the other DOE laboratories in improving the nation's educational as well as its scientific and technological competitiveness in the world. We have highly capable people here at ORNL, and we can make a difference.

Trivelpiece Recognizes Environmental, Safety, and Health Upgrade Team

Following the State of the Laboratory–1989 Address on February 6, 1990, ORNL Director Alvin Trivelpiece presented the 1989 Director's Award to Tom Row and all the members of the Environmental, Safety, and Health Upgrade (ESHU) team who ensured that the Laboratory conducted cleanup activities and took other necessary actions to bring it into compliance with federal and state environmental regulations. As a result of the efforts of the ESHU team, said Trivelpiece, the Laboratory survived the scrutiny of the Technical Safety Appraisal (TSA) Team of the Department of Energy. The ORNL team succeeded in getting the Laboratory through the TSA inspection without any "Category One" findings (serious violations of regulations).

"This was a rather large cooperative effort that was very important to all of us collectively," Trivelpiece said. "I think everyone who did the job deserves recognition."

In accepting the award, Row, acting associate director for Chemical, Health, and Safety Protection, said, "I want to thank the people in the Environmental and Health Protection Division and on the ESHU team for the efforts they put forward, which were outstanding. Our success in passing the TSA test would not have happened without a lot of cooperation and a lot of work from all the divisions in the Laboratory. That is the reason why ORNL is one of the best laboratories in the country."



Tom Row

The members of the team are J. R. Stokely, Analytical Chemistry; L. L Triplett, Biology; E. D. Collins and V.C.A. Vaughen, Chemical Technology; L. L. Brown and L. M. Ferris, Chemistry; D. N. Clark, Computing and Telecommunications; S. M. Cohn, Energy; S. L. Laman, Engineering; R. W. Peelle Engineering Physics and Mathematics; J. R. Montgomery and K. R. Thomas, Engineering Technology; H. M. Butler, J. S. Bogard, E. D. Copenhaver, D. T. Duncan, P. S. Rohwer, T. F. Scanlan, C. E. Pepper, L. E. Stratton, C. P. East, H. R. Gaddis, F. C. Kornegay, D. W. Knox, B. S. Graham, M. E. Baldwin, W. A. Alexander, Environmental and Health Protection.

C. W. Gehrs, D. D. Huff, R. K. McConathy, J. W. Johnston, Environmental Sciences; J. R. Schermerhorn, Finance and Materials; N. R. Grant, Fuel Recycle; F. E. Gethers, Fusion Energy, P. Marsh, Graphics.

D. H. Sexton, Health; B. A. Berven and D. E. Fields, Health and Safety Research; E. R. Kackenmeister, Information Services; R. T. Roseberry and D. N. Miller, Instrumentation and Controls.

J. H. Greene and R. L. Atchley, Laboratory Protection; W. H. Miller, Metals and Ceramics; M. E. Murray and M. W. Kohring, Office of Operational Readiness and Safety; A. Officer, Personnel; C. R. Vane and C. M. Jones, Physics.

D. N. Smith, C. G. Palko, C. R. Kirkpatrick, Plant and Equipment; K. A. Cummings, S. P. Ketterer, Publications; E. L. Dagley, D. K. Jennings, Quality; D. M. McGinty, Research Reactors; J. F. Wendelken, Solid State.

Scientific Visualization: New Insights By Computer

By Joyce Francis and Ross Toedte

At ORNL's Scientific Visualization Center, Joyce Francis and Ross Toedte watch a videotape animation showing the physical deformation of a stressed metallic specimen. The visual information is useful in reactor pressure vessel safety studies. The animation program is run on the Apple Macintosh II (center).

"The purpose of [scientific] computing is insight, not numbers."

Fifteen years ago, when two ORNL physicists decided to attempt to represent the dynamics of their fusion energy calculations visually, they faced a difficult task. First, they generated hundreds of line-printer plots (i.e., x's and o's on computer paper) of the plasma pressures calculated in their magnetohydrodynamics code, which simulates the behavior of a plasma under the influence of a toroidal magnetic field in a fusion research device. Standing on a table, one physicist used a movie camera on a tripod to record one frame of 16-mm film at a time of each page of computer plots, while the other sat on the floor turning the pages. The end product, though jerky and flickering, clearly indicated the patterns formed by varying plasma pressures and verified that the vorticity cell movement occurred in response to the plasma pressure changes. This movie and the results of the research were later presented at the annual American Physical Society conference.

Through the years, procedures such as this became common as researchers sought to enhance their scientific observations to obtain more meaningful results. Although the term "scientific visualization" had not yet been coined, these early efforts can be viewed as necessary precursors to today's enhancement techniques.

Scientific visualization is the processing of scientific data into an image or a series of images that allows scientists to observe and interact with their data, possibly gaining new insight. According to a panel report by B. H. McCormick et al. in *Visualization in Scientific Computing*, a special issue of *Computer Graphics* (November 1987), Richard Hamming, an expert in numerical analysis, once said, "The purpose of [scientific] computing is insight, not numbers."

Since 1988 about 50 ORNL scientists have been using scientific visualization in such areas as stress effects in metals, molecular models, heat and fluid flow in welds, and fusion plasma heating. Visualization allows scientists to manipulate huge amounts of data, to communicate visually, and to "steer" calculations to obtain meaningful results. Often scientists amass so much information that it overwhelms their ability to interpret it. Through visualization, these data can be translated into readily interpretable images or image sequences. Once these images are created, scientists can use them for peer review as well as for communicating with others less familiar with their research. Furthermore, scientific visualization helps researchers steer the scientific computing process by allowing them to interpret while the data are still being processed. This approach can allow a simulation to be interrupted and redirected or a time step to be changed when an "interesting" portion is reached. Because the scientific process involves experimentation, observation, data collection and analysis, and insight, visualization can significantly enhance productivity by reducing the time between generation of the first experimental data and the conclusions.

In 1985, the National Science Foundation (NSF) established the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign, which is one of four NSF supercomputing centers in the United States. NCSA's mission is ". . . to use the tools and techniques of leading-edge computational science to contribute to new advances in science and engineering . . . ," according to the June 1989 brochure *This Is NCSA*. Since its creation, NCSA has been at the forefront of generating interest and support for the advancement of scientific visualization through its facilities, services, research and development efforts, and educational programs.

The 1987 panel report *Visualization in Scientific Computing* (ViSC), published by the Association for Computing Machinery's Special Interest Group on Computer Graphics (SIGGRAPH), has also been instrumental in promoting federal and corporate interest in scientific visualization. This report, which was prepared by a panel of leaders in industry, academia, and government, discusses the role of visualization in the scientific process, the emerging uses of visualization in scientific disciplines, and the importance of visualization in industrial competitiveness. The establishment of NCSA and the publication of the SIGGRAPH panel report created the foundation for visualization as a research area that spans numerous disciplines.

Local Interest Is High

Staff members of the Graphics Development Section (GDS) in the Computing and Telecommunications Division (C&TD) attended several conferences at which other national laboratories, universities, and industries presented impressive examples of visualization. Curious to learn the extent of interest at ORNL in computer animations, GDS member Ross Toedte surveyed local computer users. He determined that many ORNL researchers and programmers are greatly interested in learning more about animation techniques for visualization of scientific data.

As a result, our section initiated a seminar series in January 1988 on advances in scientific and technical computing. Maxine Brown, one of the editors of the SIGGRAPH panel report and associate director of the Electronic Visualization Laboratory at the University of Illinois at Chicago, was the initial speaker for the series. Other prominent speakers included Karl-Heinz Winkler, formerly with Los Alamos National Laboratory and now deputy director for Science, Technology, and Education at NCSA; David Waltz, director of Advanced Information Systems at Thinking Machines Corporation; and Jordan Becker, assistant director of Computing Systems, IBM Research, Thomas J. Watson Research Center. To complement the seminar series, our section invited vendors of visualization hardware to demonstrate their products, which included classifications such as parallel graphics processors and image processing hardware. Pixar, for example, has built hardware around graphical techniques previously reserved for the entertainment industry but recently proven to have many applications in science.

Animation on Film

In early 1988, GDS received a request for assistance in employing animation techniques using an FR80 film recorder. The animation, which used data analyzed by Richard Bass and Janis Keeney-Walker (C&TD) for the Heavy-Section Steel Technology program at ORNL, depicts the propagation of cracks through a large metal plate. This application studies the ability of the plate to resist fracture when subjected to an external load. During manufacturing, the plate was cast from a material having varying fracture resistance, which is measured by the ability of the plate to arrest a crack propagating from a notch at the plate edge. The ORNL-produced animation illustrates the movement of the crack through the plate, the deformation of the plate, and the distribution of the associated motion energies. Such animations help reactor safety researchers determine the ability of reactor pressure vessels to withstand high water-coolant pressures without rupturing.

During the production of this film, it became apparent that some customized software development was necessary to reduce the number of production steps and, therefore, the costs. A finite-element program running on the Cray X-MP at Oak Ridge was used to generate the data, and the graphics files had to be processed on an IBM mainframe. Modifications were made to permit graphics tapes to be made directly on the Cray X-MP. These developments eliminated several data conversion steps and significantly reduced the film generation and processing costs. Although some of the software development costs can be allocated to this first animation, most of the cost benefits would be seen only in subsequent projects. The end result was a 16-mm film that runs 2 min 15 s.

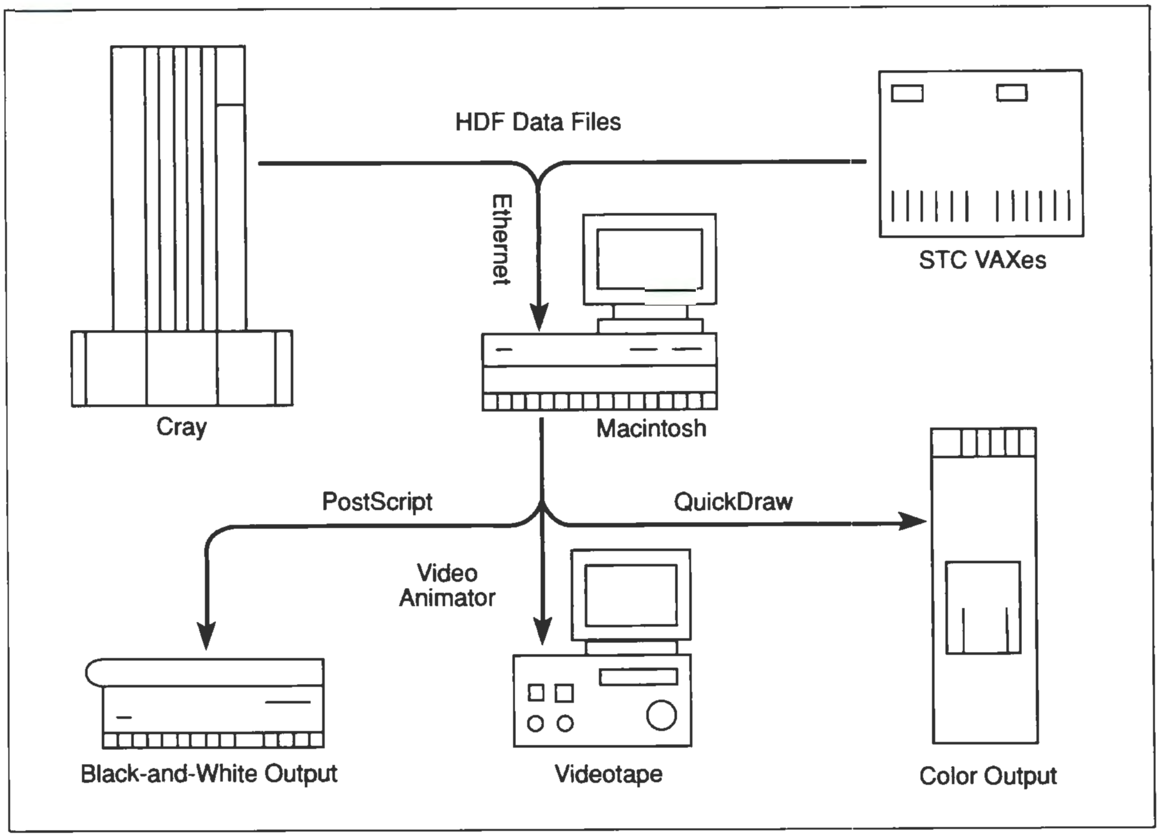
In November 1988, our section became involved in a second animation using the FR80 film recorder. This animation, which uses data analysis from Steve McGrath and Len Phillips (Applied Technology Division), depicts action in a lightweight gun barrel designed for military applications. A cross-section of the gun barrel was animated from the moment that the gun discharges until the projectile leaves the barrel. Deflections and stress buildup in the barrel were shown during this period. Several instances of previously unobserved structural behavior were quite noticeable in this animation—an example of how scientific visualization can provide insight.

Because of the software changes that resulted from the first animation, tapes for the second animation could be generated directly on the Cray X-MP, thereby cutting costs. This factor, in addition to several data reduction measures, served to greatly reduce total production costs for the animation. Data conversion costs were reduced 80%, and FR80 processing costs fell 75%. The final product was a 16-mm film that runs 6 min.

In late 1988, NCSA announced the availability of its suite of public domain software for scientific visualization. The individual software packages in this suite permit the conversion of scientific data to a graphical format, the animation of multiple images, the production of different presentation layouts for scientific graphics, and the generation of customized color palettes. Also, individual packages of this public domain software are available not only for supercomputers but also for IBM Personal Computers (PCs), UNIX workstations, and Apple Macintosh computers. Because a visualization model could now be established for a relatively small investment, GDS began to assemble a prototype visualization facility.

Although future visualization prototypes are planned for PCs and various engineering workstations, the Macintosh was selected as the initial platform. The figure on p. 32 shows how data files generated on the Cray X-MP or the STC VAXes are transferred via Ethernet to a Macintosh IIx and then output to a variety of devices. Ethernet is used to transfer image files, which can be quite large. GDS staff have consistently experienced Ethernet data transfer rates in excess of 15 kB/s. Although not ideal, this transfer rate is satisfactory for the migration

"The ORNL-produced animation illustrates the movement of the crack through the plate, the deformation of the plate, and the distribution of the associated motion energies."



The schematic shows the Graphics Development Section's prototype configuration.

of image files between computers. The visualization hardware consists of a Macintosh IIx that has a memory of 8 MB, a 40-MB disk drive, and an Apple 13-in. RGB color monitor. Once the image files are ported to the Macintosh, the NCSA software, as mentioned earlier, allows for a multitude of functions in the animation production cycle. When the selection of images has been completed, MacroMind Director, a software package designed for editing animation, is used to assemble the selected images into an animation. This package also provides for a number of animation aesthetics such as hand-retouching images, changing color palettes, integrating sound tracks, and generating titles having a number of transition effects.

The graphics output format necessary for use with the NCSA software is the hierarchical data format (HDF), which is available locally for the Macintosh and is being tested on the Cray X-MP and the STC VAXes. Our section plans to develop conversion programs for current metafile formats such as DISSPLA metafile (DMF) and Computer Graphics metafile (CGM). With these conversion programs, existing metafiles can be converted to HDF and animations produced. Other national laboratories and supercomputing centers have expressed an interest in seeing that HDF becomes a standard graphics output format.

Animation on Videotape

Several animation projects have been produced using the Macintosh prototype. One of these was a 3-D analysis performed by Janis Keeney-Walker (C&TD) for the HSST program. Analysis

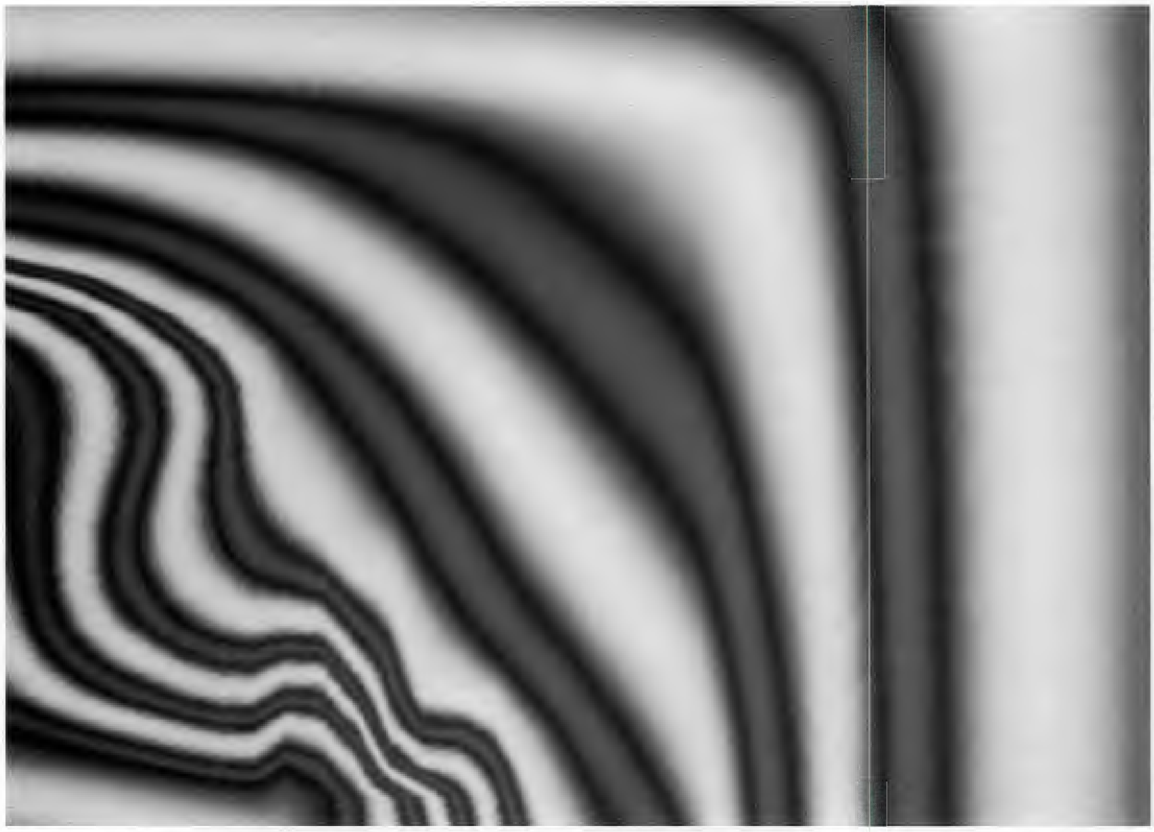
These four photographs illustrate effective stress contour evolution from an elastic plastic finite element analysis of a compact metallic specimen.

data were converted on the Cray X-MP. The figure above illustrates the physical deformation of the specimen. Individual animation segments were used to depict the evolution of stress and hydrostatic constraint contours. This animation addresses primary topics of reactor pressure vessel safety studies.

These files were transferred to a Macintosh, where they were animated with NCSA Image and edited with MacroMind Director. Our Macintosh prototype was used for final editing and the production of a 4-min and 20-s high-quality videotape.

Although it is difficult to directly compare the production of an FR80 film to the production of a videotape on the Macintosh platform, several significant differences are apparent. The FR80 still requires custom software, whereas the Macintosh can use the HDF software available from NCSA without modification. Film requires at least a one-day turnaround time (for developing), but videotape can be viewed immediately and can be reused. Visual editing of videotape can be done interactively, making it much easier to adjust aesthetic elements such as titles and audio. For film, it is necessary to generate around 24 frames/s of viewing time, yet videotape can use as few as 6 frames/s and still appear to be "moving." These differences indicate that use of the Macintosh saves considerable time and money.

Using the Macintosh model, our section has produced a prototype animation of heat and fluid flow with Thomas Zacharia of the Metals and Ceramics Division. He and a team of researchers have developed a computer model to examine the influence of heat flow and fluid flow on the



The growth of temperature contours depicts the development of molten regions in a metal plate during a welding simulation.

development of the weld pool over time. The ultimate objective is to relate the processing conditions to the structure and properties of the welding joint. The figure above shows one time step in the thermal history of the weld pool, which provides valuable clues about its development and the solidification structure. Numerical data files, which required reformatting before being downloaded to the Macintosh, provided periodic simulation "snapshots." NCSA DataScope and NCSA Image were then used to convert the data to a graphics format and produce the prototype animation.

Our section also assisted in the production of a prototype animation for Don Batchelor (Fusion Energy Division) and Johnny Tolliver (C&TD) using the Macintosh model. This animation (see color photo on the cover) represents electromagnetic plasma waves propagating from an ORNL-designed phased array antenna in a tokamak fusion device. The purpose of the waves is to drive an electron current through the plasma. The cover photograph shows that the waves propagate preferentially to one side, thus pushing plasma current in this direction. Plasma wave processes are important in fusion research because of their ability to heat plasmas to high temperatures, their ability to modify the velocity distribution of the plasma particles to produce driven currents or increased nuclear reactivity, and their usefulness in measuring plasma properties, such as density or temperature. This animation used a Cray to generate HDF files, which were subsequently downloaded to a Macintosh. NCSA Image was used to render the individual images.

Visualization Interest Group

As part of its continuing efforts to support scientific visualization at ORNL, our section established a visualization interest group called ViSCiTek. Formed in September 1989, ViSCiTek is a forum for the investigation and sharing of visualization technologies. Topics thus far have included the integration of video technology with computers, the use of alternative low-cost scientific graphics software, and the presentation of local visualization projects. Attendees at these meetings are professionals and scientists from not only all three Oak Ridge sites but also the University of Tennessee at Knoxville. Several of the attendees have been involved in one or more visualization projects, but many others are new to the technology. Future meetings will address the latest technology in visualization, the education of those new to visualization, and the extension of ViSCiTek capabilities to other computing platforms.

The future of scientific visualization at ORNL looks promising because advances in technology have made more-sophisticated equipment affordable and have expanded support to other platforms such as PCs and workstations. In support of the ORNL Strategic Plan for a Computer-Augmented Research Environment, one of the goals of our section is to help researchers incorporate visualization into the scientific process—to see that visualization becomes an integral part of their research. Whether you are a researcher seeking to establish a personal visualization station suited to your needs or a manager seeking to use visualization to communicate complex subjects more effectively to funding and regulatory agencies, the Graphics Development Section can provide information and assistance.

Much has changed in the technology of making animations in the 15 years since the two ORNL physicists made their film of line-printer plots, but the purpose for generating that film and the animations of today is still the same—gaining new insights into science.

Biographical Sketches

Joyce F. Francis is a member of the C&TD Graphics Development Section, User Services and Systems Support Department. She holds a B.S. degree from East Tennessee State University and B.A. and M.S. degrees from the University of Tennessee. She provides graphic development support for the Cray X-MP.

Ross J. Toedte is a member of the C&TD Graphics Development Section, User Services and Systems Support Department. He has a B.A. degree in computer science from Southern Illinois University at Carbondale. His current interests include computer animation, 3-D scene rendering, and video technology for computers.

Improving Airport Explosives Detection

By Carolyn Krause

At a local airport, suitcase after suitcase is placed on a conveyor system in a large van next to a jet. In only six seconds each one is screened for explosives by devices emitting X rays and neutrons. The officials have been using this technique for several weeks, and today, for the first time, they hear an alarm. They open the suspect suitcase and find a very small bomb. When they report the finding, they say they are impressed by the system because, unlike the previous detection system they had used, this one has a very low false alert rate and can detect extremely small explosives.

"ORNL and a company in New Mexico have developed a technique for screening airline luggage for hidden explosives."

Such a system exists in concept and could become a reality once a prototype is developed and tested and a company is found to manufacture working models. The new method, developed jointly by ORNL researchers led by Fred J. Schultz of the Office of Waste Management and Remedial Actions and John T. Caldwell of the Pajarito Scientific Corporation in New Mexico, is called the combined pulsed-neutron and X-ray interrogation inspection (CPNX) system. Unlike the technique currently used at some U.S. airports, this new system could detect plastic explosive bombs even smaller than the one in a suitcase that destroyed Pan Am Flight 103 on December 21, 1988, over Lockerbie, Scotland, killing 259 passengers and crew members and 11 people on the ground.

It would be potentially safer, more portable, more sensitive, more accurate, more reliable, and less expensive than the current technique being developed and used for U.S. airport bomb security. The technology, which is a spin-off from waste management research, also shows promise for detecting certain concealed drugs.

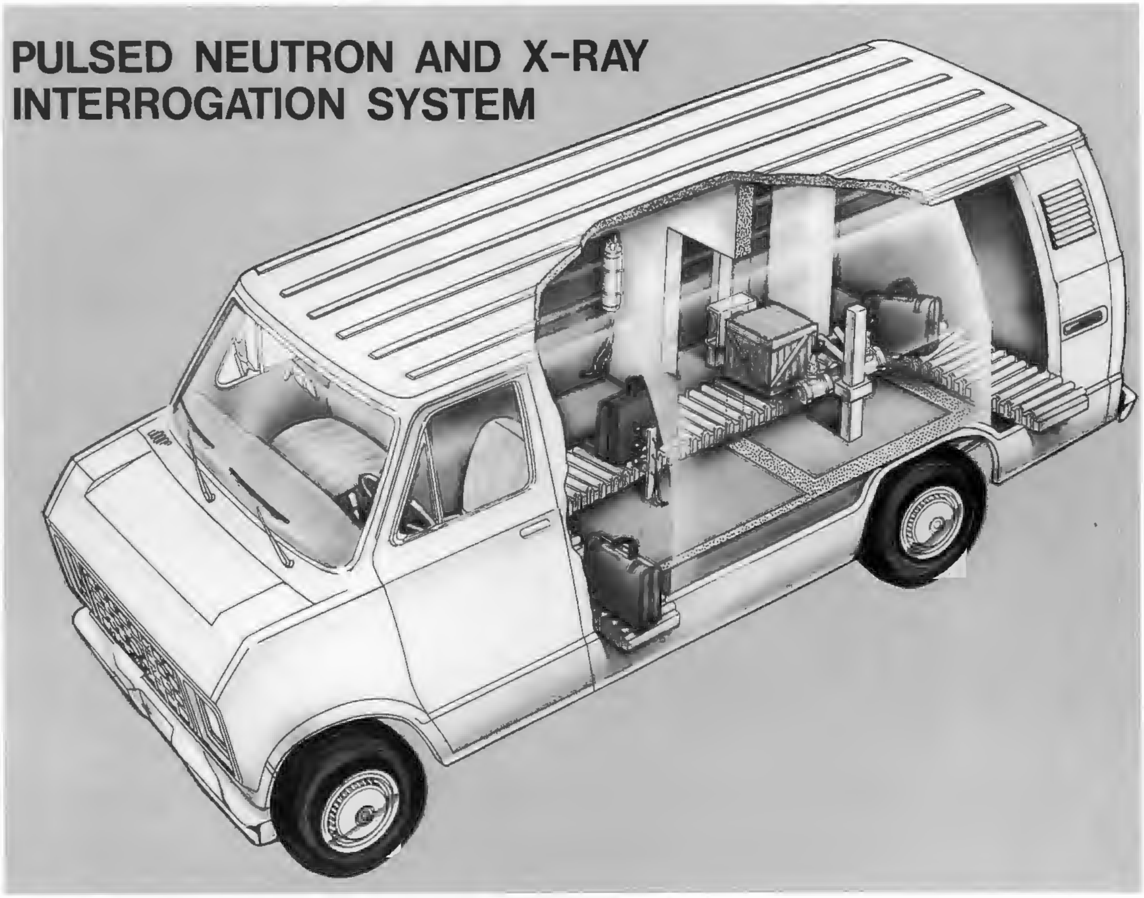
Combining a neutron probe and Superman-like "X-ray vision," the CPNX system could reveal the shapes of objects and the identity, concentration, and location of certain elements. With the help of a computer capable of recognizing certain patterns, this system could detect weapons, electronic devices, and other suspicious objects. The neutron assay system, which includes a neutron generator and detectors for gamma rays and neutrons, locates and quantifies concentrations of nitrogen, oxygen, and hydrogen. The presence of plastic explosives used by terrorists—and of many drugs—would be clearly indicated by certain concentrations of these elements.

Could Fit in a Van

Prompted by the December 1988 terrorist bombing over Scotland, the Federal Aviation Administration (FAA) has ordered the airlines to buy and install 150 thermal neutron analysis (TNA) units at airports as part of its initiative to protect U.S. citizens against the threat of bombings in commercial airliners. However, according to Schultz, the CPNX system, which consists of portable components that could fit in a van, would be safer, more sensitive, more accurate, and less expensive than the TNA system built by an industrial contractor for the FAA.

"The TNA system uses a continuous neutron source that is ten times more radioactive than our system," says Schultz. "And our neutron source can be turned on or off as needed."

Another disadvantage of the TNA device, he says, is that it cannot detect bombs lighter than 900 g (2 lb). A May 1990 report by a presidential commission probing the terrorist bomb explosion aboard Flight 103 stated that the TNA device cannot spot small plastic explosive bombs similar to the one that destroyed Flight 103. That bomb weighed about 450 g (1 lb).



"Scans in a van" may someday be an essential part of airport security. The combined pulsed-neutron and X-ray interrogation inspection (CPNX) system for detecting explosives in luggage could fit inside a van. The system was developed by ORNL and Pajarito Scientific Corporation. On the right is an X-ray tube (in front of the box) and an image intensifier system (behind the box) that converts X rays into images on a video monitor; on the left are sodium-iodide gamma-ray detectors (in front of the suitcase), and above the suitcase (top center) is a neutron generator containing tritium. A conveyor system could pass airport luggage through the van in six seconds.

"We think our system will be able to detect objects lighter than 1 lb, possibly as light as 100 g (4 oz.)," says Schultz.

A third problem with the TNA system is that it detects only nitrogen compounds, causing it to give numerous false alarms on luggage made of or holding synthetic materials containing nitrogen.

The TNA system costs up to $1.5 million. Schultz estimates that the new system could cost less than $1 million.

Schultz says that the new system, like the TNA device, could scan luggage for explosives in the six seconds required by the FAA. But, he adds, it would give off only one false alarm for every 10,000 scans, whereas the TNA device gives five false alarms for every 100 scans.

Techniques Used To Categorize Wastes

The new detection scheme combines real-time radiography (RTR)—high-resolution X-ray images viewed in real time on a video monitor—with a passive-active neutron (PAN) assay system

At the Waste Examination and Assay Facility, Don Coffey loads a drum of contact-handled transuranic waste into the passive-active neutron assay detector as part of the waste certification program.

developed by Caldwell when he worked at DOE's Los Alamos National Laboratory. Schultz conceived the idea of combining the two techniques to detect concealed explosives and drugs, and a patent application has been filed on the concept.

The RTR and PAN techniques are already being used to determine the contents of drums of radioactive waste brought to ORNL's Waste Examination and Assay Facility. RTR can be used to determine if a drum contains items not allowed by waste acceptance criteria, such as lead bricks or liquids; if the drum does not conform to waste packaging acceptance criteria, it is returned to the generator for proper repackaging.

The PAN system was implemented at ORNL because of the volume and variety of wastes here that needed to be certified for disposal in appropriate repositories. Using the PAN system in conjunction with other systems, the ORNL researchers can measure the fissile contents of drums to determine whether the drums should be categorized as low-level waste and disposed of on-site or as transuranic waste that will be eventually shipped to the Waste Isolation Pilot Plant in New Mexico for permanent storage.

X-Ray and Neutron Probes

RTR uses a high-power X ray source that passes X rays through a rotating drum of waste. The X rays are received by an image intensifier, which produces high-resolution images on a video monitor. These images reveal many important details of the contents of the drum.

High-density items, such as metals, appear very dark in the X-ray images. On the other hand, very bright spots in the images may represent thin spots in the drum walls, indicating that the drum is deteriorating and the waste should be repackaged.

The passive part of the PAN system counts neutrons produced by spontaneous fissions and α,n reactions with oxygen-17 and carbon-13 in the waste drums. The active part relies on a neutron generator whose neutrons induce fission reactions in any transuranic waste; the characteristic fast neutrons from this induced fission can be detected to give the amount of transuranic waste present.

In the proposed explosives detector system, the neutrons from the neutron generator would interact with nitrogen, oxygen, hydrogen, and carbon in the luggage, briefcases, crates, and other packages being screened. Each of these elements, when excited by neutrons, emits a gamma ray of a characteristic energy, making it possible to identify both the element and its concentration.

Eight sodium-iodide gamma detectors would detect the gamma rays and measure their energies to identify the elements of interest. The directions and intensities of the emitted gamma rays would indicate the approximate locations and concentrations of these elements.

"The more detailed and extensive the information available on the elements present," says Schultz, "the more likely that compounds typical of explosives can be detected."

The TNA device generates many false explosives alerts because it can detect only nitrogen, which is also present in melamine, a compound found in synthetic material used to make clothing and luggage. Another drawback of the TNA system is that it uses californium-252, a continuous source of neutrons, which poses more of a radiation hazard than the CPNX.

According to Schultz, "Our system is also superior for several health and safety reasons. The large amount of californium-252 in the TNA device is potentially very hazardous, whereas the small amount of tritium in the CPNX system is embedded in a metal target and poses essentially no significant radiological hazard. Furthermore, the CPNX poses only a small fraction of the radiation hazard of the TNA system because the neutrons are generated in pulses and only on demand."

Schultz is requesting $1 million to develop within a year a prototype explosives detection system to prove its capabilities for screening luggage for explosives.

Besides Schultz and Caldwell, the other contributors to the development of the CPNX concept are Don Coffey, Ron Brandenburg, David Hensley, Anne Caylor, and Babette Phoenix, all of the ORNL Office of Waste Management and Remedial Actions, and Martin Bauer of ORNL's Instrumentation and Controls Division.

According to the report of the presidential commission, "The sad truth is that the aviation security system administered by FAA has not provided the level of protection the traveling public demands and deserves. . . .The system is seriously flawed and must be changed." Schultz says that the new technique that ORNL is helping to develop could improve the nation's aviation security system.

ORNL's First Detector of Explosive Traces

The CPNX is not the first ORNL system for detecting explosives at airports. Researchers Gary Glish, Scott McLuckey, and Henry McKown, all of the Analytical Chemistry Division, have developed a compact device that can instantly detect vapors of concealed explosives at parts-per-billion concentrations. This "sniffer" technology, which consists of an ultrasensitive atmospheric sampling ion source coupled with a compact two-stage mass spectrometer, has been licensed by Energy Systems to the Finnegan Company.

Fred Schultz, co-developer of the CPNX, says that the sniffer technology is well suited for scanning persons entering airports, nuclear power plants, defense installations, or other locations thought to be terrorist targets. "This technology can detect vapors on the clothes of persons who have recently worked with explosives—for example, picked up a bomb and placed it in a suitcase. However, unlike the CPNX, the sniffer technology would not be sensitive to plastic explosives hidden inside luggage."

Microwave Processing of Radioactive Waste

By Terry White

"We are developing a microwave process to dry and concentrate highly radioactive chemical waste slurries inside their drums."

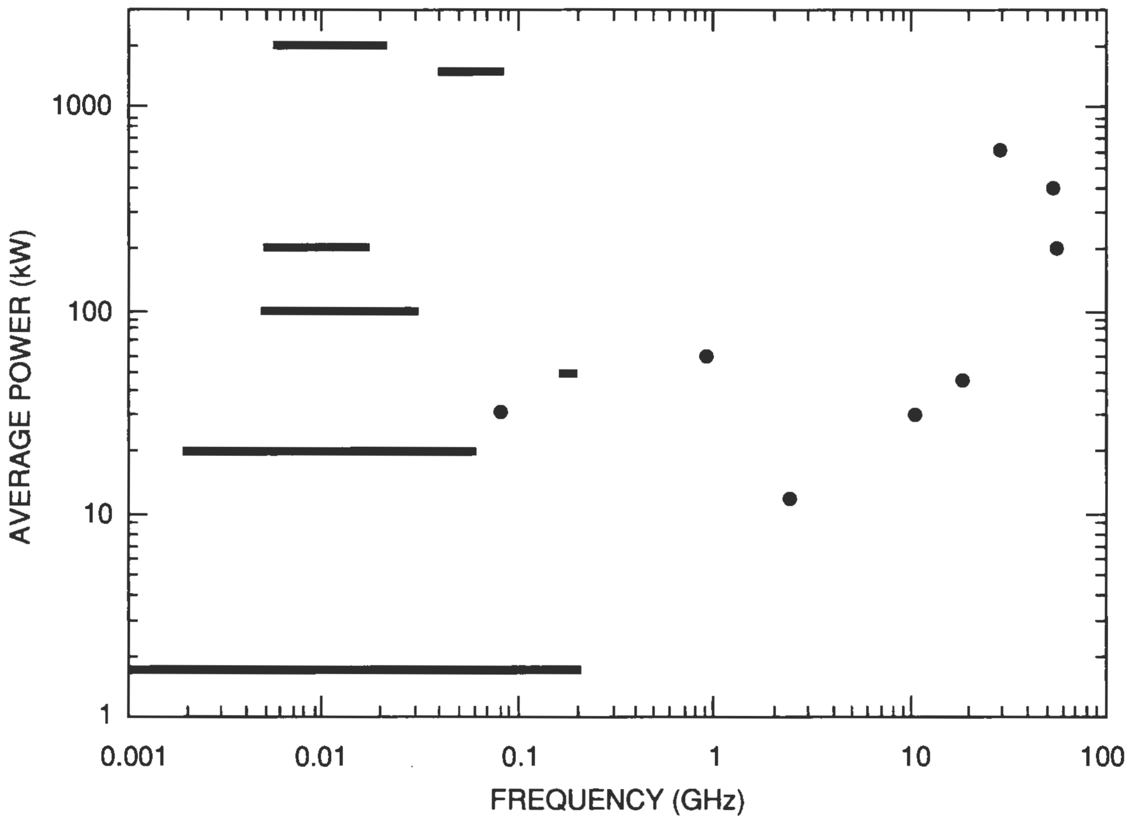
Terry White inspects his one-third-scale microwave processing experiment that dries and solidifies a 4.5-L can of simulated nonradioactive sludge.

Although many of us use microwave ovens for cooking every day, microwaves are applied to industrial and scientific processing on a much more limited scale. Some successful industrial applications of microwaves are frozen meat tempering (thawing), rubber vulcanization, bacon cooking, and pasta drying. At ORNL, the main application of microwaves has been in scientific research in the Fusion Energy Division. Over the past 30 years, our division has invested tens of millions of dollars into high average power, high-frequency, state-of-the art microwave heating systems and radiofrequency (rf) sources for heating plasmas used in fusion research (see the figure on p. 41). To develop these systems, the division employs a number of researchers knowledgeable in microwave engineering, high-voltage-power-supply engineering, and microwave heating physics.

In the past five years, microwave technology developed for plasma heating has been successfully applied by ORNL researchers to the sintering of high-quality ceramics (see "Microwave Processing of Ceramics," *ORNL Review*, Vol. 21, No. 1, 1988, pp. 48–51). More recently, I have been involved in developing techniques for using microwaves to consolidate and immobilize liquid radioactive wastes inside their containers for ultimate safe disposal.

Microwaves are electromagnetic waves having frequencies between 300 megahertz (MHz) and 300 gigahertz (GHz). A hertz is one cycle per second, and 1 GHz equals 10^9 Hz, or 10^3 MHz. The higher the frequency, the shorter the wavelength and the more cycles (changes in the electromagnetic field polarity) it can produce in a second. The ORNL sources range in frequency from 915 MHz to 53.2 GHz at a steady-state power level of >200 kW.

When electromagnetic fields interact with matter, energy is transferred from the microwave fields to the molecular bonds of the material, causing these bonds to "vibrate." This vibrational



High-power microwave and radiofrequency (rf) sources are used in the Fusion Energy Division. The dots represent fixed-frequency microwave oscillators, and the horizontal bars represent variable-frequency rf sources.

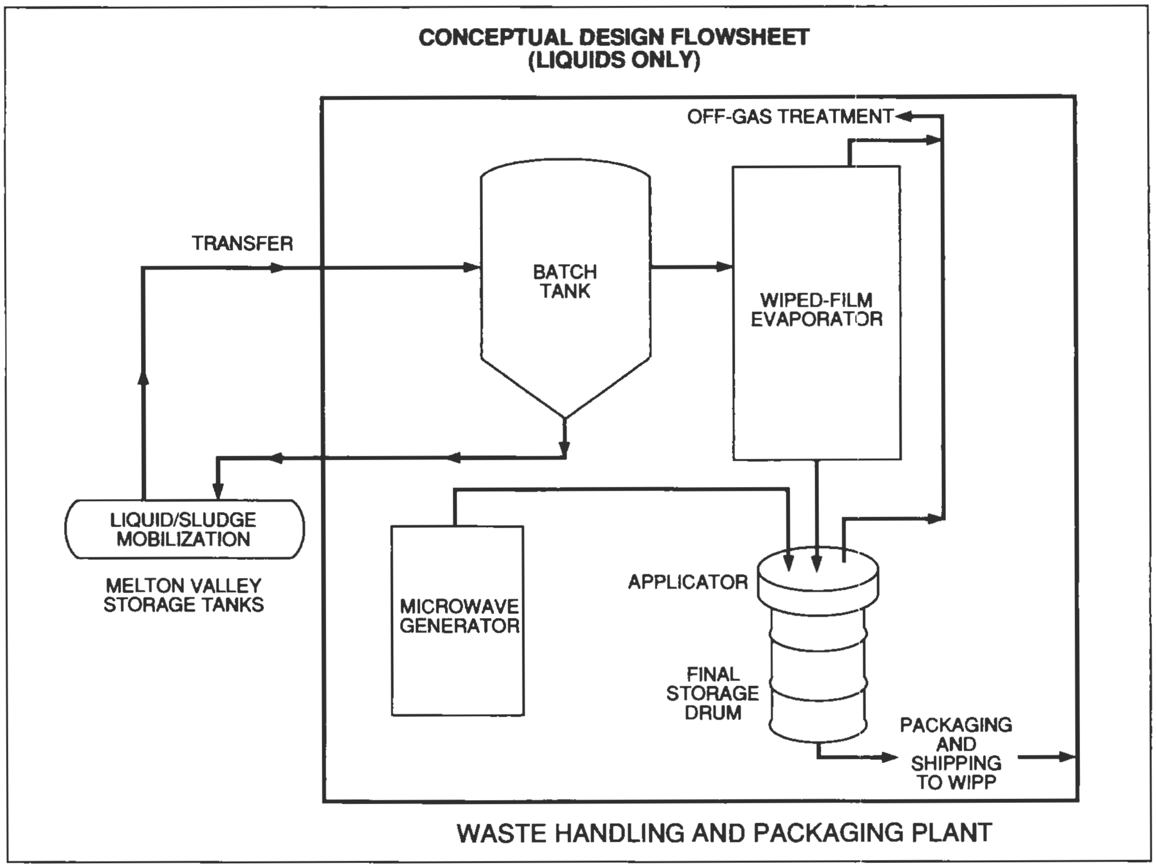
"Our goal is to prepare the wastes so that they meet federal waste acceptance criteria, permitting them to be shipped."

energy is dissipated in the form of heat in the materials. Heating can take place inside the bulk of the material or on the surface, depending upon how strongly the microwaves are absorbed.

New Treatments for Waste

A number of groups in Japan, Europe, and the United States are currently developing processes that use microwave energy for thermally treating radioactive waste. A plant-scale operation in Japan is using microwaves to melt ash contaminated with plutonium from conventional radioactive waste incinerators. In this process, microwaves couple directly to the ash, causing the ash particles to fuse together to form a monolithic solid that, upon cooling, forms a leach-resistant waste form suitable for long-term storage in a geologic repository.

Another Japanese application of microwaves removes surface contamination from concrete by heating beneath the surface of the radioactively contaminated concrete. Microwaves heat the waters of hydration in the concrete, causing the



The Waste Handling and Packaging Plant slurry processing flowsheet.

outer 1 cm of the surface to spall off. This technique has been advertised as being faster than any other conventional technique and as having minimal waste generation.

Here at ORNL, we are developing a microwave process to dry and concentrate highly radioactive chemical waste slurries inside their drums. These wastes, which contain elements heavier than uranium, are classified as transuranic (TRU) wastes. Our goal is to prepare the wastes so that they meet federal waste acceptance criteria, permitting them to be shipped to the Waste Isolation Pilot Plant (WIPP), a federal repository in New Mexico for defense transuranic wastes. This development is a collaborative effort involving the Office of Waste Management and Remedial Actions and the Chemical Technology and Fusion Energy divisions.

How the Project Started

Late in 1988, I was working on a microwave heating system for the Advanced Toroidal Facility (ATF), a fusion experiment that uses 53.2-GHz, 200-kW state-of-the-art microwave sources to heat the plasma. Because the microwave heating system was operating routinely, I began looking for new applications for microwaves. About this time, I received a message to call Doug Turner, the project manager for the Waste Handling and Packaging Plant (WHPP). The WHPP is a $245 million project, scheduled to receive funding in fiscal 1993, whose purpose will be to process and package transuranic wastes at ORNL for shipment to the WIPP in New Mexico. I hesitated to call Turner back because several years earlier we had played on the same tennis team, and I thought that he wanted a match, which I was not interested in then. Fortunately, he persisted in his attempts to reach me, and I discovered that he was interested in using microwaves to process radioactive wastes as part of his project! After some initial discussions with Turner, Jan Berry, and others working on the project, I became convinced that the application was feasible.

Fortunately, my management allowed me to transfer some of my responsibilities on ATF to other microwave engineers so that I could devote 25% of my time to the WHPP project. This action raised quite a few eyebrows among my co-workers in fusion energy, some of whom wondered why anyone would give up a secure position on a glamorous, high-tech project like ATF to become a nuclear garbage man. Although I had worked on building plasma heating systems for fusion experiments for the last 11 years, I was always looking for new ways to apply our technologies in microwave processing to areas outside of fusion.

In 1985 I, along with Hal Kimrey, another microwave specialist in fusion energy, helped to start up ORNL's microwave ceramic sintering program. I viewed the WHPP process not as just another microwave application but as a real opportunity to contribute to the solution of the radioactive waste management problem at ORNL. I had extensive literature searches carried out to determine the current state of the art for microwave processing of radioactive wastes. After about a year, I was working full-time on the project.

ORNL's Technology

How might the microwave process work in the WHPP? As shown in the figure on page 42, the radioactive sludge, stored in eight 50,000-gal tanks in the Melton Valley, is mobilized and pumped to the WHPP. The sludge is stored in a batch tank and then fed to a wiped-film evaporator. The wiped-film evaporator consists of a vertical cylindrical casing that is steam heated externally. Inside the cylinder, a large rotor containing several sets of wiping blades is turned by a motor. A thin film of slurry, fed from the top, is wiped against the casing by the rotating blades. This action produces a concentrated output at the bottom. The product is fed to the microwave in-drum applicator, where the slurry is heated further until it forms a molten salt cake. After the salt residue is cooled into a crystalline solid, the drum is packaged, assayed, and shipped to the WIPP. The microwave process alters the waste so that it meets the main requirement for disposal in the WIPP: no appreciable amounts of free liquids or free particles in the waste.

For our slurry processing application, it became apparent that microwaves had several advantages over conventional evaporation technology:

- Microwaves heat the radioactive material directly, thus eliminating the need for heating elements.

- No heat-transfer surfaces are required because of the direct heating effect.

- An in-drum microwaving process can eliminate the need for moving parts in the process, making it highly reliable and nearly maintenance free.

- Microwave generators can be isolated from the radioactive process area by waveguide transmission systems.

Currently, we are operating a one-third-scale applicator using 6 kW of 2450-MHz microwave power located in the Fusion Energy Division at the Oak Ridge Y-12 Plant. The surrogate (nonradioactive) slurry consists of mostly water and sodium nitrate ($NaNO_3$), and the remaining fraction is a complicated soup of chemicals. The slurry is mixed in a tank and pumped to the applicator where a small portion is metered into the drum. Initial microwave heating to 120°C dries the slurry and produces a friable solid that has too many free particles to meet the WIPP waste acceptance criteria. However, continued heating to 300°C soon melts the $NaNO_3$ salt residues. The end temperature is kept below

"We have developed a cost-effective process that uses a microwave applicator capable of processing the waste without arcing."

350°C to avoid NO_x gas generation. When the $NaNO_3$ cools, all free particulates are immobilized by the resolidification of the $NaNO_3$. The end product is then a very dry salt cake that has so few free particles that it meets the current WIPP waste acceptance criteria.

Microwave processing of waste inside drums is not a new idea, but we have developed a cost-effective process that uses a microwave applicator capable of processing the waste without arcing and that uses less costly microwave power. Arcing is an electrical discharge, or spark, that forms at sharp points or corners on the surfaces of metals exposed to microwave energy. Arcing may occur when chemical slurries are heated by microwaves because the electrical conductivity of the chemicals is high enough for the chemicals to behave like a metal. Dried chemical slurries will form rings of crystals around the inside of the container, and these tiny, sharp crystals will tend to concentrate the microwave fields until arcing occurs. The arc decomposes the crystals, causing toxic gases to be produced. Our method for eliminating arcing relies on carefully controlling the microwave fields in the applicator.

The microwave process is being developed in parallel with a conventional wiped-film evaporator. If the microwave process proves successful, it may supplement or even replace the wiped-film evaporator in the flowsheet. Plans call for both technologies to be evaluated at the full-scale level using surrogate waste in the Waste Development Facility (Building 2528) at ORNL. Depending upon the results of the full-scale tests and funding constraints, either the wiped-film evaporator or the microwave processes, or both, will be used in the WHPP, which is scheduled to begin operation in the year 2000.

Biographical Sketch

Terry White has been a researcher in ORNL's Fusion Energy Division since 1976. During this time, he helped design, build, and operate three high-average-power state-of-the-art microwave heating systems for fusion research. In 1985, he helped to start ORNL's Microwave Ceramic Sintering Program. In 1988, he began work on microwave processing of radioactive waste. He has served on numerous DOE microwave technology review committees. White obtained his B.S., M.S., and Ph.D. degrees in electrical engineering at the University of Texas at Austin.

Take a Number

By Alan D. Solomon
ORNL Consultant and Guest Columnist

Taking a number, or "guesstimating," is often the first step in solving a problem. For example, a reasonable guess for the square root of 2 might be 1.5, because $1^2 = 1$ and $2^2 = 4$. *Iteration* is the mathematician's way of finding successive estimates that are progressively closer to the true solution of a problem. For example, if your first estimate $x = 1.5$ for $\sqrt{2}$ is substituted into the relation

$$\text{NEXT ESTIMATE} = \frac{1}{2}\left(x + \frac{2}{x}\right), \qquad (1)$$

we find that to four decimal places NEXT ESTIMATE = 1.4167. The key step of iteration is to consider 1.4167 a new "guesstimate," redefine x as $x = 1.4167$, and use (1) all over again. The next estimate is now 1.4142, which is the correct value to four decimal places. If a more nearly accurate estimate is needed, we simply apply (1) more times.

Relation (1) is a special case of the Newton-Raphson method for solving equations. If the square root key on your pocket calculator is broken, then (1) may be extended to

$$\text{NEXT ESTIMATE} = \frac{1}{2}\left(x + \frac{a}{x}\right) \qquad (2)$$

for finding $\sqrt{a}$, with a being any positive number. Thus, for $a = 6.5$ and first guess $x = 2.0$, we obtain the *successive approximations*, or *iterates* 2.6250, 2.5506, and 2.5495. The latter value is correct to four decimal places. If your calculator cannot divide or find reciprocals, then you may want to use an iteration procedure for finding $\frac{1}{a}$ that is based on the repetitive use of

$$\text{NEXT ESTIMATE} = x(2 - ax), \qquad (3)$$

in which x is the present best estimate. For finding $\frac{1}{7}$ with the initial guess $x = 2.0$, this relation gives us 0.1200, 0.1392, 0.1428, and 0.1429. Again, the latter value is the last value being correct to four decimal places.

Iteration procedures whose successive iterates, to any number of decimal places, remain unchanged after enough iteration are said to *converge*. This is not always what happens. Consider, for example,

$$\text{NEXT ESTIMATE} = 4Ax(1 - x), \qquad (4)$$

where x is the present estimate and A is a given number. If $A = \frac{1}{2}$ and the initial guess $x = \frac{1}{2}$, then

$$\text{NEXT ESTIMATE} = 4 \times \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{2}.$$

All subsequent iterates equal this value, and the procedure converges. If we take $A = 0.7$ and the initial guess $x = 0.5$, we must perform 44 iterations before the values settle down (or converge) at 0.6429. However, if A is increased to 0.8, then after the 14th step, the iterates are alternately equal to 0.5130 and 0.7995, jumping from one value to the other. This phenomenon, called *bifurcation*, first occurs when A is approximately 0.75. When A moves slightly beyond 0.86, we find a more complex bifurcation with successive iterates jumping between the four values 0.8317, 0.4872, 0.8694, and 0.3951. The study of what happens when A moves beyond about 0.8925 and no convergence is observed belongs to the new and exciting field of *chaos*, described in a recent book by James Gleick. You may wish to explore iterative procedures on your personal computer.

RE: Awards & Appointments

Rufus Richie

Martin Marietta Energy Systems, Inc., has named **Rufus Ritchie** a Senior Corporate Fellow and **Paul Becher** a Corporate Fellow.

Colin D. West has been elected chairman of the new International Group on Research Reactors.

Thomas H. Row has been appointed ORNL director of Environmental, Safety, and Health Compliance. This directorate is composed of four offices. Newly appointed leaders of these offices are **L. Eugene McNeese,** director of the Office of Waste Management and Remedial Actions; **Jerry H. Swanks,** director of the Office of Environmental and Health Protection; **Frank C. Kornegay,** director of the Office of Environmental Compliance Documentation; and **Mark W. Kohring,** director of the Office of Operational Readiness and Safety.

Chester R. Richmond and **Donald B. Trauger** have been named Associate Laboratory Directors Emeriti.

ORNL researchers received four of the nine possible awards in the 1989 Department of Energy Materials Sciences Research Competition. **G. Malcolm Stocks** received the Sustained Outstanding Research in Metallurgy and Ceramics Award for "First Principles Theory of the Physical and Metallurgical Properties of Alloys"; **Warren C. Oliver,** the Significant Implication for DOE-Related Technologies in Metallurgy and Ceramics Award for "The Development of Use of the Mechanical Properties Microprobe for Characterizing Energy-Related Materials"; **Stephen J. Pennycook,** the Outstanding Scientific Accomplishment in Solid State Physics Award for "Atomic Resolution Imaging of Materials Structure and Chemistry Using Localized Electron Scattering in a Scanning Transmission Electron Microscope"; and **Carlos E. Bamberger,** Significant Implications for DOE-Related Technologies in Materials Chemistry Award for "Synthesis of Ceramic Whiskers."

ORNL's **Heavy-Section Steel Technology Program** has been recognized by the Nuclear Regulatory Commission as its largest and longest-running research program and for "25 years of outstanding research accomplishment."

Victor Tennery

Victor J. Tennery has been elected vice president of the American Ceramic Society.

Paul Becher

Paul F. Becher received the Robert Browning Sosman Lecturer Award from the American Ceramic Society and gave a lecture on "The Microstructural Design of Toughened Ceramics." At the society's annual meeting, he also was installed as a society vice president and was named co-recipient of the Ross Coffin Purdy Award along with **Chun-Hway Hsueh, Peter Angelini,** and **Terry N. Tiegs** for the paper "Toughening Behavior in Whisker-Reinforced Ceramic Matrix Composites."

Michael L. Santella and **Stan A. David** of ORNL and Michael C. Maguire of Sandia National Laboratories received the annual Charles H. Jennings Memorial Award from the American Welding Society for their paper "Analysis of Heat-Affected Zone Cracking in Ni_3Al Welds by Computer Modeling of Thermal Stresses."

J. Michael Simonson has been elected 1990 chairman-designate of the Calorimetry Conference, an organization of international scientists established to foster and communicate advances in calorimetry and thermodynamics.

John T. Mihalczo has been elected a fellow of the American Nuclear Society. He also has been appointed a member of the Radiation Detection Program Review Panel of the Department of Energy Office of Arms Control.

Steven E. Lindberg will deliver a lecture in September 1990 at a celebration in honor of the 100th anniversary of the founding of the Free University of Amsterdam in The Netherlands. He will speak on the need for multidisciplinary research to understand the role of global change on the cycling of metals in ecosystems.

Patricia D. Parr has been elected treasurer of the Association of Southeastern Biologists.

R. P. Wichner received the Best Paper Award from the Space Solar Power Committee of the American Society of Mechanical Engineers (ASME) for "Thermal Analysis of Heat Storage Canisters for a Solar Dynamic, Space Power System," which was presented at the 1988 ASME International Solar Energy Conference.

John Cleveland served as chairman of the recent meeting of International Atomic Energy Agency consultants to plan a coordinated research program for validating safety-related reactor physics calculations for high-temperature gas-cooled reactors fueled with low-enriched uranium.

J. M. Corum is a member of DOE's Office of Defense Energy Projects review group established to assess alloy data and structural design methods and criteria proposed for the Nuclear Assembly Test of the SP-100 space reactor.

George Courville has been named head of the Efficiency and Renewables Research Section of the Energy Division.

Robert N. Hamm has been named head of the Biological and Radiation Physics Section of ORNL's Health and Safety Research Division.

Donald L. Williams, Jr., has been appointed manager of the Performance Assurance Project Office of ORNL's Engineering Technology Division.

W. Ray Garrett and **Marvin G. Payne** have received the Excellence in Research Award of ORNL's Health and Safety Research Division for their fundamental studies of interference effects between coherent nonlinear optical processes.

Linda L. Horton has been named a member of the Advisory Technical Awareness Council of ASM International.

Judy M. Wyrick, associate editor of ORNL's *Ceramic Technology Newsletter* and the *Human Genome Quarterly*, received the Distinguished Service Award from the East Tennessee Chapter of the American Society for Information Science.

Robert D. Hatcher, an ORNL/UT Distinguished Scientist, has been named a member of the National Research Council's Board on Radioactive Waste Management.

Robert Honea

Robert B. Honea has been appointed manager of ORNL's new Work for Others Program Office.

Russ Knapp

F. F. (Russ) Knapp has received the prestigious Senior U.S. Scientist Award from the Alexander von Humboldt Foundation of the Federal Republic of Germany in recognition of his achievements in radiopharmaceutical research and the development of new agents for clinical applications in nuclear medicine.


Barbara Walton

Barbara T. Walton is a member of the Editorial Board of *Environmental Toxicology and Chemistry*, a monthly publication of the Society of Environmental Toxicology and Chemistry.

Anthony L. (Tony) Wright has been appointed ORNL coordinator of the DOE Tiger Team Activities.

Mike Shepherd has been named head of the new Video and Motion Picture Services Section of the Graphics Division of Energy Systems.

Recently named finance managers at ORNL are **Scott Herrin,** Biomedical and Environmental Sciences; **Leroy Sims,** Nuclear Technologies; and **D. Bryan Kendrick,** Environmental, Safety, and Health Compliance. Recently appointed finance officers at ORNL are **Ronnie D. Adams,** Chemistry Division; **Gerald Dean,** Instrumentation and Controls Division; and **Kimerly R. Barnes,** Engineering Physics and Mathematics Division.

Carolyn Krause, Cindy Robinson, Sharon McConathy, and **LaWanda Klobe** have been elected president, vice president, secretary, and treasurer, respectively, of the East Tennessee Chapter of the Society for Technical Communication (STC).

Three entries of Energy Systems employees placed in STC's recent International Technical Publications Competition.

Michael Huston, Donald DeAngelis, and **Wilfred Post** received a Distinguished Technical Communication award (first place) in the category of scholarly and professional articles for their journal article "New Computer Models Unify Ecological Theory."

The computer newsletter "The RAMbler" earned an award of excellence (second place) in newsletters for **Charles A. Reeves, Jr., Susan E. Hughes,** and **Linda E. Battle.**

Charles D. Scott, Charlene A. Woodward, and **Vicki T. Hinkel** received an award of achievement (fourth place) in scholarly and professional articles for their journal article "Solute Diffusion in Biocatalyst Gel Beads Containing Biocatalysis and Other Additives."

In STC's International Technical Art Competition, **John Holbrook** and **Pat Parr** received an award of excellence in interpretive illustration, line art, black and white, for "Perception of Senses." **D. J. Hoffman, Judy C. Neeley,** and **D. J. Taylor** received an award of achievement in mechanical illustration, tone art, color, for "Compact Loop Antenna for Tore Supra." This illustration won the Best of Show in Art Award in STC's local competition.

Numerous Energy Systems employees received awards in the 1990 Technical Publications and Art Competition sponsored by STC's East Tennessee Chapter. The winners in publications and then in art are listed by category below:

Awards of distinguished technical communication were given to **Charles A. Reeves, Jr., Susan E. Hughes,** and **Linda E. Battle,** in newsletters; **Carolyn Krause, Luci Bell,** and **Vickie Conner,** in house organs; **Michael Huston, Donald DeAngelis,** and **Wilfred Post,** in scholarly/professional articles; **Charles Scott, Charlene Woodward,** and **Vicki Hinkel,** in scholarly/professional articles; **Carolyn Krause, Lydia Corrill,** and **Vickie Conner,** in trade/news articles; **Mark Reeves** and **Martha Stewart,** in trade/news articles; and **Jane Kraemer** and **Alice Clayton,** technical reports.

Winners of awards of excellence were **Randall Hutton** and **Sandra Schwartz,** in brochures;

Scott Buechler, Anne Travis, and **Sandra Schwartz,** in promotional materials; **Wanda G. Jackson, Walter S. Koncinski, Jr.,** and **Larry Davis,** in periodic activity reports; **Ernest Silver** and Energy Systems staff, in whole periodicals; **Elias Greenbaum** and **Martha Stewart,** in scholarly/ professional articles; and **Arvin Quist** and **Debbie White,** in technical reports.

Awards of merit were given to **Sandra Schwartz,** in brochures; **Donald W. Jared, Walter Koncinski, Jr.,** and **Vickie Conner,** in house organs; **Margaret Givens** and the Energy Systems Fusion Engineering staff, in promotional materials; **C. Phil McGinnis, Roy A. Jacobus,** and **Luci Bell,** in scholarly/ professional articles; **R. C. Kryter, H. D. Haynes,** and **LaWanda E. Klobe,** in scholarly/professional articles; **Cheryl Koski, Lisa Xiques,** and **Ernest G. Silver,** in scholarly/ professional articles; **Carolyn Krause, Gerard Bunick,** and **Brian Hingerty,** in trade/news articles; **Lawrence W. Barnthouse, Ronald J. Klauda,** and **Douglas S. Vaughan,** in books; **Terry R. Sharp, Robert L. Wendt,** and **John E. McCorkle,** in technical reports.

Winners of awards of achievement are **Frank M. Scheitlin, Robert A. Eldridge,** and **Deborah J. Weaver,** in promotional materials; **Phyllis H. Green** and **Donna M. Watson,** in periodic activity reports; **R. B. Shelton, K. H. Zimmerman,** and **Bob Eldridge,** in periodic activity reports; **John F. McCarthy** and **Amy L. Harkey,** in scholarly/ professional articles; **Duane Graves, Eli Greenbaum,** and **Vicki T. Hinkel,** in scholarly/ professional articles; **Michael Harris, Charles Byers,** and **Frank M. Scheitlin,** in scholarly/professional articles; **Timothy Scott** and **Cindy Robinson,** in scholarly/ professional articles; **R. R. Brunson, Charles Byers,** and **Cindy Robinson,** in scholarly/professional articles; **H. Richard Hicks** and **Catherine H. Shappert,** in trade/news articles; **Dale W. Johnson, Robert I. Van Hook,** and **Ann Ragan,** in books; **Mayo Uziel** and **Nancy B. Munro,** in technical reports; **Mary S. Guy, Barbara H. Handler,** and **Alice F. Twitty,** in technical reports.

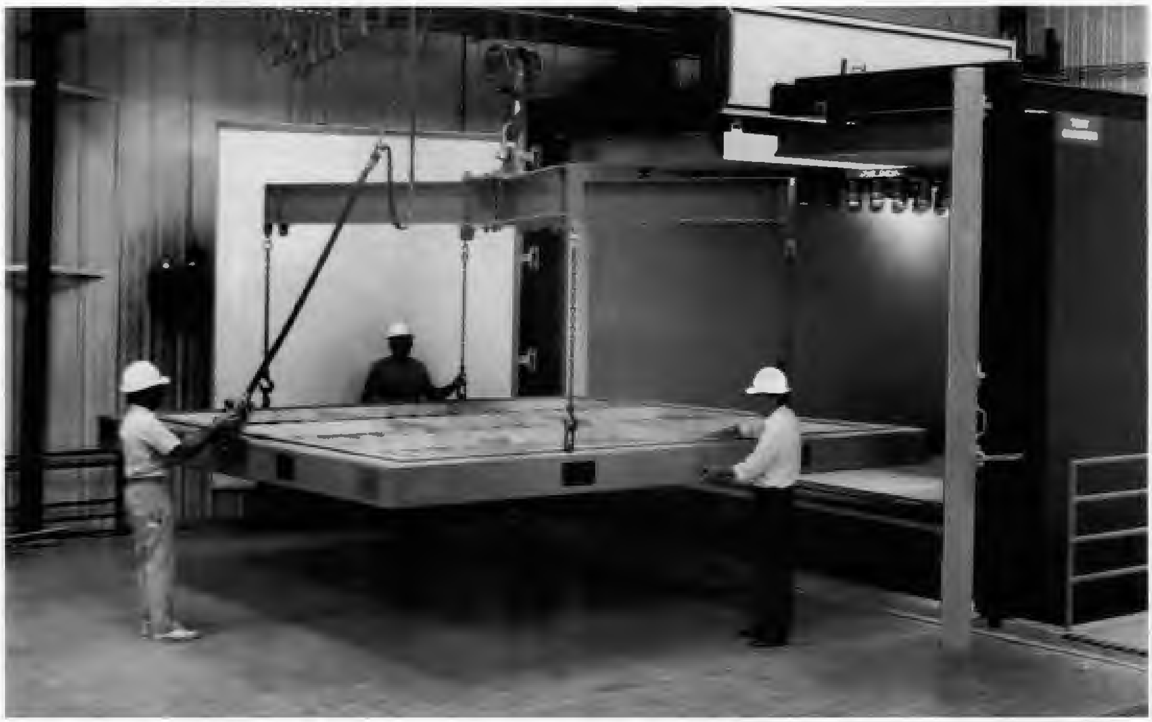
Awards given for the art competition were: in mechanical illustration, line illustration, black and white, an award of distinction to **Dami Rich** and **David Reichle,** and an award of merit to **John Holbrook** and **Barbara Walton;** in mechanical illustration, tone art, color, an award of distinction to **Judy C. Neeley, D. J. Taylor,** and **D. J. Hoffman;** in interpretive illustration, tone art, black and white, an award of excellence to **John Holbrook** and **Pat Parr;** in design graphics, brochures, an award of achievement to **Sandra Schwartz, Anne S. Travis,** and **Brenda J. Smith;** in design graphics, covers, an award of excellence to **Sandra Schwartz, Kathie Zell,** and **T. E. Shannon,** for one publication, and to **Sandra Schwartz** and **Thomas O. Tallant,** for another; in design graphics, presentations, an award of achievement to **Thomas R. Henry** and **Lynn Wright;** in design graphics, posters, an award of excellence to **Sandra R. Schwartz, Kathie L. Zell,** and **T. E. Shannon,** and an award of merit to **Sandra Schwartz** and **Ava King.**

Curtis Travis

Curtis C. Travis has been appointed a member of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel for the U.S. Environmental Protection Agency. The FIFRA panel will address the health risks of pesticide chemicals and their potential residues in food.

The Expanding Roof Research Center

By Bob Wendt and Pat Love



A crane moves test roof sections into the climate chamber of the $2-million Large-Scale Climate Simulator. The diagnostic platform, which can support a 10-ton panel, simulates a range of climatic conditions.

"The Center's primary mission is to improve the basic understanding of the thermal and physical performance characteristics of roofing systems."

If you want to make a member of the roofing industry's eyes sparkle, mention ORNL's Roof Research Center. At this DOE user facility, located near the North Portal, research is being done that answers questions of great importance to all those interested in keeping buildings dry, comfortable, and affordable.

The Center's primary mission is to improve the basic understanding of the thermal and physical performance characteristics of roofing systems by obtaining the data needed to resolve important industry-wide issues. For example, one question being investigated is, "What happens to high-performance foam insulations when blowing gases (which fill the individual cells) that are less hazardous to the environment are substituted for the current gases that reputedly deplete the ozone layer?"

Another mission of the Center is to reduce building energy consumption by improving the thermal efficiency of the roof. Many roofing materials, surface treatments, and colors have been tested on the Center's experimental apparatus.

The Center has three separate experimental facilities that address various roofing issues. The oldest and smallest is the Roof Thermal Research Apparatus (RTRA), which has been in use since 1985. There, four roofing panels [each 1.2- by 2.4-m (4- by 8-ft)] are exposed to the rigors of Tennessee weather. The RTRA is now testing the thermal performance and durability of various surface-applied roof coatings. These coatings resemble white paint but are specially formulated for their roof application.

Data collected during this winter show that the increased reflectance of the roof coating increases the energy use of the building. This situation is expected to reverse during the warmer months when a cooler roof temperature should result in lower energy consumption. Whether a roof coating will improve the energy performance of a building will depend on the climate and building functions.

The second experimental facility, which has been in use since 1988, is the Large-Scale Climate Simulator (LSCS). In this facility, roofing materials can be tested under specific, artificially created climatic conditions. The air temperatures can range from –4 to 65°C (–40 to 150°F), and the air can be desert-dry or as moisture-laden as a rain forest. Simulated solar effects can raise the roof surface temperature to 93°C (200°F).

The LSCS has contributed some interesting insights into the effect of moisture trapped in low-slope roofs such as those found on most commercial buildings and the "flat-top" houses in Oak Ridge. George Courville of the Energy Division's Building Thermal Envelope Systems and Materials (BTESM) Program and Carsten Pedersen, a visiting researcher from Denmark, confirmed findings by Canadian researcher C. P. Hedlin that even a relatively small amount of moisture (1% by volume) has a significant impact on the energy flow through porous insulation such as fiberglass. When moisture becomes trapped between two impermeable barriers (the membrane and the roof deck), it migrates through the permeable fiberglass and condenses or evaporates according to the relative temperatures of the roof (cool at night, hot during the day) and the building's interior. As the moisture migrates through the insulation and changes phase, it degrades the thermal performance. Researchers at the Center have also observed that wood fiberboard, a commonly used building material that protects the fiberglass during installation, reduces the effect of moisture in these roofs. The wood fiberboard acts like a sponge and absorbs much of the free moisture, thereby preventing it from moving within the roof.

Bob Wendt of the Center staff supervised construction of a third experimental facility, for which ground was broken in January 1990. The new Envelope Systems Research Apparatus (ESRA) will be used to study the mechanical and thermal properties of both roofing systems and residential foundation wall constructions. The three industrial groups cofunding the facility along with DOE are the Polyisocyanurate Insulation Manufacturers Association, the Society of Plastics Industries, and the National Roofing Contractors Association.

This facility will provide information on the effect of normal installation practices on five newly formulated polyisocyanurate foam insulations. These new formulations use blowing agents that are less environmentally damaging than the present materials. Careful observation of the installation process will yield answers to such questions as "Will the foam melt when the membrane is applied with hot asphalt?" and "Will the gravel spreader crush the insulation?"

The basement will be divided into four experimental chambers, permitting side-by-side studies of the energy flows through basement walls and floors. The effectiveness of vapor barriers and waterproofing will be studied, and some radon mitigation strategies may possibly be tested. These studies are being conducted by Jeff Christian, manager of the BTESM program.

At the conclusion of the initial roof testing on the ESRA, this permanent facility will be available to conduct other roofing system tests. This facility's larger size and lower height-to-roof level (compared to the RTRA) will enable the Roof Research Center to expand the services available to industry and to undertake new activities that are either impossible or impractical to accomplish in the Center's other experimental facilities.

The facility's Industry Advisory Panel is impressed with the quality and content of the work going on at the Center. The research at ORNL is expected to improve the energy

"The new Envelope Systems Research Apparatus will be used to study the mechanical and thermal properties of both roofing systems and residential foundation wall constructions."

In May of 1990 Bob Wendt briefed J. Michael Davis, DOE assistant secretary for Conservation and Renewable Energy, on a project comparing the effectiveness of various types of insulation materials. Wendt is pointing to a thermocouple that measures heat loss through the material. Bill Fulkerson, ORNL's associate director for Advanced Energy Systems, looks on from the rear.

efficiency and durability of our roofs—a comforting thought to the millions who will roof or reroof their structures in this decade.

Several publications are available, such as the proceedings of the International Symposium on Mathematical Modeling of Roof Systems and the proceedings of the Roof Wind Uplift Resistance Testing Workshop, that reflect the ongoing research at the Center. For information on publications, current projects, or user facility opportunities, contact Bob Wendt at (615) 574-0022 or Pat Love of the Center staff at (615) 574-4346.

Biographical Sketches

Bob Wendt was appointed manager of the Roof Research Center in June 1989. He assisted in planning and designing the facility several years ago in his role as ORNL Facility Planning Manager. In the early 1980s Wendt, a registered architect, managed the Innovative Structures Program for DOE's Conservation Program. Roofs of these structures ranged from earth-covered, waterproof roofs to very large, permanent, fabric roofs covering multiple structures. Before joining ORNL in 1979, Wendt worked in facilities planning at Lawrence Livermore National Laboratory.

Pat Love coordinates contracts and financial matters and organizes the workshops, conferences, and technology transfer projects for the Center. She joined the Building Thermal Envelope Systems and Materials (BTESM) Program in 1986, just before the startup of the Center, and she serves as administrator of the overall BTESM program.

Women in Science

Shannon Lucid, NASA astronaut, chats with attendees at the First Annual Today's Women in Science and Technology Conference.

About 140 college women majoring in science and engineering had a chance to meet "really superb role models," as one student said, when they participated in the First Annual Today's Women in Science and Technology Conference. The conference, cosponsored by ORNL and Oak Ridge Associated Universities (ORAU) on April 20, 1990, gave college women the opportunity to interact with women professionals and to learn about the challenges of their scientific careers.

Helen Payne of ORNL's Office of University and Education Programs coordinated the event along with Ernestine Friedman and Linda Sharp of ORAU. "The United States needs a higher percentage of women choosing science and technology careers," said Payne. "We want to support and encourage women in these career choices. We started at the college level because even at this stage people leave their fields or may not have made definite career decisions—particularly with respect to graduate school. Next year we hope to include high school students as well and to make the conference at least two days long."

The daylong conference was highlighted by a keynote address from NASA astronaut Shannon Lucid, a biochemist who has flown on two space shuttle missions. In portraying the possibilities present in the next 10 to 20 years of the space program, Lucid called the space shuttle a research and development tool and noted that all types of scientists are needed by the shuttle program. She cited examples of tremendous career opportunities for engineers, materials scientists, physicians, chemists, mathematicians, physicists, biologists, and botanists. Her profile of the crew for her last mission pointed out diverse career paths as proof that there is no one route to becoming a scientist or an astronaut. She challenged the conference attendees to "take full advantage of existing options . . . and then other opportunities will open up."

Lucid's luncheon speech was preceded by four short general presentations from women in various disciplines. Cheryl Bast of ORNL's Health and Safety Research Division, who recently acquired her Ph.D. degree in genetics, spoke on the ins and outs of graduate school; Suzette Tardif of ORAU's Marmoset Center discussed balancing a career and family; Lavonia DeCongé Watson, head of the Mathematics Department at Southern University, pointed out career opportunities in mathematics; and Tina Riedinger, University of Tennessee (UT) astronomy professor, discussed why science careers are a good choice for women today.

In the afternoon the students had a chance to interact with the members of three different panels. Each panel represented certain fields (science and mathematics education; life, medical, and environmental sciences; and physical sciences, mathematics, computer science, and engineering) and consisted of four or five professionals from those areas. Bast, Brenda Faison, Linda Horton, Linda Cain, and Susan Sherrow were the panel members from ORNL. Other members were Tardif and Donna Cragle, ORAU; Portia Hutchinson, UT Medical Center; Mary Bolden, Maryville High School; Pat DeRoos, Jefferson Junior High School; Carol Grant, Austin-East High School; Cindy Heisdorffer, Webb School; Peggy King, Harrison-Chilhowee Baptist Academy; Watson; and Riedinger. The students asked specific, technical questions about individual research as well as more general questions about problems the panelists had encountered as women science professionals in school, the workplace, and

"The United States needs a higher percentage of women choosing science and technology careers."

"This is probably one of the best programs we've been connected to."

personal life. A comfortable, open atmosphere resulted in lively interaction and candid conversations between the panel members and students.

The young women were also offered tours of ORAU's Radiation Emergency Assistance Center/Training Site and of several laboratories in environmental and physical sciences at ORNL. Women scientists and engineers led the tours of their research laboratories and facilities, which are used in areas ranging from aquatic ecology to robotics. Julie Watts of the Environmental Sciences Division (ESD), who coordinated the ORNL tours through members of the Association for Women in Science, East Tennessee Chapter, said that the experience "provided students the rare opportunity to meet women scientists in their workplaces. The enthusiastic response of the students was evident as many lingered to ask advice on their personal career choices and opportunities that might be open to them."

For many of the students, this program revealed a new world of possibilities. "I didn't realize," said one student, "that there were so many opportunities [computer modeling, geography, physics] for individuals who are not in the life sciences to be involved in the environmental sciences." A student in computer sciences said she saw opportunities she had never considered for people majoring in mathematics and computer sciences.

Perhaps the most important observation came from an older student who has returned to school: "It's good to see so many women in science." It is hoped that science will attract even more women in the years to come.

Get SMART

ORNL is lending its expertise to teachers from Chattanooga City and Roane County/Harriman schools through Science and Mathematics Action for Revitalized Teaching (SMART). With support from local businesses, industries, state and local government, and Oak Ridge Associated Universities (ORAU), science and mathematics teachers of grades K–12 will be involved in innovative teaching through planning activities, conducting summer research, attending special summer institutes, developing and using new instructional materials, and implementing new teaching strategies.

Scientists and other technical specialists at ORNL will provide guest lectures and demonstrations and perhaps lend scientific equipment to the schools in the fall of 1990. During the summer, ORNL and ORAU are offering training for the teachers on developing improved teaching materials for their courses. "This is probably one of the best programs we've been connected to," said Roane County Superintendent Jess Plemons.

"Working directly with teachers will provide important leverage in upgrading the science curricula at these schools," says Chet Richmond, director of ORNL Science Education Programs and External Relations. "The participating teachers will return to their schools with new ideas about teaching science and math. They will be the contacts at their institutions for follow-up activities and they will help in recruiting teachers to enroll in subsequent cycles of the program. We will stress 'hands-on' teaching experiences for these participating teachers."

ORNL also arranged for some teachers from both school systems to participate in the National Teacher Enhancement Program, sponsored by the National Science Foundation (NSF), which was held this summer at ORNL and four other DOE national laboratories. "Supplementing the NSF-supported program with a related DOE-supported activity," said Richmond, "is an excellent example of interagency collaboration on teacher enhancement programs that is being encouraged by representatives of federal agencies in Washington."

The partnership was established in October 1989, and about 80 Chattanooga and Roane County teachers have participated in meetings to assess the needs of their science and mathematics education programs. Over several years, a large number of the districts' teachers will participate in SMART activities. Working together in their schools, these teachers will create and support system-wide changes to improve the quality of science and mathematics education.

A Boost for Seniors

Selected high school students who are already moving toward a career in science, mathematics, or engineering will be invited to attend ORNL's Saturday Academy for Computing and Mathematics (SACAM). This program was established to reinforce the interests of these bright students and thus encourage them toward science and technology careers.

Initially, about 30 students will be selected by teachers and administrators from schools in the Knoxville/Oak Ridge area. The students, mostly seniors, will attend three-hour sessions for ten consecutive Saturday mornings. During the first year, two cycles are planned, one in the fall of 1990 and one in the spring of 1991. Each course will consist of ten sessions on different topics pertaining to mathematics and computing and will stress the application of mathematics to computing and specific scientific problems, such as robotics, neural nets, climate modeling, advanced controls, plasma simulation, and materials research.

"We have met with area math teachers and administrators to discuss the proposed program and to receive input from them," said Richmond. "They were all enthusiastic about SACAM."

Five students and one teacher may be nominated from each of six schools, whose names will be announced in the fall of 1990. The schools will change with each cycle. In addition to gaining professional enrichment, the teachers will provide continuity and support to the students and advice on projects. SACAM will also use the teachers as a reference for curriculum development.

Because ORNL is one of DOE's largest multipurpose and multidisciplinary laboratories, Richmond plans to work with several ORNL associate directors to initiate other Saturday Academies at ORNL that will address other topics.

"Many ORNL researchers have participated in science education programs over the years," said Richmond, "and many more are volunteering to help in response to Admiral Watkins' challenge to direct national laboratory talent and energy toward science education programs."

Industry Sponsors Student

The Mid-Atlantic Coca-Cola Bottling Company has agreed to pay the expenses of sending a Washington, D. C., high school student to study engineering at ORNL during the summer of 1990. The selected student, Donnell Little, 17, is a senior at H. D. Woodson High School. Industry sponsorship is a promising means of increasing the funding available for educational outreach at ORNL.

Richmond is optimistic about DOE's efforts to form partnerships and agreements with members of the private sector, such as the Mid-Atlantic Coca-Cola Bottling Company, and with state, federal, and other agencies to cooperate in educational reform. "If these model efforts are successful," says Richmond, "they may grow into regional and possibly national activities."

DOE recently signed memoranda of understanding with the Appalachian Regional Commission (ARC) and with NASA that call for collaborative work between these agencies and DOE contractor laboratories. ORNL is included in the DOE-ARC memorandum.

"I believe it is important to build suppport from private industry into our national educational reform efforts," said Richmond, "because they will be a major user and beneficiary of the nation's educational products." ornl

"I believe it is important to build suppport from private industry into our national educational reform efforts."

Much smaller than a penny, an ORNL-developed solar-powered transmitter system emits an infrared signal that has been detected at distances of more than 1 km in stationary field tests at the Laboratory. Designed to be small enough to attach to an Africanized bee to help track the bees and study their habits as they invade the United States, the chip could also be used for surveillance and telemetry.

"Further reductions in size and weight are possible and may be necessary if the microchip is to be attached to the thorax of an Africanized bee."

Infrared Microchip and Signal Receiver Being Developed

ORNL researchers have developed both a solar-powered microtransmitter system that emits an infrared signal and a prototype detection system that detects the signal from a distance at least twice as far as can be sent by current transmitters of comparable size. If improvements are made, the new technology could be used to continuously monitor the flight directions and to study the mating and foraging habits of Africanized bees, which are expected to invade the United States in 1991.

The motivation behind the development of this technology was the need for a line-of-sight system for tracking Africanized bees. However, since an earlier announcement that the technology was being developed, considerable interest has been expressed in ORNL's efforts to develop lightweight, self-powered, low-cost transmitters. Needs for this technology have been identified in such diverse areas as biological tracking, inventory control, security and surveillance, and arms control treaty verification.

Diedre and Kelly Falter, Gary Alley, and Jim Rochelle of ORNL's Instrumentation and Controls (I&C) Division working with Pam Fleming, Russ Westbrook, and Jay Jellison of the Solid State Division have developed a prototypical transmitter chip measuring about 4 × 6 mm and weighing about 65 mg. Further reductions in size and weight are possible and may be necessary if the microchip is to be attached to the thorax of an Africanized bee. The U.S. Department of Agriculture has demonstrated that a honeybee can carry at least 50 mg without adverse effects.

Current tracking methods have very limited ranges and cannot continuously follow individual insects. Preliminary field tests of ORNL's prototypic transmitter have shown that the infrared signal can be detected as far away as 1.1 km.

The chip is the result of existing capabilities at ORNL for the custom development of very-large-scale integrated circuit designs and solar cells. The microchip includes nine solar cells, a capacitor, and a laser diode, which produces the infrared signal. These are mounted as hybrid components directly on a silicon substrate, which also contains control and driver circuitry.

Both the laser diode driver switch and the transmitter control circuits (which fire pulses to activate the laser diode when the capacitor is sufficiently charged by solar energy) were designed by I&C engineers on SUN engineering workstations using the latest in computer-aided design tools. These components were integrated into a silicon chip by the Metal Oxide Semiconductor Implementation Service (MOSIS) facility in Marina del Rey, California. MOSIS is sponsored by the federal Defense Advanced Research Projects Agency and the National Science Foundation.

The infrared signal receiver takes advantage of the optical power magnification available from an 8-in. telescope. The receiver filters out solar "background noise" for daytime testing and uses special detector electronics.

The I&C researchers have proven the basic concept of a self-powered infrared transmitter microchip. However, they are trying to make the transmitter-receiver system more practical by reducing the chip weight and cost (e.g., by integrating solar cells with the control circuitry on the same substrate), developing an automated tracking system that can continuously monitor a target's movement, and devising a system for giving transmitted signals uniquely identifying codes to distinguish between multiple targets—for example, individual microchip-carrying queen bees and drones on a mating flight.

Additional funding to support further development of the chip is needed before it will be ready for full-scale production and commercial use.

Vegetation Helps Microbes Clean Up Contaminated Soils

Chemically contaminated soils may be cleaned up more rapidly by soil microorganisms if vegetation is present, according to research sponsored by DOE's Hazardous Waste Remedial Action Program.

The research, conducted at ORNL using soils collected from the Savannah River Site in Aiken County, South Carolina, showed that soils tainted with the common groundwater pollutant trichloroethylene (TCE) were decontaminated by microorganisms faster in soils surrounding plant roots than in similarly polluted soils lacking vegetation. The results of the research were published in the April 1990 issue of *Applied and Environmental Microbiology*, a journal of the American Society for Microbiology.

"Our results suggest that vegetation could be used to stimulate naturally occurring microbes to restore hazardous waste sites to safe conditions," said Barbara T. Walton, of ORNL's Environmental Sciences Division. She performed this research on biological remediation of waste sites in collaboration with Todd A. Anderson, a student in the Graduate Program in Environmental Toxicology at the University of Tennessee at Knoxville.

"Our results suggest that vegetation could be used to stimulate naturally occurring microbes to restore hazardous waste sites to safe conditions."

Soil microorganisms are known to thrive in soil regions penetrated by plant roots because the microbes are nourished by sugars, amino acids, and other substances that are released by the roots. Studies have shown that several herbicides and insecticides are less persistent in the soil's root zone than in soil without roots.

"We collected soil samples from a former disposal site for chlorinated solvents and compared microbial degradation of TCE in soil root zones with that in nonvegetated soils," said Walton. "Our findings indicate that vegetation may be used to actively promote microbial restoration of chemically contaminated surface soils and near-surface soils."

At the Savannah River Site, Walton and Anderson examined the Miscellaneous Chemicals Basin, which had been used as a chemical disposal site since around 1956. After disposal was stopped in 1974, the basin area was graded, and it became naturally vegetated with weeds, grasses, and pine trees that are now about ten years old.

"A risk assessment of the basin revealed that the contaminants had not reached the water table and

University of Tennessee graduate student Todd Anderson collects soil samples at the Miscellaneous Chemicals Basin at the Savannah River Site. He and toxicologist Barbara Walton of ORNL have found that chemically contaminated soils may be cleaned up more rapidly by soil microorganisms if vegetation is present.

posed no immediate threat to public health or the environment," said Terry Hazen, project officer at Westinghouse Savannah River Company, which operates the Savannah River Site for DOE.

In six-day experiments with the four most common plant species on the site, Walton and Anderson found up to twice as great a TCE loss in the vegetated soils as in the nonvegetated, contaminated soils. They also found that microbes from a legume's root zone could break down TCE to yield carbon dioxide, whereas the control samples—soils without living microbes and nonvegetated soils—did not.

Atmospheric Carbon Dioxide Responds to Fossil Fuel Emissions

Rising concentrations of atmospheric carbon dioxide could intensify the "greenhouse effect" in which the atmosphere absorbs infrared radiation from Earth's surface, resulting in climatic change that includes substantial warming in many regions. One approach to slowing global warming is to reduce the use of fossil fuels, the primary cause of atmospheric CO_2 increases.

However, modeling studies performed by ORNL's Environmental Sciences Division suggest that concentrations of atmospheric CO_2 will continue to rise, although much more slowly, even if fossil fuel burning is reduced to 50% of the current level. Results obtained by William Emanuel, Anthony W. King, and Wilfred M. Post show that CO_2 releases from fossil fuels must be as low as *one-sixth* the current amount for atmospheric CO_2 concentrations to remain approximately constant.

Between 1750 and 1987, the carbon content of Earth's atmosphere increased by 150×10^{15} g in response to the injection of 200×10^{15} g from fossil fuel combustion and cement manufacturing. In other words, the increase in the carbon content of the atmosphere is less than the contribution from fossil fuels and other human activities. The accumulation of CO_2 in the atmosphere is less than the amount introduced by fossil fuel burning largely because of uptake by the oceans, which contain about 50 times more carbon than the atmosphere. Thus, atmospheric CO_2 concentrations might be expected to decrease after an abrupt reduction of fossil fuel emissions as the oceans continue to absorb carbon from the atmosphere.

Three sets of processes are responsible for the uptake of carbon from the atmosphere by the oceans: (1) the CO_2 exchange across the air-sea boundary, (2) the incorporation of surface water carbon into carbonate compounds, and (3) the transfer of carbon from surface water to deep water by mixing and circulation. The two-way exchange of carbon between the air and sea appears to be the most important process for determining the response of the oceans to atmospheric CO_2 following a sharp reduction in fossil fuel emissions. The reason is that turnover times of carbon in the upper layers of the ocean are rapid compared with the atmospheric response time associated with the flux from the atmosphere into the oceans.

These processes are taken into account by a widely applied model of carbon turnover in the atmosphere and oceans. Scientists are modeling the carbon cycle to try to determine how much of the additional CO_2 introduced to the atmosphere by increased fossil fuel burning would be removed from the atmosphere.

The ORNL simulations using this carbon turnover model indicate that atmospheric concentrations of CO_2 will not decrease, even if fossil fuel emissions are reduced to half of current levels. CO_2 uptake by the oceans was estimated for different scenarios in which fossil fuel emissions are reduced to two-fifths, one-fourth, and one-sixth of the current level (the 1989 value of 6×10^{15} gC/year). The ORNL group used data on fossil fuel releases between 1860 and 1987 provided by Gregg Marland and others of the Environmental Sciences Division and measurements of changing concentrations of CO_2 in ice-core air collected by scientists at the University of Bern in Switzerland to describe past changes. The ORNL results indicate that uptake by the oceans cannot be relied upon to offset continued fossil fuel burning, even at significant levels of reduction.

Models having more temporal resolution may be needed to make accurate assessments of the response of the atmosphere-ocean system to quick emissions reductions. The linkages between climate and the carbon cycle on time scales of decades may be important.

The ORNL researchers point out that additional atmospheric carbon may be absorbed by changes in vegetation and soils, such as planting trees and slowing the clearing of tropical moist forests. Also, elevated levels of atmospheric CO_2 may stimulate plant productivity, perhaps leading to more uptake of atmospheric carbon.

Dinobusting in New Mexico

Thanks to Alan Witten's acoustic imaging technique, the skeleton of the enormous Seismosaurus, possibly the longest dinosaur ever found, is rapidly being unearthed from its site in New Mexico. Witten, an engineer in ORNL's Energy Division, has used his technique to image 10 to 12 bones.Two of the bones he located have been excavated thus far. One was of a neck vertebra whose position shows that the neck is curved back in rigor mortis. The team has also removed the base of the tail, other vertebrae, a pelvis, and several ribs from the 37-m- (120-ft-) long dinosaur's skeleton.

By showing the paleontologists where to dig, Witten's technique has shortened the excavation time from 10 to about 2 years. Because they know precisely how deep a bone lies, they can clear away surface earth quickly with modern machinery rather than tediously with picks and shovels. And because several bones have been positively located, it is much simpler to locate the remaining bones in this undisturbed skeleton. Speed of excavation is a major achievement in a field that, although of enormous popular interest, does not draw much funding.

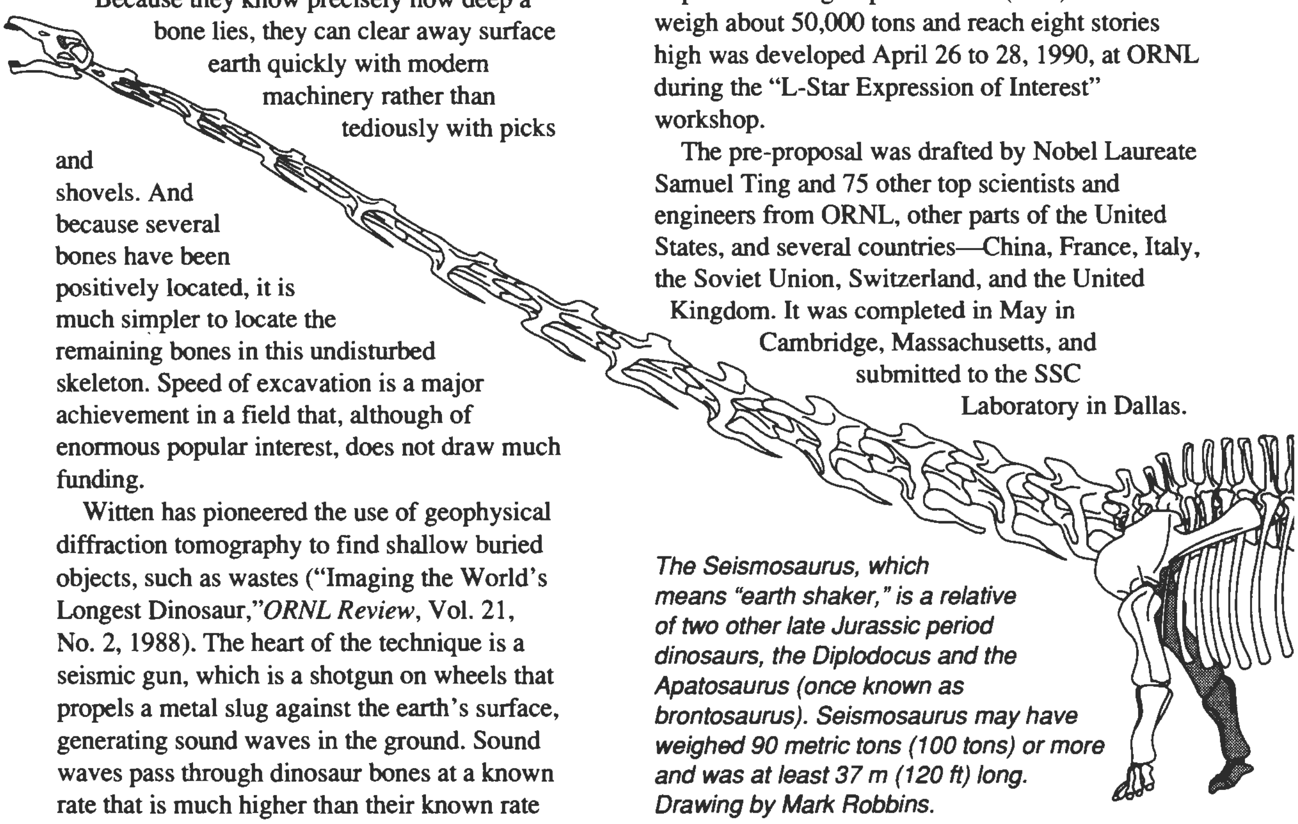
Witten has pioneered the use of geophysical diffraction tomography to find shallow buried objects, such as wastes ("Imaging the World's Longest Dinosaur,"*ORNL Review*, Vol. 21, No. 2, 1988). The heart of the technique is a seismic gun, which is a shotgun on wheels that propels a metal slug against the earth's surface, generating sound waves in the ground. Sound waves pass through dinosaur bones at a known rate that is much higher than their known rate through sandstone at the site. The image of the bone and its location are constructed by comparing the known speeds of sound through the sandstone and bone as the sound reaches a set of 29 microphones in a nearby bore hole (one of three at the site). The technique is particularly effective for locating such a large dinosaur because the huge bones are fairly easy to image.

Witten has given information on his "dinobusting" technique to *Weekly Reader*, Time-Life Books, and a couple of grade school science textbooks. He would like to continue imaging the Seismosaurus but currently has no plans to return to the site because no additional funding is available.

SSC Detector Bid Submitted

A pre-proposal to build a particle detector for the Superconducting Super Collider (SSC) that would weigh about 50,000 tons and reach eight stories high was developed April 26 to 28, 1990, at ORNL during the "L-Star Expression of Interest" workshop.

The pre-proposal was drafted by Nobel Laureate Samuel Ting and 75 other top scientists and engineers from ORNL, other parts of the United States, and several countries—China, France, Italy, the Soviet Union, Switzerland, and the United Kingdom. It was completed in May in Cambridge, Massachusetts, and submitted to the SSC Laboratory in Dallas.



The Seismosaurus, which means "earth shaker," is a relative of two other late Jurassic period dinosaurs, the Diplodocus and the Apatosaurus (once known as brontosaurus). Seismosaurus may have weighed 90 metric tons (100 tons) or more and was at least 37 m (120 ft) long. Drawing by Mark Robbins.

This pre-proposal is in competition with 13 other pre-proposals (five major ones) for $6 million to further develop a proposal for building a massive detector. A decision on which groups will be awarded funds is expected in October.

The SSC is a multi-billion-dollar national project proposed to be built in Texas. It will accelerate protons to an energy of 20 trillion electron volts in both directions around a 54-mile ring. The SSC will be the world's largest tool for studying the basic nature of matter and energy.

Recently, ORNL was awarded $388,000 from the SSC Laboratory to conduct research to improve the technical performance of detectors for the SSC. The award includes $200,000 this fiscal year for basic detector studies and $188,000 for improving detector subsystems. The work will be coordinated through the new Oak Ridge Detector Center.

If the L-Star proposal is approved, ORNL will be heavily involved in the development of a calorimeter for the detector as well as the system integration of the entire detector. This calorimeter is used to determine the kinetic energy of particles, such as protons, neutrons, electrons, and gamma rays.

Another involvement of ORNL with the SSC is through the Southern Association for High Energy Physics (SAHEP), an organization formed by approximately 20 universities, laboratories, and private industries. This organization, of which ORNL is a member, is collaborating with the Detector Center on design and development of various parts of generic and specific SSC detector systems.

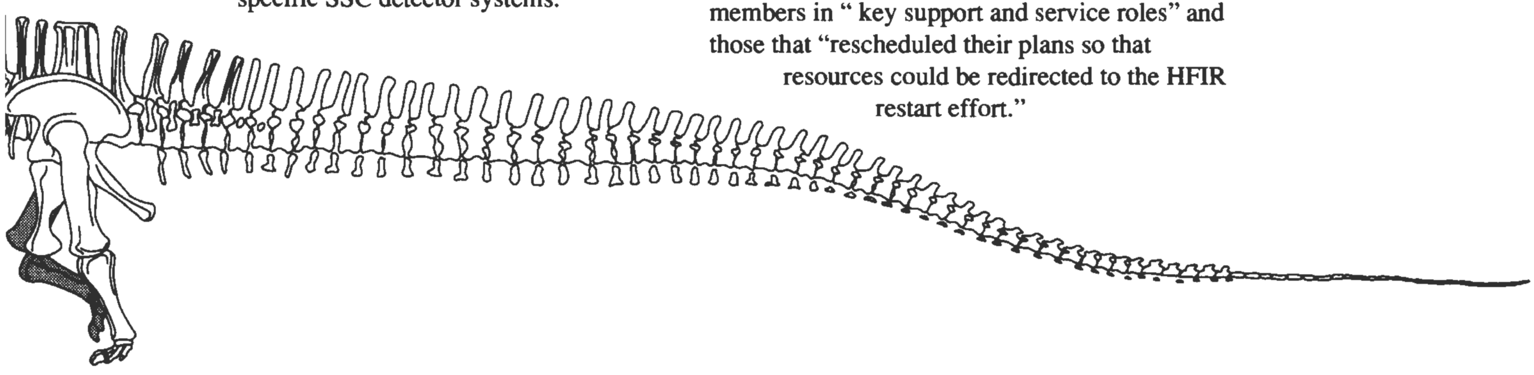
HFIR Back to Full Power

On May 18, 1990, ORNL's High Flux Isotope Reactor was restored to full-power operation at 85 MW, a major milestone for the Laboratory's research reactor programs. This event marked the first time since November 14, 1986, when the reactor was shut down for maintenance, that the HFIR has operated at its full-power limit.

The HFIR remained shut down for three-and-a-half years because of concerns about pressure vessel embrittlement and reactor management issues. In March 1987, four other ORNL research reactors were shut down, one permanently. In January 1990, the HFIR began operating at 11 MW, and in April DOE gave ORNL permission to raise the reactor's power level in stepwise fashion to 85 MW.

According to Jackson B. Richard, ORNL director of Reactor Operations, "The HFIR, the world's most powerful research reactor, is a vital facility at ORNL that is essential for physical sciences research and the production of radioisotopes. The fact that it is once again available for these important missions is of note to the worldwide scientific and medical community."

Richard credits the Laboratory staff for participating in the "difficult struggle" to restart the HFIR and three other research reactors (the Tower Shielding Reactor was restarted in December 1989). Besides the restart team, Richard cites the work of the ORNL staff members in " key support and service roles" and those that "rescheduled their plans so that resources could be redirected to the HFIR restart effort."



An ORNL-developed method for using high-intensity electric fields to control solvent-extraction processes improves performance efficiency 100 times while using only 1% of the energy required by devices now in use. Here, Timothy Scott (left) operates the electrically driven emulsion-phase contactor while Ron Brunson works with a related device, the electric-dispersion reactor.

Efficient Chemical Recovery System

An ORNL-developed separation system for rapidly recovering chemicals dissolved in water has been licensed by Martin Marietta Energy Systems, Inc., to two U.S. companies.

Using pulsed electrical fields to control solvent extraction, the new ORNL method separates chemicals up to 100 times more efficiently than devices now in use, while using considerably less energy and space. The extracted chemicals may be either valuable products or pollutants.

Analytical Bio-Chemistry Laboratories of Columbia, Missouri, will develop the technology for use in analytical laboratory equipment. National Tank Company of Tulsa, Oklahoma, will incorporate it into large-scale processing systems for the metals and petroleum industries.

Solvent extraction is a separation technique widely used by industry to purify products. In solvent extraction, a substance is transferred from one liquid by dissolving it into a second one that does not mix with the first liquid. The movement of a substance from one liquid to another is called mass transfer. To increase mass transfer rates, conventional solvent-extraction systems agitate the mixture using mechanical mixers, which require energy to operate.

By subjecting the liquid mixture to high-intensity electric fields, ORNL researchers have obtained mass transfer rates 100 times greater than those achieved by mechanical systems. The ORNL system is also energy efficient, using 1% of the energy required by a mechanically agitated system. Because of its higher efficiency, the recovery method can be accomplished in vessels that are one-tenth the size of those used in conventional solvent extractors.

The technology, called the electrically driven emulsion-phase contactor, forces water containing the chemical through a nozzle between two electrodes. There a pulsed electrical field shatters the water particles into tiny drops that are passed through a solvent. The chemical in the water transfers to the solvent, from which it is recovered by conventional means.

Tim Scott and Bob Wham invented the technology, and Charlie Byers contributed to its development. All are members of the Chemical Technology Division. The research was supported by DOE's Office of Basic Energy Science, and the licenses were negotiated by Glen Prosser of the Energy Systems Office of Technology Applications.

Precision Etching Technology

Energy Systems has granted commercial rights to SEMATECH, INC., for technology improvements developed at ORNL that could enable U.S. manufacturers to produce better semiconductor chips for the electronics industry.

The technology involves precision etching techniques using plasma (ionized gas) to fabricate high-density semiconductor chips. Precision etching is a critical step in producing semiconductor chips.

The developers of the etching techniques are Chin-Chi Tsai and Lee A. Berry of ORNL's Fusion Energy Division and Steven M. Gorbatkin of the Solid State Division.

SEMATECH is a consortium of 14 U.S. semiconductor fabricators. Manufacturers could use improved chips to produce computer electronic products that are more compact and powerful.

Under a Work for Others agreement with SEMATECH announced in 1989, ORNL researchers will pursue additional refinements to the licensed technology and evaluate several experimental etching concepts for fabricating high-density semiconductor chips. After SEMATECH selects the best technology, it will be transferred to a U.S. tool manufacturer who will incorporate the technology into a production tool.

Iridium Generator for Heart Patients

A radionuclide generator system designed and developed at ORNL to improve the diagnosis of heart diseases has been licensed by Energy Systems to Scintillation Technologies Corporation of Maryville, Tennessee. The company plans to market the generator in conjunction with a gamma camera system it has developed. This is the first license for a radiopharmaceutical developed at ORNL for clinical use.

The iridium-91*m* generator is in the final stages of animal toxicity testing required by the Food and Drug Administration before clinical testing can begin in the United States. The first tests of the device on American patients are expected to begin in September 1990 at the Houma Heart Institute in Houma, Louisiana, which is located in a parish having one of the highest incidences of heart disease in the nation. The patented generator, which was conceived in 1981 and developed over six years using funds from DOE's Office of Health and Environmental Research, has already been tested in more than 600 patient studies in several hospitals in Belgium, the Federal Republic of Germany, Finland, and France.

The small bedside generator uses an activated carbon column to separate the short-lived decay daughter, iridium-191*m*, from its parent radionuclide, osmium-191 (which is being produced again by ORNL's High Flux Isotope Reactor). The osmium-191, which has a two-week half-life, is retained at the top of the column, and the rapidly decaying iridium-191*m* radioisotope is flushed by an eluting solution

"ORNL researchers will . . . evaluate several experimental etching concepts for fabricating high-density semiconductor chips."

Russ Knapp demonstrates a prototype of the iridium-191*m* generator developed for bedside injection of the short-lived isotope directly into a patient's bloodstream. The technology has been licensed to a Maryville firm that plans to manufacture and market the generator, along with a heart-imaging system the company has developed.

"This is the first license for a radio-pharmaceutical developed at ORNL for clinical use."

through the column for immediate injection into a patient's vein.

Because the iridium-191*m* decay daughter has a 4.96-s half-life (it degrades completely into a nonradioactive substance after ~2 min in the body) and the isotope emits gamma photons of a suitable energy, it is safe and produces high-quality images of the heart. Most important, its short half-life allows tests to be repeated rapidly on the same patient, enabling physicians to gauge the effects on the heart of exercise and drug therapy.

Each year in the United States, heart function tests are performed in about 500,000 adults and about 20,000 children born with congenital heart disease. The generator is expected to be particularly useful for evaluating heart function in adults and, because of the low radiation dosage from the iridium isotope, for diagnosing the nature of congenital heart defects in children.

The cross-section model shown in the photograph on this page represents the generator, which would hold osmium-191 placed on specially treated activated carbon. (An actual generator would be completely enclosed by lead.) The rectangular box is a microprocessor-controlled pump that pushes an acidic saline solution through the generator to remove the iridium-191*m*, produced from osmium-191 decay; it also pumps another solution to neutralize the saline solution as it leaves the generator.

The large syringe mounted on the stand contains a normal saline solution that is used to manually flush the iridium-191*m* quickly into the patient's bloodstream, which takes the isotope to the heart. A rapid series of pictures are taken with a gamma camera imaging device to evaluate the passage of the radioactive blood through the vascular system and heart chamber. The information obtained on the heart's pumping efficiency indicates whether the heart is healthy or diseased.

The device was invented by F. F. (Russ) Knapp, Jr., leader of the Nuclear Medicine Group in ORNL's Health and Safety Research Division, in collaboration with Tom Butler, now retired from ORNL, and Claude Brihaye, a visiting scientist from Belgium. Glenn Prosser, of the Energy Systems Office of Technology Applications, handled negotiations for the licensing agreement.

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Next Issue

ORNL researchers' experiments with the HERMIES-III robot (shown here in action) will help them develop an intelligent, unsupervised robot for hazardous environments.