Volume 21 Number Two 1988

# REVIEW

Oak Ridge National Laboratory

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*Volume 21* *Number Two 1988*


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

**ON THE COVER**

ORNL's laser ablation technique for producing thin films of high-temperature superconducting materials is an example of the "gee whiz" achievements described in Herman Postma's recent "State of the Laboratory" address. See page 2. (Photograph by Bill Norris.)


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# Features



# Departments

# State of the Laboratory: "Gee Whiz" Achievements

By Herman Postma

*"'Gee Whiz' discoveries can be the stuff from which the United States could gain and sustain a competitive edge in science and technology and in the world marketplace."*

On February 2, 1988, Herman Postma delivered his last State of the Laboratory address as ORNL director. He is now senior vice-president of Martin Marietta Energy Systems, Inc.

As I look back over my 14 years as director of Oak Ridge National Laboratory, I am impressed by the many discoveries and developments that have occurred here, both expected and unexpected. Most have resulted from perseverance and technical virtuosity, but in some cases, dumb luck has played an important role. Such achievements are often due to serendipity—the ability to recognize important results not sought after. This combination of good luck and researcher intelligence has produced many surprising and even improbable findings at ORNL—the kind that make even cool-headed scientists and jaded science writers say, "Gee whiz!"

"Gee whiz" discoveries can be the stuff from which the United States could gain and sustain a competitive edge in science and technology and in the world marketplace. ORNL's serendipitous developments help Laboratory groups to be the first and best in a field, solve problems, attract outstanding talent, encourage innovation, create markets for products, and stimulate economic growth. I salute ORNL's "gee whiz" achievements of 1987—the theme of my final State of the Laboratory address.

I will also discuss other important ORNL developments in science and technology, elaborate on some 1987 milestones, announce the winner of the annual Director's Award, and present an outlook and retrospective. Following are the theme-related technical highlights.

TECHNICAL HIGHLIGHTS: GEE WHIZ

# *ORNL Demonstrates Microwave Processing of Ceramics*


The alumina cup on the right, which has been heated by high-frequency microwaves, is much denser than its unheated counterpart.

ORNL fusion energy and materials researchers have found that, compared with conventional heating, high-frequency microwaves can produce stronger, denser ceramic products at lower temperatures. This discovery could revolutionize ceramics processing and the quality of ceramic products.

The microwave-ceramic project started about four years ago as a result of conversations between Hal Kimrey and ORNL ceramists Paul Becher and Matt Ferber. Kimrey was trying to determine why gyrotron windows through which microwaves are passed eventually fracture. After Kimrey and the ceramics group did some modeling, they recognized that microwaves at high frequencies could be used to heat ceramics to melting temperatures.

The researchers, led by Kimrey of the Fusion Energy Division and Mark Janney of the Metals and Ceramics (M&C) Division, are using a gyrotron to produce the microwave energy for this new process. The project is ideal for an interdisciplinary laboratory; M&C offers ceramics expertise, and the Fusion Energy Division offers the processing technology because it has one of the few gyrotrons of this type available in the world. The gyrotron was originally used for plasma heating at the Elmo Bumpy Torus, an ORNL experimental fusion device that was shut down in 1984. Gyrotron technology provides, for the first time, significant average power (200 kW, continuous wave) in the upper microwave frequency regime (28 to 140 GHz).

The idea of using microwaves for processing ceramics is not new, but the ORNL researchers are the first group to heat-treat large ceramic parts using this approach. Kimrey is the first to microwave process samples as large as 320 cm$^3$. Experiments have shown that high-purity alumina can be heated rapidly and uniformly using microwaves having a frequency of 28 GHz. Ceramics processed this way easily reach the temperature at which they sinter—form a highly dense, coherent mass without melting—and avoid the formation and growth of interparticle necks, which limit densification at the typically slow conventional heating rates.

The new ceramic processing technique employs an ORNL microwave furnace that is about 15 times the size of a typical microwave oven. With this furnace, the research team has demonstrated

Mark Janney checks a glowing silicon carbide cylinder that has just been heated with low-frequency microwaves in an ORNL furnace.

Samples of various ceramic "green bodies" formed by conventional processing will be "fired," or heated to sintering temperatures, by microwaves from an ORNL gyrotron.

that microwaves can uniformly shrink and strengthen certain ceramics and ceramic composites. In microwave heating, energy is absorbed throughout the volume of a material. As a result, the material heats uniformly without variations, or gradients, in temperature. In conventional radiant heating, energy is absorbed only at the material's surface and moves by conduction into the material's bulk. Because thermal conduction takes time, temperature gradients exist within the material being heated to the sintering temperature. Fracture-causing stresses are created by these gradients because some parts of the material shrink faster than others.

Several benefits were expected as a result of the microwave processing. The more uniform temperature distribution provided by microwave processing leads to more uniform shrinkage and more uniform ceramic microstructures. The resulting high density increases the material's strength and resistance to fracture. The microwave process may also increase the speed and decrease the cost of producing ceramic products. Using conventional radiant heating, manufacturers can produce high-density ceramic products at temperatures approaching 1600°C. Using microwave heating, ORNL researchers have increased the densities of alumina samples to 97% of theoretical density, at temperatures as low as 1100°C! This was a totally unexpected gee-whiz result that still has not been explained.

Applications for the new process could include ceramics for advanced gas turbine engines, lightweight armor for defense purposes, and ceramics for electronics, including improved high-temperature superconducting materials that conduct electricity with zero resistance and heat loss. Other uses could be the production of specialty glasses and the joining of ceramic parts. Advanced engines, which operate at high temperatures to maximize fuel efficiency, require heat-resistant ceramic components instead of metal parts, which would melt at such high temperatures. Ceramics are also needed to build tough, lightweight helicopter seats to protect pilots and for a new generation of armored personnel carriers and tanks that are lighter and faster than their heavy steel predecessors.

*"Researchers at ORNL are testing the microwave technique on the new superconducting ceramics to see whether it can reduce their brittleness and enable them to carry more current."*

The ORNL microwave process can produce monolithic ceramics without adding the impurities required in conventional processing. This ability offers a distinct advantage, because eliminating or reducing the amount of impurities increases the high-temperature strength of monolithic ceramic substances such as alumina, silicon carbide, silicon nitride, titanium boride, and titanium nitride.

The method is also suitable for processing ceramic composites and whisker-reinforced or particle-reinforced ceramics. All these materials have high fracture toughness, hardness, compressive strength, and tensile strength. Microwaves may prove particularly useful for strengthening large, complex, ceramic parts after they are formed and processed by conventional means. Researchers at ORNL are testing the microwave technique on the new superconducting ceramics to see whether it can reduce their brittleness and enable them to carry more current.

## ORNL Makes Films and Crystals of High-Temperature Superconductor

Thin films of high-temperature superconducting materials are needed for basic research and for the manufacture of components for computers, compact electronic devices, and radiation detectors. Many laboratories have sought to fabricate films from the superconducting oxides discovered last year, particularly the yttrium-barium-copper-oxygen (Y-Ba-Cu-O) ceramic. In 1987, scientists David Geohagan, Douglas Mashburn, Djula Eres, Douglas Lowndes, Brian Sales, and Lynn Boatner, of ORNL's Solid State Division, made crystalline thin films from both the $YBa_2Cu_3O_7$ superconductor and one of the same family in which holmium (Ho) is substituted for yttrium.

Although conventional deposition techniques such as sputtering and thermal co-evaporation can be used to deposit these superconducting materials on a substrate, obtaining the correct deposition conditions simultaneously for dissimilar elements such as yttrium, barium, and copper causes severe problems. ORNL scientists used a novel pulsed-laser technique called laser ablation to overcome these problems and layer the elements in the proper ratios. They were able to fabricate partially oriented, crystalline thin films of both $YBa_2Cu_3O_7$ and $HoBa_2Cu_3O_7$ on strontium titanate ($SrTiO_3$) substrates.

In this process, pulses of ultraviolet light from an excimer laser were focused onto the bulk superconducting ceramic. Each pulse ablated, or vaporized, part of the material onto a nearby substrate. The researchers found high-fluence deposition conditions that resulted in films having the same stoichiometry (ratio of elements) as the parent target specimens. They also found that, after oxygen annealing, the laser-deposited films have a partially crystalline orientation and exhibit superconductivity at the same liquid-nitrogen temperature as the bulk specimens. Laser ablation produces thin films more rapidly, provides more precise control, and is simpler to use than other deposition techniques.

ORNL scientists have also used the "flux technique" to grow single-crystal research specimens of several of the superconducting ceramics. Single crystals of these materials, which grow in the form of thin square or rectangular plates, are valuable for investigating the basic physical and electronic properties of this new class of materials.

The properties of these crystals are already being determined, using X-ray analysis, transmission electron microscopy, ion bombardment, and ion channeling. In particular, ion-channeling methods are being used to study defect production and damage mechanisms in these materials.

The production of both thin films and single crystals of superconducting ceramics was made possible by existing ORNL materials processing capabilities. These techniques were developed in unrelated research efforts, yet they have helped advance the new science of high-temperature superconductors—an outcome that would have seemed improbable a year ago.

ORNL's laser ablation technique has produced thin films of high-temperature superconducting material. The bright light in the center is emitted by the plasma generated when an excimer laser beam vaporizes a pellet of superconducting material for deposition on a substrate.

## Computer Model Shows Learning

Physicist Bill Dress of ORNL's Instrumentation and Controls Division has a bug in his computer—not the type that crashes computer programs, but a synthetic, adaptive insect created by a computer program. This unique program demonstrates that an artificial "neural network" can "learn" and improve its responses to stimuli.

Dress's bug and its offspring have simulated brains, eyes, mouths, and feelers. When created, the insect has no "knowledge" of its environment; it must learn from scratch how to respond to pain (skull and crossbones) encountered at the edges of the computer screen and to pleasure, in the form of food (Diet Coke), near the center of the screen.

In the ORNL computer model, the synthetic, adaptive insect "brain" consists of around 200 simulated nerve cells, or neurons, each of which communicates with about 20 other neurons by means of hard connections. In contrast, more than 10 billion neurons make up the human brain, each communicating with hundreds or even tens of thousands of other neurons.

*"The ORNL work on 'neural nets' is a step toward designing fully adaptive, synthetic intelligent systems, such as robots, to perform jobs too complex, boring, or dangerous for humans."*

Evolution is also important in this model. The operation of the brain and its mechanisms for processing incoming data from the simulated sensory organs are just too complex to be programmed in detail for a viable, fully functional creature. The model has about 50 parameters, representing neuron firing rates, intensity of touch and vision, contraction strengths of muscle cells, etc. Each of these parameters may be thought of as a gene ready to be improved in a process of evolution, and the primitive bug's responses are used to reveal which parameter changes are beneficial.

The human brain is also vastly superior to the ORNL program because its neurons operate simultaneously, like a parallel processing machine. The ORNL simulation partially compensates for this lack of parallelism by using a very-high-speed microprocessor in conjunction with a personal computer.

To simulate the insect's central nervous system, Dress uses a high-speed Novix NC4016 microprocessor that has nearly the processing speed of a much more expensive IBM 3033 mainframe computer. Because of its extensive parallel internal organization, this advanced microprocessor runs the neural network model at rates exceeding 100,000 connection updates per second, allowing the bug's neural network to respond almost as quickly as humans do to new sensory information. To develop the model, Dress wrote a program for an Apple Macintosh personal computer that simulates the bug's environment and serves as its experiment control station.

The neural network, which uses the principles of mutation and natural selection to "evolve" a neural architecture for a particular use, is designed to process information that is coded as the pulse frequency. Dress calls his computer simulation a frequency-based model of an artificial neural network.

How does the evolutionary process work in the ORNL model? The first few bugs barely functioned, ignoring the food and caring little about the pain. After a few generations, a descendant creature learned to avoid the edges of the screen—pain. It also learned to like food when its "taste buds" sufficiently evolved to convey the appropriate pulse frequency (information) to its brain.

The insect at the skull and crossbones "feels pain" because it is receiving a "jab" of high-frequency input through a few feeler cells. The high frequencies disrupt the flow of information through the network. Being jabbed is enough to break anyone's concentration! At the food center, the insect "feels pleasure" because it is receiving lower-frequency input from a large number of taste cells.

Each synthetic insect is allowed to create one offspring at a time. The computer program measures the performance of the offspring and compares it with that of its parent. If the offspring shows no improvement over the parent, the computer program "kills" it and creates a new descendant by making a small random mutation to one of the parent's genes (parameters). After 20 or 30 tries, spanning perhaps five or six generations, the bug's performance greatly improves—it learns to seek the food and avoid the pain of the screen edges.

The ORNL work on "neural nets" is a step toward designing fully adaptive, synthetic intelligent systems, such as robots, to perform jobs too complex, boring, or dangerous for humans. Dress believes that a few hundred high-speed microprocessors similar to the one used for this project, each processing a network of a few thousand simulated neurons, could be used to build a reasonably large simulated brain in the near future. Such a brain would give a robot the "intelligence" to learn, function, and respond in rather complex environments.

## Soil Microbe May Destroy PCBs

Since the late 1960s, we have known that polychlorinated biphenyls (PCBs) are highly toxic to humans. Regulation of PCBs in the United States was established in 1976 by passage of the Toxic Substances Control Act; their manufacture has since been banned in this country. Yet PCBs

D. L. (Dusty) Hill checks the lysimeters used for the PCB biodegradation tests on the floodplain of Bear Creek.

persist in the environment because of their previous widespread use as dielectric fluids in electrical transformers. On the Oak Ridge Reservation, and on sites all over the United States, some of the soil remains contaminated with PCBs.

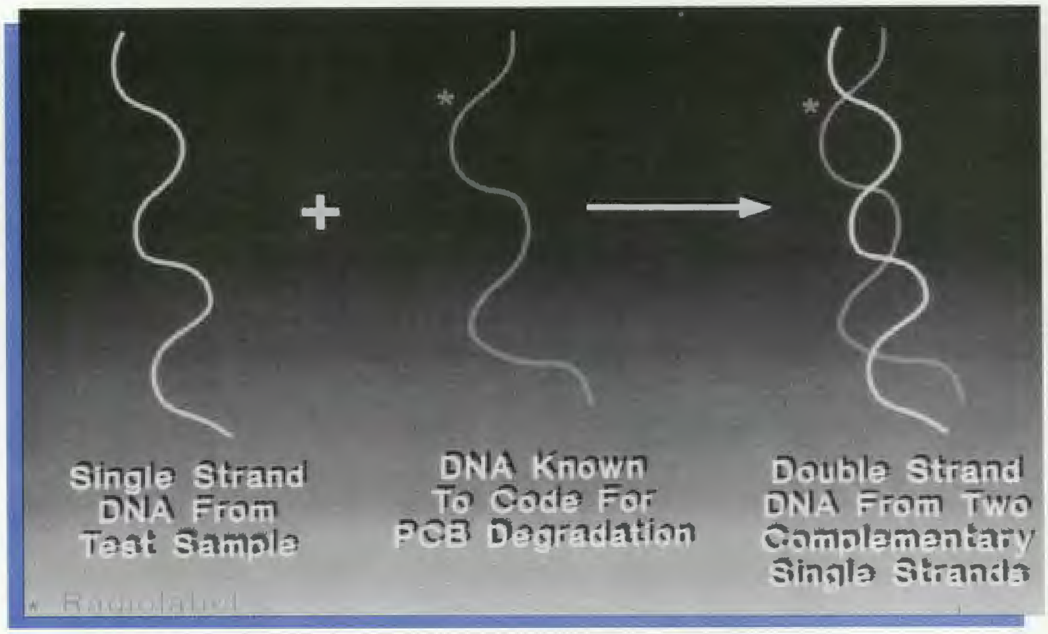
ORNL researchers are investigating the possibility that some soil microorganisms may be able to reduce the level of PCBs in contaminated soils. Early results are promising.

Studies were conducted on a PCB-contaminated site in the Bear Creek floodplain near the Oak Ridge Y-12 Plant. The research team included staff members from ORNL's Chemical Technology and Environmental Sciences divisions (spearheaded by Terry Donaldson and Tony Palumbo); the Oak Ridge Research Institute, a minority-owned technology firm headed by Nathaniel Revis; the University of Tennessee (UT) Institute of Applied Microbiology, led by David C. White (UT-ORNL Distinguished Scientist); and Gary Sayler of UT. This project grew from a recent study of microbial treatment of hazardous wastes, supported by the ORNL Director's R&D Fund.

The microbe-PCB tests were carried out during the summer and fall of 1987 using six lysimeters made from drums cut in half and filled with contaminated soil. The tests were made to determine the soil conditions that are most helpful in promoting effective microbe destruction of PCBs. Using one lysimeter as a control, researchers pumped air through and added various levels of fertilizer and carbon sources to the other five lysimeters. Three of the lysimeters were inoculated with cultures of microorganisms that are normally present in the test site soil and that had been identified by genetic probe assays as capable of degrading PCBs.

In preliminary laboratory studies, soil samples from all lysimeters except the control showed immobilization and biodegradation of a radiolabeled monochlorinated biphenyl, a compound mimicking PCBs. Biodegradation was most pronounced in soil samples inoculated with the identified soil-indigenous microorganisms, suggesting that they play a key role in the PCB destruction.

Results of the ORNL-led studies also suggest that proper management of contaminated areas could increase PCB degradation by indigenous




A gene probe assay was used to determine the presence of PCB-degrading microorganisms in soil. Single-strand DNA from the indigenous microorganisms in the soil is combined with a radiolabeled single-strand DNA known to code for PCB degradation. If the two strands are complementary, they will combine to form double-strand DNA. This DNA form is identified by the radiolabel after the residual single-strand DNA has been removed. The extent of formation of double-strand DNA indicates the genetic capabilities of various microorganisms to degrade PCBs in the soil.

organisms. It appears that aerating, watering, and adding nutrients to the contaminated soil to encourage the growth of PCB-degrading microorganisms could benefit many sites.

The PCB degradation study was completed at the end of 1987. Its favorable results have sparked the interest of sponsors and colleagues across the country. What is most surprising about this serendipitous finding is that microorganisms capable of destroying PCBs may be naturally present in contaminated soil but will not degrade PCBs effectively unless conditions are favorable.

## ORNL Increases Laser Tuning Range 2000-Fold

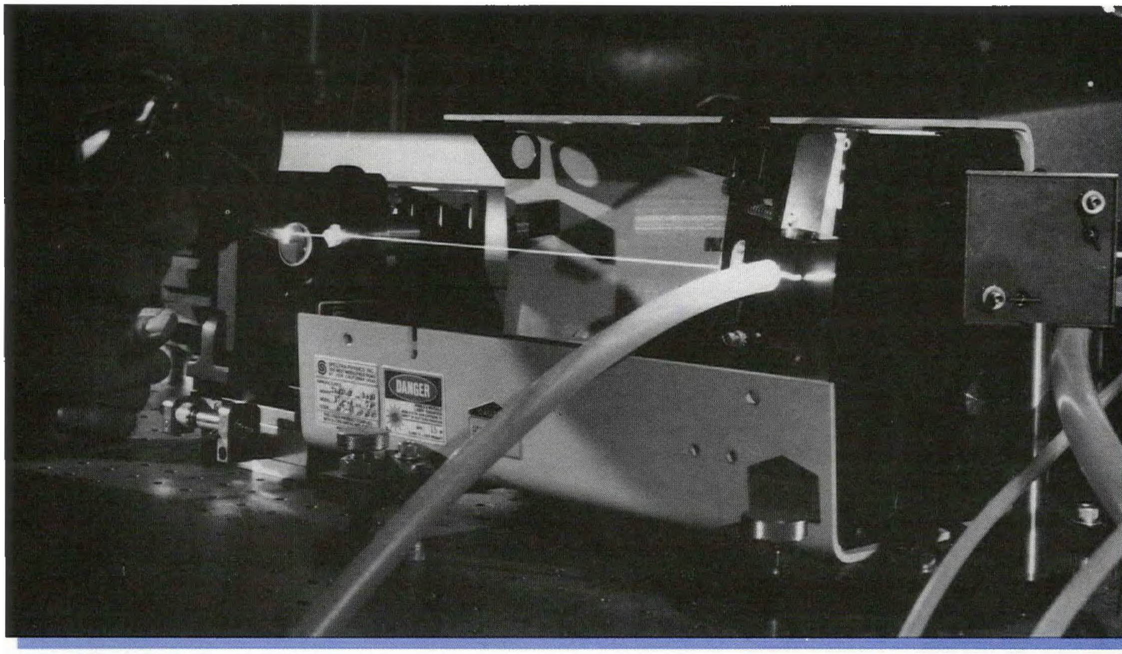
Measurements of the details of atoms and molecules have been made possible by lasers. Because laser light can be "tuned" to a pure color, or particular wavelength, it can be used to evoke a specific effect in an atom or molecule (e.g., emission of a photon). Until now, most lasers could be tuned over only a small range of wavelengths, which limited their experimental uses. For example, the commercially available, high-resolution, continuous-wave, monochromatic dye lasers have been able to scan continuously over only ~30,000 resolution elements, using three tuning elements.

However, a dye laser recently developed at ORNL by Mike Ramsey and Bill Whitten of the Analytical Chemistry Division offers two improvements over the tuning abilities of commercial versions: its single tuning element simplifies operation by scanning continuously over the entire gain bandwidth provided by the laser, roughly 60 million resolution elements, or 2000 times the range of commercial dye lasers!

The ORNL laser's superior tuning capabilities are the result of several unique features:

- a single crystal of photorefractive barium titanate is used as the tuning element;
- a dynamic holographic grating is "written" into the crystal, to narrow the laser's spectrum to a single color; and
- a mechanism is installed which moves the output mirror and crystal in unison to alter the length of the laser cavity (space between the laser's two end mirrors, where a beam of coherent light waves travels).

This third feature makes it possible to tune the wavelength of the ORNL laser beam by simply changing the length of the laser cavity, much as a



This dye laser developed by ORNL's Mike Ramsey and Bill Whitten has simpler operations than and 2000 times the tuning range of commercial dye lasers having comparable resolution. Here, Whitten adjusts a laser mirror for maximum output.

violinist changes string length to alter pitch.

The ORNL improvements in laser tuning are expected to have applications in both dye and diode lasers and, because of their magnitude, will likely open some new avenues for research in this area.

## ORNL Develops Energy-Efficient Separation System

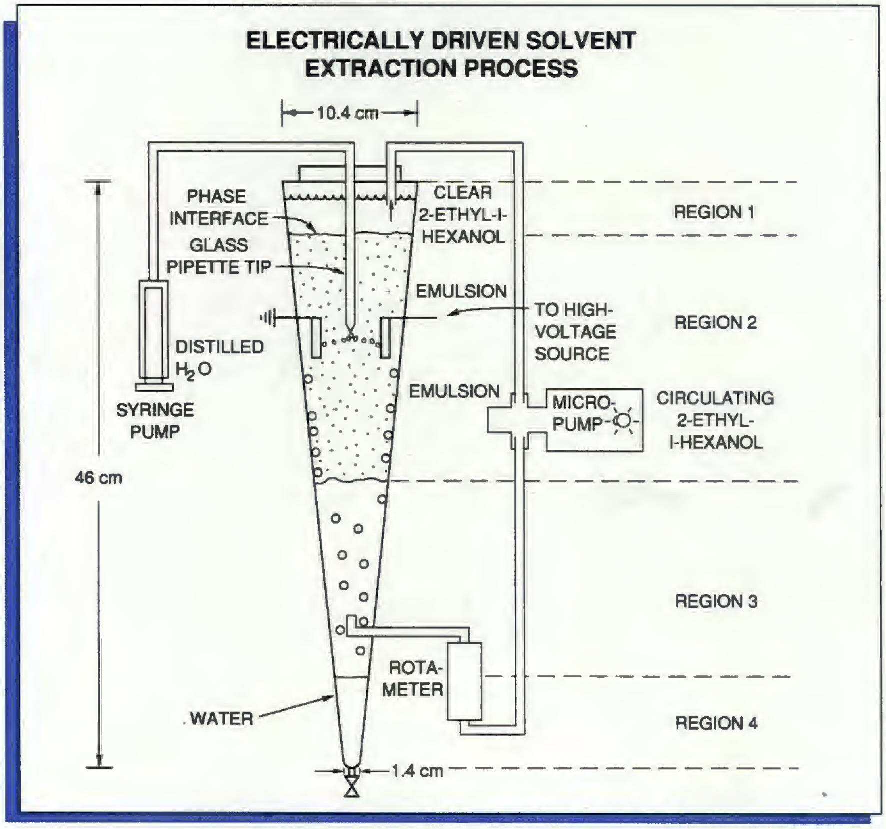
A new solvent-extraction system that is potentially more efficient than any existing system has been developed at ORNL. By applying a pulsed electric field to a solvent-extraction system, researchers have greatly increased the mass transfer rates achieved, making separations with this system rapid and energy-efficient.

Solvent extraction, a separations technique widely used for industrial product purification, conventionally uses mechanical agitation to remove a substance from one liquid by dissolving it into a second, immiscible liquid in the system. The rate of mass transfer between the two liquid phases is controlled by the properties of the liquids and the degree of contact or mixing achieved.

To increase mass transfer rates, conventional solvent-extraction systems agitate the mixture using mechanical mixers—an energy input to the system. However, experiments by Tim Scott, Charlie Byers, and Bob Wham in ORNL's Chemical Technology Division have shown that mass transfer rates as much as 10 to 16 times greater than those of conventional systems can be achieved using a smaller input of energy by subjecting the liquid to a pulsed, direct-current, or alternating-current electric field. The electric field emulsifies the liquids into micron-sized droplets and causes rapid droplet oscillation. The ORNL system has been successfully demonstrated in the separation of acetic acid from a water solution into methyl isobutyl ketone.

ORNL's development of this advanced solvent-extraction system was stimulated by previously completed basic research studies of oscillating droplets in a pulsed electric field. The new system achieves higher mass transfer rates because the pulsed electric current produces much smaller droplets (µm- vs mm-sized droplets) and, consequently, 1000 times greater contacting surface area per unit volume of liquids than the conventional, mechanically agitated systems.

Because the surface area for a given volume is much larger in the ORNL system, the equipment required to produce a given amount of separated




Schematic of a possible experimental system for studying an electrically driven solvent extraction process.

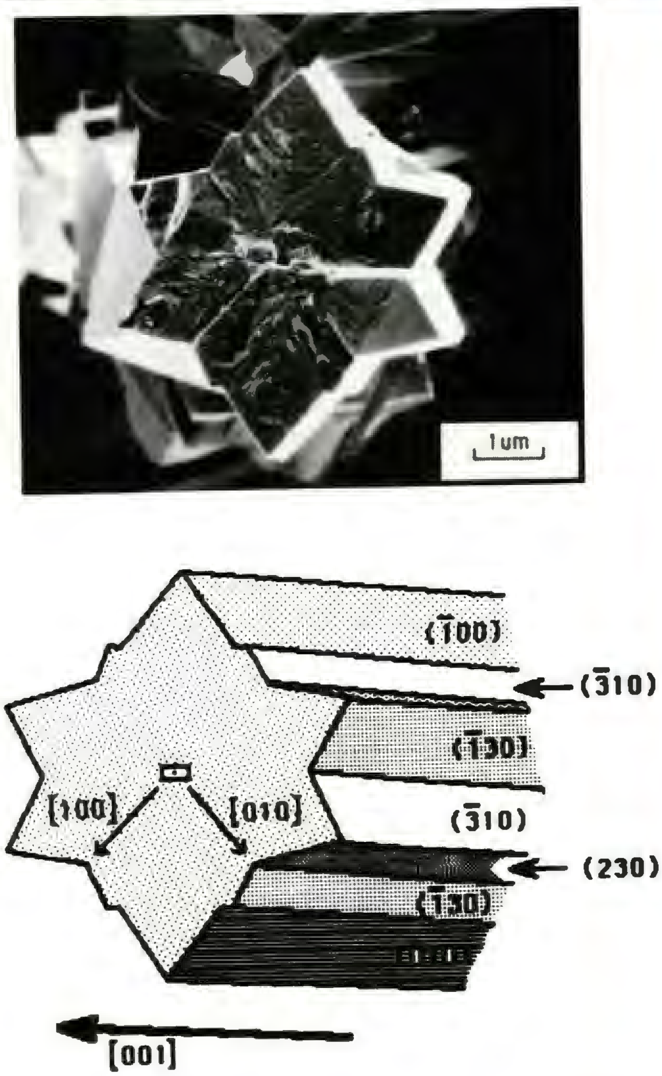
product is much smaller than conventional systems. That is, the volume and mass transfer are inversely proportional so that, if the surface area is increased by a factor of ten, the volume required for a given extraction in the new pulsed-field system is one-tenth that of the conventional system. The ORNL researchers also found that the energy input required for ORNL's electrically agitated extraction system is <1% of the input required for an equal-volume, mechanically agitated system.

## New Way To Make Titanium Nitride Whiskers To Strengthen Ceramics

Thin whiskers made of single-crystal ceramics are desirable reinforcing agents for advanced ceramic composites. By absorbing the stress energy of the composites, the whiskers increase the tensile strength of these materials and decrease their tendency to fracture. Titanium nitride (TiN) has many properties that make it a promising material for reinforcement whiskers: resistance to high temperatures, extreme hardness, high electrical conductance, and relative chemical inertness (it will not react with its ceramic host). However, until another serendipitous ORNL discovery in 1987, it had not been possible to produce TiN whiskers in sufficiently large amounts for testing in composites.

In that year Carlos Bamberger, of ORNL's Chemistry Division, discovered a high-temperature reaction using a complex oxide of sodium and titanium and sodium cyanide that produces a high yield of single-crystal TiN whiskers. The gold-colored whiskers range in diameter from 0.5 mm to 2 mm.

In the original exploratory work, Bamberger reacted the molten sodium cyanide with titanium dioxide or several titanium mixed oxides at the same high temperature. These reactions produced TiN powder. When Bamberger used a different compound, containing both sodium and titanium, as the starting oxide, a similar reaction occurred. Surprisingly, the product was not a powder but single-crystal TiN whiskers! The underlying chemistry for the production of these beautiful golden whiskers has not yet been unraveled.




FRACTURE CROSS SECTION OF WHISKER AND PRELIMINARY CRYSTALLOGRAPHIC ANALYSIS
The analysis is based on an assumed [001] whisker growth direction. Many whiskers need to be analyzed using this technique and TEM in order to determine orientations conclusively.
X12,000

This micrograph shows the fracture cross section of a titanium nitride (TiN) whisker. The whiskers, which can strengthen ceramics, have been produced chemically at ORNL.

# *ORNL Aids Development of World's First Promethium Laser*

Promethium has held an important place in ORNL's history. This highly radioactive element was first produced and identified at ORNL in 1945 and now, 43 years later, ORNL has played an important role in developing the world's first promethium laser.

While conducting research on the properties of actinide elements, scientists in ORNL's Solid State Division developed a unique method for growing single crystals doped with radioactive ions. When scientists at DOE's Lawrence Livermore National Laboratory (LLNL) began trying to develop the first promethium laser, they relied on ORNL to produce a series of promethium-doped single crystals and glasses to be subsequently tested at LLNL for lasing action.

Cabell Finch and Lynn Boatner of the Solid State Division, aided by technicians using the glove box facilities in ORNL's Operations Division, provided the needed materials for the LLNL researchers. The result of this collaboration was the first successful promethium laser. This new room-temperature laser may be useful for satellite-to-submarine communications because, when its output frequency is doubled, the resulting light can be transmitted through water.

The promethium-doped glass used for this first-attempt promethium laser has a patented lead-phosphate composition containing trivalent promethium-147 that was recently developed at ORNL by Brian Sales and Boatner. The LLNL program used this material to successfully produce four-level laser emissions at wavelengths of 933 and 1100 nm. This ORNL glass also represented a technological tour de force by overcoming the problem of radiation damage to the host medium that previously had prevented laser operation in materials doped with highly radioactive ions.

As-cast lead-indium-phosphate glasses doped with promethium-147. Materials of this type were prepared at ORNL and used as the lasing medium in the world's first promethium laser operated at Lawrence Livermore National Laboratory. Such a laser could be used for satellite-to-submarine communications.

## Merging Beams of Atoms and Ions to Study Electron Capture

A new apparatus for merging beams of ions and atoms for studying electron capture has been developed in ORNL's Physics Division. The system is used to study low-velocity collisions that occur when a fast beam of multiply charged positive ions is merged with another beam of neutral atoms moving in the same direction. The situation is analogous to two fast runners on a relay team who interact with each other—pass a baton—at slow relative velocities. In this case, the baton is an electron being passed from a neutral hydrogen atom to a positively charged ion. Studies of collision processes such as electron capture are important for understanding the behavior of plasmas, such as those that exist in magnetic fusion research devices (e.g., ORNL's Advanced Toroidal Facility). Electron capture is a dominant process at the edge of the fusion plasma, where neutral hydrogen atoms interact with ions of impurities present. These interactions affect the temperature of the plasma and, thus, its ability to sustain fusion reactions.

Several merged-beam experiments involving hydrogen atoms and oxygen or nitrogen ions were performed successfully by Charlie Havener, Saiful Huq, Herb Krause, Peter Schulz, and Ron Phaneuf of the Physics Division. The ion beams were produced by ORNL's electron-cyclotron-resonance ion source. In the merged-beams technique, two fast beams of reactant particles having nearly the same velocity are directed along the same path, making their relative velocity small. The technology of such experiments is demanding because intense, stable, highly-charged ion beams must be merged with a neutral beam in an ultra-vacuum environment. The physicists' goal in this work is to determine absolute physical quantities such as the collision cross section, which in this case is related to the probability that an ion will capture an electron from a neutral atom.

Recent ORNL electron-capture cross-section measurements for collisions of hydrogen atoms with oxygen ions stripped of five electrons represent two firsts. They are the first successful merged-beams experiments involving collisions of multiply charged ions with atoms and the first such experiments to be carried out at near-thermal, very low (electron-volt-range) collision energies.

It has been speculated that the weakly attractive polarizing force between the reactants may cause an atom to orbit around a heavier ion in such slow collisions, just as gravitational attraction may cause meteorites to be captured into orbiting trajectories around planets. The formation of such a "temporary molecule," or quasi-molecule, could increase the electron-capture cross section at very low velocities—that is, make it easier for the ion to snatch an electron from the atom.

The merged-beams method is ideal for studying these very-low-energy collisions. Recent ORNL measurements of cross sections for hydrogen atom-oxygen ion and hydrogen atom-nitrogen ion collisions indicate that the cross sections can dramatically increase as collision velocities decrease. The results may be interpreted as evidence for the formation of quasi-molecules.

Charlie Havener checks the apparatus used to merge beams of hydrogen atoms with oxygen or nitrogen ions to study electron capture.

## Biological Monitoring Program Pinpoints Toxicity Sources

Recent environmental inspections, audits, and reviews of Energy Systems facilities have focused on our discharges of hazardous chemicals and radionuclides to the Oak Ridge Reservation. The Tennessee Department of Health and Environment and the U.S. Environmental Protection Agency (EPA) have called for reductions in these discharges to make our facilities comply with state and federal environmental regulations. In 1985 and 1986 these organizations issued pollutant discharge permits to the Oak Ridge facilities, which required ORNL to set up a biological monitoring program to determine the impacts of facility discharges on area streams and evaluate the effectiveness of remedial actions.

In the past year or so, under the direction of Jim Loar, staff members of ORNL's Environmental Sciences Division (ESD)—Arthur Stewart, Marshall Adams, Harry Boston, and George Southworth—working with Michael Ryon and John Smith of the Health and Safety Research Division and Lynn Adams Kszos of UT, have developed biological monitoring plans for ORNL, the Y-12 Plant, and the Oak Ridge Gaseous Diffusion Plant. Tasks include:

- measuring the toxicity of waste discharges and the streams receiving them;
- monitoring the bioaccumulation of contaminants in plants and other organisms in streams and on land; and
- determining the types and abundance of fishes and benthic invertebrates in streams.

The plans, approved by the state and EPA, have been carried out using a network of monitoring sites throughout the Oak Ridge Reservation.

ORNL's approach to biological monitoring calls for a variety of methods, ranging from laboratory bioassays and manipulative field experiments to routine ecological surveys.

From left, Mark Harris, Mike Ryon, and Bill Kyker census the fish populations in an Oak Ridge Reservation stream as part of the required biomonitoring program. These surveys help determine the health of the stream before and after remedial action.

Ecological effects are assessed at various levels of biological organization. One study may monitor the health of individuals in a fish population, and another may evaluate the number of species making up the entire fish community. The plans combine established monitoring protocols with innovative state-of-the-art techniques (including some that were developed at ORNL) to document regulatory compliance and ensure protection of the environment.

This monitoring program also has made some important contributions to science. Program results will be used by ESD scientists in performing theoretical and experimental stream studies for the National Science Foundation to test hypotheses on stream ecosystem disturbance and recovery. Results to date show evidence of the ecological impacts of facility discharges on local streams and their recovery following treatment or discharge reduction.

Laboratory tests on water fleas and other species have shown that episodic discharges of chlorine are largely responsible for the toxicity of White Oak Creek and several tributaries. Chlorine was also the dominant toxic agent in the upper East Fork of Poplar Creek above New Hope Pond and in Mitchell Branch near ORGDP.

Biological monitoring at the Y-12 Plant provided evidence of significant recovery of life in upper Bear Creek following neutralization of the S-3 waste disposal ponds. After the acidity level was lowered in these ponds, fish became much more abundant in the creek. In fact, this region of the creek became a new home for the mountain redbelly dace, a pollution-sensitive species that would have found the upper reaches of the creek uninhabitable several years ago.

Besides determining environmental compliance and contributing new scientific information, biological monitoring can guide remedial actions by pinpointing sources of environmental damage. Because chlorine has been found to play a large role in the toxicity of area streams, efforts can be focused on stopping the chlorine discharges. Biological monitoring also can assess the effectiveness of remedial actions, as in the Bear Creek case.

## New Evidence on Induced Chromosomal Aberrations

It has long been believed that chemical mutagens cause heritable changes in organisms by binding to DNA, the genetic material in cells. In

The biomonitoring program was initiated in 1984 at Bear Creek, west of the Y-12 Plant, and now covers all of the Oak Ridge Reservation.

fact, scientists have looked for evidence of chemical binding to DNA to determine whether a subject has been exposed to a particular chemical mutagen.

New evidence obtained by Gary Sega of ORNL's Biology Division casts doubt on this assumption. His work suggests that several chemical mutagens found to cause detectable genetic changes in mouse reproductive cells bind to a protein called protamine, rather than to DNA. Protamine is found in sperm.

Sega's hypothesis that protamine, rather than DNA, might be the critical target for the induction of heritable chromosome damage has been verified by experimental results. Walderico Generoso of the Biology Division has found that acrylamide, a mutagenic chemical that is widely used in paper processing and water treatment, induces dominant-lethal mutations and heritable translocations in mouse sperm. Yet virtually no evidence could be found of this chemical binding to DNA.

Sega has determined that, although acrylamide does not bind significantly to DNA, it does bind strongly to the protamines in the germ-cell stages of development that are sensitive to genetically damaging chemicals. This work implies that screening that finds no evidence of the mutagenic chemical's binding to DNA cannot be used to conclude that no exposure to a genetic hazard has occurred.

Waldy Generoso (left), Isao Yoshikawa (of Japan), and Gary Sega have found that certain chemical mutagens, such as acrylamide, may induce genetic damage in mammalian germ cells by binding to special proteins rather than to DNA.

# *ORNL Robot Moves Between Obstacles, Finds and Reads Meter*

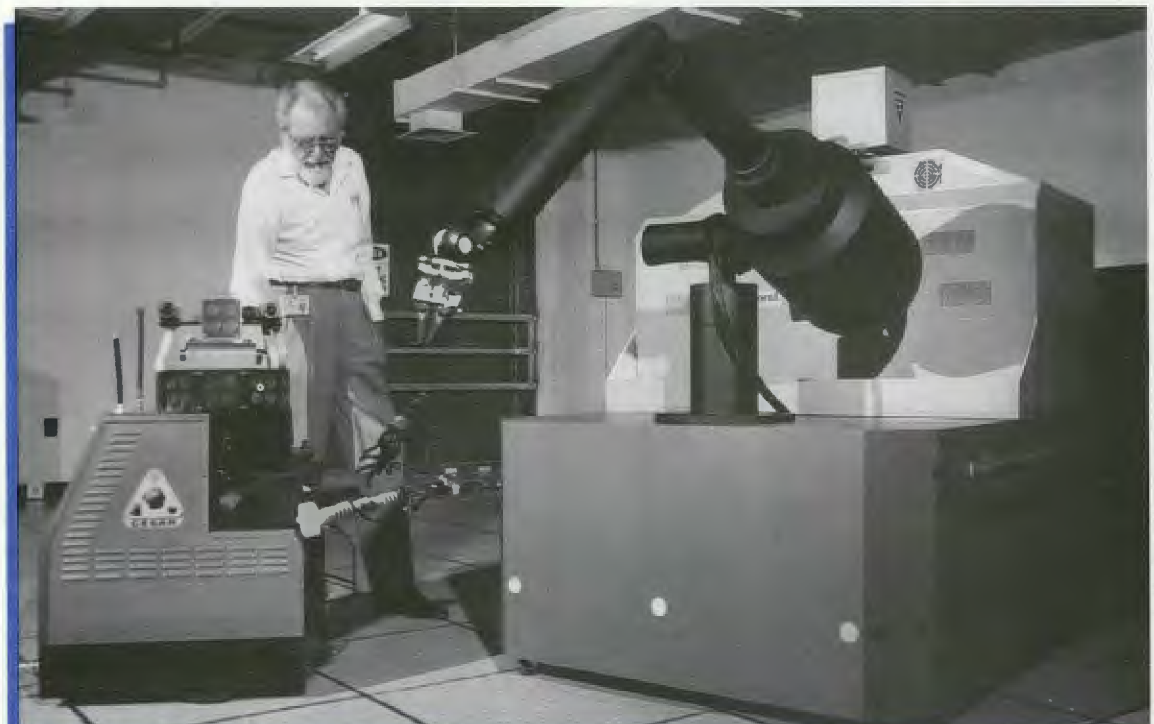
It can move between obstacles, pick up and move small objects, and search for, adjust, and read meters on a control panel. It seems to have human capabilities, but it is an autonomous robot developed at ORNL.

ORNL's Center for Engineering Systems Advanced Research (CESAR) has developed a robot that can plan its own path, maneuver around obstacles, and retrieve information. Called HERMIES-IIB, the robot is one in the Hostile Environment Robotic Machine Intelligence Experiment Series (HERMIES) of intelligent machines that ORNL is programming to demonstrate navigation, obstacle avoidance, and machine vision. It is one of the world's most computationally powerful robots; its on-board computing power is equivalent to that of about eight VAX 11/780 processors.

CESAR is supported by the Department of Energy, the Department of Defense, the National Aeronautics and Space Administration, and other sponsors. DOE, DOD, and NASA are interested in the development of intelligent machines that are needed to perform work in environments too hazardous for humans. These environments include high-radiation zones, areas having explosives and hazardous chemicals, underground mines, underwater operations, and space.

In 1987 ORNL researchers—Barry Burks, Gerard de Saussure, Chuck Weisbin, and Judson Jones of the Engineering Physics and Mathematics Division and Bill Hamel of the Instrumentation and Controls Division—developed programs and sets of rigid rules called algorithms that have improved the performance of HERMIES-IIB, permitting it, for example, to recognize a panel and read a meter. The robot is the most recent HERMIES device. Work is under way to develop HERMIES-III, a more advanced, self-powered, mobile robot.

Equipped with two arms, three TV cameras, motors, sonar sensors, and an eight-node NCUBE



Design team member, R.R. Feezell, inspects full-scale models of HERMIES-IIB (left) and the latest ORNL robot, HERMIES-III (right). The new model will have the same on-board parallel computer, dual cameras, and sonar equipment as HERMIES-IIB but will incorporate a laser range-finder and a seven-degree-of-freedom manipulator to extend the capability of HERMIES into human-scale manipulation as well as navigation and surveillance.

parallel processor, HERMIES-IIB senses its position relative to objects in the environment, plans its path to a goal, moves around obstacles to reach the goal, manipulates objects, and retrieves information (e.g., snaps a photograph of a reading on a meter).

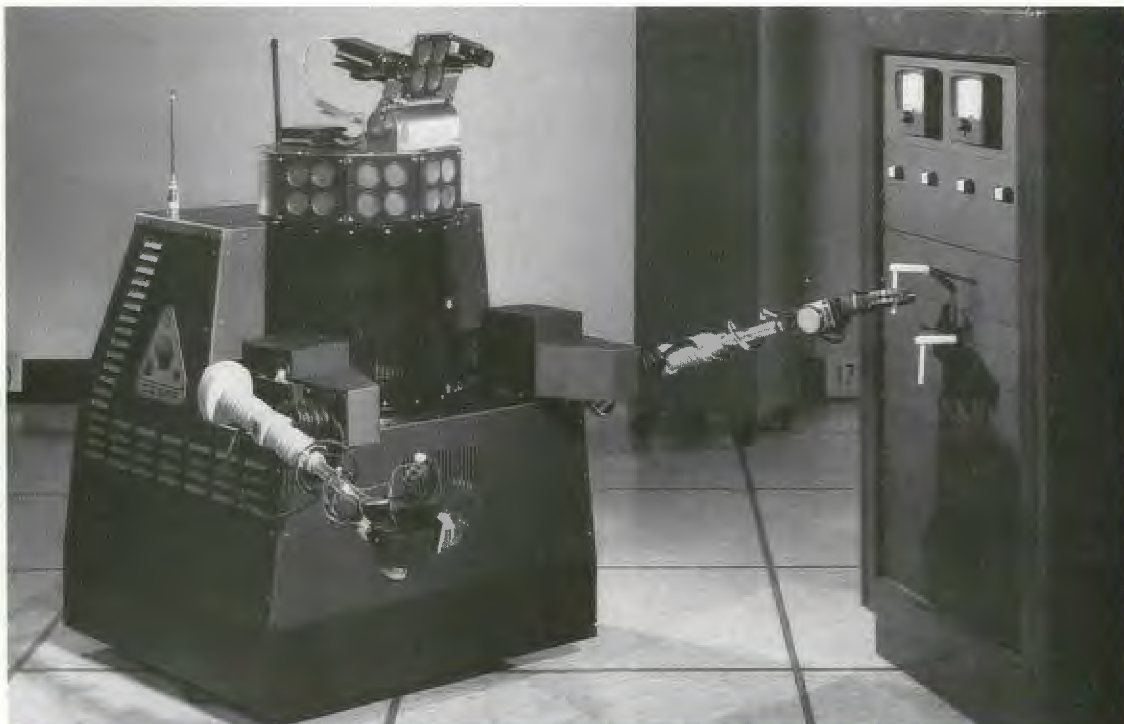
HERMIES-III will be smarter than HERMIES-IIB. Its "brain" will have more processing power for rapid reasoning, learning, and decision making. It will outperform HERMIES-IIB in sensing the environment, largely because of its high-resolution vision using a laser scanner.

HERMIES-IIB's manipulators are made by Zenith/Heathkit—the same arms used on the HERO home robot. However, HERMIES-III will have two dexterous manipulators based on the ORNL-developed CESAR Research Manipulator, or CESARM, design.

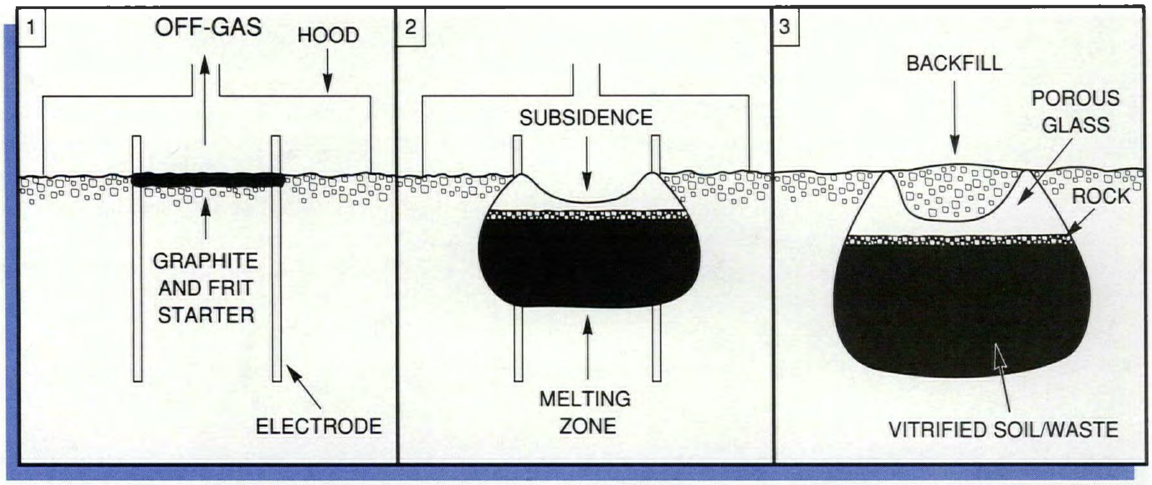
CESARM is a seven-degree-of-freedom arm, one of only two or three in the world. Six degrees of freedom are required to arbitrarily position the end-effector or "hand" of a manipulator within an unobstructed work space. The seventh, or "redundant," degree of freedom allows greater flexibility in positioning the links that make up the arm. Compared with arms lacking redundant degrees of freedom, the CESARM is better at complex tasks in confined or obstructed areas.

CESARM, adapted from a manipulator tested in ORNL's Consolidated Fuel Reprocessing Program, weighs about 250 pounds and can lift 35 pounds, a weight-to-capacity ratio of about 7. This ratio is 3 to 4 times smaller than that of typical industrial manipulators, which are necessarily heavy and rigid to ensure precise performance of repetitive operations.

ORNL has developed a kinematic algorithm that controls the motion of CESARM, allowing it to avoid obstacles and to reach into confined areas. This mathematical method for collision avoidance specifies the timing and angle for the movement of each arm joint (shoulder, elbow, or



ORNL's robot HERMIES-IIB adjusts the control panel and prepares to read the meter.




Schematic shows Pacific Northwest Laboratories' (PNL) patented method for in situ vitrification of radioactive wastes. ORNL and PNL showed that the method could be scaled up so that many tons of soil contaminated with cesium and strontium could be encapsulated in a single glass block.

wrist). The algorithm has successfully guided CESARM in moving around its support post without contacting it.

## In Situ Vitrification Isolates Radioactive Waste

ORNL's waste-related work is not confined to making plans, writing documents, monitoring, and cleanup. We also are involved in waste R&D and technology demonstrations to evaluate different methods of dealing with waste problems.

In 1987 two researchers in ORNL's Environmental Sciences Division, Brian Spalding and Gary K. Jacobs, collaborated with J. Gary Carter and Sydney S. Koegler of the Battelle Pacific Northwest Laboratory (PNL) to demonstrate PNL's patented method for in situ vitrification of radioactive wastes. The project showed that the method could be scaled up so that many tons of contaminated soil could be encapsulated in a single glass block. The soil used in the demonstration was contaminated with cesium and strontium.

In this process, electrical currents are passed through a large volume of contaminated soil, using molybdenum electrodes. As a result, the soil temperature is raised to the point that the soil melts into a glass (vitrifies). The resulting glass block, which immobilizes the soil and its wastes, is leach resistant. That is, water cannot seep into the immobilized soil and carry its radioactive contents to the environment.

On July 20, 1987, ORNL and PNL personnel completed in situ vitrification in a test trench, melting a 20-ton mass of soil and crushed limestone backfill in a 110-h period. The soil was melted to a desired depth of 2 m. The molten mass tended to move parallel to the long axis of the trench rather than symmetrically around the square array of the electrodes, making it simpler than expected to achieve a total melt of the materials. Core sampling performed on the vitrified soil after a two-month cooling period revealed that 99.88% of the cesium and 99.99% of the strontium had been retained in the trench. The waste-laden glass proved to be durable, leach resistant, and able to retain off-gases.

This test trench is half the size of ORNL's typical liquid-waste seepage trenches. These trenches, which have a high concentration of low-level radionuclides within a relatively small volume, are prime candidates for stabilization and closure using in situ vitrification.

In situ vitrification in this ORNL test trench melted a 20-ton mass of soil and crushed limestone backfill in a 110-h period. The melting generated little cesium or strontium in the off-gas. The resulting waste-laden glass block (with embedded electrodes in the melted zone) proved to be durable and leach resistant.

# Milestones

Capsules are being welded for insertion in the HFIR pressure vessel. These will later be retrieved and tested to determine the extent of neutron-induced embrittlement.

## HFIR

In March 1987, DOE ordered four ORNL reactors shut down because of concerns about management and oversight of reactor operations. A fifth reactor, the High Flux Isotope Reactor (HFIR), has been shut down since November 1986 because of evidence of embrittlement in the pressure vessel. DOE decided to close two of the five ORNL reactors permanently—the Oak Ridge Research Reactor and Tower Shielding Facility.

In 1987, extensive plans and preparations were made to restart the HFIR, a Class A reactor, and the remaining two Class B reactors—the Bulk Shielding Facility and the Health Physics Research Reactor. Restart was delayed because of a number of well-publicized events. We are probably our own worst enemy, because we have not been prompt enough in carrying out some actions, and we have not paid attention to all the details required to ensure that our facilities operate as intended. As a result, the projected time for restart has been repeatedly set back. ORNL's critical facilities—nuclear and nonnuclear—will require a level of concern, management attention, and quality assurance that we have not been practicing, but that we must begin to practice.

One of the major reactor events in 1987 was the HFIR pressure vessel test. This hydrostatic test showed that the vessel could be operated safely for another ten years if run at 85% of design power.

## HTML

The High Temperature Materials Laboratory (HTML) is now a functioning research and user center. It is a magnificent building that has extraordinary equipment and houses some of the world's best ceramic researchers. The HTML's

research equipment has been obtained to allow researchers to relate the changes in the physical and mechanical properties of materials to corresponding changes in microstructure and micro-chemistry.

On July 15, 1987, American Matrix, Inc., became the first official user of the HTML. American Matrix is a Knoxville-based firm that specializes in the manufacture of silicon carbide whiskers.

Staff members, users, and visitors enjoy the elegant interior design of the High Temperature Materials Laboratory.

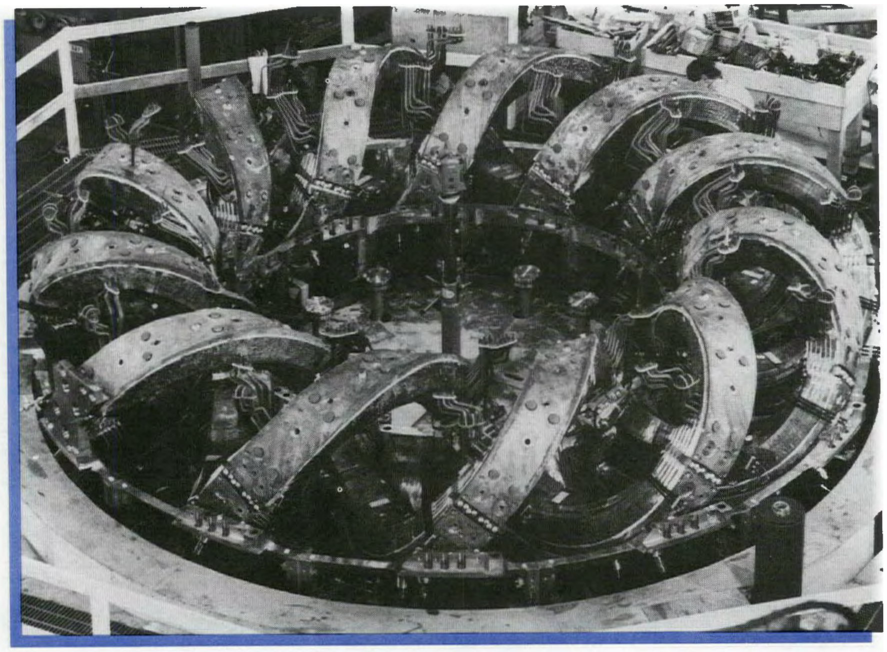
construction was completed in early 1987, and the attractive new building was fully occupied by April 15, when a dedication ceremony was held. The three Metals and Ceramics Division groups in the building specialize in structural ceramics, making the HTML a focal point for high-temperature ceramics research at ORNL.

The HTML is a user facility for industrial and university researchers and for ORNL staff members. A "user center" staff at the HTML maintains equipment and assists users. Special

## ATF

In December 1987, ORNL's new fusion experiment—the Advanced Toroidal Facility (ATF)—was completed for less than its projected cost of $20 million. The ATF, the product of a four-year design and construction effort, produced its first plasma in January. It is now ready to begin the experimental program.

The ATF vessel containing the plasma, or fusion fuel, is shaped more like a cruller than a regular doughnut, the shape of the more familiar tokamak. Like the tokamak, the ATF is a toroidal magnetic confinement experiment. Unlike the tokamak, which confines its plasma partly by means of a current and operates in a pulsed mode, the ATF is a special type of stellarator, called a torsatron, that confines its plasma only by external magnetic fields and could operate continuously (in the steady state).



The Advanced Toroidal Facility, which was completed in December 1987, produced its first fusion plasma in January 1988.

The configuration of the ATF's confining magnetic field is based on pioneering studies done by the Fusion Energy Division's Plasma Theory Section. As the plasma pressure increases, the configuration is predicted to self-stabilize, which should allow relatively high beta values to be reached. Beta, the ratio of the plasma pressure to the magnetic pressure, is the key to efficient operation of toroidal fusion devices. One goal of the ATF experimental program is to determine the limits of plasma pressure and stability in this configuration and to use the results to guide the improvement of toroidal concepts, including the tokamak.

The design and construction of the ATF involved unusually close cooperation among a number of organizations within Energy Systems. The complexity of the design, the precision required for fabrication and assembly, the high level of quality assurance, and the aggressive schedule adopted demanded extensive R&D and development of innovative fabrication and assembly techniques. The Confinement Section of the Fusion Energy Division had primary responsibility for the project but relied heavily on the Y-12 shops and maintenance staff and Energy Systems' Computing and Telecommunications, Engineering, and Procurement divisions.

## Large Coil Task

The Large Coil Task (LCT) Program was completed September 2, 1987, concluding a ten-year international collaboration in the design, construction, and testing of superconducting magnets for fusion devices. Upon completion of the test program, Paul Haubenreich was cited by DOE for his "dedicated project management and technical leadership in making the LCT one of the largest successful international collaborative efforts ever undertaken by the Department of Energy."

Six 40-ton superconducting magnets, one each from EURATOM (represented by the Federal Republic of Germany), Japan, and Switzerland, and three from the United States, were operated at liquid-helium temperatures in the International Fusion Superconducting Magnet Test Facility here. This test stand was designed, fabricated, and operated by ORNL, aided by contributions from the Y-12 shops and maintenance staff and the Engineering Division. The reliable operation of the test stand and the excellent performance of the magnets resulted in the attainment of several

Gernot Zahn (left) of the Federal Republic of Germany (FRG) and R. E. Bohanan (now retired from ORNL) prepare the EURATOM superconducting magnetic coil for its return to the FRG after completion of the Large Coil Task.

records for superconducting magnets and invaluable technical understanding.

In October 1985, the lid to the large vacuum tank was set in place, and no maintenance was required before completion of the experiments 22 months later—the end of August 1987. The tank thermally isolated 400 tons of helium-chilled magnets and structure linked by several kilometers of piping and thousands of welds. The test facility was available for test preparation and coil testing 57% of the time, close to the availability goal of 60%. This availability level is considered an outstanding achievement.

The test program set the following records:

- largest coils (in size, weight, or stored energy) to operate at a magnetic field strength of up to 9 teslas,
- largest adiabatically stabilized coils,
- largest coil having conductor made of niobium-tin alloy,
- largest coil ever operated in the superconducting mode at a helium temperature as high as 8 K (normal operation was at 4 K).

More important than these firsts is the attainment of detailed understanding of the magnets' behavior. More than 2000 sensors were used to document the response of each coil to a variety of thermomechanical conditions. For example, a separate "pulse" coil was used to simulate the magnetic field fluctuations to which magnets will be exposed in a magnetic fusion device.

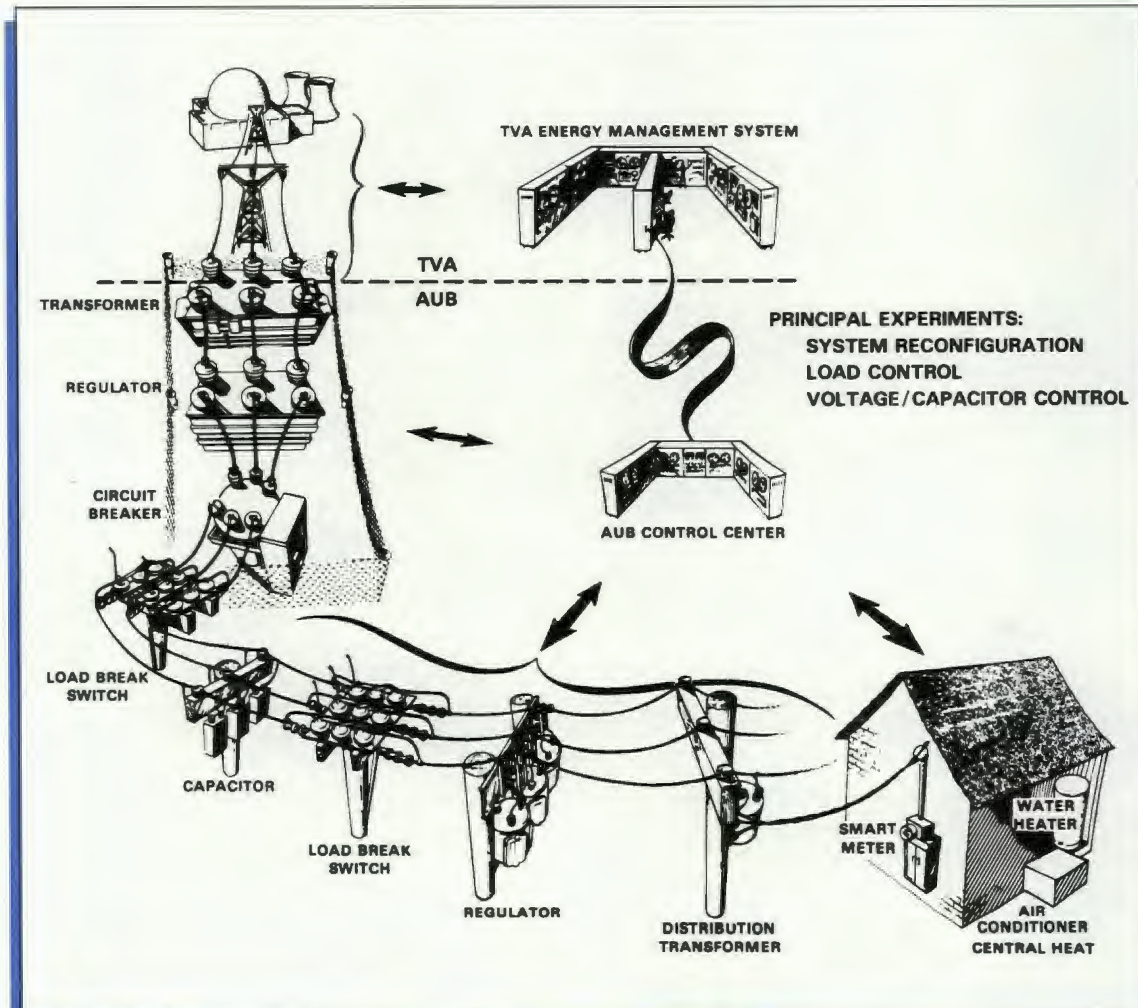
These data have been compared with the computer models used in coil design. The validated or improved models that result from this analysis will be used to design magnets for future fusion devices, such as the International Thermonuclear Experimental Reactor. The LCT participants have prepared a summary report that evaluates experimental findings and recommends designs and manufacturing techniques for making more reliable and economical fusion magnets.

## Athens Automation and Control Experiment

In the fall of 1987, the Power Systems Technology Program of ORNL's Energy Division completed the two-year Athens Automation and Control Experiment, which was conceived at ORNL ten years ago. ORNL managed this $15-million, DOE-sponsored test on the distribution system of the Athens Utilities Board (AUB) in Athens, Tennessee.

The experiment examined the effects of using centralized computer control and new electronic communication equipment for remote computerized monitoring and operation of the AUB distribution system, one of the 160 municipal utilities that purchase power from the Tennessee Valley Authority. Compared with the traditional mode of operation, AUB found that ORNL's integrated approach reduced energy costs, restored interrupted power more quickly, and increased the reliability of providing electricity to more than 10,000 customers.

These results from the experimental operation of what has become the nation's most highly automated electricity distribution system should influence the design and operation of the next

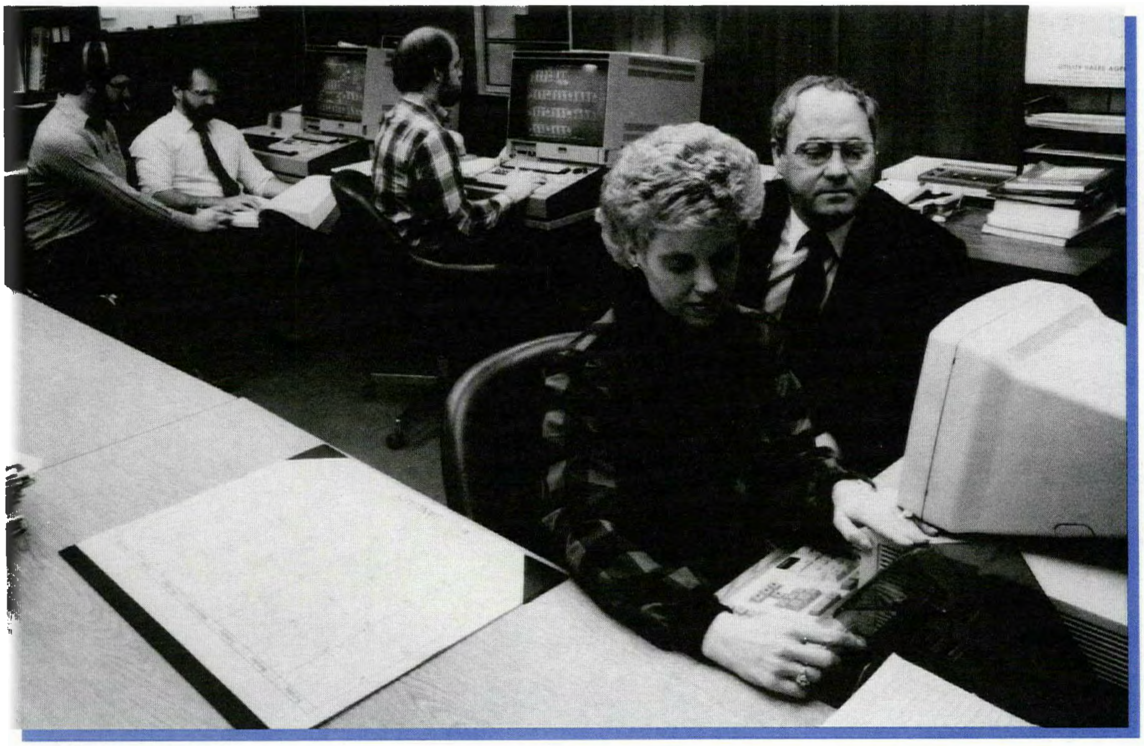



This schematic shows the advanced components and systems used to monitor and control the largest U.S. integrated, automated, electricity distribution system. ORNL managed the three principal experiments on the Athens system.

generation of U.S. electric power systems. The Athens distribution system has demonstrated that new technologies can increase a utility system's control of power delivery. Just about every part of the system is automated, including voltage regulators, circuit breakers, switches, capacitors, hot-water heaters, and home-heating and air-conditioning systems. The system's ability to detect maintenance problems before they become serious has saved AUB thousands of dollars.

Since the energy shortages and rising energy costs of the 1970s, electric utilities have become interested in load management (i.e., changing electricity use patterns to reduce the demand for electricity during peak periods) to lessen the need for expensive new generating capacity. The AUB system operators accomplish load management by monitoring and controlling electricity distribution and use. To flatten AUB's peak loads, the system shifts electricity use by water heaters, space heaters, heat pumps, and air conditioners in 1000 homes to another time of day when the demand for power is less, normally without inconveniencing customers. These computer-controlled actions were taken as part of the "load control" experiment, begun in 1986.

The system can also control voltage levels to reduce losses of saleable electricity. In addition, it



The Athens Utilities Board electricity distribution system is monitored by and operated from the computerized control room.

can transfer loads from one part of the system to another automatically to reduce energy costs, shorten power outages, and increase power distribution reliability. These actions were taken as part of the "voltage/reactive power" experiment and the "system reconfiguration" experiment, both begun in 1985.

The Athens experiment demonstrated that automation can reduce the cost of distributing electricity. Calculations show that reducing transmission and distribution energy losses by 1% would save the U.S. utility industry about $160 million annually. Using automated load management to reduce U.S. utility peak loads by 1% would save $5 billion and increase available electrical capacity by 4800 MW.

ORNL researchers were responsible for integrating existing and evolving monitoring and communication technologies into an innovative integrated distribution control system. Automated methods for load control, voltage control, and load transfers have been tested separately by other utilities, but the Athens distribution system is the first to integrate all three capabilities into a flexible system.

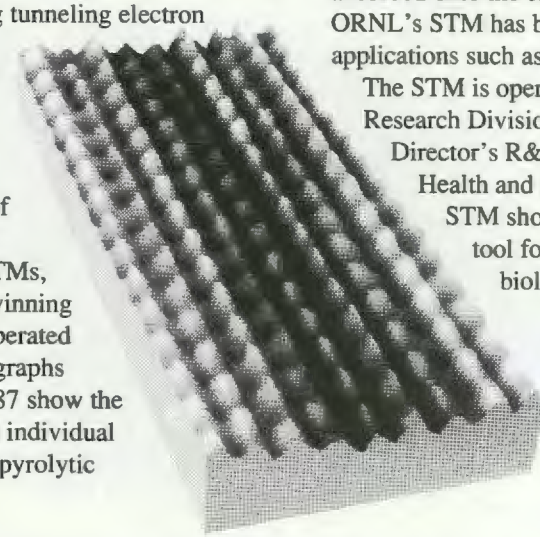
ORNL developed a high-speed data acquisition system that can measure power system changes caused by automated capacitor switching, load transfers, and load control. As a result of this monitoring capability, the AUB can determine quickly how to redistribute power use to reduce daily operating costs and peak demands for power.

Besides DOE, ORNL, AUB, and TVA, the Athens experiment participants include the Tennessee Valley Public Power Association, the Electric Power Research Institute (EPRI), a utility advisory group of ten utility experts from across the United States, and faculty and students from the University of Tennessee at Knoxville and the Tennessee Technological University at Cookeville. Thanks to help from the federal government and utility experts, AUB now enjoys the largest integrated automated electric distribution system in the United States.

## Fluid-Based STM

A fluid-based scanning tunneling electron microscope (STM) was constructed at ORNL in 1987, more than eight months ahead of schedule. The new STM can image individual atoms of samples in air and under water; first-generation STMs, based on a Nobel Prize-winning development, could be operated only in a vacuum. Micrographs obtained in the fall of 1987 show the electronic density around individual atoms of highly oriented pyrolytic graphite and the locations of fatty acid molecules adsorbed onto the carbon atoms of this graphite. ORNL's STM has been used for other biological applications such as detection of a tobacco virus.

The STM is operated by the Health and Safety Research Division and is supported by the Director's R&D Fund and DOE's Office of Health and Environmental Research. The STM should prove to be a remarkable tool for both surface science and biological research.



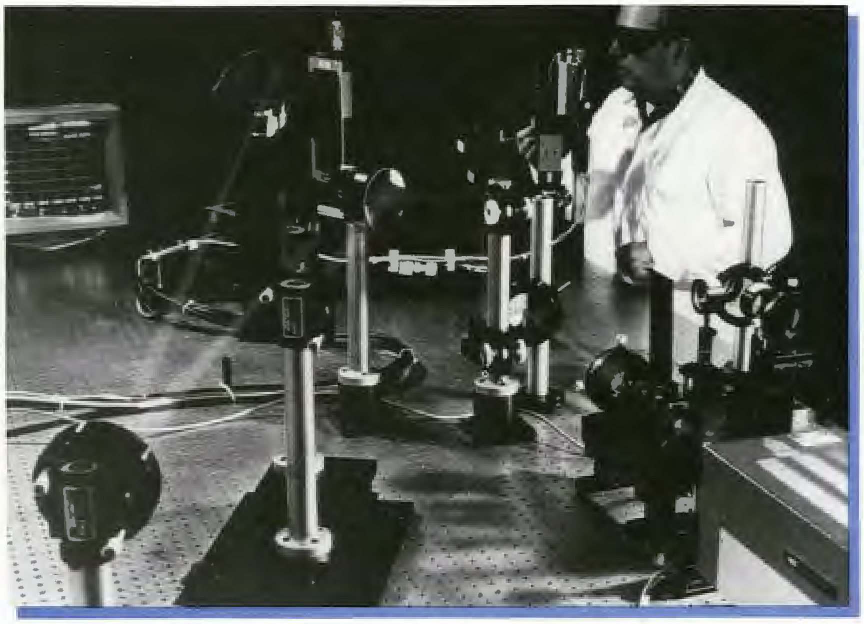
This micrograph, produced by the STM, shows the electronic density around individual atoms of highly oriented pyrolytic graphite and the locations of fatty acid molecules adsorbed onto the carbon atoms of the graphite.

## Optical Scatterometer

In 1987 an advanced instrument called an optical


Jim Mantovani of the University of Tennessee checks the data-acquisition equipment for the fluid-based scanning tunneling electron microscope (in front of bell jar). Inset: In the fluid-based STM the sample is placed just beneath the needle (just left of center).

scatterometer was completed and operated for Strategic Defense Initiative (SDI) applications. It is needed to evaluate the performance of SDI optical components, including mirrors and windows. This work was done as part of ORNL's Optics Program sponsored by the U.S. Army Strategic Defense Command. The highly automated scatterometer, located in the ultraclean environment of the Optical Component Characterization Laboratory at the Oak Ridge Gaseous Diffusion Plant, was designed and fabricated under subcontract by Toomay Mathis and Associates. It can operate at multiple wavelengths and measure the ability of optical components to transmit and reflect light. It is used in support of the development of infrared surveillance (heat-sensing) optics.



Ulys Fulmer makes an adjustment to the detector assembly on the Oak Ridge optical scatterometer.

## Chemical-Weapons Stockpile Disposal Analyzed

In December 1987, ORNL completed the final programmatic environmental impact statement on the disposal of U.S. stockpiles of chemical weapons, including nerve gas, now stored at eight facilities in eight states. The three-year effort for the U.S. Army was led by Sam Carnes of the Energy Division. Congress ordered the final disposal of the stockpiles of chemical weapons by September 1994.

Since December 1987, the 2200-page, three-volume, final document has been used by the Army in public hearings on disposal alternatives held throughout the country. Options evaluated in the report included on-site incineration of the hazardous chemicals and transporting them by various means to regional depots or a central depot for incineration. Since the hearings, the Army has made a programmatic decision to incinerate the stockpiles on-site.

A team from ORNL's Energy, Health and Safety Research, Environmental Sciences, Engineering Physics and Mathematics, and Chemical Technology divisions and from Energy Systems' Computing and Telecommunications and Engineering divisions and the Information Resources Organization prepared the impact statement. The team interacted with the Army sponsor and contractors, as well as with representatives from host communities, to

- develop state-of-the-art technical support studies analyzing the risks and possible impacts of the disposal alternatives, including the risks to persons and resources along transportation corridors;
- establish transportation guidelines;
- develop emergency planning concepts;
- identify opportunities for mitigating and managing risks.

ORNL's assessment resulted in the development and use of a "decision analytic approach," in which multiple measures of the public health and environmental impacts and risks were considered to identify the environmentally preferred alternative. Screening of alternatives on the basis of the predicted public health effects and environmental impacts was followed by consideration of the potential for risk reduction by emergency planning and preparedness. The final step was to compare the alternative preferred by the Army—on-site incineration of the stockpiles at the eight storage installations—with the likely preferences of persons living near the storage installations.

At the Toole Army Depot in Utah, chemical weapons are destroyed in the incinerator complex (behind the trucks) known as the Chemical Agent Municipal Disposal System.

The ORNL impact statement was part of the information that the Army recently used to make a programmatic decision about disposal. The Army also considered information about disposal costs, technical feasibility, national security, political feasibility, public opinion, and vulnerability to sabotage and terrorism. ORNL is now assisting the Army in preparing site-specific environmental impact documents for each of the eight sites.

A leaking rocket is packed in a protective "pig" at the Anniston Army Depot in Alabama prior to shipment for incineration.

## Roof Research Center

Developing roofs that are better able to contain heat in buildings—or keep it out, depending on the season—is a goal of DOE. Constructing roofs that last longer is a goal of the roofing industry.

The Roof Research Center and the associated Roof Thermal Research Apparatus make up a unique industry-oriented user facility.

Phil Childs inspects the Large-Scale Climate Simulator, which is the heart of the Roof Research Center. The environmental chamber is designed to test flat or pitched roof systems for a wide range of weather-related conditions.

Thus, DOE has established the Roof Research Center (RRC) at ORNL to work with industry on improving both thermal efficiency and durability of roof construction systems for residential and commercial buildings. The RRC, supported by DOE's Building Thermal Envelope Systems and Materials Program, is a unique industry-oriented user facility. It is guided by an advisory panel of key figures from the manufacturing, research, and user sectors of the industry and is expected to have industrial sponsors.

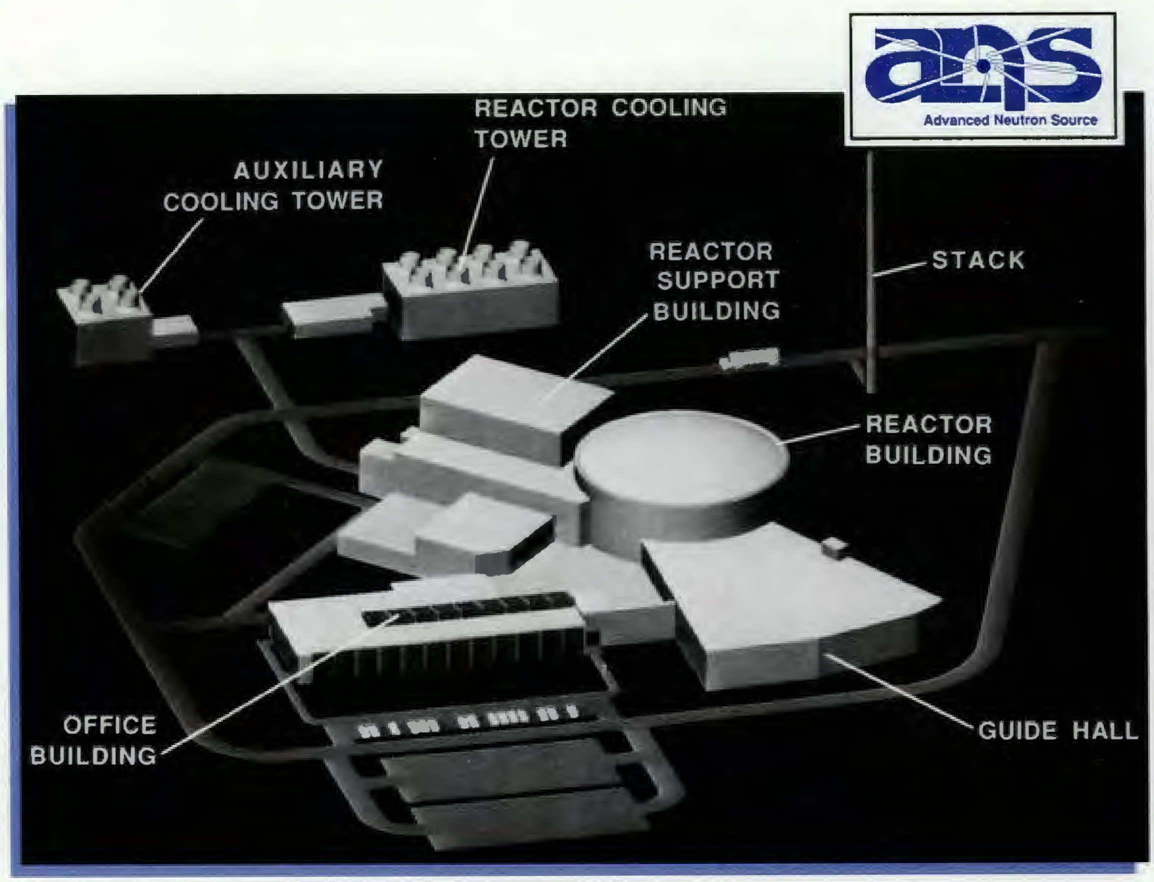
When petroleum shortages developed and oil and other energy prices increased in the 1970s, roofing systems began to receive attention from energy researchers. They focused on how to improve the energy efficiency of roofing systems and where to find substitutes for expensive and extensively used petroleum-based roofing products. Out of this effort, many new roofing materials and systems were developed, and the roofing industry has come to understand the need to study overall system performance rather than to simply focus on isolated properties of individual elements. The RRC provides industry with unique facilities for testing composite roofing systems and has set new standards for roofing research.

The centerpiece of the RRC, which is managed by Paul Shipp, is the Large-Scale Climate Simulator. Completed in August 1987, this environmental chamber is designed to test flat or pitched roof systems for a wide range of weather-related conditions. Surface temperatures can be varied from -40°F to 200°F, and humidity, pressure, and precipitation can be controlled simultaneously. When the chamber is fully operational, the responses of any roof specimen to mechanical stresses, water, and energy flow can be measured precisely for any climate conditions found in the United States.

Roofing specimens can be shuttled in and out of the simulator quickly and easily on testing platforms, which allow specimen construction and instrumentation to take place outside the main chamber, minimizing chamber downtime. These platforms can handle roof panels as large as 12 feet square and as heavy as 10 tons. Such capabilities make the RRC facility efficient and economical for roof research.

## Advanced Neutron Source Facility Design

We have made progress in developing an improved design of the Advanced Neutron Source (ANS), which we used to call the Center for Neutron Research (CNR) or the HFIR-II (after the High Flux Isotope Reactor). The planned ANS facility layout and architecture includes a reactor building, an office building for visiting scientists




The proposed design of the Advanced Neutron Source facility separates the reactor operations areas from the experimental space and offices for the 1000 users expected each year. This design was prepared by Hanna Shapira of ORNL's Engineering Technology Division on the basis of requirements and criteria devised by the Engineering Division of Energy Systems.

Inset: The ANS logo, a winning design by Vic Pardue of the Chemical Technology Division, selected from 163 entries.

The heart of the Pressure Vessel Research Users' Facility will be this 500-ton nuclear reactor pressure vessel shipped by barge in 1987 from Chattanooga to Oak Ridge. The complete PWR pressure vessel was unloaded near ORGDP from two special transporters at the end of a specially prepared access road that leads to the banks of Watts Bar Lake.

and reactor staff, a building for neutron-scattering and physics experiments, a reactor support building to house heat exchangers and other reactor equipment, cooling towers, and the facility stack. Planners have paid careful attention to personnel control and security, control of contamination and noise, focal points, and aesthetics. We have funding to continue this design work, and we are hopeful that the ANS will be built and operating by the mid-1990s.

## Pressure Vessel Research Users' Facility

In September 1987, a complete nuclear reactor pressure vessel was shipped from Combustion Engineering, Inc., to ORNL by barge and placed near the K-700 building complex at Oak Ridge Gaseous Diffusion Plant (ORGDP) close to Watts Bar Lake. The commercial vessel originally cost $10 million; ORNL obtained it free, having to pay only a couple hundred thousand dollars to move it up the Tennessee River. This thick-walled, 500-ton vessel will be the heart of the planned Pressure Vessel Research Users' Facility. The facility will be used for flaw inspection and analysis and possibly to determine the best techniques for annealing (heating) aging pressure vessels of this size to strengthen them and prolong their operating lifetimes.

This new user facility for reactor safety has been planned by ORNL's Engineering Technology Division, in conjunction with DOE and the Nuclear Regulatory Commission (NRC).


J. Robert Merriman (left), ORNL's associate director for nuclear and engineering technologies, presents the 1987 Director's Award to Thomas H. Row for his work as manager of ORNL's Nuclear and Chemical Waste Programs. Row is now director of the new Environmental and Health Protection Division.

Users are expected to include government researchers, vendors of light-water-reactor components, utility companies, and EPRI.

Once appropriate funding is arranged, the conceptual design of this new user facility and equipment will begin. In the meantime, the vessel will be used for specific R&D activities. One early effort will determine the location, orientation, size, and density of flaws in this vessel to validate or, if necessary, modify the flaw distributions currently assumed in probabilistic safety methods for operating reactors. Later, remote nondestructive examination techniques will be developed for in-service applications and certification.

The vessel may be used to develop practical techniques for whole-vessel annealing, which might make it possible to extend the licensed lifetimes of many aging commercial nuclear reactors. Other studies may examine the effects on the vessel of hot-and-cold-water mixing under operating reactor conditions. Such studies, which build on research carried out at ORNL for the NRC and DOE, should help ensure reactor vessel integrity in U.S. commercial nuclear power plants.

## 1987 Distinctions

In 1987 ORNL and the University of Tennessee appointed four new Distinguished Scientists (see "News Notes" sections of 1987 issues of the *Review* for biographical information on these men). This highly developed, cooperative program that brings topnotch scientists to the area continues to go well.

In 1987 ORNL received four I•R 100 awards, one more than we won in the previous year and about as many as we had been winning for several years. DOE laboratories received 30% of the awards, and ORNL was cited for developing 4% of the best technologies in 1987.

In the past several years, I have given a Director's Annual Award. This year I want to recognize ORNL's Nuclear and Chemical Waste Programs, headed by Tom Row, for achievements in waste management. The programs have accomplished an incredible amount in the last few years and, in 1987, achieved a number of milestones. The success in recognizing ORNL's environmental problems and in determining, planning, and implementing their solutions is the result of the contributions of six ORNL divisions. The Environmental Sciences Division offers extremely good capabilities for understanding and applying scientific expertise to waste management issues. The Operations Division has implemented our waste management programs. The Environmental Compliance and Health Protection Division has monitored the Oak Ridge Reservation and worked overtime to deal with crises and to devise sound environmental recovery plans. The Chemical Technology Division has advanced the technology of waste management through R&D and has set up the Waste Management Technology Center at ORGDP. ORNL's Analytical Chemistry and Plant and Equipment divisions and the Engineering Division of Energy Systems continue to make field measurements and contribute to design and construction for remedial action. I thank the members of these divisions for bringing their scientific and technical skills, management, and dedication to the solution of these environmental problems and for confirming my faith that we are on a sound road to recovery from our legacy of environmental abuses.

# *Outlook*

What is the outlook for 1988? During this time of management transition, we will be moving in new directions and must pay even greater attention to the administrative and technical details of our tasks to ensure that we remain in a position that allows us to select the type of work we do.

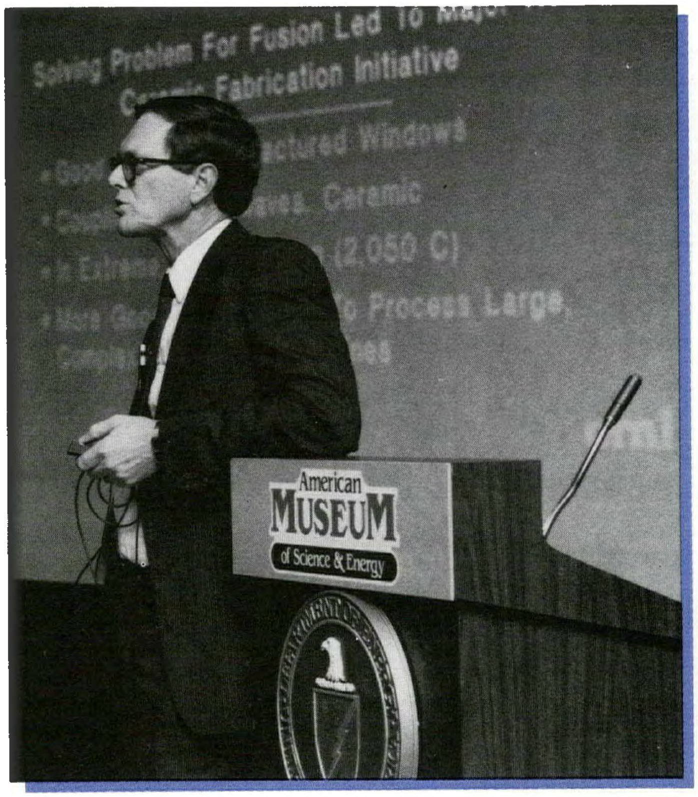
Fortunately, 1988 is not a year of great budgetary concern. We will have tight spots; for example, funding for the high-temperature, gas-cooled reactor work and the Advanced Controls Test Operation has been reduced. However, despite all the budget cuts and difficulties experienced by the nation, science funding remains in relatively good shape. Because the type of work we are involved in was not put under great budgetary pressure, the Laboratory has not suffered from cuts related to reductions of the U.S. budget deficit. ORNL probably will not grow in 1988, but we should accomplish most of the goals identified in our program plans.

Alex Zucker listens to Postma's final State of the Laboratory address. Zucker had been ORNL acting director for just two days when the address was delivered.

As you know, Alex Zucker is the acting director of ORNL, now that I have become senior vice president of Energy Systems. A search for ORNL's new permanent director is under way by a search committee, headed by Associate Director Murray Rosenthal. A new director is expected to be appointed by the end of the summer of 1988. It is important that you cooperate with the acting director and participate in selecting the permanent director by suggesting candidates. Because a transition is occurring, this is a golden opportunity for staff members to ask questions and provide input to steer the Laboratory in new, important directions.

# *Retrospective*

In thinking about ORNL's new directions and strategies, we should be aware of recent trends that affect the way we do business. These influences have made us realize that certain actions should be taken that we did not consider important in the past. I will discuss three major "waves" of crisis events that we should have anticipated and that have affected us greatly.




Postma reviews past ORNL achievements and discusses the Laboratory's future.

The first of these waves was the call for increased safeguards and security. The terrorist acts in the world, the great concern about the vulnerability of nuclear material to theft and sabotage, and the need for conventional security to protect our employees and physical resources have resulted in new measures. We had to make extensive efforts to train our guards and add physical protection. The security group did a magnificent job on this large undertaking, without intruding on or disturbing most employees or operations. We cannot relax completely, but we're over the greatest urgency to upgrade security and safeguards.

The second large wave was the growing concern about environmental abuses that occurred over the years for a variety of reasons at the Laboratory and in the Oak Ridge area. We are well on the road to recovery. We understand the problems, we now know how to solve them, we have laid plans for remedial and preventative actions, and we have cut down on the production of waste. Our ability to understand, manage, and resolve environmental problems has been demonstrated, but it has required a tremendous effort and has been costly. I have honored the people who have participated strongly in that effort. They have done a magnificent job. The total bill for complete environmental recovery at ORNL has been estimated at $1.5 billion; in contrast, at the site of the Hanford Engineering Development Laboratory, the cleanup bill is estimated at $100 billion. Across the DOE system, large sets of problems must be solved in the next 20 years. We at ORNL are at the forefront in laying the groundwork for environmental recovery, restoration, and rehabilitation.

The third major wave, which is hitting us now, has to do with questions about our ability to prove and ensure that our critical facilities are managed so that they will operate as intended. We have been reluctant to take all the QA steps necessary. The reactor shutdown saga has revealed some surprising situations that never should have been allowed. We must change our attitude and rededicate ourselves to carrying out all essential QA steps, or else we will not be permitted to operate our critical facilities. Our work culture must adapt

Clyde Hopkins, O. B. Morgan, and Fred Mynatt chat after delivery of the State of the Laboratory address. Hopkins is Energy Systems president, Morgan is director of ORNL's Fusion Energy Division, and Mynatt is ORNL associate director for reactor systems.

to this call for greater responsibility, and we must make a commitment to check every detail to ensure that facility operation meets the appropriate standards. We still have a great deal of work to do on this problem. Alex Zucker is committed to an increased emphasis on QA. Clyde Hopkins, Energy Systems president, and I want to make sure that the lessons learned at ORNL are learned across Energy Systems. We need your involvement and dedication.

Over the years, several events have affected the nature of research at the Laboratory. During the energy crisis in the 1970s, ORNL grew and diversified, increasing its efforts in coal, biomass, and conservation R&D. Today elements of a recurring energy crisis persist, but the nation is complacent and unconcerned about possible energy shortages. As a result, an amazing transition has taken place: ORNL, once primarily a nuclear research laboratory, now has a conservation research program much larger than its nuclear program.

Because ORNL is a federal laboratory, we have had to make sure that the Laboratory's resources are available to all parts of the federal government. In the last few years, work at ORNL for agencies other than DOE has grown to about $100 million. This "work for others" has been a central ingredient for Laboratory diversification and has helped support our researchers when funds for energy research have been tight. Most of us would prefer to focus on simple missions. But DOE has no energy missions, making it difficult for ORNL to focus on energy R&D. The situation can change rapidly if new energy-related crises occur, so we must be ready. Our strategy has been to stay involved in critical energy areas to prepare us for managing those problems when they recur.

In the area of technology transfer, Energy Systems signed its 18th licensing agreement in late 1987. Since the program started in 1984, Energy Systems has licensed more technologies to industry than have all other DOE laboratories combined. In 1987, for the first time, ORNL inventors were given royalty checks for their innovations. The U.S. government realizes that to be at the forefront of global economic competition we must be at the forefront of scientific competition. We must continue to transfer technological developments to American industry to ensure its competitive place in world trade. I think we've been extraordinarily successful in this venture—Energy Systems' technology transfer program has become a model for many laboratories.

In the past few years, we have greatly increased our cooperation with industry. Industrial users will soon be conducting research at the High Temperature Materials Laboratory and the Roof Research Center. ORNL researchers will be collaborating with industrial researchers through new industrial R&D consortia in ceramics, semiconductor processing, electronics applications, and software development.

Many university guests are already working with ORNL researchers. In 1987, we hosted about 2000 guest researchers, or the equivalent of nearly 600 full-time guests. We welcome them and are enthusiastically looking toward continuing these liaisons because they give us vigor and new ideas and lead us in new directions.

ORNL is a marvelous place. I appreciate the thrill and honor of working with so many superb, dedicated, and innovative people for these 14 exciting years. ornl

*"In 1987, we hosted about 2000 guest researchers, or the equivalent of nearly 600 full-time guests."*

# Susan Whatley: From Fast Track to Slow Boat

By Luci Bell

*"You can do anything you really want to do, at any age!"*

"You can do anything you really want to do, at any age!" This was the philosophy Susan Whatley learned from her first mentor–her grandmother. Growing up in Oak Ridge as the second oldest of ten children in the family, Susan may have found these words a little hard to believe. However, they stuck in her mind, and she has proven them true during her 28 years of employment at the Oak Ridge National Laboratory. She has accomplished what few women have dared even to try–moving from a secretarial position to technical staff engineer, section head, and program manager at ORNL (while also serving as president of a national professional society).

## Secretary

Susan was hired by the Atomic Energy Commission (AEC) as a clerk in the Personnel Division the summer following her graduation from high school in 1954. Independent-minded even then, she recalls that she ignored parental advice and married between her junior and senior years of high school. She then persuaded teachers to let her change from academic courses to shorthand and typing, because she wanted to be prepared for a job after finishing high school. In those days, most families did not urge young women to attend college, and she knew if there was college money available in her family of six girls and four boys, it would be for her brothers. Susan remembers failing the typing test for AEC employment at first. She was able to convince the tester that she needed another trial and barely passed the second time. That same persistence and determination to succeed have been evident in her career since then.

To be near her husband serving in the Armed Services, Susan left Oak Ridge and moved to Kentucky during the war years; their first child was born there. When a family decision was made to return to Oak Ridge in 1956, she hired in at ORNL, this time as a stenographer in the Personnel Office. A second child arrived, and, after taking time off for the birth (no paid maternity leave was available then), Susan hired in again–this time as a secretary in the Isotopes Division. Claiming to have been "backward" and shy at first, Susan began to gain confidence and to actively seek better positions. After winning a secretarial post she particularly wanted, she told her boss, John Gillette, director of the Isotopes Division, that she needed a new typewriter. "John asked me how much would it cost," Susan recalls with a smile. "When I told him, 'Ten thousand dollars,' his eyebrows went up!" Nevertheless, his answer was "If you can justify it, we'll consider it." She did, they bought it, and Susan gained one of the first new Mag-tape word processors at ORNL. Becoming an expert word processor with this state-of-the-art equipment, she soon had the opportunity to work on larger, more complicated, and more rewarding projects–some of them laboratory-wide in scope.

The advantageous location of her office (the lobby of the Isotopes Building) also allowed her to meet important people from throughout ORNL and well-known visiting scientists from other areas of the country and the world. "Everybody was equal," Susan says, "and the technical staff would take time to explain their work, show what they were doing. They seemed to enjoy their work so much! She learned a great deal of useful information through these contacts. Nowadays we would probably call this "networking," but at that time Susan had no particular career goals in mind. She was simply interested in all that was happening, and she was learning that scientists are not some special breed; they laugh, talk, and make mistakes just like other people. She began to think that work in some technical area could be a lot of fun.

Susan's husband became ill with cancer in 1964; for the next five years, she devoted most of her time and energy to caring for him and their family, trying to keep their lives in order. After her husband died in 1969, Susan took a long look at her resources. She says, "I knew I couldn't raise my children the way I wanted on a secretary's salary, so I decided to go back to school. By that time, I had been associated with technical people long enough to know that I was as intelligent as the next person and that I really was interested in doing technical work." She approached Gillette about becoming a laboratory technician, but was told that she couldn't be a technician because she was a woman. "In fairness," Susan says, "I knew the policy was partly a measure to protect women of child-bearing age from exposure to radiation. Although I was upset at the time, John really did me a favor, because that made me even more determined to find a way to have a technical career."

## Student

By this time Susan was confident that she could handle a technical college curriculum. Seeing her commitment, Gillette helped rearrange her work schedule to allow her to take classes at the University of Tennessee (UT). She started by choosing classes that she thought would interest her and that could also apply to some type of technical college degree, if she became sure she wanted to pursue that goal. Her first class was chemistry, which was available through the UT Evening School. With babysitting provided by her parents, Susan went directly from work to class, arriving home about 11:30 p.m. after back-to-back chemistry lecture and lab.

Successfully completing this first class in 1970, Susan went on to take calculus and honors physics. By this time, she had asked ORNL management for permission to take daytime classes, because UT offered few night classes for a technical undergraduate degree. Laboratory management cooperated by rescheduling her work so that she could take at least two classes per quarter. About this time she met, and soon married, Marvin Whatley, an engineer with the Fuel Recycle Division. Their marriage and the merger of two families resulted in a home with six children, rather than just two. Marvin was very supportive of Susan's career goals even before their marriage, she says, and has always encouraged her to excel mentally and scholastically.

After struggling with the heavy responsibilities at home and at work in 1971 and 1972, Susan asked for part-time employee status. Again ORNL management was cooperative. In 1973 and 1974, Susan worked part-time and began to train her own secretarial replacement. "By now," Susan says, "there were five college students in our family!" She decided to ask for a two-year leave of absence to complete her degree in a shorter time.

In 1975 when Susan was a junior at UT, she applied for an Oak Ridge Associated Universities (ORAU) summer student fellowship at ORNL. Management didn't know exactly how to handle this, because she was still officially an ORNL employee on leave of absence. However, she did receive the fellowship and worked at ORNL that summer for Chuck Scott of the Chemical Technology Division, doing electrophoresis work. Susan discovered that she really enjoyed doing research. By the time she returned to UT full-time that fall of 1975, she was sure that she wanted to complete a B.S. degree in engineering and then work toward a graduate degree.

*"I knew I couldn't raise my children the way I wanted on a secretary's salary, so I decided to go back to school."*

## Engineer, Graduate Student

Following graduation from UT in 1976, Susan worked for one quarter as a UT teaching assistant while she considered how best to pursue a graduate engineering degree. Discovering that she

*"For the first time I realized that it was up to me to either say 'I can't do this' or to take hold and start doing it. I decided it was a lot more fun to take hold and do it."*

could accomplish this through UT's Evening School, Susan applied for employment and was hired again at ORNL–this time as an engineer–in 1976. Three more years of graduate courses at night earned Susan an M.S. degree in engineering. These were exciting, challenging, and often difficult years. Susan says she kept running into problems because of her unusual educational background. For example, a professor recommended that she take a certain math class. Following his advice, she found herself in a theoretical analysis class with a group of mathematics Ph.D. candidates. She had no difficulty handling the complicated analysis aspects of the course, but she had never taken a class in trigonometry or geometry, so she was sometimes at a loss for the simple trig functions to use in the analyses. She said this deficiency was a source of amusement to her engineer husband and her classmates. Fortunately, most of the emphasis (and credit) in the class came from laying out the problems correctly, and nobody worried much about her being unable to recall a trig function.

## Research Engineer

Meanwhile at ORNL, Susan was doing reactor safety research for Tony Malinauskas and Bob Wichner. The Nuclear Regulatory Commission (NRC) wanted their group to model a loss-of-coolant accident in the primary loop of a light-water reactor–an accident scenario very much like the event that later actually occurred at Three Mile Island. Susan was given the assignment of developing this model and designing an apparatus to test it. She expected her superiors to tell her how to go about this, but instead was told to just go do it. This was a challenge, since her engineering curriculum did not include a design course, and she had never designed anything! She didn't back away from it, however. Susan says, "For the first time I realized that it was up to me to either say 'I can't do this' or to take hold and start doing it. I decided it was a lot more fun to take hold and do it."

After she modeled the accident scenario and designed the facility to test it, the whole team traveled to Washington D.C. to present these plans to the NRC. The NRC board was enthusiastic about the project but by this time had no money to fund the work. Susan then designed a smaller fission-product flow experiment that could be performed in a hood, but that too failed to receive funding, as did a third design for doing flow studies in a pressurized vessel. This was discouraging, to say the least. Susan says that when asked during a performance review what management could do to help her work, she replied "Give me a project that will last more than six months!"

She was given a new assignment, this time studying the crystalline structures of sol-gels with Rex Leuze. In November 1979, after nearly a year of this research, Don Ferguson, director of the Chemical Technology Division, called to ask if she would be interested in being technical assistant to ORNL's Associate Laboratory Director for the Physical Sciences, Alex Zucker. Susan was interested. When Zucker called her for an interview, she happened to be dressed in jeans and a khaki shirt, conducting a sol-gel experiment. She finished the experiment and later went up to talk to him.

After a couple of hours of general discussion, Zucker asked if she'd like the job of technical assistant. At that time, Susan was just completing her master's thesis and had already decided that time spent as a working engineer would advance her career more than time spent studying for a higher degree. She accepted Zucker's offer on the spot.

## AD Assistant

Susan worked as Zucker's assistant for about 18 months; during that time she realized that the job offered opportunities for interaction with people from technical areas throughout ORNL and a great vantage point from which to plan her next career move. She learned a great deal from her association with Zucker, including some extremely valuable management concepts: for example, the belief that management exists to make life easier for the research staff (rather than the reverse), and that management should relieve the research staff of as many administrative tasks as possible to allow them freedom to do their most important work– research.

"Another thing Alex taught me was the danger of using a position of power to have something done without considering the consequences. Anytime I went to support groups for help, I learned to investigate what might be interfered with in order for them to drop what they were doing and work on my job. From Alex I learned how to obtain really good cooperation from support personnel by giving them the consideration and courtesy they deserve," Susan explains.

During her final year as Zucker's assistant, Susan began investigating the entire three-plant area to identify the job she wanted next. She interviewed for positions in the Engineering Technology, Operations, and Fusion Energy divisions, but her preference was a job working with Leuze that became available in the Chemical Technology Division. Susan discussed the assignment with Ferguson, who said he felt the job was not right for her. Later he called to say he was creating a new Technical Support Section in the Division and to offer her the job of section head. At first Susan turned it down, because she preferred something in a more technical area. But she later reconsidered and decided to accept the job on a temporary basis.

## Section Head

Her new position encompassed the supervision of support services for the technical staff, such as drafting and editing, as well as administrative assistance to the division director. "That turned out to be a fun job," Susan now says. "You never knew exactly what types of problems would come up each day, but you could be sure that hundreds of problems of various types would come through the door. There was always lots going on, and plenty of interaction with people in other divisions throughout the Laboratory."

## NRC Program Manager

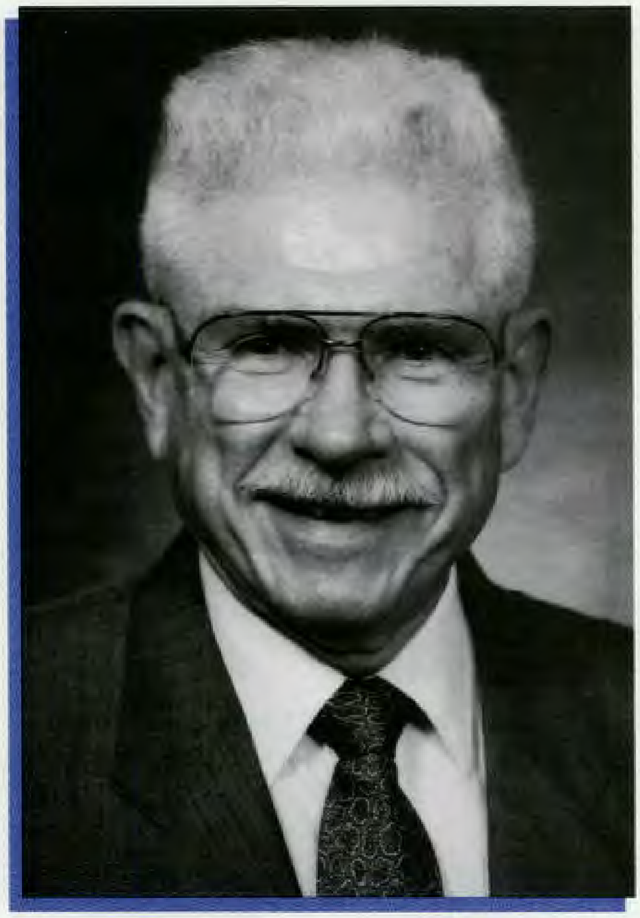
Obviously Susan is a "people person" and skilled in interacting with people. Personal interactions have been an important part of her career, she points out. She enjoyed working with Division Director Don Ferguson, and when he

*"Give me a project that will last more than six months!"*

retired early in 1983, both Ferguson and the new division director, Ray Wymer, asked her to remain as section head to give administrative continuity during the changeover. Susan agreed and stayed on for another year.

From section head, Susan then moved into an NRC program manager's position, remaining a part of Chem Tech but overseeing NRC's geological repository work under way in several divisions of ORNL.

*"Marvin was so totally supportive. Super supportive!"*



## National Society President

Susan had also worked actively in the Society for Women Engineers (SWE) for several years and, in 1985, she advanced from president-elect to president of the national SWE organization. The Society had some major financial and organizational difficulties at that time. Susan found herself with the responsibilities of resolving personnel problems, totally restructuring the accounting system, and reorganizing a financial structure that had been "in the red" for at least two years. "I learned a lot that year," Susan says now. "I learned you can do a lot of things if you can delegate. Martin Marietta was supportive during that difficult year, which involved a great deal of travel and many days away from her work here.

Of the technical work, Susan says she tried to stay available to Gary Jacobs, who was her NRC program manager replacement, for the sake of continuity. However, she appreciated the reduction of her workload by ORNL management that allowed her to perform the necessary duties as SWE president. She credits Jacobs with actually handling the program work during the first six-months of her SWE presidency in 1985.

## DOE Program Manager

In March 1986, while still serving as SWE president, Susan accepted a Department of Energy (DOE) position as ORNL's manager of the Transportation Operations Program Support Office of DOE's Office of Civilian and Radioactive Waste Management. During her remaining term as the SWE leader, Susan says it was really tough handling the responsibilities of both jobs. She was constantly on the road, making speeches and pulling the SWE back together. While in Oak Ridge, she worked constantly to catch up on the heavy workload in her new job. "In fact," Susan says, "It would have been impossible except that Marvin was so totally supportive. Super supportive. He took over almost all of the household duties; he challenged me to stick with it; he affirmed my ability." When she speaks of her husband, Susan's appreciation is evident.

## On Secretaries

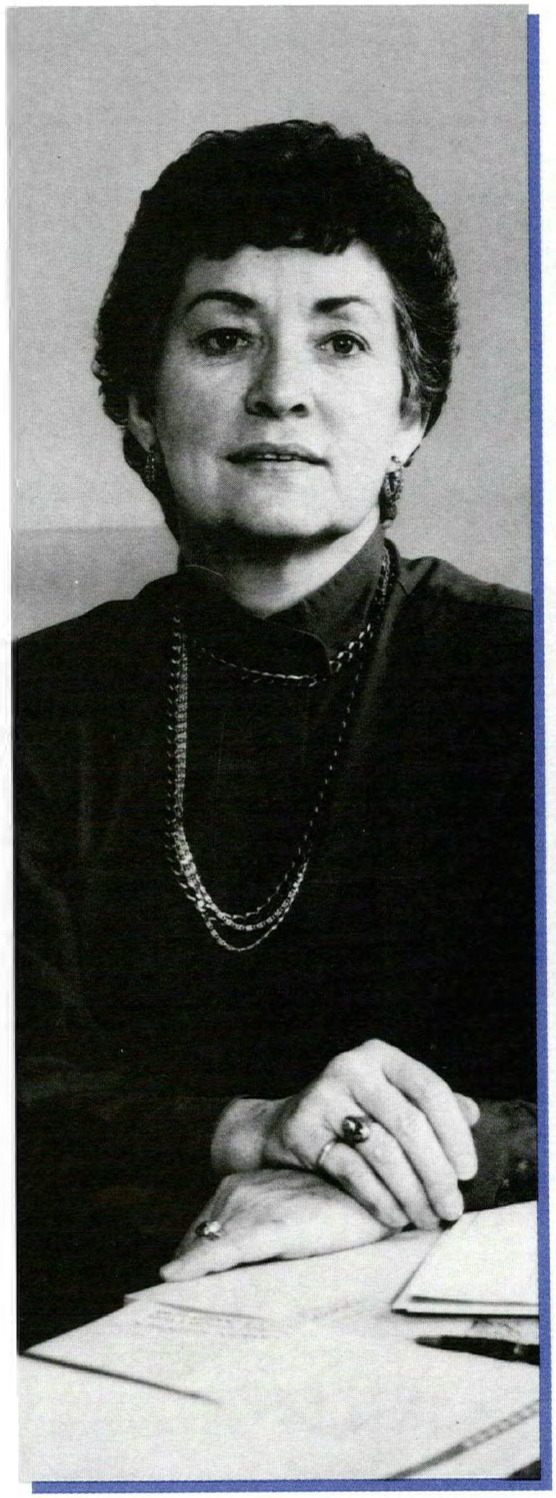
Her workload at ORNL was also made much easier because Susan now had her own secretary. "I've probably had some of the best secretaries at the Lab," she adds. "I give them as much responsibility and as much variety of work as I possibly can, because they grow from it. Secretaries are really valuable individuals, if you will give them the opportunity to contribute. I wanted to give them the chance to learn as much as possible and help them move on to better jobs.

And some of them have done exactly that." Having been a secretary herself, Susan may appreciate secretarial services more than most technical staff members. "I really believe the technical staff could make better use of their time if they had more secretaries available," Susan states. "It's counterproductive to have senior research staff doing photocopying and word processing."

## On Changes at ORNL

Has she noted any changes at ORNL since she first started working here? "Yes," said Susan. "On the negative side, there is more micromanagement from DOE, Oak Ridge Operations Office, and Martin Marietta. There is hardly any case where you can decide on something and then go *do* it. The chain of approvals required for any action grows longer every year. Paperwork requirements have mushroomed, and sometimes I feel there is more emphasis on form than on content."

Susan also sees some positive changes. Many more opportunities for women in engineering exist today than in the past. Women in the field are now the norm rather than the exception, and they are generally accepted and treated well. Typically 20% to 30% of any university's engineering



*"Women must learn to lobby for themselves . . . to achieve their career goals."*


*Susan Whatley is still seeking new horizons.*

students will be women, and most of these graduate near the top of their class. "Of course," Susan adds, "Most women who enter engineering were near the top of their high school class also." The current president of Tau Beta Pi, national engineering honor society, is a Knoxville woman (Martha Martin, an engineeer with the Tennessee Valley Authority).

However, few women are in top-level management positions here or in similar institutions across the country. Susan would like to know why the gap in salary level and benefits increases between men and women engineers over their years of employment. In her own case, Susan discovered that after several years of working at ORNL her job classification and salary were several notches below those of the men who had attended graduate school at UT with her and who held a lower academic standing than her own. When she brought this to the attention of management and insisted on equal standing and remuneration, the situation was corrected. However, she accepts some of the blame for the discrepancy. "I assumed that I would be given raises and promotions if I did my job well," Susan says. "I didn't realize how important it is to *ask* for the promotions and raises you want and how necessary it is to keep your supervision informed at all times about what a really great job you are doing."

Susan also believes some of the fault lies with the way women are trained to think about themselves. From childhood, our culture teaches women not to respond unless they are asked, not to be aggressive in pursuing goals.

"Women tend to assume that management will take care of them," Susan says. "They don't seem to realize they are responsible for their own career. They have to take the initiative, not only in *doing a good job* but in letting their supervision *know* that they're doing a good job and that they expect appropriate rewards–in promotions and salary–because of it."

Women must learn to lobby for themselves, Susan believes, in order to achieve their career goals. Great stamina and sacrifice are required to move into the top positions and stay there. Perhaps many women feel they have the option to refuse to seek such positions, while most men do not. Men often believe they alone are responsible for achieving the standard of living they want for their family. Of course, with the increase in divorce rates, more women may feel the pressures of being the sole support for their families and may seek advancement with greater determination.

## New Horizons

Both Susan and Marvin retired on March 1, 1988. As they move into this new phase of their life together, Susan says she would like to see a survey done to find out how many women who achieve higher management positions conclude that those jobs are not worth the struggle and perhaps not what they really want. However, Susan's not planning to conduct such a survey or stay to find out if anyone else will. She and Marvin own a customized 40-ft sailboat (which Marvin named *Susan*, of course) and are sailing to faraway places. Their first few months of retirement have been spent sailing in the Caribbean, where they have been many times before. After the new boat is thoroughly checked out, they plan to make a lifetime dream come true and sail around the world! Susan Whatley is still seeking new horizons. ornl

**Engineers at Energy Systems**

| | Total number of engineers | Number of women engineers | Percent of engineers who are women |
|---|---|---|---|
| 1978 | 1841 | 44 | 2.4% |
| 1988 | 1864 | 152 | 8.2% |

*In ten years, the number of women engineers at Energy Systems has more than tripled.*

# Mentoring:

# A Programmatic Approach

*"What are the mentoring practices that help an inexperienced employee on the road to success?"*

Lee Iaccoca credits them for helping to shape his career. T. J. Peters and R. Waterman's *In Search of Excellence* applauds them for fostering innovation and excellence. John Naisbitt's *Megatrends* notes their influence in white collar occupations. Rosabeth Kanter's *Men and Women of the Corporation* discusses how they help capable employees of top corporations advance. Daniel Levinson's *Seasons of a Man's Life* describes how they help men succeed through life's various stages. Gail Sheehy, in *Passages* and in *Pathfinders*, says that career women especially need them.

These best-selling authors all point out the importance of having mentors–wiser and more experienced persons willing to share their special knowledge to guide another's personal and career development toward success. Since the mid-1970s, more than 400 articles, nearly 100 doctoral dissertations, and the books mentioned above, plus others, have been written on the advantages of having mentors. Nearly all of these focus on the informal, spontaneous mentoring (typically through the "Old Boy Network") that benefits those few people lucky enough to be chosen by a mentor to receive special help.

Research has shown, however, that women and members of minority groups are those least likely to receive such informal mentoring. Consequently, some corporations are establishing more formalized, voluntary mentoring programs to ensure that all capable employees who would like to have the benefit of a mentor have access to the wisdom, broader perspective, and insight provided by such an association. Martin Marietta Energy Systems, Inc., with the approval and guidance of its Personnel Management Improvement Committee (PMIC), made up of functional vice presidents and other top managers, initiated a mentoring pilot program in 1987. This program reached completion in January 1988, and its evident success has led to plans for an additional formal mentoring program to begin operation in August or September of 1988.

What are the mentoring practices that help an inexperienced employee on the road to success? There are many ways a mentor can help: for example, by actual teaching of skills, by providing good advice (including advice on the "political" climate and system within an organization), by helping the employee set realistic career goals and learn how to achieve them, and by providing information (including "sensitive" or "insider" information that may not be readily available to a new or junior employee). A mentor is sometimes in a position to influence work assignments, providing more challenging, more rewarding, or "greater visibility" jobs than would otherwise become available. A mentor can also be of great value to a less experienced person simply by being a successful role model. All of these mentoring aids may actually help a capable employee gain competence in a particular job faster than would be possible without a mentor.

Mentors can also help their chosen "mentee" gain self-confidence through encouragement and praise for good work and progress and by demonstrating trust and friendship in both personal and work-related activities. Since the mentor often has "connections" with company employees on a higher managerial level, mentoring often involves increasing other people's perceptions of the mentee's competence by public or private praise (which increases their "visibility" to those in positions of power), by nominating or sponsoring the mentee for more advanced career moves, and, if need be, by protecting the mentee from unjust attack or blame (though mentoring should not include protecting people from gaining useful experience through the results of their own errors).

Though informal mentoring may be older than Socrates, it is only in recent years that companies have begun using more formalized mentor programs to encourage leadership development and upward mobility. As a part of the recent Energy Systems pilot program in this area, a survey was conducted to determine the scope and patterns of mentoring in a research and development environment such as the Oak Ridge facilities.

The survey found that more males than females considered themselves to have been involved in mentor relationships. Most of the mentoring involved white males as both mentor and mentee, with significantly less mentoring involvement shown by females and minorities at all three plant locations surveyed. The most prevalent mentoring behaviors listed by survey respondents were: demonstrating trust, teaching aspects of the job, and assigning challenging tasks. The survey also showed that mentoring has occurred in many types of organizations and at many different levels of employment within Energy Systems. Such mentoring relationships do not develop automatically, however, and may never develop at all for some very capable employees, particularly women and minorities.

To make up for the lack of mentoring opportunities for these groups, the Energy Systems pilot program was heavily weighted toward the involvement of women and minorities. A group of 14 mentees deemed most likely to benefit from such a program was selected from those indicating interest in participating. Mentors were selected by a variety of methods: each mentee was asked to name several persons whom they felt would be beneficial to them as a mentor; suggestions from management identified persons well-suited for acting as mentors; and volunteers were recruited in areas where it was felt that additional mentors were needed.

A great deal of planning effort, including detailed interviews with all parties, was involved in providing a good "match" between mentee and mentor. The pilot program went to great lengths to make sure that everyone felt comfortable with the arrangements and to provide as much flexibility as possible in the individual approaches to mentorship. Sponsoring organizations of both the mentee and mentor are asked to approve work time to be spent on the program.

The mentors were asked primarily to act as facilitators, offering suggestions, critiques, and encouragement and providing or making accessible the resources that might not otherwise be available to the mentee. Provision was even made for a "no-fault divorce," in cases where the relationship simply did not work out between mentor and mentee (although this provision was not used by anyone in the pilot program).

The apparent success of the pilot has led to a continuation of the Energy Systems mentor program. The demand is such that plans are being made for a new group to be "matched" with mentors and to begin the mentoring process at the beginning of each quarter, rather than only once per year.

The mentor program, as presently envisioned, will be a joint effort between Human Resource Development personnel and the Equal Employment Opportunity office at ORNL, under the enthusiastic leadership of Lynda Lewis and Joyce Conner. The primary goal of the program is to broaden salaried employees' understanding of career choices and help them build support networks of peers and managers within the organization through a beneficial association with individuals serving as mentors and role models.

Some Energy Systems managers are already convinced that this formalized approach to mentoring is proving successful in helping employees meet individual career goals. For example, George Jasny, Energy Systems' vice president for engineering and computing, says that his "whole view of mentoring has been expanded" by the pilot program's successes. After two years of operation, the mentoring program will be evaluated by the Energy Systems PMIC, and a decision will be made concerning the establishment of a permanent, formalized, mentor program at ORNL.–*Luci Bell*

***"Though informal mentoring may be older than Socrates, it is only in recent years that companies have begun using more formalized mentor programs to encourage leadership development and upward mobility."***

# Women in the work force: How are we doing at ORNL?

*Has affirmative action been effective in providing opportunities for minorities, including women? Does it work? How well does it work at Oak Ridge National Laboratory? Employment statistics for women workers during the past 20 years at ORNL make it evident that something has certainly made a difference.*

The effort to equalize opportunities for minorities in the work place really began in 1964, when the Equal Employment Opportunity Commission was created by the Congress through passage of the Civil Rights Act, Title VII. The aims of this legislation, to ensure that minorities are not discriminated against in the job market, were made more enforceable by Executive Order 11246 (also called Order 4), which was handed down in 1965. This order established the Office of Federal Contract Compliance and mandated the preparing and filing of affirmative action plans for organizations (such as Martin Marietta Energy Systems, Inc.) that fit the established guidelines. It was not until 1972, with the passage of Revised Order 4, that affirmative action goals for women became a requirement. This amended act prohibits discrimination in employment because of race, color, religion, sex, or national origin.

So how are we doing at ORNL? Has affirmative action really made a difference for women? Employment statistics indicate that some positive changes have been made. In 1968, women represented 14.5% of the total ORNL work force (276 of 5381). Today that percentage is nearly doubled, with women employees now making up 28.5% of the total employment at ORNL (1485 of 5210).

An even more impressive change has occurred in the types of jobs that women employees hold. Nearly 60% of female employees in 1968 performed office or clerical work, and only 6.9% held jobs in the professionals category. A meager 0.5% of women were classified as officials or managers. Things are a bit different today. Women make up almost 20% (18.8%) of ORNL's professional workers in 1988, which includes women working as scientists and engineers. In fact, nearly one-third (27%) of the female workers at ORNL are in the professionals category, and about half that number work in the sciences.

Deborah S. Barnes is ORNL's site manager of the Affirmative Action Program.

Today nearly 9% of ORNL's officials and managers are women. Although not a large percentage, it certainly represents a significant increase over the 0.5% of women in that category at ORNL in 1968. Even so, nearly 52% of all women currently employed at ORNL are working in office or clerical positions. This seems to suggest that less progress has been made than most women would wish. However, the skill levels required of office and clerical workers have increased so much during the past 20 years that the work they perform bears little resemblance to the office and clerical jobs of two decades ago.

Women at ORNL have made significant advances, although not all female employment goals have been reached. A disturbing recent trend may interfere with this progress. Recent statistics from the U.S. Department of Labor indicate a noticeable decrease in the number of women entering the biological and physical science professions. If this trend continues, the pool of female scientists from which Energy Systems and other organizations can hire professional workers will be smaller. A general population decline in the 22-year-old category may also result in fewer young science graduates, and especially fewer female scientists, from which to hire employees. Studies to identify the reasons for the decreasing enrollment of female students in the scientific disciplines are under way, but the actions taken to address the problem thus far have had minimal funding and only limited results.

A more positive note for women's employment prospects in the future can be found in the Bureau of Labor statistics that show an increase in the number of women enrolling in engineering fields. Although the potential increase in women engineers does not balance the projected decline in the number of women scientists, it provides hope that women professionals in technical areas will continue to be available for hire at ORNL.
*–Deborah Barnes*

# IMAGING THE WORLD'S LONGEST DINOSAUR

By Carolyn Krause

*"The ORNL technique should speed up the excavation of the dinosaur by a factor of five."*

When Alan Witten and Chris King returned to their motel room in Jemez Springs, New Mexico, on the evening of April 25, 1988, they could hardly wait to view the video screen for a picture of the dinosaur. A television program on dinosaurs was not what they had in mind, however. They were about to use a computer program to generate the most accurate image of buried dinosaur bones ever obtained.

They had spent a whole day in the field gathering data—in essence, shooting pictures of the longest dinosaur ever discovered—a 110-ft-long Seismosaurus that lies buried 8 to 10 ft below federally owned land about 60 miles northwest of Albuquerque. Shooting is a good term in another sense, too, because they used a cannon-like gun to fire steel slugs into the ground, producing the sound waves on which imaging is based.

"We were tired but excited when we viewed the image that night," says Witten, leader of the Applied Physical Sciences Group in Oak Ridge National Laboratory's Energy Division. He and King, an employee of the U.S. Army, showed a printout of the images to Wilson Bechtel when they saw him two days later. Bechtel, a paleontology buff, was thrilled. So was David Gillette, manager of the Seismosaurus Excavation Project, former curator of paleontology at the New Mexico Museum of Natural History in Albuquerque (where Bechtel works as a volunteer), and now state paleontologist of Utah (Antiquities Section of the Division of State History) in Salt Lake City, after he telephoned Witten at the motel on April 26 and received the news that the ORNL technique worked.

Gillette heads a team of national laboratory scientists and museum volunteers. The dig is being funded by the National Geographic Society and followed avidly by filmmakers for TV science programs (e.g., David Attenborough's new series on fossils for the British Broadcasting Corporation to be shown next spring).

On April 26, Gillette made arrangements to meet with Witten at ORNL to co-author scientific papers on dinosaur imaging. While at ORNL from May 23 through May 25, Gillette gave a seminar entitled "High-Tech Search for the World's Longest Dinosaur," which was attended by 400 persons.

## Value of Remote Sensing

"Remote-sensing techniques tested by ORNL and two other Department of Energy national laboratories could change the face of field work in paleontology and put paleontologists in the 20th century," said Gillette. "In paleontological excavations, we work blind. Remote-sensing techniques used for the first time at the Seismosaurus site for dinosaur exploration take some of the guesswork out of the search.

"These high-tech methods, particularly the ORNL imaging technique, could make it easier for paleontologists to obtain funding for digs," he added. "If we can use this technique to accurately map the positions of the bones, we can responsibly calculate the amount of labor time needed for the excavation, the number of volunteers needed, the amount of rock that must be removed, and the amount of disturbance expected at the site during excavation."

The ORNL acoustic technique tested in late April at the site determined the precise positions, depths, and sizes of the buried bones of a large part of the Seismosaurus skeleton. It showed

Artist's interpretation of Seismosaurus (foreground) compared with Diplodocus (background), a dinosaur in the same family. The Seismosaurus now being unearthed in New Mexico is the longest dinosaur ever discovered. Drawing by J.T. White.

promise for accurately locating other buried remains, thus allowing faster excavation and retrieval of brittle bones.

"This is a fantastic technique," said Bechtel. "It tells us whether to dig horizontally or vertically for the next bone and how far to dig before reaching it." Gillette predicts that the ORNL technique could permit paleontologists and volunteers to unearth the Seismosaurus in two years rather than as many as ten years. "The ORNL technique," he says, "should speed up the excavation of the dinosaur by a factor of five."

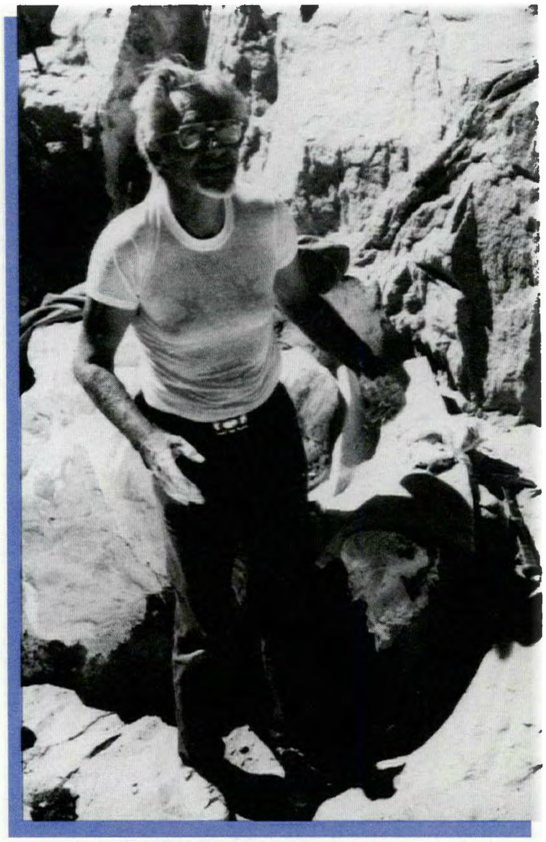
Los Alamos National Laboratory (LANL) and Sandia National Laboratories (SNL) have also been testing remote sensing techniques at the Seismosaurus site. These techniques include magnetometer surveying (LANL), ground-penetration radar (SNL and LANL), and scintillation counting (LANL) to measure gamma-ray emissions from the radioactive, uranium-containing dinosaur bones. All techniques have the advantage of being nonintrusive and nondestructive, yielding information without damaging the bones.

Normally, when paleontologists dig for skeletons, they use hammers and chisels to remove the outer rock, plaster and burlap to cover and protect the unearthed brittle bones, and lumber and steel to transport the bones to pickup trucks. These methods have been used by paleontologists since 1890.

The ORNL technique and other remote-sensing techniques could allow paleontologists and volunteers to reach the remains more quickly by using heavy equipment, including a backhoe, a machine with an articulated arm and scoop. Because the ORNL technique shows promise for locating each bone, backhoe operators could know which direction and what distance to dig to reach the next bone.

Witten and King are expected to return to the sand-and-sagebrush site later this year to obtain a more complete image of the Seismosaurus. "Terrain and an insufficient number of properly located boreholes prevented us from imaging the skeleton from one end to the other in April," said Witten. "So we asked that the site be leveled and that boreholes be drilled in the right positions to enable us to image the dinosaur, which is curved because of rigor mortis."

The ORNL technique may be used to locate dinosaur bones in several other sites in the West. To avoid unnecessary disturbance of the environment, paleontologists try to confine their digging to sites where remains are known to be present. The acoustic imaging technique should



Wilson Bechtel takes a break from covering a Seismosaurus bone with plaster.

help minimize disruption of this federal wilderness area.

The ORNL technique, which employs a gun-like device to generate sound waves, a string of microphones in a hole to receive them, and an innovative data-collection device, also has been used on the Oak Ridge Reservation to image underground features such as large rocks and buried pipes. The technique may be used to locate and image groundwater and hazardous wastes, guiding decisions about where to bury wastes and which waste sites to clean up first. It may also detect leaks from buried drums of wastes.

The development of ORNL's "acoustic tomography system" was supported by DOE and now is sponsored by the Army, which is interested in its applications for imaging buried hazardous wastes.

## Sizing Up Seismosaurus

In 1979, Jan Cummings and Arthur Loy of Albuquerque discovered the first Seismosaurus bones. In 1985, four hikers in the Jemez Mountains discovered several vertebrae that had been exposed by weathering and erosion. The find was reported to the New Mexico Museum of Natural History. Gillette, who was curator of paleontology there at the time (having left his faculty position at Southern Methodist University), launched a preliminary excavation that uncovered eight vertebrae, a piece of thigh bone, and other skeletal parts. Since then, the tail and hip have been exposed and 25 vertebrae have been removed.

Based on the size of the vertebrae and the results of remote-sensing techniques, Gillette estimates that the Seismosaurus is more than 110 feet long, making it 20 to 40% longer than its close relatives, the Diplodocus (87 feet) and the Brontosaurus (85 feet). It is thought to have weighed about 50 tons, making it lighter than Brachiosaurus, the 80-ft giraffe-necked supergiant believed to have weighed 80 tons.

Because of its great size, this four-legged, long-necked, long-tailed, plant-eating dinosaur was named Seismosaurus by Gillette. "Other supergiant dinosaurs from the Late Jurassic period have names like Ultrasaurus and Supersaurus. After some thought and reviewing of dictionary words, I named it Seismosaurus. This name came to me in the middle of the night after someone had suggested naming it superdupersaurus." The Seismosaurus, meaning "earth shaker," is a new dinosaur genus that belongs to the Diplodocidae family.

Besides its great length, the Seismosaurus find is scientifically important because the bones are not completely fossilized like those of most unearthed dinosaurs. The original bone material is believed to have been preserved for 144 million years, the estimated age of the dinosaur.

Studies of Seismosaurus bone chemistry at LANL also may lead to a revision of the theory of

Transporting delicate tail vertebrae, each weighing in excess of 500 lb, is a difficult task.

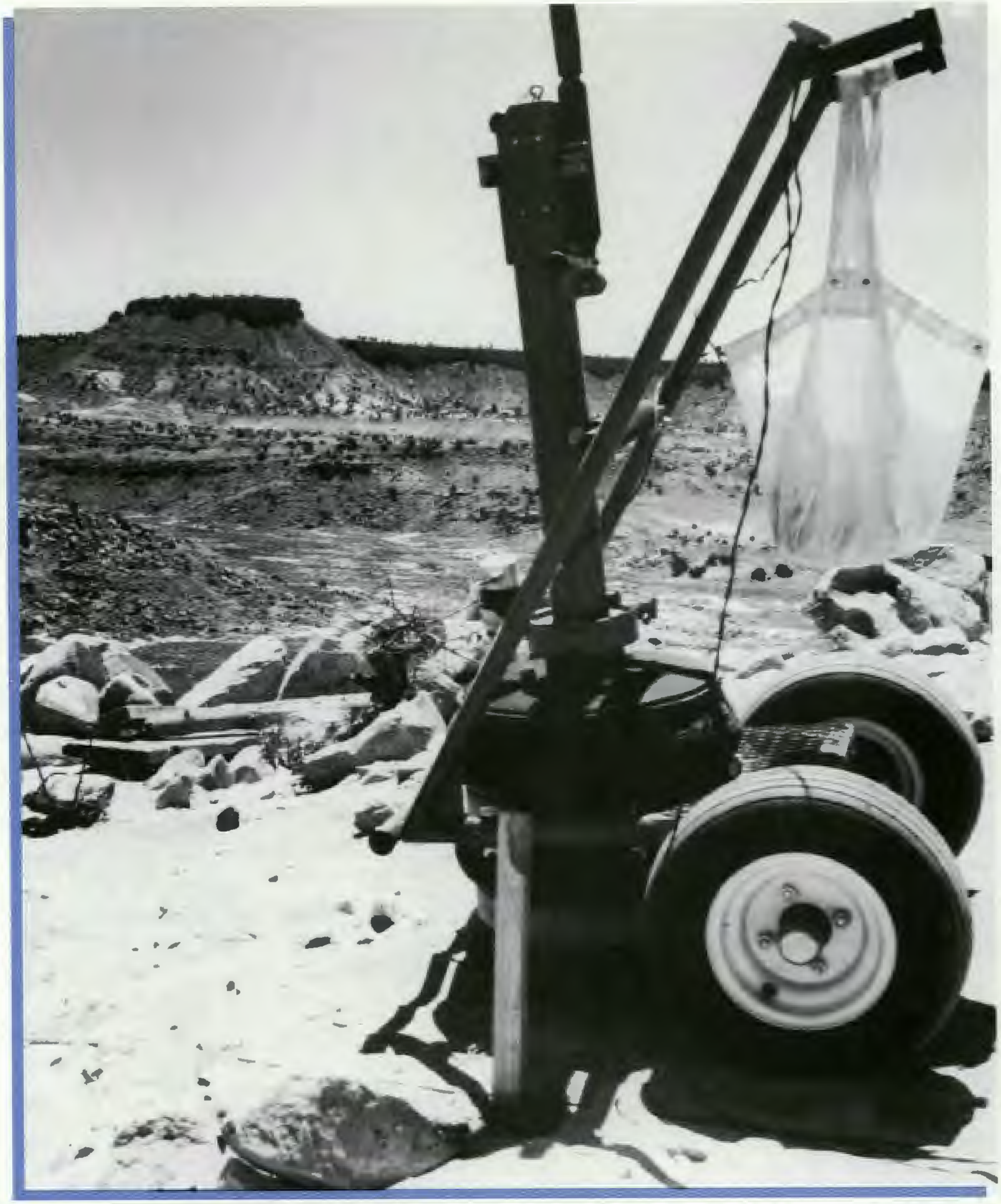
fossilization. The current theory is that bone molecules are replaced individually by molecules of other minerals. Results from studies of Seismosaurus bone suggest that bone chemistry remains relatively unchanged as molecules of other minerals settle in the voids.

In June 1988, Gillette obtained an excavation permit from the Bureau of Land Management (BLM) in the U.S. Department of the Interior to allow his group to dig much deeper on federally owned land for the dinosaur. BLM personnel have already proven useful in helping the group remove bone. In July, after the biting "no-see-um" insects left, digging began in earnest.

Reconstructing the Seismosaurus skeleton for display at the New Mexico Museum of Natural History will take years, Gillette says. For every day spent excavating a bone, two to three days of work in the laboratory are required to remove bone-adhering rock, using pneumatic tools similar to dental drills. "Seismosaurus may be excavated in two to five years," Gillette says, "but it will take 40 to 50 person-years to clean up and repair the bones. The total cost for excavation, repair, and mounting would be about $2 million."

## How ORNL Became Involved

In 1986, Gillette interested LANL scientists in providing technical advice and assistance on the dinosaur recovery project. Roland Hagan of LANL, who has been involved in LANL projects to decipher the location of buried Seismosaurus bones using scintillation counting and ground-penetration radar, knew about Witten's below-ground imaging technique. He called Witten and



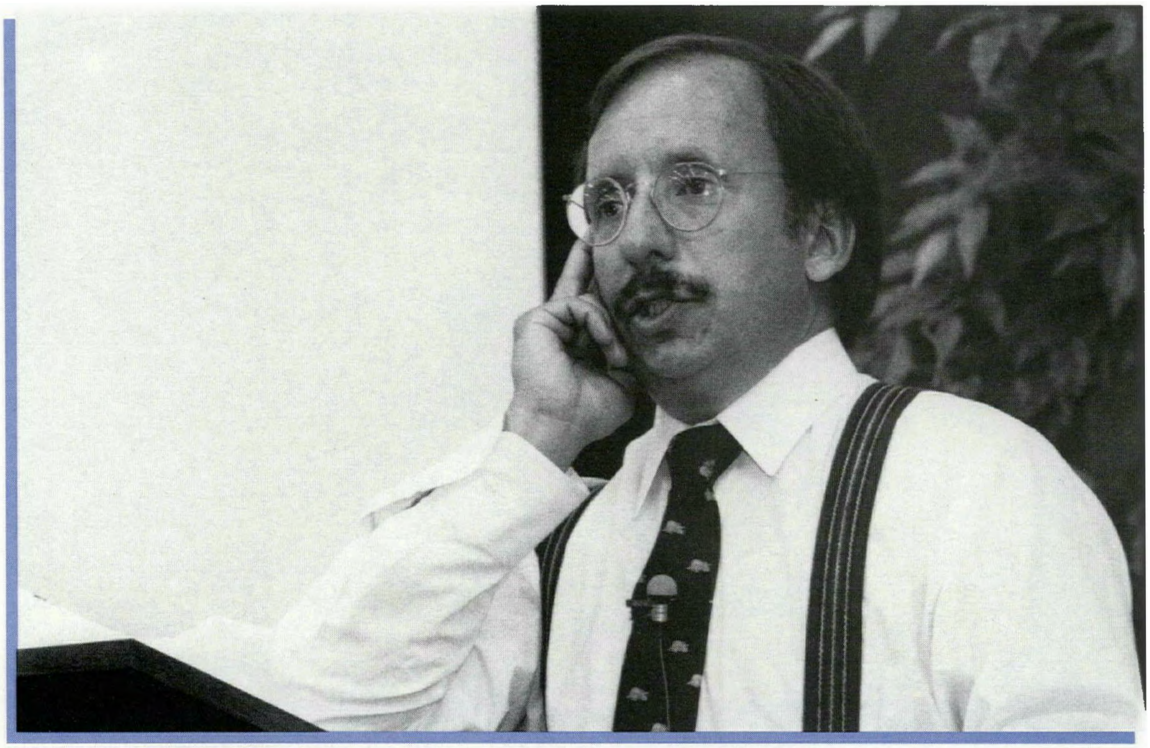
It's quiet here at the Seismosaurus site, but the cannon-like noise source of ORNL's acoustic tomography technique can "shake the earth" a little in search of the buried skeleton of the "earth shaker."

suggested that he test his acoustic technique to determine if it could image a large dinosaur in sandstone. Witten sought and obtained internal funding to cover his transportation and housing expenses to the site.

For the sonic technique to image the dinosaur, the speed of sound through the dinosaur bones must be significantly different from that through the sandstone. The speed is determined by the density of the material—the denser the material, the faster the sound penetrates it.

Witten asked for a bone sample to determine if sonic tomography is feasible for dinosaur imaging. On February 10, Witten received a sample of bone from Seismosaurus's tail. He asked Bill Simpson of ORNL's Metals and Ceramics Division to run ultrasound tests on the dinosaur bone. By the first week of March, Simpson determined that high-frequency sound waves pass through the Seismosaurus tail bone at a rate of 12,500 ft/s, within the normal range for bone.

Members of the excavation team examine some of the large exposed tail vertebrae. Portions of these bones have been plastered for protection. In the background are cutouts showing the locations of previously removed tail vertebrae.



Gillette ponders a question from the audience after his seminar, "High-Tech Search for the World's Longest Dinosaur."

Witten's consultations with geologists, including ORNL's Bill Staub, revealed that sound travels through sandstone at the Seismosaurus site at speeds of 1400 to less than 8000 ft/s. "We produced an image of part of the Seismosaurus because the difference between the sound speed in the dinosaur bone and that in the host sandstone is sufficiently large," says Witten.

The ORNL apparatus consists of a commercially available "noise source"—a gun-like device at the ground surface to create low-frequency sound waves in the soil; a streamer—an array of listening devices (microphones) lowered to a desired depth in a borehole; an innovative 32-channel data-acquisition system designed by Witten in collaboration with Scott Stevens of the Energy Division and researchers at the University of Rochester's Medical Ultrasound Laboratory; and a "supervisory" personal computer that controls data collection.

The computer-driven data-acquisition device images the buried dinosaur by measuring the time it takes for transmitted sound waves to penetrate the sandstone and bone and reach the microphones at various depths. By comparing the known speeds of sound through the sandstone and bone with the actual on-site measurements, it is possible to construct an image of the buried dinosaur. The image construction is achieved by a computer program developed by Witten.

"The Seismosaurus site," says Witten, "is a test bed for new applications of our sonic-geophysical imaging technique. We hope our technique will help paleontologists find and excavate dinosaurs more easily and quickly."

In the meantime, Witten's technique has been receiving considerable media attention, specifically, the Associated Press, Knoxville newspapers and TV stations, and *Insight*. Boston's WGBH will show Witten's technique in early December 1988 on its TV series, "Discover–The World of Science." Witten's sights may be focused below the ground, but, from a media point of view, he is a rising star. ornl


Alan Witten (left), Gillette, and Chris King sport DINO BUSTER T-shirts.

## Other Unusual Requests

**Alan Witten's sound grasp of acoustics and his development of a sonic technique for imaging subsurface features has earned him a number of unusual assignments. He has been asked by the U.S. Army to reconstruct images from acoustical data gathered by the Army in the demilitarized zone in Korea. The purpose: to image tunnels to Seoul that might be used by the North Koreans in a possible attempt to sabotage the Summer Olympic Games.**

**He has also been asked by an executive officer in the Division of Engineering at Brown University about the feasibility of acoustic imaging to locate an old fort built by George Washington and a gravesite; both have stone walls that lie buried several feet below the ground in Virginia.**

# RE: Awards and Appointments

C. T. Liu

James E. Turner, Jr.

Richard Genung

**C. T. Liu** was one of six recipients of the 1988 Ernest Orlando Lawrence Memorial Awards of the Department of Energy. He was recognized "for outstanding contributions to the establishment of scientific principles for the design of new alloy systems having high-temperature strength and ductility and for their successful application in advanced energy production systems, such as coal conversion, and in energy conservation devices."

**Liane B. Russell** has achieved the rank of senior corporate fellow of Martin Marietta Energy Systems, Inc.

**James E. Turner, Jr.**, has been appointed an Energy Systems corporate fellow.

**Richard Genung** has been appointed director of ORNL's Chemical Technology Division.

**Fred C. Hartman** has been appointed acting director of ORNL's Biology Division, replacing **Stephen V. Kaye**, who returned to his former position as director of the Health and Safety Research Division.

**Charles D. Scott** has been elected a director of the American Institute of Chemical Engineers.

**Cornelius Klots** received the annual Excellence in Research Award of ORNL's Health and Safety Research Division "for his outstanding contributions in the application of thermodynamics to the important area of atomic and molecular clustering phenomena."

**Barry Berven** has been named head of the Environmental Measurements and Applications Section of ORNL's Health and Safety Research Division, replacing **Rowena O. Chester**, who has joined the Energy Systems' Data Systems Research and Development Organization.

**Margaret B. Emmett** has been named head of the Nuclear Code Development Section in the Nuclear Engineering Applications Department at ORNL. The department is part of Energy Systems' Computing and Telecommunications Division.

At the WATTec Awards Luncheon in February 1988, several Energy Systems employees involved in ORNL projects were honored. They are **Vickie E. Lynch**, Distinguished Achievements in Technology Award, East Tennessee Chapter, Association for Women in Science; **Elijah Johnson**, Outstanding Scientific Achievement Award, East Tennessee Chapter, National Organization for the Professional Advancement of Black Chemists and Chemical Engineers; **Paul R. Kasten**, Outstanding Service Award, Oak Ridge Chapter, Tennessee Society of Professional Engineers; and the late **Joy Huffstetler**, a posthumous Distinguished Service Award, East Tennessee Chapter, American Society for Information Science.

"The Energy Place," a multi-image slide presentation describing ORNL, received an award of achievement in the international Audiovisual Competition sponsored by the Society for Technical Communication (STC). The entry was photographed primarily by **Lewis McCrary**, produced by **Jim Richmond** and **John Ridley**, and written and directed by **Joe Clark**.

*The Hood River Conservation Project: Cooperation and Community Conservation* by **Eric Hirst**, Pacific Power and Light Company, and The O'Haras, Oak Ridge consultants in technical communication, received an award of achievement in the category of technical reports in the 1988 International Technical Publications Competition sponsored by STC.

**Sandra Schwartz** and **D. J. Hoffman** received an award of achievement in STC's International

Technical Art Competition for her color rendering of *Compact Loop Antenna for TFTR* (Tokamak Fusion Test Reactor at Princeton, New Jersey).

**Jeanne Dole**, **Vickie Conner,** and **Jane Eggers** received the Francis E. McKinney "Best of Show" Award of the 1987-88 Technical Publications Competition sponsored by STC's East Tennessee Chapter at the awards celebration on February 17, 1988. Their award-winning entry was a brochure, *Affirmative Action: Working Together Makes It Work.* In the STC/ETC Technical Art Competition, **Michael Darnell** and **Steve Combs** received the "Best of Show" Award for a drawing of a *Repeating Three-Barrel Pellet Injector* for refueling fusion devices.

Nineteen entries from Energy Systems received awards in the 1987-88 Technical Publications Competition sponsored by the STC's East Tennessee Chapter. The entries and winners earning awards of distinction were: *Affirmative Action: Working Together Makes It Work,* **Jeanne Dole**, **Vickie Conner**, and **Jane Eggers**, brochures category; *CDIAC Communications*, **David Fowler**, **Lydia Corrill**, and **Kathie McKeehan**, newsletters; *Technology Applications Bulletins,* **Christina Sekula**, **Scott Buechler**, and **Kathie McKeehan**, whole periodicals; "Fission Product Tellurium Release Behavior Under Severe Light Water Reactor Accident Conditions," *Nuclear Technology* (April 1987), **Jack Collins**, **Morris Osborne**, **Dick Lorenz**, and **Donna Reichle**, scholarly/professional articles; and *The Hood River Conservation Project: Cooperation and Community Conservation*, **Eric Hirst**, Pacific Power and Light Company, and The O'Haras, consultants in technical communication, technical reports.

Receiving awards of excellence were: *A Primer for TSO and TSO/ISPF*, the staff of ORNL's User Services Section, software combination user and reference guides; *Chemical Technology Division of the Oak Ridge National Laboratory*, **Luci Bell** and **Ginger Ross**, promotional materials; *Nuclear Safety*, **Ernest Silver** and **Susan Hughes** and the MAXIMA Corporation Nuclear Safety staff, whole periodicals; "Helium Effects on Void Formation in 9Cr-1MoVNb and 12Cr-1MoVW Irradiated in HFIR," *Journal of Nuclear Materials* (1986), **P. J. Maziasz**, **R. L. Klueh**, and **J. M. Vitek**, scholarly/professional articles; and *Computer Integrated Manufacturing in the Oak Ridge Y-12 Plant: A Technology Baseline*, **Amy Harkey**, **H. E. Harper**, and the IRO Publications Section, technical reports.

Recipients of awards of merit were: *Welding Science Newsletter*, **S. A. David**, **J. M. Vitek**, and **P. H. Wilson**, newsletters; *Robotics and Intelligent Systems Program*, **Charles Weisbin**, **Patricia Greeson**, and **Vickie Conner**, promotional materials; *Oak Ridge National Laboratory FY 1987-1992*, **Jeanne Dole**, **Vickie Conner**, and **Mark Sollenberger**, periodic activity reports; and *Special Atom-Probe Field-Ion Microscopy Symposium*, **M. K. Miller**, scholarly/professional articles.

Entries and winners who earned awards of achievement were: *Introduction to the Central Computing Facilities*, the staff of ORNL's User Services Section, brochures; Cray Summaries Manual, the staff of ORNL's User Services Section, software reference guides; *Oak Ridge National Laboratory REVIEW*, **Carolyn Krause**, **Lydia Corrill**, and **Bill Clark**, house organs; "Experimental Studies of Fission Product Release from Commercial

**Fred C. Hartman**

**Cornelius Klots**

**Vickie E. Lynch**

Eric Hirst

R. Julian Preston

Marilyn A. Brown

Light Water Reactor Fuel under Accident Conditions," *Nuclear Technology* (August 1987), **Morris Osborne, Jack Collins, Dick Lorenz**, and **Donna Reichle**, scholarly/ professional articles; and *Navy Mobility Fuels Forecasting System: Phase III Report*, **G. R. Hadder, Mary Guy**, and the IRO Publications Section, technical reports.

Four entries of ORNL and Energy Systems received awards in the 1987-88 Technical Art Competition sponsored by the East Tennessee Chapter of STC. The entries and winners are *Compact Loop Antenna for TFTR*, **Sandra Schwartz**, Information Resources Organization (IRO) Publications Section, and **D. J. Hoffman**, award of distinction in the category of industrial/technical graphics; *Fission Product Barriers and Retention Properties of Fuel Elements for a Pebble-Bed High-Temperature Gas Reactor: (a) Particle; (b) Fuel Element*, **Shawna Parrott** and **Ernest Silver**, award of achievement in industrial/technical graphics; *Repeating Three-Barrel Pellet Injector*, **Michael Darnell** and **Steve Combs**, award of distinction in industrial/ technical graphics; *A Slide Totally Computer Generated Using MAPPER Software by Computer Associates (CA) Graphics*, **Lee Shugart** and **LeJean Hardin**, award of merit for their line art drawing in the category of design graphics.

**R. Julian Preston** is president-elect of the Environmental Mutagen Society.

**Martin S. Lubell** has been appointed advisory editor for the journal *Cryogenics*.

**James D. Regan** is one of two ORNL scientists (Peter Mazur is the other), each of whom is senior author of two papers designated as Citation Classics by the Institute for Scientific Information. Regan's first paper, entitled "Evidence for Excision of Ultraviolet-Induced Pyrimidine Dimers from the DNA of Human Cells in Vitro," was published in a 1968 issue of *Biophysical Journal*. The second paper, co-authored by Regan and former ORNL scientist Richard B. Setlow, is entitled "Two Forms of Repair of Damage to DNA in Human Cells Damaged by Chemical Carcinogens and Mutagens" and was published in a 1974 issue of *Cancer Research*.

**Stephen H. Stow** has been named to the Education Advisory Committee of the American Geological Institute and has been appointed chairman of the Membership Committee of the Geological Society of America.

**D. E. Todd** has received the 1988 Technical Achievement Award of ORNL's Environmental Sciences Division.

**Sidney P. du Mont III** has been named manager of the Environmental Projects Program in ORNL's Nuclear and Chemical Waste Programs.

**Barry L. Burks** has been appointed technical assistant to **Bill Appleton**, acting associate director for the physical sciences at ORNL. **Linda Horton** continues to serve as technical assistant to ORNL Acting Director **Alex Zucker**.

**Marilyn A. Brown** has been elected a national councillor of the Association of American Geographers.

**Carl Burtis** has been elected president of the American Association for Clinical Chemistry.

Two Energy Systems graphic artists received six medals in the presentation graphics category of the Computer Graphics Competition of the national Computer Graphics Association. They are **LeJean Hardin**, one gold and two silver medals, and **Peggy Brooks**, two silver and one bronze. ornl

1 9 3 4 2 6 5

# Choosing a Top Candidate is Not Easy

By V.R.R. Uppuluri

*This is the third in a series of* Take a Number *items on voting and elections from a mathematician's point of view.*

The top candidate among three choices may not be the same as the top candidate after one of the three choices has been removed. Consider the following example provided by Michael Hilliard of ORNL's Energy Division.

A convention committee met to decide the location of the next annual meeting of a national society. Three sites had been suggested—Atlanta, Boston, and Chicago–but the committee needed to come to a consensus on the order in which to pursue the three sites. The committee of seven decided that after each member listed his or her preferences, in order, it would combine the preferences by using a simple procedure. Each time a city was rated as first choice, it would receive three points; for each second-place rating, a city would receive two points; and for each third-place rating, the city would receive one point. The ballots were collected, showing the following results.

| | Ranking by 3 voters | Ranking by 2 voters | Ranking by 2 voters | Total points |
|---|---|---|---|---|
| Atlanta | first (9 pts) | second (4 pts) | third (2 pts) | 15 |
| Boston | second (6 pts) | third (2 pts) | first (6 pts) | 14 |
| Chicago | third (3 pts) | first (6 pts) | second (4 pts) | 13 |

Thus it was decided to investigate Atlanta first, Boston second, and Chicago third. The meeting was adjourned, and the chairman was congratulated on his "consensus-making" skills.

The next morning, after all the committee members had gone home, the chairman received a call from the member who had recommended Boston. "I'm sorry," she said, "but I've just discovered that the annual meeting of the International Society of Snake Charmers will be in Boston the same week we were planning for and they've booked all the hotels. I'm afraid we'll have to drop Boston from the list." The chairman expressed his regret and then returned to the project of investigating Atlanta as a site for the meeting. He wondered, however, if the ordering of the cities might have been different if Boston had not been an option. "Surely the withdrawal of the middle-ranked city should not affect the ranking of the other two cities," he thought. To satisfy himself that this would not happen, he recounted the ballots, omitting Boston and giving only one or two points to Atlanta and Chicago depending on their order. His results are shown in the following table.

| | Ranking by 3 voters | Ranking by 2 voters | Ranking by 2 voters | Total points |
|---|---|---|---|---|
| Atlanta | first (6 pts) | second (2 pts) | second (2 pts) | 10 |
| Chicago | second (3 pts) | first (4 pts) | first (4 pts) | 11 |

Now Chicago was preferred to Atlanta, although it ranked *last* in the earlier result. The chairman considered two options: calling all the members back to a meeting to see if they wanted to change their minds or abiding by the earlier decision. He decided to tear up the second table, call the Atlanta convention bureau, and hope that no one else would ever consider the problems with this "consensus" technique.

## *The Making of the Atomic Bomb*

**By Richard Rhodes, Simon and Schuster, New York, 1986, 886 pages.**
Reviewed by Richard Ward, Computing and Telecommunications Division of Martin Marietta Energy Systems, Inc.

*"Early chapters portray the scientists who unraveled the mysteries of the atom and atomic fission, such as Leo Szilard, Ernest Rutherford, and Niels Bohr."*

This comprehensive book by Richard Rhodes, a free-lance writer from Kansas City, received the 1987 Pulitzer Prize for nonfiction. His sharp literary style and his understandable presentation of the technical details involved in creating the first atomic bomb should impress even the most discriminating scientific reader. The book includes extensive footnotes and an excellent bibliography.

This is probably the most complete treatment yet of the scientific and technical achievements that harnessed the power of the atom to end World War II. Rhodes chronicles events from just before the turn of the century, when the atom was still a mystery, to the first demonstrations of its awesome power, in August 1945, in the bombing of Hiroshima and Nagasaki. An epilogue contains a brief discussion of the hydrogen bomb, referred to at the time of its development as "The Super." The book includes fascinating portraits of the key scientists involved, detail on the interactions of politics and science during the 1930s and 1940s, and an interesting discussion of war as a catalyst for the production of increasingly effective weapons.

Early chapters portray the scientists who unraveled the mysteries of the atom and atomic fission, such as Leo Szilard, Ernest Rutherford, and Niels Bohr. Rhodes tells how Szilard, with the assistance of Edward Teller and Eugene Wigner (formerly an ORNL director and now an ORNL consultant), persuaded Albert Einstein to write a letter to President Franklin D. Roosevelt, to point out the potential of atomic fission for weapon use.

The chapters on Rutherford and Bohr focus on their research that led to our present concept of the atom. Rutherford discovered the atomic nucleus by bombarding gold foil with alpha particles, and Bohr accounted for the observed atomic spectra by developing a remarkably simple atomic model in which the electrons surrounding the nucleus occupy quantized nonradiating orbits. Bohr's visage was cast over much of the development of atomic theory and the atomic bomb. He originated many of the fundamental concepts of quantum mechanics, the most famous being his theory of complementarity: that a fundamental particle, such as an electron, has characteristics of both a particle (matter) and a wave (energy). Later Bohr saw the atomic bomb as another example of complementarity, having both the power to destroy and the power to end all major wars.

"The Long Grave Already Dug," chapter 4, deals in part with Harry Moseley, Rutherford's talented colleague who measured the X-ray spectra of the elements to confirm the Bohr-Rutherford atomic model. Moseley's career was cut short by his death at Gallipoli on August 10, 1915, in World War I. Rhodes relates that Robert Millikan wrote in a public eulogy that Moseley's loss alone made the war "one of the most hideous and irreparable crimes in history." At the close of this chapter, Rhodes presents the theme that recurs throughout the book: that each war promotes the development of weapons that kill with ever greater efficiency. In World War I, the machine gun was developed to such a level of efficiency that, as Rhodes notes, "In the Battle of the Somme, on July 1, 1916 . . . at least 21,000 men died in the first few hours, probably in the first few minutes, and 60,000 the first day."

A later chapter records the shift of momentum in atomic research from Europe to the United States. Ernest O. Lawrence developed the cyclotron at the University of California in Berkeley, making it possible to bombard the atom with high-energy particles to determine the nature of its constituents. Lawrence also invented the calutron, which was later used (on a much larger scale) in Oak Ridge to produce enriched uranium for the Hiroshima bomb. Rhodes points out that no individual or institution can slow the progress of science and discovery. Atomic fission, first discovered by Otto Hahn and Fritz Strassman at the Kaiser Wilhelm Institute for Chemistry in Berlin in 1939, was quickly achieved by others as well. Rhodes implies that the momentum of scientific research alone would have led to the concept of a controlled fission reaction, and eventually an atomic bomb, regardless of the circumstances. World War II and the very realistic fear that Germany might "build the gadget first" undoubtedly accelerated this development. In discussing the interactions of science and politics, particularly the political control of science to achieve specific wartime objectives, Rhodes tells of the formation of the Office of Scientific Research and Development (OSRD). Under the direction of Vannevar Bush, this was the first umbrella organization in charge of atomic bomb research. Rhodes portrays the civilian-controlled OSRD as lacking the authority and connections to administer the complex task of constructing an atomic bomb.

General Leslie Groves of the Army Corps of Engineers was put in charge of the program, newly named the Manhattan Engineer District, in September 1942. The following incident describes Groves' gung-ho attitude: "Groves immediately attacked his worst problems and solved them . . . (He) approved a directive that had been languishing on his predecessor's desk throughout the summer (of 1942) for the acquisition of 52,000 acres of land along the Clinch River in eastern Tennessee. Site X, (they) called it. District Engineer Marshall had thought to wait to buy the land at least until the chain reaction was proved.

"On September 23, the following Wednesday, Groves' promotion to brigadier came through. He hardly had time to pin on his stars before attending a command performance in the office of the Secretary of War (Stimson). . . Groves described how he intended to operate (the Manhattan Engineer District). Stimson proposed a nine-man committee to supervise. Groves held out for a more workable three and won his point. Discussion continued. Abruptly Groves asked to be excused; he needed to catch a train to Tennessee, he explained, to inspect Site X. The startled Secretary of War agreed and Leslie Richard Groves, the new broom that would sweep the Manhattan Engineer District clean, departed for Union Station."

The Manhattan project approached its culmination on the desert plains of the Jornada del Muerto in New Mexico, with the test firing of the plutonium implosion bomb (code-named Trinity). Reactions of the scientists present, which ranged from technical descriptions to poetry from the *Bhagavad Gita*, testify to its fearsome success. Rhodes also records the reactions of those who survived the bombings at Hiroshima and Nagasaki. The crescendo of scientific discovery and success in the book's early chapters is counterbalanced by the tales of human misery in the chapter titled "Tongues of Fire." Rhodes tries to deal with both the scientists' moral dilemma in creating a weapon capable of such destruction and the rationalizations of U.S. military and political leaders for using that weapon in civilian bombings. "Under the brutal pressures of World War II," Rhodes says, "the atomic bomb became that war's most efficient weapon."

A scientific background will help the reader to appreciate the wealth of technical detail in Rhodes' book, but it is not a requirement. *The Making of the Atomic Bomb* deserves to be read by both scientists and nonscientists as a history of important scientific achievement and the impacts of war upon science. ornl

*"Rhodes also records the reactions of those who survived the bombings at Hiroshima and Nagasaki."*

# Books in Print

## The following books were authored or edited recently by ORNL staff members

(whose names appear in bold)

*The Economic Feasibility of Recycling: A Case Study of Plastic Wastes*, **T. R. Curlee**, Praeger Press, New York, 1986, 368 pages.

*Energy Efficiency in Buildings: Progress and Promise*, **Eric Hirst** et al., American Council for an Energy Efficient Economy, Washington, D.C., 1986, 328 pages.

*The Psycho-Social Impacts of Hazardous Technology*, **John Sorensen, Jon Soderstrom, Emily Copenhaver, Sam Carnes** et al., State University of New York Press, Albany, 1987, 233 pages.

*Heavy Metals in the Environment*, Vols. 1 and 2 (Proceedings of International Conference, September 15-18, 1987, New Orleans), ed. **S. E. Lindberg**, CEP Ltd., Edinburgh, United Kingdom, 1987, 1008 pages.

*Carcinogen Risk Assessment*, ed. **Curtis C. Travis**, Plenum Press, New York City, 1988, 210 pages.

*Oak Ridge Model Conference Proceedings* Vol. I, *Waste Management*, Parts 1-3 (October 13-16, 1987), compiled by **T. H. Row**, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, 1987, 1317 pages.

*Oak Ridge Model Conference Proceedings* Vol. II, *Environmental Protection* (October 13-16, 1987), compiled by **T. H. Row**, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, 1987, 448 pages.

*Oak Ridge Model Conference Proceedings* Vol. III, *Health and Safety* (October 13-16, 1987), compiled by **T. H. Row**, Martin Marietta Energy Systems, Inc., Oak Ridge, Tennessee, 1988, 435 pages.

*Rules, Decisions, and Inequality in Egalitarian Societies*, ed. **S. F. Rayner** et al., Gower Press, Farnborough, United Kingdom, 1988, 190 pages.

*Advances in Welding Science and Technology* (Proceedings of an International Conference on Trends in Welding Research, Gatlinburg, Tennessee, May 18-22, 1986), ed. **S. A. David**, ASM International, Metals Park, Ohio, 1986, 838 pages.

*Principles and Applications of Resonance Ionization Spectroscopy*, **G. S. Hurst** (formerly of ORNL) and **M. G. Payne**, Adam Hilger Ltd., Bristol, United Kingdom, 1988, 440 pages.

*Scattering, Deformation and Fracture in Polymers* (dedicated to the late Wallace C. Koehler), ed. **G. D. Wignall** et al., Materials Research Society (MRS) Symposium Proceedings, Vol. 79, MRS, Pittsburgh, 1987, 454 pages.

*Alpha Counting and Spectrometry Using Liquid Scintillation Methods*, **W. J. McDowell**, Nuclear Science Series, Radiochemistry Techniques, National Academy of Sciences-National Research Council, Office of Scientific and Technical Information, U.S. Department of Energy, Oak Ridge, Tennessee, 1986, 114 pages.

*A Hierarchical Concept of Ecosystems*, **R. V. O'Neill, D. L. DeAngelis** et al., Monographs in Population Biology, Princeton University Press, Princeton, New Jersey, 1986, 253 pages.

*Hypercube Multiprocessors 1986*, **M. T. Heath**, Society for Industrial and Applied Mathematics, Philadelphia, 1986, 286 pages.

# HFIR Shutdown Stops Production of "Wonder Element"

Dr. Yosh Maruyama, oncologist at the University of Kentucky Medical Center, has developed a new medical procedure using $^{252}Cf$ to successfully treat patients with glioma, a previously 100% fatal type of brain tumor.

What element was unknown until 1950, costs $27 million per gram, and can be used to detect explosives in luggage, analyze coal for its sulfur content, and treat brain cancer? The "wonder element" is a rare radioactive isotope named californium-252 ($^{252}Cf$).

Total production of this artificial isotope in the western world has been only about 8 g since its discovery by Glenn Seaborg in 1950, and almost all of it was made in ORNL's High Flux Isotope Reactor (HFIR). Despite its scarcity, the californium isotope's unique properties have made it useful in many ways—so many that a two-day workshop was held in Oak Ridge during April 1988 to discuss the growing needs for californium and the means for producing enough to meet those needs.

Californium-252 owes its usefulness in so many different applications to its unique combination of properties:

- a half-life of 2.645 years, which is long enough to provide a useful service life yet short enough to produce a high specific activity (high radioactivity per unit mass), coupled with
- a 3.1% branching decay by spontaneous fission, which produces a strong emission rate of $2.3 \times 10^9$ neutrons per second.

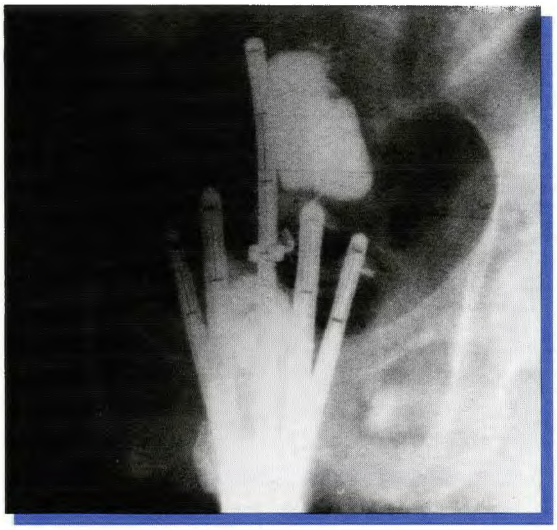
The Department of Energy, through its Office of Basic Energy Sciences, is solely responsible for the U.S. production and processing of $^{252}Cf$. The DOE Office of Nuclear Materials Production is largely responsible for the isotope's distribution through the ORNL-based Californium-252 Industrial Sales/Loan Program, administered by the Chemical Technology Division. Through these DOE-sponsored programs, the $^{252}Cf$ is produced by the irradiation of curium targets in the HFIR. The targets are then processed in the ORNL Transuranium Processing Plant (TPP) to separate the $^{252}Cf$ and convert it into a mixed californium-palladium oxide form that can be transported to the ORNL Californium Facility for additional chemical processing and milling. The prepared californium is then loaned to other government agencies, private medical institutions, and universities, or sold, at cost, to industrial concerns as the bulk oxide and as palladium-californium alloy (or cermet) pellets and wires (see photos on page 70).

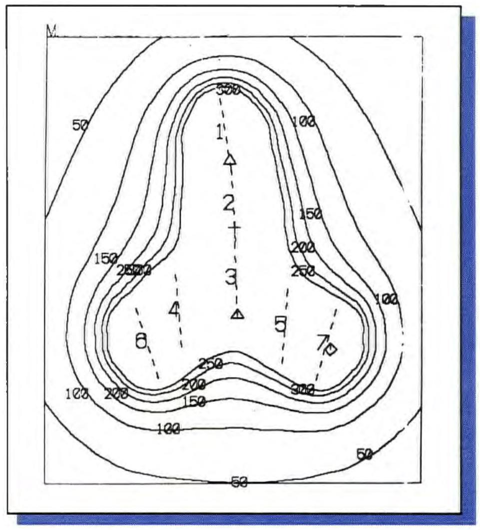
The HFIR at ORNL is the sole producer of the $^{252}Cf$ isotope for the United States and the entire western world because it is the only free-world facility capable of sustaining the continuous high neutron flux required to make californium-252 in usable quantities. The Soviet Union is also known to have facilities for making it. However, the western nations' stockpile of this useful isotope has been steadily decreasing since November 1986, when the HFIR was shut down to investigate reactor management and pressure vessel embrittlement problems.

The half-life of the californium isotope is long enough that the supply at ORNL is not yet exhausted. At the end of March 1988, 1.3 g of the precious isotope remained in inventory. Of that amount, 0.4 g was out on loan, and 0.9 g was stored at ORNL. Unless $^{252}Cf$ production is resumed very soon, however, the supply may not last through 1990. Medical researchers and others who use the californium as a powerful neutron radiation source are concerned and would like to see the HFIR restarted as soon as possible.

Even though the $^{252}Cf$ production rate will decline slightly when the HFIR is restarted at the recommended 85% power level, the reactor's startup will be greatly welcomed by doctors and cancer patients at the Medical Center of the University of Kentucky (UK) in Lexington. Californium-252 has been used there, and in other medical facilities in the United States and Japan, to treat cancers of the brain and the cervix with results that are characterized as "darn good" by UK oncologist Yosh Maruyama. During the April workshop at Oak Ridge, Maruyama reported that $^{252}Cf$ has proven to be a powerful weapon against cancer, particularly the large tumors of the cervix and brain that cannot be successfully treated with


Patient with cervical cancer, about to receive an afterloaded $^{252}Cf$ implant at the University of Kentucky Medical Center. Professor Maruyama (center) is assisted by nurse Sharlene West (left) and neutron curator Dr. Jose Feola (right).






This X ray (left) shows the positioning of stainless steel tubes containing $^{252}Cf$ implanted in the vaginal canal and cervix of a cancer patient. A computer-generated plot (right) indicates the radiation dosage produced by these implants at various tissue depths.

other types of radiation therapy. Maruyama's clinical trials using the $^{252}Cf$ neutron therapy have shown 5-year patient survival rates ranging from 94% for victims of a "low-stage" IB cervical cancer to 54% for patients with advanced-stage IIIB cervical cancer and 18% for severe-stage IVA cancers. His $^{252}Cf$ neutron therapy procedure has also achieved survival rates of 15 to 20% among patients having malignant glioma, a brain tumor that was previously untreatable and invariably fatal.

In treating brain cancer, the physicians implant tiny 30-µg "seeds" of the radioactive californium isotope into the large tumors. Powerful neutron radiation from this isotope then destroys the cells of the tumor from within, causing less damage to the healthy tissue nearby than conventional treatments using gamma radiation or X rays. To treat cancers of the cervical lining, doctors use a different technique, implanting stainless steel tubes containing $^{252}Cf$ directly into the patient's uterus or vaginal canal and using X rays to position them for maximum radiation exposure to the cancer cells (see illustration above). The surrounding cancerous cells thus receive a lethal radiation dose, while the sensitive bladder and rectal tissues are spared. Patients treated successfully with $^{252}Cf$ have bombarded their congressmen and DOE with letters requesting the rapid restart of the HFIR so this important cancer treatment and research can continue.

As the Oak Ridge workshop confirmed, however, the uses of $^{252}Cf$ have spread far beyond the medical field. Since Seaborg's creation and discovery of it, this isotope has been important in basic studies of the atomic chemistry and physics of the heavy actinide elements. A $^{252}Cf$ neutron activation analysis technique is also being used, at Oak Ridge and other locations, to measure levels of as many as 65 different elements in environmental materials such as soil, sediments, slags, and sludges. Detection limits have ranged upward from <1 part per million for some samples. Activation analysis sources used for these and other industrial applications may range from a few milligrams to as much as 200 mg (at one facility) of the $^{252}Cf$ (compared with the microgram quantities used in the medical sources). The sensitivity and reasonable cost of activation analysis techniques may lead to their wider application in environmental remediation efforts to detect hazardous contaminants and may further increase the need for $^{252}Cf$.

Nondestructive assay instruments that use the californium isotope's neutron beams to identify and measure the fissile materials in a sample are used commercially for the assay of reactor fuel pins and for remotely measuring levels of fissile materials inside sealed waste packages. Studies are also under way to determine the usefulness of californium-252 based nondestructive assay instruments for monitoring flowing solutions, such as waste streams at nuclear facilities. On-line instrumentation for measuring the sulfur content of bulk coal at coal-fired steam plants or other industrial facilities has already been developed and is currently being tested.

Since 1980, $^{252}Cf$ has also been the primary neutron source used as a standard for both personnel and reactor neutron dosimetry. It is, in fact, the only neutron source available that will satisfy the current criteria of the Nuclear Regulatory Commission for calibrating neutron dosimeters. Commercial dosimeter processors must have a reliable californium-252 production source, such as the HFIR, if they are to continue meeting these criteria. The Neutron Dosimetry Group at the National Bureau of Standards is also engaged in the development and application of standard neutron fields, such as those of $^{252}Cf$ and uranium-235 ($^{235}U$), for neutron dosimetry standards, neutron detector calibrations, and reaction rate cross section measurements.

Neutron radiography is another area in which the demand for $^{252}Cf$ is expected to greatly increase. Neutron radiography uses the penetrating power of neutron beams to examine the interior structures of materials in much the same way that X rays reveal the structures of human bones and organs. Because its neutron radiation can penetrate heavy closed containers, such as luggage, $^{252}Cf$ can be used to detect hidden explosive devices without damaging the luggage. Neutron beams can also detect minute discontinuities within explosives encased in small metal coverings, providing quality control and greater safety in the production of bullets or missile warheads. Neutron radiography is the only method that can detect the extremely small pockets of moisture that may remain within airplane wings or other vital industrial machine parts after manufacture to cause subsequent internal corrosion in aluminum and other metals or the degradation of bonds in composite structures. These and other applications of neutron radiography make it a useful tool for numerous medical, academic, and industrial institutions.

Although $^{252}Cf$ and other radioisotopes are not the only sources of neutron beams (reactors and accelerators are even more powerful neutron sources), the relatively low cost and the ease of transporting, shielding, and using a neutron-producing radioisotope such as $^{252}Cf$ make it the logical choice in many situations requiring neutron radiography. The annual demand for $^{252}Cf$ for neutron radiographic applications alone is expected to increase to 300 mg by 1989 and to 500 mg by 1990.—*Luci Bell*



Pellets (~2g), made of $^{252}Cf$ and palladium oxides, are broken out of their carbon crucible forms prepared in the TPP (left photo) and milled into ~5-cm wire lengths (bottom of right photo) in the ORNL Californium Facility. The wires are loaded into aluminum tube containers (top right) with screw-cap ends, placed in a protective overpack, and shipped to commercial firms to be fabricated into various source forms.

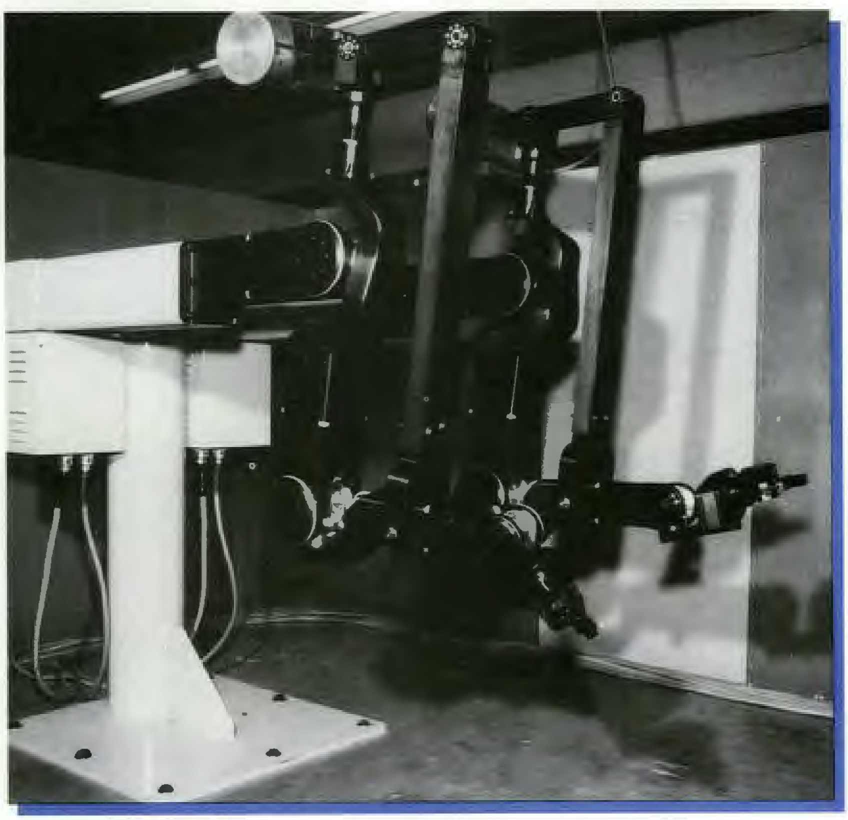
# ORNL Builds Manipulator for NASA

The Laboratory Telerobotic Manipulator (LTM) will be completed by ORNL in December 1988 and delivered to the Langley Research Center of the National Aeronautics and Space Administration (NASA). Results from experiments with the LTM could guide the design of intelligent machines that will assemble, repair, and maintain the proposed U.S. space station.

The LTM is a double set of dexterous master and slave arms developed within ORNL's Instrumentation and Controls (I&C) Division for the U.S. space program. Since late 1987, about 20 machinists in the Plant and Equipment Division have been building the telerobotic arms. Software to operate the LTM is being developed by I&C engineers.

NASA has an ambitious robotics program because of its commitment to use intelligent machines—rather than astronauts—to assemble, repair, and maintain the U.S. space station. NASA has determined that it is not feasible to use astronauts to assemble the modular space station in orbit. According to one estimate, 300 astronauts would be required and the cost would be prohibitive.

In addition, extravehicular activities such as making external repairs are extremely risky for humans. They must be prepared to exist in a vacuum and cope with microgravity, temperature extremes, and high levels of radiation. To avoid endangering humans (and possibly reduce costs), NASA favors the aggressive development of robotic machines for work in space.



Because of ORNL's expertise and experience in building servomanipulators and in developing robotic hardware, NASA turned to ORNL for assistance in developing autonomous robotic machines for possible space station construction and maintenance by the late 1990s. The $5-million LTM project resulted from a $75,000 study carried out by ORNL for NASA in 1986 to determine how advanced manipulators could be used for space station tasks. ornl

*"Results from experiments with the LTM could guide the design of intelligent machines that will assemble, repair, and maintain the proposed U.S. space station."*

# HTML Cited by *R&D* Magazine

Albert A.Chesnes of DOE helped obtain funding to build the HTML and support research there.

DOE's High Temperature Materials Laboratory (HTML) at ORNL has been selected for "high honors" in the Laboratory of the Year competition of *Research and Development* magazine. Key individuals were recognized May 6, 1988, for their roles in making the HTML a prize-winning research facility.

The selection was announced in the magazine's May issue. From a record number of submissions, the judges selected a Laboratory of the Year, two "high honors" winners, and one "special mention" recipient.

Copies of the plaque presented by the magazine were distributed at a May 6 ceremony held to honor key persons involved in funding, designing, building, and operating the HTML. Alex Zucker, ORNL acting director, paid tribute to Albert A. Chesnes, director of DOE's Heat Engine Propulsion Division of the Office of Transportation Systems under Donna Fitzpatrick, the Assistant Secretary for Conservation and Renewable Energy and the chief sponsor of the HTML. Zucker said that Chesnes and Fitzpatrick (who was not present) "have been instrumental in getting this building funded and supporting much of the research going on here."

Joe Lenhard, assistant manager for energy research and development for DOE's Oak Ridge Operations, said, "The HTML is a world-class research institution and a unique national user facility. It integrates materials research and will help make high-tech materials research results available to industry to increase our nation's economic competitiveness."

Lenhard recognized Chesnes for his "continued program support through tough and good budget times" and for being a "good headquarters program boss and friend." Lenhard also recognized Zucker. The HTML, he said, "was Alex Zucker's brainchild over 10 years ago. He organized meetings, took the concept to DOE headquarters, and persuaded the right people to believe in it."

"The HTML," said Chesnes, "is recognized by the outside scientific community as being a worthwhile endeavor. It gives us a warm feeling that our efforts weren't wasted and that we made a decision that is right.

"The architect-engineer and construction company transformed a unique conceptual plan into a world-class facility and did it on time and within budget. But none of this would have happened without the dedication, patience, persistence, and monumental efforts of the people at Oak Ridge."

Chesnes cited Vic Tennery, HTML director, "for his untiring efforts, his imagination, and his dedication." He said that he expects the HTML to be not only a great facility but also an efficient, productive laboratory because of the highly skilled personnel working there.

Also honored were representatives of Deeter Ritchey Sippel of Pittsburgh, the architect for the HTML; A. M. Kinney, Inc., of Cincinnati, the design engineer; Blaine-Hays Construction Company of Knoxville, the construction contractor; and ORNL's Metals and Ceramics Division staff, who helped prepare the competition entry.

## New Electron Microscope Installed

A new ultra-high-resolution transmission electron microscope has been installed in the Materials Analysis User Center in ORNL's High Temperature Materials Laboratory.

The highest-resolution microscope commercially available in the world today, the JEOL 4000EX instrument at ORNL provides a point-to-point resolution of 0.18 nm or better. It is one of only ten such instruments in the United States, the first in the Southeast, and the first to be installed in a national laboratory.

The microscope provides images at the atomic level of crystal structures. It will be used by ORNL researchers and industrial users to study high-temperature materials, including interfaces and boundaries in ceramics, the structure of precipitates and inclusions in ceramics and metal alloys, and the structure of ultra-fine crystalline particulates.

## New Radiation Calibration Lab

ORNL's new Radiation Standards and Calibration Laboratory, designed as a regional resource for improved radiation monitoring and health protection, was dedicated June 10. The first of its kind in the Southeast, the new laboratory will become an accredited National Bureau of Standards (NBS) Secondary Calibration Facility that will serve DOE and its contractors as well as other governmental and private users.

When fully outfitted in late 1989, the shielded, hexagonal, two-story tower will house an array of NBS-standardized radiation sources for instrument calibration. These sources—emitters of gamma, alpha, beta, and neutron radiation as well as X rays—will be used to determine and improve the measurement accuracy of both portable monitoring and survey instruments and personnel dosimeters. The director of operations at the new facility is Robert Halliburton of ORNL's Environmental and Health Protection Division.

## Innovative Disposal Technique for ORNL's Low-Level Wastes

ORNL has demonstrated an innovative "tumulus" disposal technique that should improve confinement of the Laboratory's low-level radioactive solid wastes. Use of tumulus disposal at ORNL is the first U.S. application of an above-grade disposal concept.

*"The HTML," said Chesnes, "is recognized by the outside scientific community as being a worthwhile endeavor."*

L. C. (Red) Williams inspects a vault of low-level radioactive solid waste at ORNL's tumulus site.

In tumulus disposal, compacted wastes are isolated in sealed concrete vaults placed on a reinforced concrete pad called a tumulus pad. Once filled with vaults stacked two high, the pad will be covered with a layer of earth.

The wastes include contaminated glassware, paper, rags, gloves, residues, and laboratory equipment. The tumulus pad—consisting of high-density cements on a subsurface layer of gravel, sand, and a thick plastic liner—is designed to minimize migration of stored radionuclides into groundwater by leaching.

The tumulus is one of a series of engineered "greater confinement" approaches being demonstrated at ORNL as alternatives to the past practice of disposal in shallow, unlined trenches. Benefits include improved isolation of wastes from the environment, long-term monitoring, and more efficient use of existing disposal areas.

## Cleaning ORNL's Environment: A Progress Report

In the next 25 years, ORNL can expect to spend more than $1 billion cleaning up ORNL's radioactive and chemical wastes, upgrading waste management facilities, and building new facilities to ensure that the Laboratory meets all environmental standards. Already, ORNL has made an aggressive start in meeting state and federal environmental regulations through its Remedial Action Program. Some outstanding 1987 achievements include:

- a Resource Conservation and Recovery Act (RCRA) Facilities Assessment, which summarizes information on ORNL's solid-waste management units and waste area groupings;
- the completion of 332 piezometer wells for obtaining information on groundwater level and flow and on soil permeability and the installation of 8 hydrostatic-head measuring stations to evaluate regional groundwater flow;
- the drilling of 76 water-quality monitoring wells;
- the completion of maintenance and surveillance plans for surplus contaminated facilities (such as the Molten Salt Reactor

Experiment) and waste sites [e.g., solid-waste storage areas (SWSAs) and contaminated pits and trenches];

- the emplacement of 3000 $yd^3$ (2550 $m^3$) of fill in SWSA-5 to counteract subsidence of waste trenches; and
- signing of a formal contract (in August) with Bechtel National, Inc., to complete the remedial investigation feasibility study of ORNL, as required by RCRA, to identify problems, propose solutions, and evaluate their potential impacts.

This year, ORNL plans to demonstrate dynamic waste compaction, grouting, and capping in 19 trenches of SWSA-6. If these "closure" techniques prove feasible, they may be used to better isolate wastes in the rest of SWSA-6 and the other waste sites.

## Wastewater Treatment Plant Contract Awarded

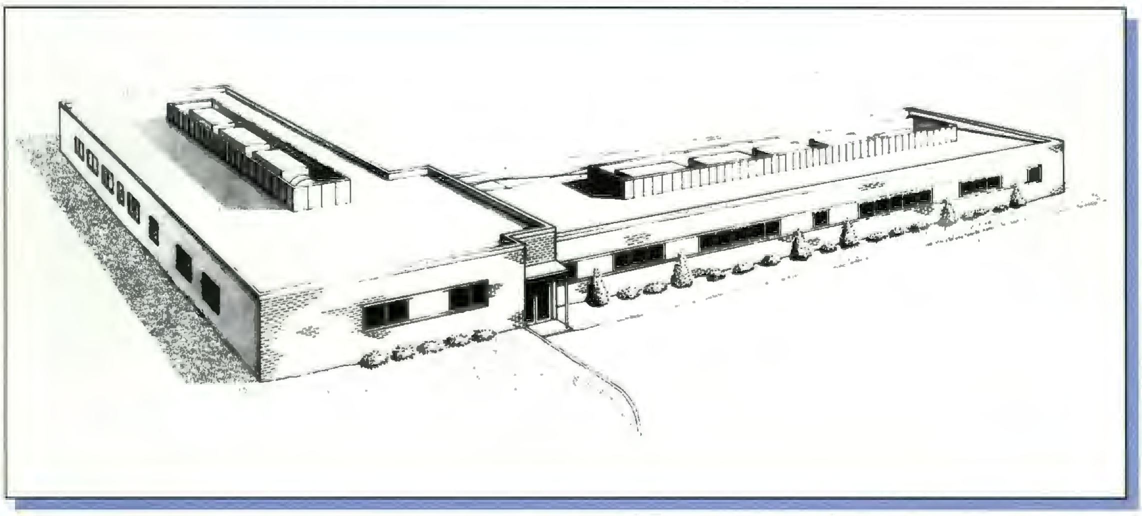
DOE has awarded a $4 million contract to Tibbetts Mechanical Contractors of Anderson, Indiana, for construction of a wastewater treatment plant at ORNL. Designed to treat nonradiological industrial wastewater containing trace quantities of heavy metals, the new facility will enable ORNL to meet regulations of the U.S. Environmental Protection Agency under the Clean Water Act. Completion of the construction is scheduled for September 1989.

## Mass Spectrometry Lab Being Built

Groundbreaking ceremonies were held March 16, 1988, for the new Mass Spectrometry Laboratory (MSL) for ORNL's Analytical Chemistry Division. The new lab, to be located just south of Building 4500-South, will house laboratories, offices, and supporting facilities.

"Mass spectrometry is one of the most vigorous research areas and most powerful technical tools in chemistry today," says Werner Christie of the Analytical Chemistry Division. "ORNL has one of the leading U.S. mass spectrometry operations. Although they have been termed a national resource, these operations have been limited by inferior facilities and inaccessibility. We think the new state-of-the-art MSL facility will be 'user friendly' for collaborators inside and outside the Laboratory."

The new MSL facility is being built in two separate phases. Phase 1 should be completed in late fall, about the time that work on Phase 2 is expected to start. When completed in 1989, the MSL will contain the most comprehensive collection of mass spectrometers in the United States. ornl



Artist's conception of ORNL's new Mass Spectrometry Laboratory, which will contain the most comprehensive collection of mass spectrometers in the United States.

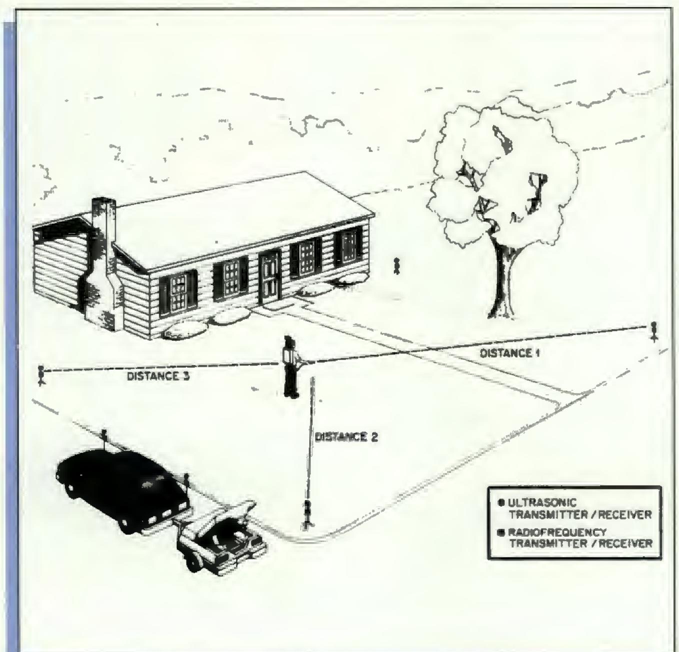
# RE: Technology Transfer

# *Chemrad Licensed to Market USRADS*

Energy Systems has licensed a Texas firm, Chemrad Corporation, to manufacture and market a compact, highly automated environmental survey device based on the Ultrasonic Ranging and Data System (USRADS) developed at ORNL. Chemrad, a small manufacturer and supplier of health physics devices and services, plans to expand its operations to Oak Ridge to produce and service the new system.

The USRADS was developed by Barry Berven and Guven Yalcintas, of ORNL's Health and Safety Research Division, working with Michael Blair and Charlie Nowlin, of the Instrumentation and Controls Division, and others. It has been used for ORNL's recent radiological assessments of more than 10,000 private, public, and commercial properties in nine western states. The object of the work, sponsored by DOE, is to clean up radioactively contaminated properties.

In the western areas suspected of containing slightly radioactive uranium mill tailings, surveyors took radiation readings using USRADS. With this system, ultrasound signals are transmitted each second from the surveyor's backpack. A computer receives these signals and pinpoints the surveyor's exact position by triangulation. Simultaneously, radiofrequency signals from a portable instrument used by the surveyor to measure radioactivity levels are received and processed by the computer, thus linking the surveyor's position with the radiation measurements. The USRADS equipment can pinpoint the location of buried wastes within 6 in. over an area of 5 acres. It does not have the interference problems typical of conventional radiofrequency sources and therefore can be used in areas having obstacles such as trees and houses.




Radiation and distance readings sent each second from three or more stationary transmitter-receivers and from the USRADS surveyor's backpack are relayed to the computer's receiver. Using triangulation, the computer instantly calculates the surveyor's exact position and links it to the measured radiation level at that location.

Months of work and millions of dollars in labor costs were saved by using USRADS to perform the DOE site surveys for radioactive wastes.

The ultrasonic system can also be used to locate chemical deposits and other soil or subsurface contaminants and should be useful in guiding cleanup efforts at hazardous waste sites. The royalty-bearing license with Chemrad is the 19th signed by Energy Systems since late 1985 to commercialize new technologies originating at Oak Ridge government facilities. Under a DOE-approved formula, royalties received under such licensing agreements are shared with the inventors and used to support additional technology transfer activities. ornl

# *1987 Patents Honored*

At the annual Patent Luncheon, held this year on April 25 at the Garden Plaza Hotel, Martin Marietta Energy Systems, Inc., honored 25 employees of the Oak Ridge facilities who shared in 21 patents awarded for work-related inventions during 1987.

**C. T. Liu** received a "golden acorn" pin from the Energy Systems Inventors' Forum for his 10th patent award, becoming the 19th Energy Systems staff member to have been awarded 10 or more patents.

Three ORNL employees–**Terry N. Tiegs**, **C. T. Liu**, and **Richard A. Todd**–were named patentees for two inventions each in 1987.

The ORNL patentees for 1987 are: .

**C. T. Liu**, Metals and Ceramics Division, for "Long-Range Ordered Alloys by Addition of Niobium and Cerium";

**C. T. Liu** and **Carl C. Koch**, (now at North Carolina State University in Raleigh), for "Ductile Aluminide Alloys for High Temperature";

**Richard A. Todd**, Instrumentation and Controls Division, for "Closed-Loop Pulsed Helium Ionization Detector";

**Roswitha A. (Rose) Ramsey**, Analytical Chemistry Division, and **Richard A. Todd**, Instrumentation and Controls Division, for "Pulsed Helium Ionization Detection System";

**Terry N. Tiegs**, Metals and Ceramics Division, for "Method for Preparing Configured Silicon Carbide Whisker–Reinforced Alumina Ceramic Articles";

**Paul F. Becher** and **Terry N. Tiegs**, Metals and Ceramics Division, for "Silicon Carbide Whisker–Zirconia Reinforced Mullite and Alumina Ceramics";

**K. C. (Ken) Liu**, Metals and Ceramics Division, for "Self-Aligning Hydraulic Piston Assembly for Tensile Testing of Ceramics";

**Charles W. Forsberg**, Chemical Technology Division, for "Boiling Water Neutronic Reactor Incorporating a Process Inherent Safety Design";

**Tuan Vo Dinh**, Health and Safety Research Division, for "Practical Substrate and Apparatus for Static and Continuous Monitoring by Surface-Enhanced Raman Spectroscopy";

**Arthur J. (Artie) Moorhead**, Metals and Ceramics Division, for "Copper-Silver-Titanium Filler Metal for Direct Brazing of Structural Ceramics";

**Paul A. Haas**, **Vic L. Fowler**, and **Milton H. Lloyd** (retired), Chemical Technology Division, for "Preparation of Nuclear Fuel Spheres by Flotation-Internal Gelatin";

**F. F. (Russ) Knapp Jr.**, and **Thomas A. Butler** (retired), Health and Safety Research Division, and Claude Brihaye, visiting scientist from the University of Liege, Liege, Belgium, for "Osmium-191/Iridium-191*m* Radionuclide Generator";

**Elias Greenbaum**, Chemical Technology Division, for "Method of Producing Metallized Chloroplasts and Use Thereof in the Photochemical Production of Hydrogen and Oxygen";

**Charles D. Scott**, Chemical Technology Division, for "Method and Apparatus for Continuous Annular Electrochromatography";

**Richard J. Fox**, Instrumentation and Controls Division, for "Fiber-Type Dosimeter with Improved Illuminator";

**F. W. (Wally) Baity**, **Daniel J. Hoffman**, and **John W. Whealton**, Fusion Energy Division, and Thomas L. Owens, consultant from McDonnell Douglas, for "Radiofrequency Coaxial Feedthrough Device";

**Lynn A. Boatner** and **Brian C. Sales**, Solid State Division, for "Lead Phosphate Glass Composition for Optical Components." ornl

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**NEXT ISSUE**

Supercomputers for research and visualization of data will be explored.