Oak Ridge National Laboratory

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

ON THE COVER

Zig-zag chemical bonding at the interface between atomic columns of cobalt silicide (brighter circles on left) and atomic columns of silicon is magnified nearly 50 million times in this electron micrograph, which images both materials at atomic resolution with a brightness (or contrast) directly related to their atomic number (Z). The Z-contrast technique, developed at ORNL by Steve Pennycook, greatly improves electron microscope imaging and was highlighted in the State of the Laboratory Address by Alex Zucker, ORNL's Acting Director in 1988. An updated version of the address begins on p. 1.

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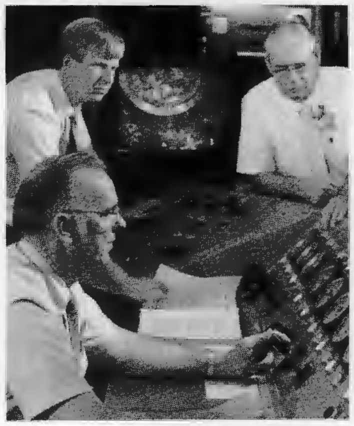


STATE OF THE LABORATORY 1978–88:

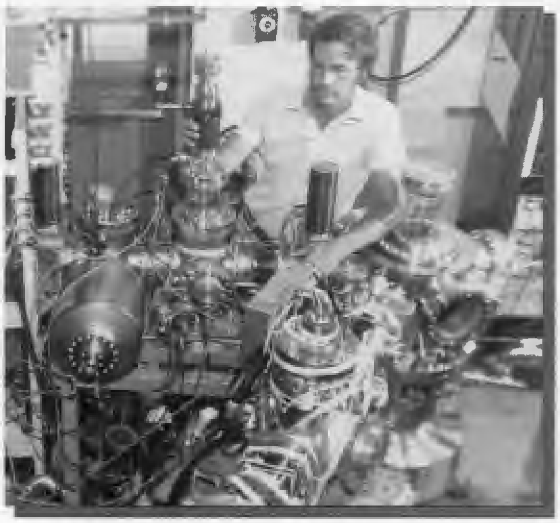
Years of CHANGE *at ORNL*

By Alexander Zucker

The history of Oak Ridge National Laboratory can be divided into three eras: the first—from the mid-1940s to the mid-1970s—was devoted to the development of nuclear energy for electrical power generation; from 1973 through 1980, ORNL work was focused on finding solutions to the energy crisis; and in the third era—roughly the past ten years—the Laboratory has evolved into a multiprogram research and development laboratory having a variety of energy-related missions of national importance. In this 37th Annual State of the Laboratory address, I will describe research highlights and trends during the decade of 1978 through 1988—years of change at ORNL.

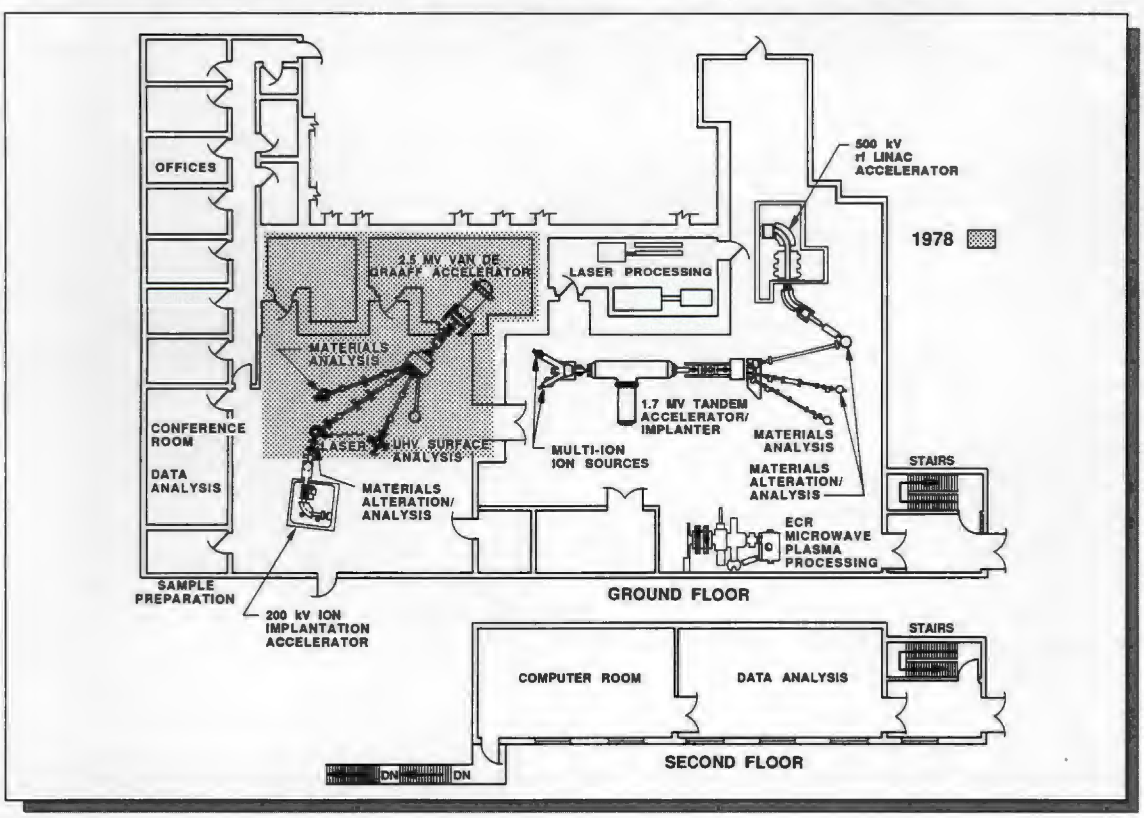
Materials Research

Perhaps the most dramatic development at the Laboratory in the past ten years has been the rise of materials research and development, led by the Solid State and Metals and Ceramics divisions. Materials science at ORNL has grown considerably in size and stature on all fronts. Besides a number of scientific accomplishments, some of which I will note here, new state-of-the-art materials science facilities and equipment have been built and developed at ORNL that have garnered worldwide attention. One example is the Surface Modification and Characterization (SMAC) Collaborative Research Center in the Solid State Division. From its inception in 1977 by Bill Appleton, now ORNL associate director for Physical Sciences, and his colleagues, the facility has expanded considerably in physical size, equipment, and number of users. The facility now occupies almost 11,000 ft^2, compared with only 1560 ft^2 in 1977, and it served about 60 external users in FY 1988. Equipment at the SMAC facility, which in 1977 consisted of a single 2.5-MV Van de Graaff accelerator, has expanded to include a laser processing facility, an ECR microwave plasma processor, and four different accelerators dedicated to both the modification and analysis of material surfaces. The newest accelerator, an EATON NV-500 capable of producing 500-keV ion beams for ion implantation at currents up to 1 mA, is being installed. This machine represents the latest technology for high-energy high-current ion implantation.

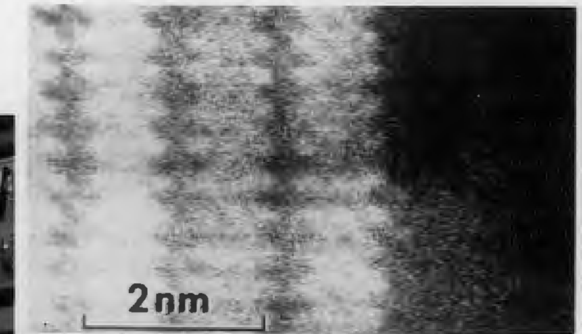


Left: This 1977 photograph shows Bill Appleton, now ORNL associate director for Physical Sciences, conducting an ion-beam implantation experiment at the new SMAC facility.

Right: From left, Terry Sjoreen, Steve Withrow, Jim Moore, Ron Feenstra, and O. E. Schow set up experiments in 1989 at the SMAC Facility, using its lasers and accelerators to improve materials by modifying their surface characteristics.



Bottom: ORNL's Surface Modification and Characterization Collaborative Research Center has expanded considerably in ten years.



These intimate views of the structure of a high-temperature superconducting material are made possible by the new Z-contrast technique developed by Steve Pennycook (shown here) for the scanning transmission electron microscope.

Our technical achievements in materials science have helped establish ORNL's leadership in this area. An outstanding example of our efforts to better characterize and understand materials is the recently developed technique for producing very-high-resolution electron micrographs of semiconductors and the new high-temperature superconducting materials. These intimate views of the structure of the yttrium-barium-copper oxide superconductors are made possible by the new Z-contrast technique developed for the HB-501 dedicated scanning transmission electron microscope by Steve Pennycook of the Solid State Division. This method combines atomic-level spatial resolution with chemical sensitivity to allow high-resolution structure imaging and simultaneous identification of constituent atomic species having a minimum difference in atomic numbers of ~5%. Using this approach, we may learn how the new superconducting materials transmit electricity at temperatures as high as 100 K for some compositions.

A dramatic example of our ability to modify materials to meet emerging needs is the development of advanced nickel aluminide alloys. This effort, spearheaded by C. T. Liu of the Metals and Ceramics Division, has developed materials whose yield strength increases with temperature (instead of decreasing as is common with conventional materials) without degrading other important properties.

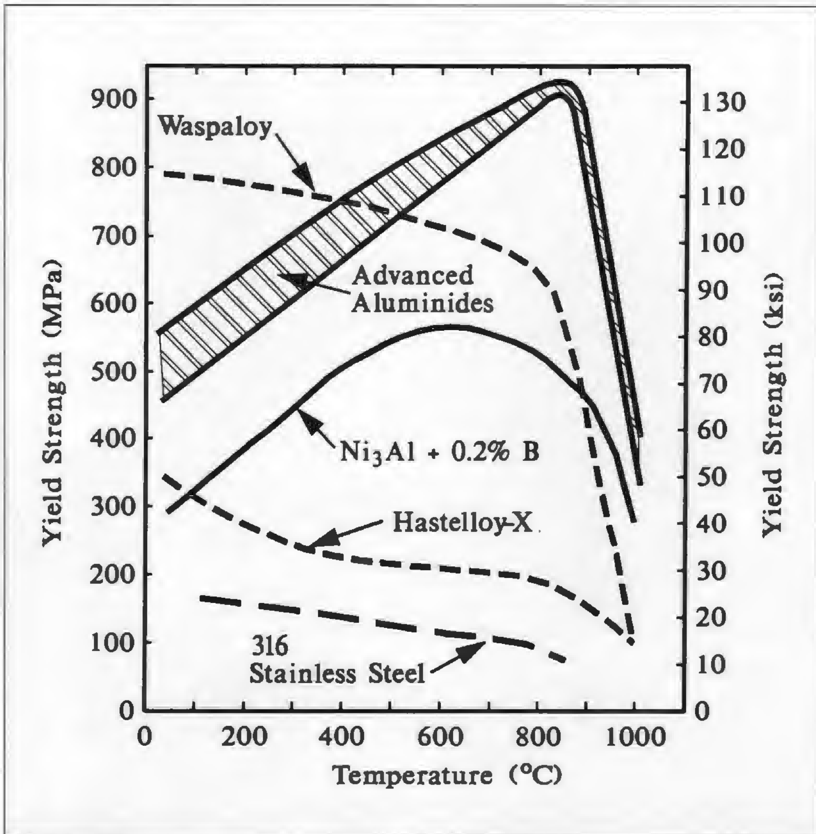
Because of their utility in elevated-temperature applications, many industrial firms have been interested in commercializing nickel aluminides. In the past three years, through efforts by Metals and Ceramics personnel, in conjunction with the Energy Systems Office of Technology Applications, the use of this material has been licensed to Cummins, Armada, ARMCO (a steel developer), Metallamics, and Valley-Todeco. These companies represent an astounding variety of commercial applications, including nonautomotive diesel engines, turbochargers, glass molds, tools, heating elements, and corrosion-resistant and wear-resistant components.

Interest in the nickel aluminides continues to grow, and other applications are being explored.

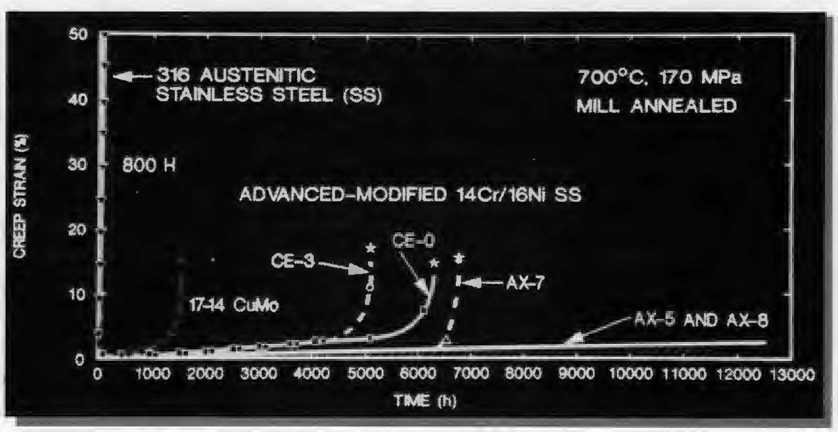
For example, until recently these alloys could not be used in casting applications because of their relatively low strength in the as-cast condition. Now Liu's group has developed a new aluminide alloy having good castability in addition to good ductility and strength.

ORNL's alloy development is not limited to aluminides. Recently, Phil Maziasz and Bob Swindeman of the Metals and Ceramics Division have designed new stainless steels and alloys that are more creep resistant than ordinary stainless steels at a sustained temperature of 700°C and at stresses up to 170 MPa. During long periods under stress at high temperatures, many materials continually deform, or creep (by dislocation slippage and sliding along grain boundaries), and may break at stresses that would not normally affect the same materials during short-term applications. Although type 316 stainless steel, an industry workhorse, is creep resistant under many adverse conditions, it fails quite rapidly at temperatures of 650° to 700°C.

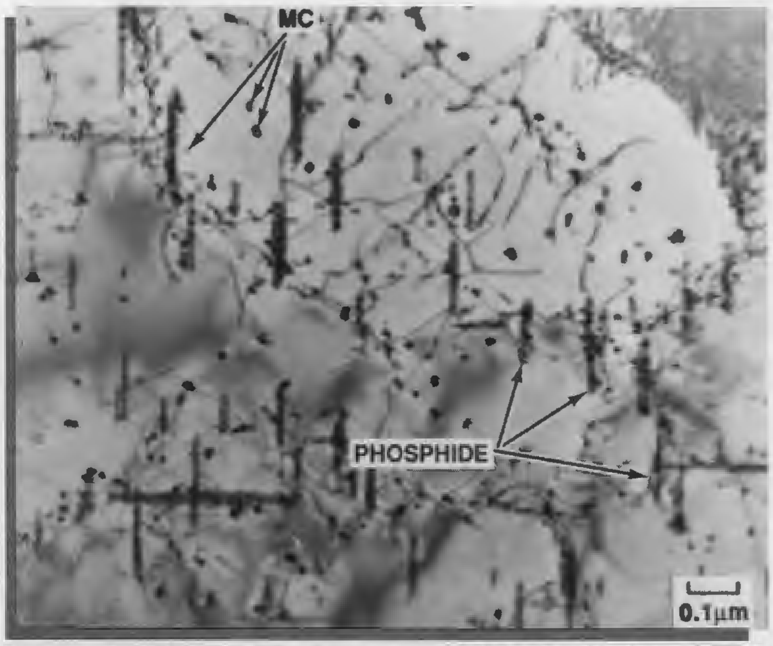
Using analytical electron microscopy, Maziasz and his colleagues, while studying the unusual, nonequilibrium effects of neutron irradiation on various iron-chromium-nickel stainless steel alloys, noted that small precipitates of various metal carbides and phosphides formed throughout the materials during irradiation. Because small precipitates can make steels creep resistant by pinning dislocations and preventing the grain



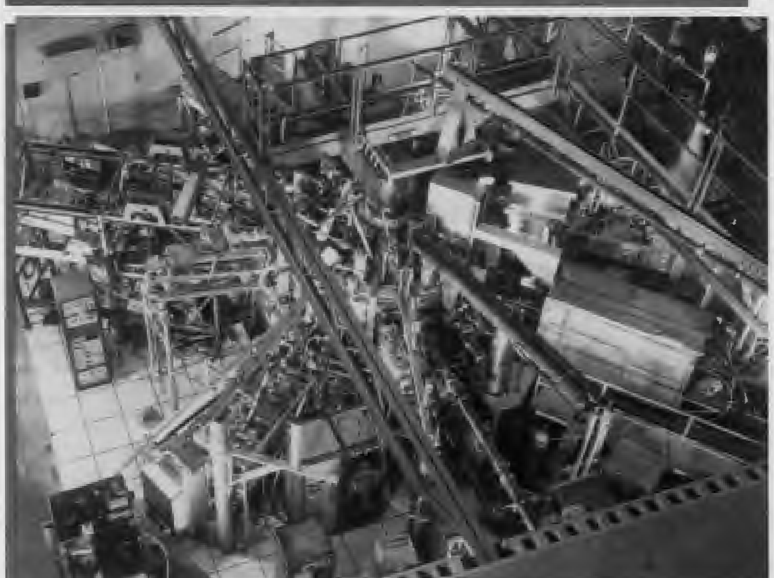
Advanced aluminides developed at ORNL are stronger than commercial alloys at elevated temperatures.



Advanced iron-chromium-nickel stainless steels designed and modified at ORNL are 1000 times more creep resistant than type 316 stainless steel.



ORNL's minor modifications to iron-chromium-nickel steel produce fine dispersions of metal-carbide and phosphide precipitates, increasing the alloy's creep resistance.



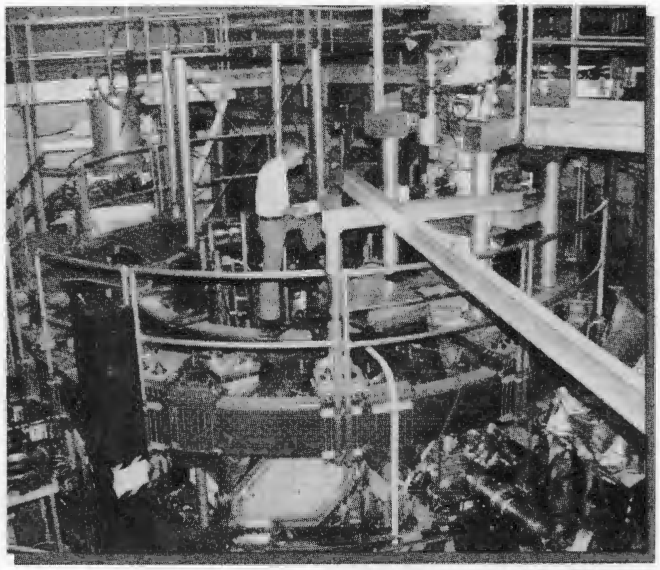
The Impurity Study Experiment-Beta (ISX-B) Facility provided information about plasma instabilities that guided the design of the magnetic structure of ORNL's Advanced Toroidal Facility (ATF).

boundaries from sliding, the researchers decided to try to modify the composition of the steel so that the precipitate microstructures they observed in the irradiated steels would be recreated during high-temperature creep conditions. By carefully altering the amounts of carbon, phosphorus, and other elements in the alloy, they were able to "design" a creep-resistant steel based on scientific judgment, not trial and error. Their design strategy has since been used to develop creep-resistant iron-chromium-nickel steels for the boilers of advanced coal-fired steam plants and to develop new low-activation iron-chromium-manganese steel alloys for fusion power applications.

Fusion Technology

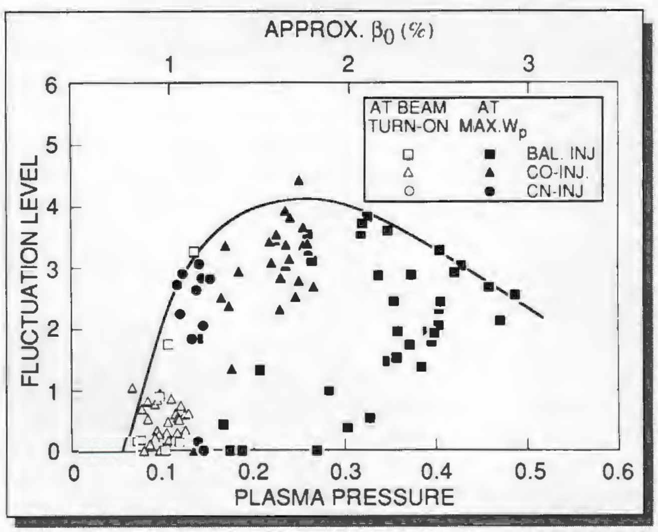
Fusion technology development has been an important mission of the Laboratory since the early 1950s. One important research area is plasma stability, particularly as the plasma pressure is increased. Ten years ago at ORNL we studied the effects of increasing plasma pressure stability in the Impurity Study Experiment-Beta (ISX-B) Facility, a doughnut-shaped tokamak device. In ISX-B, as the plasma pressure was raised by increasing the heating power, energy losses across the confining magnetic field were found to increase, thus effectively limiting the plasma pressure. It is believed that the increased losses were caused by turbulence-driven plasma instabilities.

In 1988, we started up a new fusion research device—the Advanced Toroidal Facility (ATF)—a stellarator, not a tokamak. In a tokamak, the helical magnetic field lines that confine the plasma are produced by a combination of fields from external coils and from a current flowing toroidally in the plasma. In a stellarator, the fields are produced by external helical and circular coils. The ATF was built to very close specifications in an effective and successful collaboration between the Fusion Energy Division, the Energy Systems Engineering and Computing and Telecommunications organizations, and Y-12 Maintenance. In the ATF, the magnetic structure is designed to minimize some instabilities that generate plasma turbulence. During operation of the ATF, the instability level increases at first; however, as the pressure is raised, the turbulence decreases and the plasma attains what is called a "second stability" region. This evidence of second stability observed in the ATF is a major event in fusion research and correlates well with the expectations of the fusion research community.



A 1988 view of the ATF.

Besides plasma stability, plasma fueling has long been a problem facing fusion researchers. Injecting fusion fuel, such as deuterium or tritium, into a multimillion-degree fusion plasma is a difficult technical challenge. ORNL, however, has developed plasma fueling techniques that are now being used in the world's largest tokamaks. Our pellet fueling technology involves freezing a pellet of deuterium (heavy hydrogen) and shooting it like a bullet into the center of the hot plasma. This is now the method of choice for tokamak fueling.

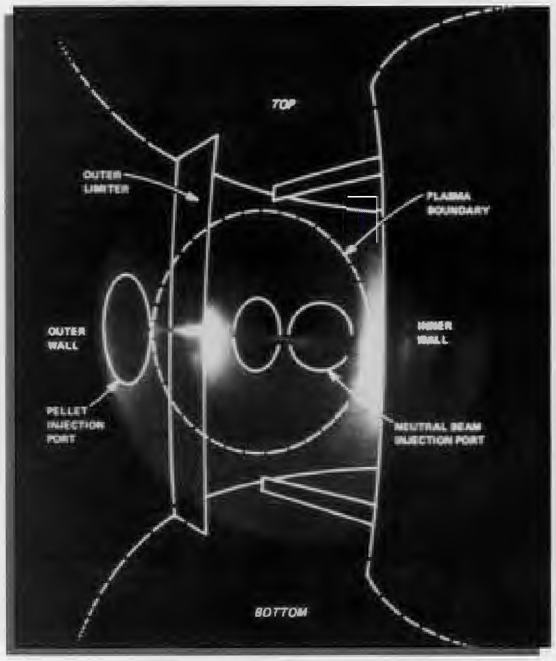


As plasma pressure rises in the ATF, plasma instabilities increase at first. Then turbulence decreases and the plasma enters the region of "second stability."

Pellet fueling was pioneered at ORNL in 1978 under the leadership of Stan Milora and Chris Foster. In the early experiments, 1-mm-diam pellets were accelerated to about 100 m/s. Ten years later, we now accelerate pellets as large as 2 to 6 mm to velocities up to 2800 m/s. The pellets must be larger and travel faster to reach the center of the new fusion devices, which are successively increasing in size. To accomplish these goals, we have developed an electron beam accelerator that vaporizes the back end of longer pellets (12 mm by 4 mm) so that they thrust forward like miniature rockets. The best end velocity so far attained for this size pellet is 250 m/s. ORNL-developed pellet fueling devices are now being used on many world-class tokamaks, including the Joint European Torus (JET) of the European Community and devices at the Princeton Plasma Physics Laboratory.

Nuclear Physics

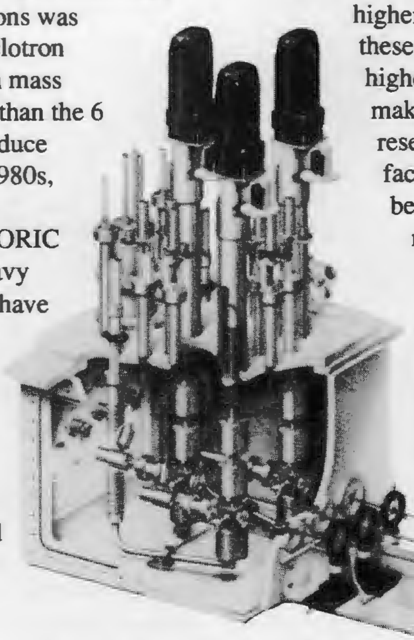
Nuclear physicists at ORNL are interested in measuring the reactions produced by heavy ions (ranging in mass from helium to uranium) when they are accelerated and directed at nuclei in a



ORNL's first hydrogen pellet experiment for refueling fusion plasma was carried out in 1978 at the ISX-B Facility.

stationary target. The parameter of interest for reactions between the projectile and target nuclei is the energy per atomic mass unit of the accelerated ion.

About ten years ago, the principal Laboratory facility that accelerated heavy ions was the Oak Ridge Isochronous Cyclotron (ORIC). However, for ions with mass greater than 40, it supplied less than the 6 MeV per nucleon required to induce nuclear reactions. In the early 1980s, we installed a 25-MV tandem accelerator and coupled it with ORIC as part of the new Holifield Heavy Ion Research Facility. We now have a fine, world-class facility that provides a range of ions with energies above 6 MeV per nucleon and serves several hundred users each year.

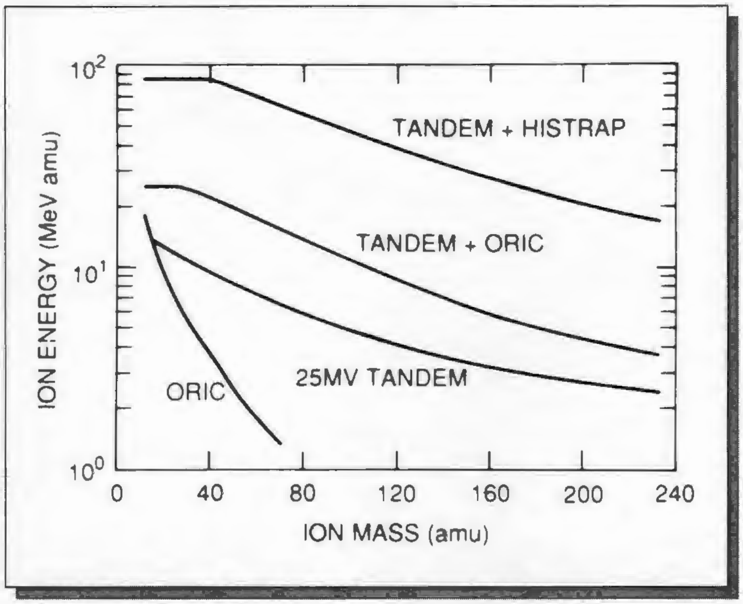


ORNL-developed pellet injector refuels the plasma at the Joint European Torus (JET) in England. The device propels pellets of three different diameters (2.7 mm, 4 mm, and 6 mm) at a maximum velocity of 1500 m/s.

To remain leaders in the field of atomic physics, we have proposed the construction of a Heavy Ion Storage Ring for Atomic Physics (HISTRAP), a synchrotron that accelerates and decelerates heavy ions. It can also "store" these particles, keeping them circulating for a long time. Ion storage is made possible by a very high vacuum of 10^{-12} torr. Jim Johnson and colleagues of the Physics Division have built a HISTRAP Prototype Vacuum Test Facility, which has achieved 5×10^{-12} torr—a record in the Western Hemisphere and matching pressures achieved in Europe. This tour de force is essential for making HISTRAP work.

Because European accelerators now provide higher energies than American ones, ORNL physicists have spearheaded some experiments there. One outcome of this research is the demonstration of why higher energy is useful for studying nuclear and atomic physics. Recently, at the GANIL facility in France, Fred Bertrand, Jim Beene, and Dan Horen of the Physics Division identified nuclear "giant resonances" using an oxygen-17 beam at 1500 MeV (84 MeV/nucleon). Giant resonances in nuclei are collective modes of nuclear excitation in which an appreciable fraction of the protons and neutrons of the nucleus move together. More than ten years ago, Bertrand used protons at ORIC to find giant quadrupole resonances, a difficult undertaking because of the background levels. His results were first met with skepticism, but later experiments with heavier and higher-energy particles confirmed that these resonances do, indeed, exist. The higher energy of the French machine makes possible new progress in this research; by contrast, the Holifield facility can accelerate an oxygen-17 beam to only 375 MeV (22 MeV/nucleon), permitting identification of a giant resonance that looks more like a pygmy resonance.

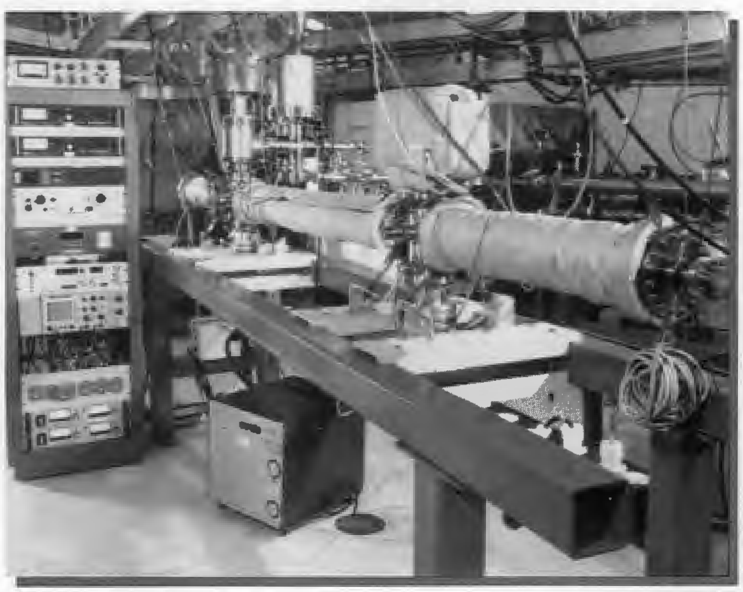
Even with their lower energy, the ORNL accelerators, in both the single and tandem mode, continue to be extremely useful tools for studying heavy-ion behavior. As a result, a large number of guest researchers visit ORNL from all over the nation and the world to participate in research at Holifield. Over the last ten years, a "nuclear village" having a pleasant campus-like atmosphere has grown near the swan pond. The Holifield accelerators constitute an official DOE user facility, and the nearby Joint Institute for Heavy Ion Research contains offices, sleeping rooms, and laboratories built and paid for by the state of Tennessee through the University of Tennessee and Vanderbilt University. This veritable hotbed of nuclear physics research attracts users throughout the year.



Accelerator ion energies at ORNL would improve significantly with the addition of the proposed Heavy Ion Storage Ring for Atomic Physics (HISTRAP).

Chemical Science and Technology

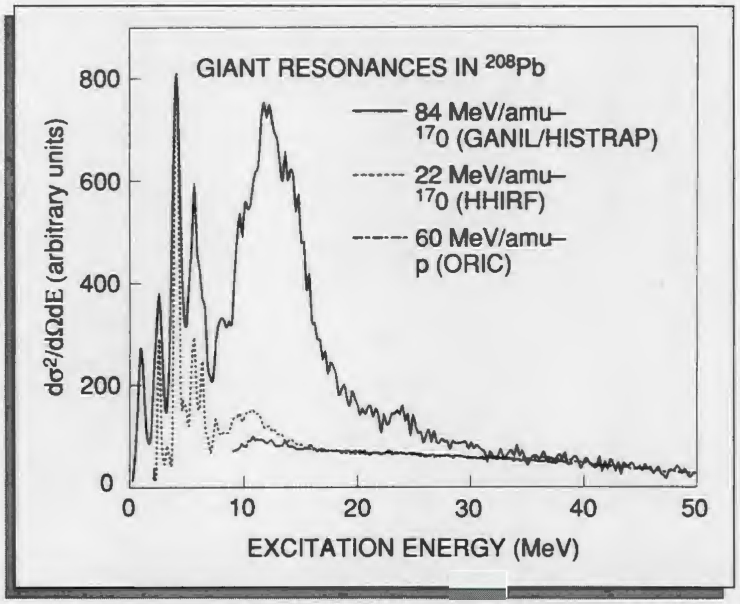
Chemical science and technology at the Laboratory have had varying levels of support from DOE during this decade. Funding for the Chemical Technology Division decreased from 1981 to 1988, largely because of a decline in nuclear energy development, including fuel reprocessing and recycling technology. Recently, the transfer of isotopes activities to the division, an increase in waste management activities, and new programs supported by DOE-Defense Programs have all contributed to an increase in funding support for the division. With nearly 400 employees, it is the largest research division at the Laboratory.



The HISTRAP Prototype Vacuum Test Stand has achieved a record-high vacuum of 10^{-12} torr, making ion storage possible.

A steady program sponsor of chemistry research in this division has been the Nuclear Regulatory Commission (NRC), which sponsors research supporting the current generation of light-water reactors. In one NRC project, researchers have measured the varying amounts of tellurium released from nuclear fuel for different degrees of fuel cladding oxidation. This important work helps determine source terms used to compute the amounts and types of radioactive materials expected to be released from nuclear reactors under accident conditions.

In the Chemistry Division, research projects range from investigating the structure of water, coal, and polymers to characterizing the chemistry of underground rocks. Recently, geochemists Don Palmer and Ed Drummond developed a new theory to explain the migration of natural gas (methane) in geologic formations, a



ORNL researchers have identified giant resonances in ^{208}Pb nuclei using proton beams of varying energies at ORNL and at the GANIL facility in France.

The ORNL Joint Institute for Heavy Ion Research contains offices, sleeping rooms, and laboratories for visiting nuclear physicists.

phenomenon that has puzzled scientists for a long time. They showed experimentally that the decay of kerogen and other organic materials forms acetate, a common constituent in oil field brines. The acetate migrates in solution through the rock strata toward the surface. The acetate then decomposes to form carbon dioxide and methane. Cap rocks hold the methane in place, forming a reservoir. This mechanism explains the existence of large reservoirs of natural gas in the water-saturated upper portions of many sedimentary basins.

In the Analytical Chemistry Division, Gary Glish, Scott McLuckey, and Henry McKown have developed an explosives detector that uses sensitive and sophisticated mass spectrometry techniques. This device essentially sniffs the air for suspect chemicals at levels as low as fractions of a part per billion and, in a few seconds, determines whether an explosive is present. Because of the threat of terrorist bomb explosions in commercial airliners, this development has been of considerable interest to people working on improving airport security, as well as to our DOE sponsors of the project. Energy Systems has licensed part of this technology to the Finnigan Corporation for commercial development.

Environmental Sciences

In the past ten years, the Laboratory's research in environmental and ecological sciences has built an international reputation for excellence in its interdisciplinary approach to environmental problems. While growing in prestige and stature, the Environmental Sciences Division has built and occupied a new environmental sciences building, established a National Environmental Research Park, and experienced a considerable increase in funding—from $9 million to $38 million. Ten years ago, the division had 160 employees and 66 guests; today it has 200 employees and 200 guests. It is not only a lively, interesting place for our employees

Jim Travis measures varying amounts of tellurium released from nuclear fuel for different degrees of fuel cladding oxidation.

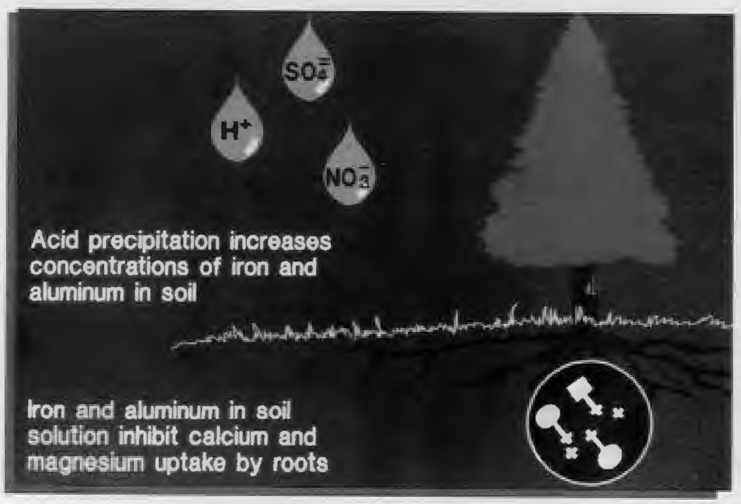
Right: In the Analytical Chemistry Division, Gary Glish (left), Scott McLuckey, and Henry McKown have developed an explosives detector that uses mass spectrometry to sniff the air for traces of suspect chemicals.

to do research on important global issues but also is a magnet for outside research collaborators. More university students and faculty assignees are hosted by environmental science researchers than by those of any other ORNL division. In recognition of its worldwide leadership in environmental research and its role in educating future scientists, a DOE National High School Science Honors Program workshop in environmental science was held at ORNL in 1989.

For more than ten years, our environmental scientists have been studying the effects of acid rain and other forms of acidic deposition on forests and lakes. Many of us have seen the negative effects of acid rain on the forests of New England. Ernie Bondietti and others in the division have developed an explanation that describes the mechanism by which acid rain retards tree growth or decreases tree resistance to natural stresses such as disease, insect attack, or drought. They found that sulfuric and nitric acids, pollutants formed by the burning of fossil fuels, are carried by wind and clouds and deposited through fog, rain, or snow to the soil, where they liberate iron and aluminum ions from the soil to be taken up by the trees. In calcium-poor soils, trees will ingest these liberated iron and aluminum ions in preference to normal nutrients such as calcium and magnesium. This response weakens the trees and makes them more vulnerable to additional stresses.

In recent years, the Environmental Sciences Division has been shifting its research focus from the local environmental effects of energy production to global environmental problems. For example, we are addressing the causes of atmospheric ozone depletion and climate changes that may result from increased global carbon dioxide levels—the greenhouse effect. We are initiating studies on the environmental effects of globally distributed contaminants, erosion, desertification, urbanization, ocean pollution, reduction in species diversity, deforestation, and resource depletion. We need to determine how serious the global environmental effects of these phenomena may be and whether they are amenable to mitigation. This global emphasis is reflected in establishment of the Center for Global Environmental Studies at ORNL, headed by R. I. Van Hook.

About 1.5 million hectares of high-elevation U.S. forests are declining in growth, and many trees are dying earlier than expected. Acid precipitation has been blamed for this decline.



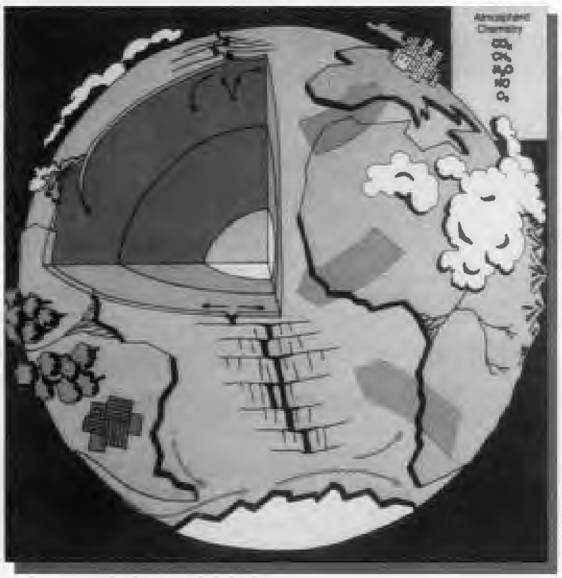
Observations of an unprecedented decline in tree growth led to ORNL's hypothesis of a mechanism to explain the phenomenon.

Biology

Although ORNL's Biology Division is smaller than it was ten years ago, much exciting research continues on the forefront of mammalian genetics, protein engineering, human genome mapping, and other important topics. Biology Division researchers Salil Niyogi and Audrey Stevens have been studying the human epidermal growth factor (EGF) and producing variations of this protein using protein engineering, or site-directed mutagenesis, techniques. By binding to its specific cell surface receptor, EGF initiates a cascade of biochemical events leading to regulated cell growth. Certain amino acid residues in the EGF protein—the active sites—are responsible for making the EGF bind to tissue molecules and promote cell growth. However, Niyogi, Stevens, and their associates have cloned genes that produce EGF mutants—proteins whose active sites are replaced by other amino acid residues. Some of these mutants, while retaining the ability to bind to the receptor, are deficient in sending the signal for accelerated growth; thus, their presence could block the binding and action of normal EGF. Niyogi's research team is collaborating with John Cook and others in the Biology Division in testing whether these mutants will consistently retard, rather than promote, the rapid growth of cells. If EGF mutants that slow rather than accelerate cell growth can be produced, they might be useful in retarding the growth of tumor cells.

Health and Safety Research

In the Health and Safety Research Division, ORNL has been at the forefront of developments of the scanning tunneling microscope (STM), a recent invention by researchers at IBM that allows incredibly detailed surface studies on the atomic level. At ORNL, a photon STM has been invented to supplement the recently built electron STM (with which we have recently imaged DNA). This fascinating device, which uses a helium-neon laser and fiber optics, was developed by Tom Ferrell and Bruce Warmack and University of Tennessee graduate student Robin Reddick. The new microscope will image details as small as 100 nm, or one-sixth of a wavelength of visible light—a resolution thought impossible for many years. Unlike the electron version, the photon STM does

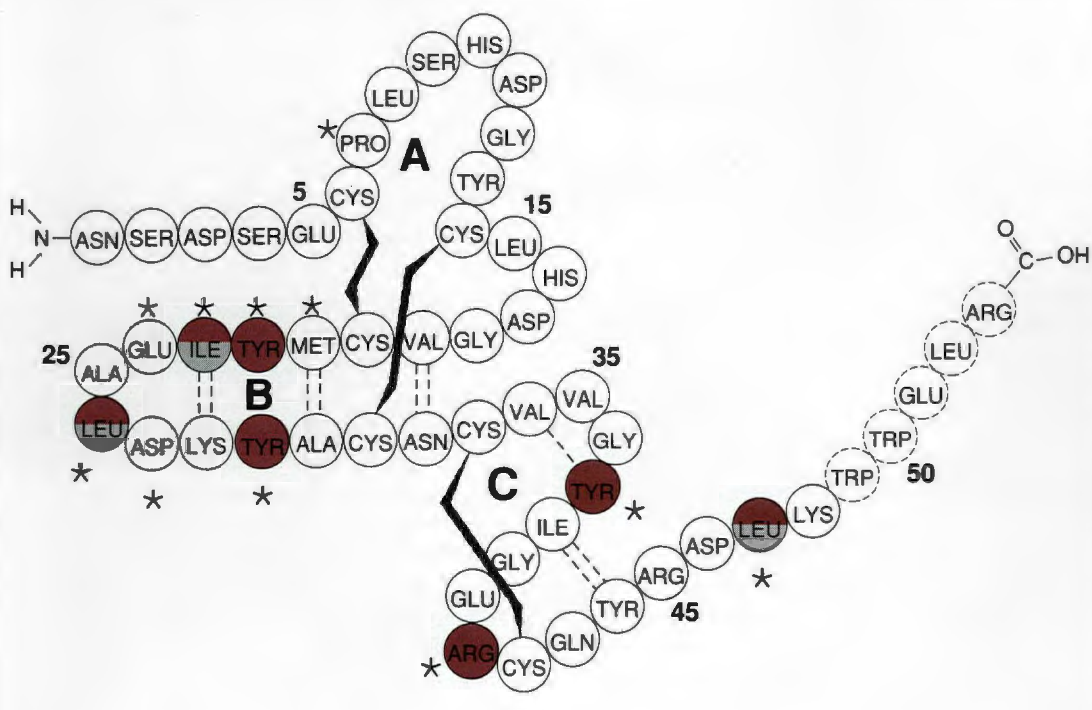


ORNL's Center for Global Environmental Studies will examine critical issues such as climate change, ozone depletion, globally distributed contaminants, ocean pollution, biodiversity, deforestation, resource depletion, erosion, desertification, and urbanization.

not require the samples to be coated with conducting materials, making possible the visualization of optical and other insulating surfaces such as live biological samples.

Reactors

High Flux Isotope Reactor. The operating staff of the High Flux Isotope Reactor has long awaited permission to restart the research reactor, which has been idle since November 1986 when evidence of embrittlement in the pressure vessel was found. (Editor's note: On April 18, 1989, the HFIR was restarted; see details in "R&D Updates" on p. 38.) Three other reactors shut down in March 1987 because of management problems remain closed, even



Asterisks indicate amino acid residues that have been substituted.
Red indicates residues important for binding to EGF receptor.
Gray indicates residues alteration of which may produce anti-growth substances.

The red circles in this model of human epidermal growth factor represent amino acid residues that are binding sites to enable controlled growth. Substitution of amino acids at the red and gray sites may produce substances that retard growth.

Audrey Stevens (left) and Salil Niyogi (not shown) conduct research on producing and investigating mutant EGF proteins. Marilyn Maupin is inserting a protein sample for analysis.

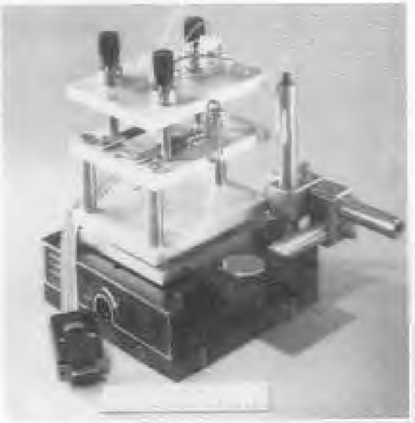
though the management problems have been addressed. In the past two years at the HFIR, we have doubled the staff, instituted new practices, and addressed all operational and safety concerns. Results of a pressure test of the HFIR pressure vessel in the summer of 1987 indicated that it can operate safely at 85% of full power for the next ten years.

Restarting the HFIR has been important for many reasons, not the least of which are the many research projects that were suspended when the HFIR was shut down. In particular, users of the National Small-Angle Scattering Facility at the HFIR have been eager to resume their research. Over the years this facility, jointly sponsored by DOE and the National Science Foundation, has been used by as many as 110 researchers annually. Before the HFIR shutdown in late 1986, more than 20,000 specimens—10 a day—had been analyzed in this facility using neutrons from the HFIR.

Preparing the HFIR for restart has been a very demanding, difficult job requiring a great deal of money and extra efforts by our staff. The people in the Research Reactors Division have done an exemplary job, raising both the HFIR and the Laboratory to a new plateau of capability for managing difficult operations.

Gas-Cooled Reactor Research. In October 1988, a loss-of-coolant accident was simulated at a high-temperature gas-cooled reactor—the 15-MW(e) AVR—in the Federal Republic of Germany. ORNL staff members were actively involved in the experiment, which proved that a reactor core heated up because of loss of all coolant will eventually cool down on its own without causing fuel failure or release of radioactivity. The AVR test demonstrated the inherent safety characteristics of the high-temperature gas-cooled reactor.

John Cleveland of the Engineering Technology Division was an active participant in the planning and execution of this important experiment. He was present at the German reactor to review plans and preparation for the test, to assist in data evaluation and calculations, and to obtain test results for further analysis and examination in the United States, where ORNL has been the leading DOE laboratory in gas-cooled reactor research for many years. The AVR test results demonstrate a fundamentally different approach for ensuring safe and economical generation of electricity with nuclear power—that is, to rely primarily on inherent reactor characteristics for safety, thus reducing the number and complexity of engineered safety systems. The test was an important demonstration of this technology and its safety.

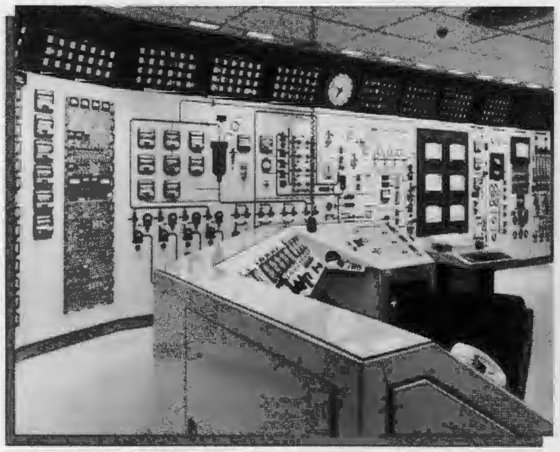


Robin Reddick (left) and Sherry Sharp, two UT students, prepare the photon scanning tunneling microscope for use. Inset: the heart of the microscopic device developed at ORNL.

ORNL recently produced this electron STM image of double-stranded DNA (magnification: 20 million times).

Advanced Neutron Source. The Advanced Neutron Source (ANS) is the research reactor we hope to build to replace the HFIR. This reactor will produce a much higher neutron flux than the HFIR or any other reactor in the world. In the past year we selected a split-core configuration for the ANS design as a result of joint studies by ORNL and Idaho National Engineering Laboratory. Currently, Left: The High Flux Isotope Reactor control room has a new look in 1989.

Right: The National Center for Small Angle Scattering Research at HFIR was quite active in the first 10 months of 1986, the year the HFIR was shut down. Keeping track of the many experiments were the late Wally Koehler (left) and George Wignall, now director of the center.



Bottom left: ORNL's Neutron Scattering Facility, which opened in 1967, has been modified and improved over its 22-year lifetime. Shown here are ORNL's Joe Cable (right) and Jaime Fernandez Baca, a postdoctoral staff member from the University of Maryland.

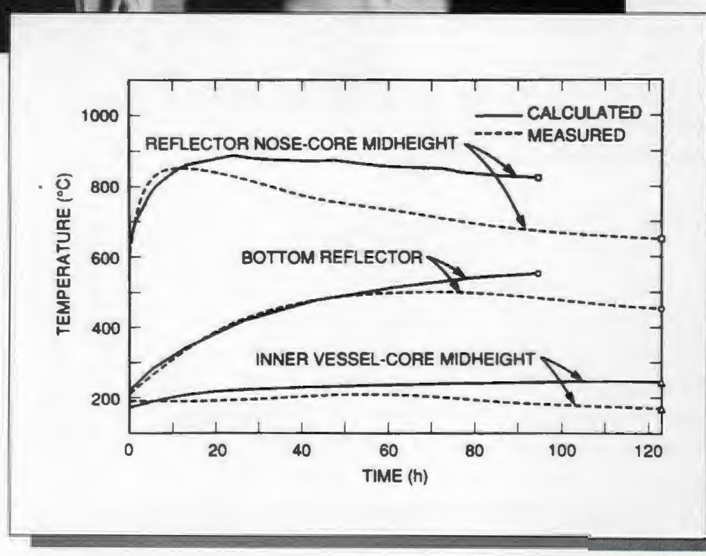
researchers are addressing a potential problem in the ANS—corrosion in the fuel cladding. Working with Bill Montgomery, pipefitters C. R. Kelly and W. D. Clark have prepared the ANS Corrosion Loop Test Facility for operation. This test facility will guide the selection of aluminum cladding material for the uranium silicide fuel, which will be cooled by heavy water.

Support Groups

Without our various support groups, we could not operate this national laboratory. One support function that has been particularly important in the past couple of years is quality assurance (QA). Quality assurance has received much more attention recently, and we are all more aware of its importance. We have developed a graded approach to QA for our facilities and programs. The basic QA document is NQA-1, a set of guidelines for managing a nuclear facility. All divisions are writing new QA plans (49 out of 94 plans are completed); by the fall of 1989, all divisional plans and a QA plan for the entire Laboratory should be complete.

The Safety Department is another group that plays a vital role in the Laboratory's operations. Safety is, and must remain, highest on our agenda. In 1988, ORNL was recognized for safety efforts by the Award of Honor from the National Safety Council and by the Outstanding Performance Award from DOE. ORNL had the lowest lost workday case incidence rate of all the DOE research and development facilities. Our frequency of off-the-job disabling injuries also dropped to the lowest rate in 10 years, but it is still too high—much higher than the number of on-the-job disabling injuries. We had two lost-time accidents in 1988, which is unacceptable. Our employees should not be injured either on or off the job; the same holds true for our many guest

ORNL's John Cleveland, shown here (third from left) in the AVR control room, was a key participant in a loss-of-coolant experiment at the German gas-cooled reactor. Inset: The heated reactor actually cooled down faster than was predicted by conservative calculations.



true for our many guest researchers and visitors at the Laboratory.

An area of growing importance to the Laboratory is health physics. In a major effort to upgrade our radiation protection activities, we have purchased 125 portable health physics instruments and put up 8360 new signs telling employees what to do in radiation zones. We have increased training of our staff to ensure that they know how to minimize their exposure to radiation in the workplace. In 1988, we trained more than 3000 employees in radiation protection, compared with 500 in 1986.

To further ensure that our employees are safe and that we are in compliance with state and federal environmental regulations, other support groups have been very active in waste management and remedial action at the Laboratory. Ten years ago low-level radioactive waste was collected in bags and dumped into unlined trenches. Today, increasing awareness and concern for our environment has led to the elimination of shallow-land waste burial. The same type of waste is now compressed, loaded into concrete vaults, and placed on a specially drained concrete pad, called a tumulus. Because the waste has a half-life of 30 years, this engineered storage facility must isolate the waste from the environment for 300 years. In 1988, tumulus disposal was demonstrated as an effective means of waste handling at ORNL by the Energy Systems Engineering Organization and ORNL's Chemical Technology, Environmental and Health Protection, Environmental Sciences, and Plant and Equipment divisions. Tumulus pads built today may well last 3000 years.

Another waste management technique no longer used at ORNL involves liquid streams.

In the recent Emergency Avoidance Solidification Campaign, about 50,000 gal. of radioactive liquid waste from ORNL was solidified and stored in concrete vaults, making tank storage space available for future wastes.

Ten years ago we injected low-level radioactive liquid waste mixed with cement into underground shale. Today we store these wastes as liquids or solids in lined containers. Recently, in our Emergency Avoidance Solidification Campaign, 50,000 gal of liquid waste was solidified and stored in concrete vaults in an interim storage facility. This action freed up tank space for future radioactive liquid wastes.

Other Research Highlights

There have been so many technical achievements at ORNL in important scientific areas that it is difficult to mention more than a few of them. Dramatic developments have occurred in the areas of parallel processing and robotics, sciences that were in their infancy ten years ago. The OPSNET Parallel Computer, developed by John D. Allen and Philip L. Butler of the Instrumentation and Controls Division, received a 1988 R&D 100 Award from *Research & Development* magazine. This computer can efficiently and inexpensively run a program emulating the decision-making processes of human experts in such fields as robotics and medical diagnosis.

The Engineering Physics and Mathematics Division has completed the development of a robot, HERMIES-III, which is designed to be smarter and more agile than its predecessor, HERMIES-IIB. The new robot weighs more than a ton and is about the size of a small car, over 4 times larger than the old one. The increase in size was necessitated by the upgrade to a much more powerful computer and on-board batteries and a more sophisticated and versatile arm. Much effort has been devoted toward developing software and algorithms for the HERMIES-IIB, which can now be adapted for the new robot. These developments will increase the robots' abilities to sense, map, navigate, deal with unexpected events, learn, and perform vision-guided manipulation.

From September 1987 to June 1988, ORNL and the University of Tennessee observed Numerical Linear Algebra Year. Numerical linear algebra was pioneered in the 1950s by ORNL and UT. Now we are both rapidly developing parallel computing capabilities for solving complex scientific problems, using numerical linear algebra methods. During the Numerical Linear Algebra Year, 36 leading researchers from 11 countries, who specialize in numerical linear algebra and related areas of scientific computation and computer science, visited UT and ORNL. Major activities during the year included more than 50 seminars held at ORNL and UT, three short courses on major topics attended by more than 100 area scientists, a meeting in Knoxville of the American Mathematical Society, and the Gatlinburg X Conference on Linear Algebra, which was attended by more than 90 invited researchers, 30 from foreign countries. The mathematical researchers identified three important areas of research requiring near-term resolution: eigenvalue computations on parallel computers, parallel sparse–matrix computations, and portability of software across architectures.

Competitiveness in science, technology, and commercial ventures has become an issue in the past decade. The decline of an American product in world sales and the rise of a competing Japanese product have become familiar occurrences. In recent years, the United States has lost the world market for absorption chillers, large heat pumps used for heating and cooling commercial buildings. However, Bob DeVault, of ORNL's Energy Division, may help reverse that trend. He has developed a gas-fired, triple-effect absorption chiller, which has recently been licensed by the Trane Company, working with the Gas Research Institute. The remarkable aspect of this achievement is that, in this reasonably mature industry, DeVault has developed a machine that is 50% more efficient than its predecessors.

User Facility Highlights

Interactions with the academic and industrial communities are important at ORNL, and our user facilities are central to many of these interactions. From 1978 to 1988, the number of official DOE user facilities at ORNL has increased from 3 to 12, and the number of users and guests has tripled. In 1988, we had 2300 outside users of these facilities, 30% of these from industry (compared with ~5% ten years ago). The High Temperature Materials Laboratory, one of our newest facilities, now has 41 user agreements with universities and private companies, and more than 60 research proposals have been approved.

An interesting and innovative new user facility of considerable interest to industry is the Roof

HERMIES-III (left) is smarter and more agile than its predecessor robot, HERMIES-IIB (right).

Research Center, dedicated in 1988. In a test-bed environment where conditions can be carefully controlled, roof materials and designs can be tested for properties such as thermal efficiency and durability. This facility will be a central feature of our cooperative research programs with roofing industries. Selection of the best roofing materials and designs are important economic considerations for new and renovated construction.

Another user facility, which has already been mentioned, is the tandem accelerator at the Holifield Heavy Ion Research Facility. The accelerator established a new world record this year by operating at 25.5 MV on the terminal. The voltage increase was made possible by the joint design development work of researchers from ORNL and the National Electrostatics Corporation.

The unique Nuclear Orientation Facility (NOF) was a new addition to the UNISOR Isotope Separator at Holifield in 1988. It is funded by Oak Ridge Associated Universities (ORAU), the University of Tennessee, Vanderbilt University, DOE, and a number of other universities. This device, the most powerful of its type in the world for the study of nuclear-level properties, is operated by ORAU as part of the Holifield facility. The first NOF experiment involved a total of 20 researchers, including 3 international research associates, 3 UNISOR staff members, 6 faculty members, and graduate students from 8 universities. UNISOR, which is a very productive research consortium, serves as a flagship in our research relations with ORAU.

The Oak Ridge Electron Linear Accelerator (ORELA) positron source, part of the ORELA user facility, was constructed and installed at ORNL in 1988. Producing a beam of 1.1×10^8 slow positrons per second, the source has applications in analytical chemistry, chemical physics, materials characterization, and in the biological sciences. Its developers, Les Hulett and Dave Donohue, of the Analytical Chemistry Division, and T. A. Lewis, of the Instrumentation and Controls Division, did their own design work, improvised, and used low-cost assistance from workers at the Anderson County Sheltered Workshop to wrap the target-room solenoid with its required 1500 ft of aluminum wire, strung with 60,000 ceramic insulating beads. Though put together on a shoestring budget and operated on the "leftover" gamma energy from the electron bombardment of ORELA's tantalum target, the new facility provides a higher and easier-to-control positron source than facilities at other institutions.

Exploratory Studies Program

The research that led to development of the ORELA source began about ten years ago, as an ORNL "seed money" project. I will conclude by describing our exploratory studies program, out of which so many innovative and exciting research programs have grown. The Seed Money Program was initiated in 1974, when we realized that many of our people had good ideas that were not funded. (It is interesting how good ideas can spring up when you lose your funding!) In 1983, the Director's Research and Development Fund was added to this research incubation effort, and the total funding for what is now called the Exploratory Studies Program has grown from less than $200,000 in 1974 to about $7 million in 1988. The program has helped many fledgling projects grow into important research advances. About 25% of the Laboratory's R&D 100 Awards during this time originated in this program, a remarkable payoff on investment.

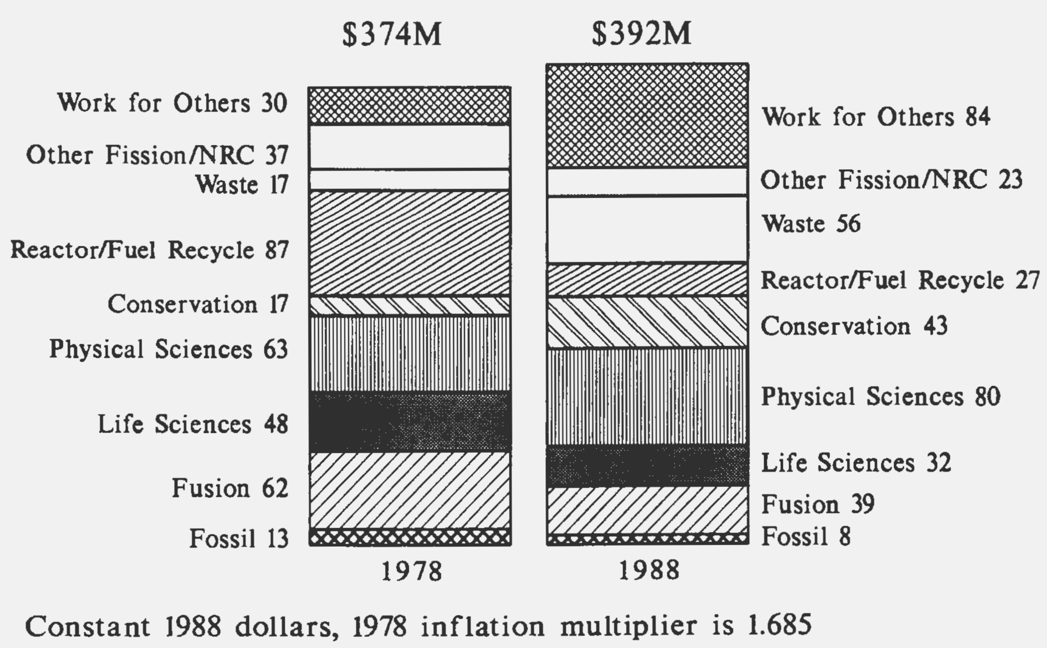
The current Exploratory Studies Program includes some of the most important work at the Laboratory today, such as HISTRAP, superconductivity, laser-based photochemical vapor deposition, biotechnology for waste treatment, metal and carbon matrix composites, and sequencing methodology for the human genome initiative. All of these vital research areas are, in fact, at the very heart of the Laboratory today.

Funding Fluctuations

Research projects, progress, and direction are dependent on funding, which has undergone considerable change at ORNL over the last ten years. In constant 1988 dollars, the Laboratory's operating funds have increased from $374 million in 1978 to $392 million for 1988. Some areas that were very prosperous ten years ago are not so anymore. Funding for fusion and life sciences has decreased, while support for physical sciences has increased. However, about $10 million of the increase for the physical sciences is money obligated for the HFIR.

Energy conservation has been our most successful program, increasing from $17 million to $43 million and becoming the largest technology program at the Laboratory today. In 1978, reactor fuel recycle work was a major program and, coupled with reactor research, accounted for a large fraction of Laboratory work. That area is rather small now, and funding for waste technology has recently been the major growth area. The NRC and fission-related work has decreased, but our work for federal agencies other than DOE has expanded. Through our Work for Others programs, we make unique contributions to solving problems of national importance that are still in line with our major DOE missions.

After preparing this address and having to choose only a few to highlight from among so many outstanding achievements, my conclusion is that ORNL is a splendid laboratory. In reviewing the recent past and present, I think that, in a sense, we are also seeing the future. Today's research accomplishments at ORNL will be part of this country's civilization tomorrow. That is what this Laboratory is about. We carry out important science and technology missions to make the future for all of us better, more interesting, and more fulfilling. That is what we do, and that is what so many excellent people have done again in 1988. ornl



ORNL's operating funds have increased from $374 million in 1978 to $392 million for 1988 (in constant 1988 dollars). Funding for fusion and life sciences has declined, but funding for the physical sciences (including research reactors) has increased.

Competitiveness Begins at Home

This article was transcribed from a speech given by ORNL's new Laboratory Director, Alvin W. Trivelpiece, following a presentation by Alexander Zucker, ORNL's former Acting Director, at the Annual State of the Laboratory Address on February 28, 1989.

"We need to be serious about competing and to be taken seriously as a competitor in the world's research and development efforts."

First, I want to thank Alex Zucker for his superb summary of the programs and activities at the Laboratory. In the two months I have been here, I have been trying to find out what is going on at the Laboratory. Tonight is the first time I really found out. I appreciate Alex's remarks; I was taking notes.

One of the themes I noticed in Alex's talk is that research and development involves a process of change, and that we, as a national laboratory, need to be able to respond both to inflicted change and to the changes we may cause to occur. We need to be a competitor. We need to be serious about competing and to be taken seriously as a competitor in the world's research and development efforts. We need to keep in mind that "Competitiveness begins at home."

Competitiveness is, of course, a popular buzzword today. It has acquired that kind of status; it is popular in Washington; everybody uses it. It is so popular, in fact, that you almost need to define what you mean on any particular occasion when you use it. Our U.S. budget deficit and trade deficit are probably the two major reasons competitiveness is getting so much attention. Some people seem to think we are failing to do something that will keep us competitive.

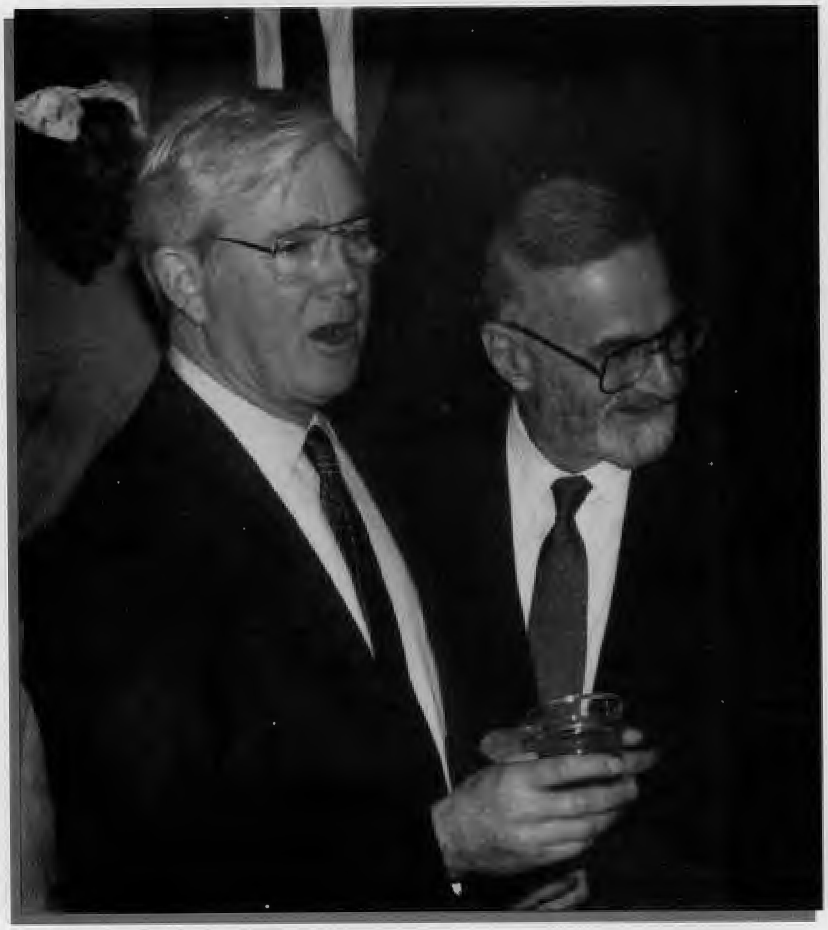
So, what should we do? One of the answers we hear is higher tariffs. It is suggested that if we impose higher tariffs, that will make us competitive. Or, we should control our high-technology exports so that other nations do not get our technology and sell back to us what we have discovered and invented, as is happening now. Some people claim the solution is to make it easier to get patents for work done at DOE laboratories. Other proposed solutions are to increase quality control, increase our science and technology literacy, and lower the capital gains tax. I am sure many of you have heard this extensive list of things we should do. It is easy to come up with a quick list of "solutions."

On the other hand, competitiveness remains a very complex, very severe, very stubborn problem. One of my concerns, and it relates to the Laboratory, is that there has really been an erosion of science and technology leadership in the United States. This has severe implications for the underpinnings of our economy. As many of you know, U.S. economist Bob Solow recently received the Nobel Prize for Economics. Much to the relief of our nation's scientists and engineers, he discovered that science and technology are the underpinnings of our economy. I think most of us who are scientists and engineers have known this all our lives, so it is really rather comforting that an economist finally discovered it!

Even so, there are a lot of indices showing that perhaps we scientists and engineers are not doing as well as we should toward being competitive. For example, the number of publications by European scientists now exceeds that of American scientists. In 1978, one-third of the patents in the United States were granted to foreign inventors. Today, ten years later, that number is up to half of our patents. Eighty percent of the payloads going into space are put there by the Soviet Union. Forty percent of the physics doctorates and half the engineering doctorates are granted to foreigners in the United States. In 1970, there were 1200 doctorate degrees given in mathematics; this year there will be only 700, and only half of those are being granted to Americans. A recent survey comparing high school seniors of 13 literate countries shows that our students are dead last in knowledge of biology, and eleventh out of the thirteen in chemistry.

So, we are not doing a good job in several respects. We are not doing well at converting basic and applied research and development into useful products. Other countries are doing better. Part of our competitiveness

"We need to think seriously about how we can compete."



that about. One of the goals is to increase the public's awareness of the competitiveness and technology leadership problem. Another is to create circumstances in which cooperation among industries and the public sector can take place to improve our ability to compete. And a third is to change the policies of the United States federal government in ways that will improve our competitiveness.

problem is not just that we have gotten worse, it is that the other nations are competing more effectively with us. We no longer have the only game in town.

A lot of people in our country would like to do something to fix this problem, and some things are getting started. One of the most important is the National Council on Competitiveness, headed by John Young, who is also president of Hewlett Packard. The Council has already done a lot of work and worrying about this problem. Of course, it is fortunate for us that Norman Augustine, the president of Martin Marietta, is also a member of the Council. Their main objective is to improve the ability of American workers to compete on an international level. They have identified some goals they consider appropriate in trying to bring

Our new Energy Secretary certainly seems to support these goals. In remarks prepared for his confirmation hearing, Secretary of Energy designate, Admiral James Watkins, said, "I know that the Department of Energy's national laboratories are home to some of the world's brightest and most innovative scientists and engineers. These creative minds are a precious national asset and will be encouraged not only to continue their basic research, but also to improve the process by which new technologies are transferred to American industries, small businesses, and universities. The laboratories will also have a growing role in helping high schools and universities motivate young people to seek vocations as the scientists, mathematicians, and engineers of tomorrow. We are not doing enough in our nation to encourage young people, and particularly the growing number from minority backgrounds, to pursue careers in science and engineering."

We at ORNL definitely agree. These goals of basic research and development, technology transfer, and education are things that we as a

Fred Mynatt and his wife accept congratulations during the social hour. As associate director in charge of ORNL's research reactors, Mynatt received the 1988 Director's Award in recognition of the "superb efforts of everyone involved in preparing the High Flux Isotope Reactor and three other reactors for restart in 1989."

Laboratory are in a position to do well. Just because we share the goals of Energy Secretary Watkins, however, does not automatically mean that programs in these areas will develop at ORNL. Even though ORNL is an outstanding place, the competition is getting tougher. We need to think seriously about how we can better compete, and that's why I chose as this talk's theme "Competitiveness begins at home."

What this theme means is that competitiveness is really everybody's business. It means *thinking* competitively, *cooperating* so that we can be competitive, *organizing* our resources in a team effort to make the Laboratory operate as a whole to compete.

Many of you may be familiar with the writings of Alfred Demming, who makes the point that

Bill Eads (left), director of ORNL's Instrumentation and Controls Division, chats with Herman Postma, former Laboratory Director and now senior vice-president of Martin Marietta Energy Systems, following the State of the Laboratory address. At right is Al Ekkebus, assistant to ORNL's director.

America grew, in its early history, through a process of rugged individualism. People went out and conquered the land individually. Winning as an individual has been very important in America. This individualistic culture served America very well during its pioneer days. And the culture of Japan, which is based on cooperation and team effort, rather than individualism, serves that country very well in today's internationally competitive trade situation. Perhaps we, in this country and in this Laboratory, need to take a look at the situation in which we find ourselves and try to compete in a way that involves cooperation, rather than the individualistic efforts that characterized the past.

This kind of cooperation involves more than just scientists and engineers getting together over coffee. It involves support personnel, in fact everybody at the Laboratory; furthermore, I think it also involves DOE Headquarters and the DOE Operations Offices. We need to focus on what is critical and get on with it in a way that maximizes

Research Reactors Division Wins Director's Award

Following the State of the Laboratory address and his talk on competitiveness, ORNL Director Alvin Trivelpiece presented the 1988 Director's Award to the Research Reactors Division, citing the "outstanding efforts of many individuals there." Key leaders of the division include, from left in front, Pete Lotts, division director; Jane Eggers, head of the Training and Procedures Section; Bill Craddick, head of the Reactor Technology Section; Walt Brown, head of the Management Systems Support Section; Roy Fenstermaker, Quality Assurance director assigned to the Research Reactors Division; and Dave McGinty, head of the Reactor Compliance Section. Absent from the photograph is Tom Dahl, head of the Reactor Operations Section.

our effort. It's a matter of national importance; we each need to do our part in contributing to this cooperative effort. I'll say it again—"Competitiveness begins at home."

In the two months since I came to ORNL, I have been very impressed with the people and programs. I am still learning—assimilating as much as I can, as fast as I can. It is a little like drinking from a fire hose, because there is so much that goes on here. I plan to do all that I can to help the Laboratory compete, but we need to understand that our national budgetary constraints may continue for some time, and the competition is getting tougher. What *I* do is not nearly as important as what *you* do to help us compete. Only you can put together the kind of team effort that will really make the Laboratory work in competition today. ORNL has a proud history, a lot going for it, and should have a great future. Let's work together to make it the best it can be.

Market Research Aids Technology Transfer

By Warren Siemens and Ernest Cadotte

Professor Ernest Cadotte (right) reviews a market analysis project with MBA students Richard Cox and Jennifer Evans.

The scientific community at Oak Ridge National Laboratory is dedicated to pushing back the horizons of scientific knowledge and advancing technology. Although it is usually not their primary intent, ORNL researchers may develop innovative software, instruments, machines, materials, and processes that can be valuable in the commercial sector. The Office of Technology Applications (OTA) of Martin Marietta Energy Systems, Inc., was created to evaluate the commercial value of these innovations and to identify and license firms to market them. Since 1985, the OTA has licensed technologies developed at the DOE installations managed by Energy Systems to 32 companies. Most of these innovations were from ORNL.

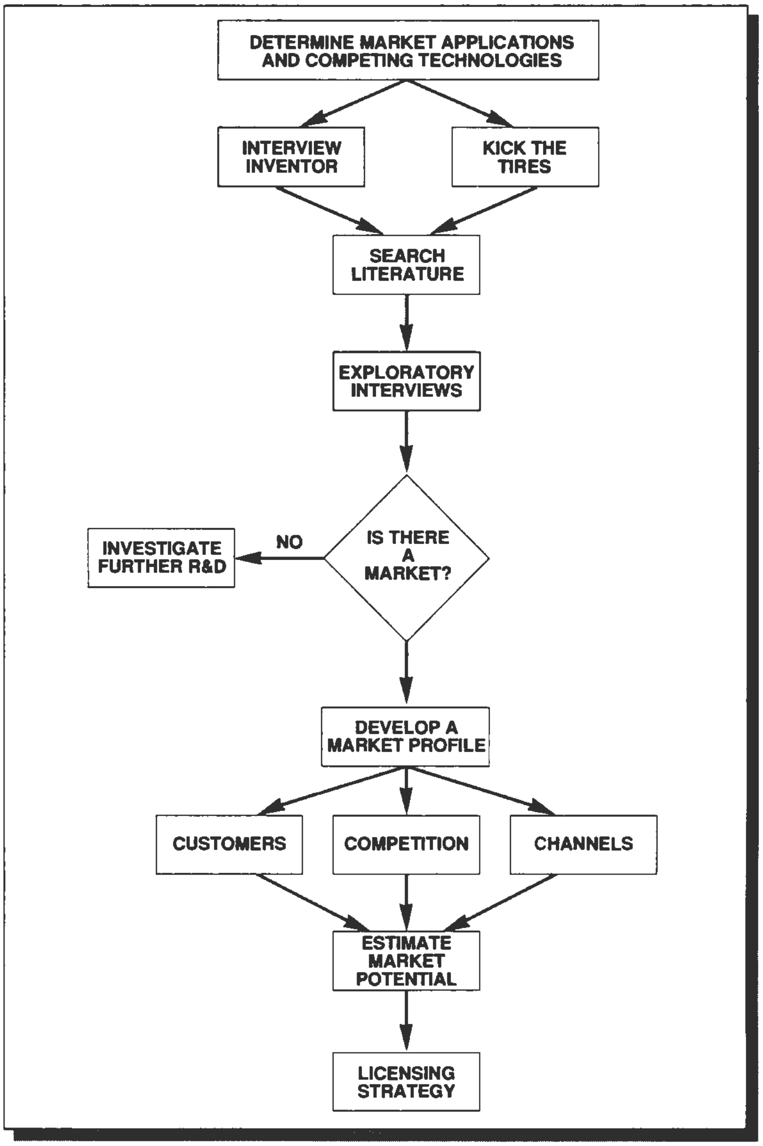
For each invention identified as having commercial development potential, the OTA staff oversees a marketing opportunity analysis (MOA), using an approach that is unique among government research laboratories. Ours is a team effort that includes University of Tennessee (UT) students pursuing master of business administration (MBA) degrees, their UT College of Business professor, and OTA staff members. Our successful record of technology transfer and the quality of the MBA graduates testify to the value of this teamwork approach.

The OTA was established in 1984 because it was apparent that many ORNL inventions have commercial value. The staff soon realized that, in most cases, the licensing strategy would benefit from an MOA. Warren Siemens, OTA director, conceived the idea of a joint marketing research program with the UT Center of Excellence in New Venture Analysis. With the help of Ernest Cadotte, UT professor of marketing, a cooperative program was set up to train the MBA students as market analysts while they assist the OTA staff in preparing MOAs for ORNL inventions having potential commercial value.

The cooperative program has been in place since March 1986 and has employed a total of 15 MBA students as market analysts. The students have gained experience on a variety of projects, including market studies on biocatalytic beads, advanced structural ceramics, nickel aluminides, the triple-effect absorption chiller, the HERMIES robot, nuclear medicine agents, cellulose recovery, and microwave sintering. In 1988 alone, 52 MOAs were completed by the students.

The UT program's success can be attributed to its team basis. Each new project is initiated by an OTA staff member, who is assisted by an MBA student under Cadotte's supervision. Working together, they map out the scope of the MOA, the specific information needed, and a timetable for delivering it. It is then the responsibility of the MBA student to complete the project as defined. Cadotte guides the student on how to (1) structure the work, (2) find marketing information, and (3) interpret the research results. He meets with the student on a regular basis to trouble-shoot difficult problems and to oversee the quality of the work.

In later stages of the project, the team members meet regularly to review progress and adjust the project's scope, direction, or timetable as needed. An OTA licensing specialist is kept informed of important developments and any data that may have implications for licensing the technology. This team approach has been very effective, and we have developed a high level of confidence in the quality of these marketing analyses.



Schematic of our marketing opportunity analysis process.

The MOA Process

Imagination and creativity are essential in identifying, sorting out, and following up on the possible markets and applications for ORNL inventions. The process we have developed is outlined in the figure shown here. An interview with the inventor, which provides an opportunity to "kick the tires" of the new technology, is the first step. The student analyst should learn enough from the interview to structure a literature search on the market applications, potential customers, and suppliers of related technologies. Next, a series of exploratory interviews are held to determine how much interest the business sector has in the invention. If the invention seems commercially viable, a more detailed profile of customers, competitors, and distribution channels may be warranted. Ultimately, all of this marketing information is passed on to the OTA staff, who use it to formulate a licensing strategy.

Interviewing the inventor is the best initial step toward gaining information on potential applications and competing technologies. Besides telling the analyst about his

Bill Carpenter (center) discusses marketing career opportunities with UT students Mike Moeller (left) and Scott Smith.

innovation, the inventor is likely to be tied into a network of other scientists having similar interests, some of whom work in industry. These contacts can be helpful in assessing the commercial potential of the invention and may serve as a networking link to marketers and other decision makers who can provide insight into associated business issues related to the invention.

The initial interview with the scientist should provide the market analyst with an overview of the invention and its potential value to business and industry. The student analyst must learn: (1) the problem or need that the invention addresses, (2) any current solutions (competing technologies) for solving the problems, and (3) strengths or weaknesses of the invention relative to these competing technologies. The analyst will also try to determine which applications are likely to be most important to industry in terms of benefit gained and/or size of market.

"Kicking the tires" during the initial interview means learning some of the details of the invention and/or the jargon of the discipline. The analyst needs some familiarity with the technology to be able to meaningfully discuss the invention. Becoming conversational with the technology requires observing the invention in operation and asking the inventor what is going on at each step in the process. In short, it allows the analyst to see, hear, and feel the invention. It adds a level of clarity and understanding that cannot be gained from reading technical papers. At the end of the interview, the analyst should be able to explain the invention in simple terms and in the language of the scientist.

A literature search is the next step in the MOA process to better identify the potential markets and any competing technologies. At first, the market analyst uses a "shotgun" approach, exploring the leads provided by the inventor. At this point, there is no way to know which market applications have the greatest potential or which firms would be the best candidates for licensing. The literature search should uncover information the inventor does not know. When thoroughly informed on the market possibilities, the analyst can ask better questions, carry on more meaningful discussions with company representatives, and avoid embarrassing gaps in knowledge in future interviews with potential developers.

The analyst should start the literature review process by assembling a list of key terms from the information provided by the inventor. Vicky Punsalan, an ORNL librarian, has been very helpful in this process by broadening the list of references and including terms more suitable to the business market. Using key terms, one of ORNL's reference librarians conducts a computer search of several business data bases. The analyst then reviews the annotated citations for any mention of anticipated market applications, competing technologies, and the associated industries. It is important to identify trade associations and journals, the major players in the industry, and recent trends and developments relating to the invention. A second literature search may be warranted in some cases to narrow the field to a more relevant set of industries, brands, and suppliers.

A series of exploratory interviews is used to evaluate the "real" market opportunity for the invention. Networking is the key to gathering market information at this stage. Usually, the secondary or published information available on the commercial application of a new technology or its potential markets is limited, so that the analyst must depend on his contacts with technical experts, trade association representatives, and executives of potential licensing firms to obtain relevant information. During interviews with these individuals, the market analyst will attempt to determine the level of industrial awareness and interest in the technology, the types of problems or needs it addresses, and the market's perception of the invention's value relative to existing products.

Starting with a list of key informants provided by the scientist or discovered in the literature search, the market analyst will interview an ever-widening circle of interested parties. The first interviews are very general; the analyst looks for any clues regarding potential applications, competing technologies, major competitors, and distribution channels. Later, as the analyst develops a better view of the technology's market opportunity, the interviews are more structured. In any case, the requisite skill is to recognize a clue and follow it up with a series of questions designed to flush out the details. The informants are also queried about others in the industry who might know more about a potential application or have a different perspective on the technology.

With each interview, the analyst discovers new pieces to the puzzle. Soon, a fairly consistent pattern begins to emerge, and opinions and statistics are repeated often enough to be categorized. If there is any market interest in the invention, it becomes apparent at this stage. As a rule of thumb, the invention should create a high level of interest, even excitement, among potential adopters or licensees to be viable in the marketplace. If it does not, either the technology, the market, or the potential licensee is not ready.

"The requisite skill is to recognize a clue and follow it up with a series of questions."

A market profile is often the next step in the MOA. After the exploratory interviews are completed, the MOA team must decide how to proceed. If there is little interest in the invention at its current state of development, the OTA licensing specialist may recommend that the project be put on hold until the technology is further developed.

If considerable interest in the invention is evident, the MOA team will recommend development of a detailed profile on the more promising market applications and competing technologies. The profile would entail a thorough investigation of the potential market (number of customers, their geographic distribution, purchase size and frequency, benefits sought, and price/performance requirements). Key competitors would be studied to determine their relative size, market share, breadth and depth of product line, marketing practices, and decision trends, and to identify key decision makers. Information about distribution channels would be gathered, such as the typical methods of distribution; size and number of wholesalers, brokers, or other intermediaries; and their protocols of doing business.

The level of effort expended on a market profile will depend on a subjective estimate of the market potential of the invention and the complexity of the markets. From the information gained in the exploratory interviews, the licensing specialist can identify several of the most promising market applications and determine whether a more detailed analysis is warranted. If the technology is of interest only to a market niche, a limited market profile may be all that is needed.

"A search of secondary sources is the preferred method of gathering information for a market profile."

A search of secondary sources is the preferred method of gathering information for a market profile. Government publications, trade association magazines, and financial reports of key competitors are useful sources that can be obtained quickly and easily.

If the invention represents an improvement on existing technology, data are usually available on industry size, sales trends, market segments, marketing practices, distribution channels, and major competitors. For example, the triple-effect absorption chiller developed recently at ORNL represents a significant advance in gas-fired air conditioning systems. In preparing the MOA for this innovation, the market analyst easily found extensive published information on the heating and air conditioning industry and on manufacturers of this type of air conditioning system.

If the invention represents an entirely new technology, little information may be available on the target market and the analyst will need to investigate products in parallel or related industries. The growth patterns, size, distribution channels, and nature of competing or analagous products will help the MOA team predict market acceptance and growth of the new technology. For example, the adoption pattern for carbon fibers in the aerospace, automotive, and sporting-goods industries might be useful in predicting the adoption pattern for whisker-reinforced ceramics. Like the carbon fibers, ceramics may be used to replace some of the metal and plastics found in aircraft, automobiles, and sporting equipment. Early identification of the technologies that compete with the invention is very important. A liberal interpretation of customers, competitors, and distribution by the analyst in the early stages is also helpful.

Widespread, but ill-defined, interest in the invention may alert the licensing specialist to the need to conduct a survey of potential producers and users. An example is the survey of the electric power industry done recently to determine possible interest in using the power-electronics technology developed at the Oak Ridge Gaseous Diffusion Plant.

A market survey might also be conducted if there is the possibility of organizing a consortium to exploit the technology on an industry-wide basis. For example, through the OTA, a survey was conducted during the summer of 1986 to determine the feasibility of an industrial consortium to support the development of advanced structural ceramics. In surveys of this type, the MOA team seeks to establish the level of interest in the new development or process, the nature and scope of potential applications, and how these vary by type and size of firm.

Licensing Strategy

OTA's ultimate objective in using the MOA, of course, is the licensing of a new technology developed at the Oak Ridge complex. With the MOA information, the OTA staff can develop a successful licensing strategy for the invention. This might include a recommendation to pursue additional, focused research and development to make the invention more attractive to industry. More often, the strategy will include an action plan containing (1) a set of target firms, (2) a plan to inform the firms of the licensing opportunity, (3) recommendations for structuring a deal, and (4) a timetable for completing the licensing process. The successful culmination of the MOA team effort is the rapid and effective penetration of the new technology into commercial markets. ornl

Warren Siemens (right), director of the Office of Technology Applications, and staff member Glen Prosser assist MBA student Jane Crooks in preparing market opportunity studies for some ORNL biomedical and chemical technology developments.

The MBA Experience

It's not surprising that students in the MBA program at the University of Tennessee compete for a market analyst position in the Energy Systems Office of Technology Applications (OTA). This is an excellent opportunity to gain authentic "hands on" experience in conducting market analyses for new products. The skills learned in actually conducting a marketing opportunity analysis (MOA) cannot be learned from textbooks. Experience is the teacher as the student gains an understanding of the process and becomes proficient at conducting interviews, spotting important clues, searching out information sources, and interpreting the final results.

In real-life situations, the student learns to deal with unstructured, and usually unexpected, problems. All MOAs are difficult, and those for state-of-the-art technology are the most difficult. Often only limited market data are available from the traditional sources. It is not always obvious what the market for an invention may be nor who the competitors are. Thus, the student may start out on the journey without a road map, gradually learning the way to structure the problem and solve it. The student who accomplishes this will be more confident and better prepared to become involved in entrepreneurial efforts after graduation.

The OTA experience provides students with a variety of business-related projects besides the market analyses. For example, MBA student Ed Foote developed promotional literature for marketing nickel aluminides and an explosives sensor licensed by ORNL. Similarly, student Glen Prosser developed brochures on the technologies available for licensing at ORNL and on the Energy Systems licensing process. After graduation, Glen joined the OTA staff as a business analyst and licensing specialist.

Another student, Jane Brewer, designed and executed a survey on the feasibility of an industrial consortium in which ORNL and interested companies would collaborate to develop advanced structural ceramics. That study was recently published in the *Ceramics Bulletin*. She also developed a marketing plan for ORNL's Roof Research Center. Student Jennifer Evans is developing a management information system to help track the licensing efforts of OTA and its relations with current and prospective licensees.

Two other students, Mike Moeller and Scott Smith, developed a business plan to help guide the commercialization of diamond-coating technology. They are also studying industrial alliances around the country to identify factors that might help ORNL in developing future consortia. Doug Ayers, a recent student in the program, has helped to streamline the MOA process by preparing guidelines for developing profiles on key competitors and for conducting a mini-MOA. Doug is now a market analyst for the UT Research Corporation.

Often, the students initiate extra projects that are helpful to the OTA staff. For example, Prosser and Ayers volunteered to review ORNL's technology transfer process and promotional materials and have made a number of important recommendations for improvements. Foote spotted some weaknesses in the technology review process and suggested useful revisions.

Perhaps the most important benefit to students working as OTA market analysts is the opportunity to work with three types of mentors—the OTA licensing specialists and the inventors, as well as their college professors. Each has a different perspective on how to approach a problem, search out alternative solutions, and work with others in the process. Each helps teach the student how to thrive and succeed in today's high-tech business environment. ornl

RE: Awards & Appointments


Pete Lotts


Bill Appleton


Charles Baker


Steve Lindberg

The **Research Reactors Division,** directed by **A. L. "Pete" Lotts,** received the 1989 Director's Award for its work in preparing the High Flux Isotope Reactor for restart. (See "Competitiveness Begins at Home" on p. 20.)

Bill R. Appleton has been named ORNL associate director for Physical Sciences. He had been acting associate director since February 1, 1988.

Fred W. Young, Jr., has been named director of the Solid State Division. He had been acting director of the division.

Charles C. Baker, former director of the Fusion Power Program at Argonne National Laboratory, has been named associate director for Technology in ORNL's Fusion Engineering Division, replacing **Lee Berry,** who has increased his technical activity and become responsible for program analysis and development within the division.

Steven E. Lindberg has been elected chairman of the U.S. National Atmospheric Deposition Program.

Robert H. Gardner, Robert D. Hatcher, Stephen Hildebrand, Sankar Mitra, and **David S. Shriner** have been elected Fellows of the American Association for the Advancement of Science. Hatcher, a UT-ORNL Distinguished Scientist, has also received the first Distinguished Service Award of the Geological Society of America. Hildebrand has also been appointed to serve on the Public Policy Committee of the American Fisheries Society.

George E. Taylor, Jr., has been appointed to the editorial board of the *Journal of Environmental Quality*.

Stephen H. Stow has been appointed to the review board for the State of Louisiana Board of Regents.

Tom Ferrell and **Bruce Warmack** have received the annual Excellence in Scientific Achievement Award of the Health and Safety Research Division for their development of the photon scanning tunneling microscope.

John H. Sorensen has been appointed to the National Research Council's Subcommittee on Earthquake Research of the Advisory Committee to the U.S. Geological Survey.

Bruce L. Kimmel has been appointed a member of the Advisory Panel for Ecosystem Studies by the National Science Foundation's Division of Biotic Systems and Resources.

Curtis C. Travis has been appointed to the National Academy of Sciences Committee on Biomarkers for Immunotoxicology.

Po-Yung Lu has been named head of the Information Research and Analysis Section of the Health and Safety Research Division, replacing **Tim Ensminger,** who has transferred to the Energy Division.

In the 1989 International Technical Communication Competition of the Society for Technical Communication (STC), an award of merit was given in the category of scholarly and professional articles to a journal article by ORNL researchers on plant growth in a carbon-dioxide-enriched atmosphere. The authors, who earned an award of distinction in the East Tennessee Chapter competition, were **Richard J. Norby, Elizabeth O'Neill,** and **Robert J. Luxmoore,** and the editor was **Jane Kraemer.**

Sandra R. Schwartz and **C. P. Frew** received the "Best of Show" Award in the 1989 Technical Art Competition sponsored by STC's East Tennessee Chapter.

ORNL and Energy Systems employees receiving awards of excellence in the 1988–89 Technical Publications Competition sponsored by STC's East Tennessee Chapter were **Susan E. Hughes, Charles Reeves, Jr.,** and **Allyn Zerby,** newsletters; **Felicia M. Foust** and **Vic Tennery,** promotional materials; **Ernest G. Silver,** whole periodicals; **Amy L. Harkey, Marsha K. Savage,** and **Gay Marie Logsdon,** scholarly and professional articles; **Jonathan Woodward** and **Luci Bell,** scholarly and professional articles; **Roger D. Spence, Anthony L. Wright,** and **Frank M. Scheitlin,** scholarly and professional articles; and **Glenn F. Cada, James M. Loar, Michael J. Sale,** and **Ruby Thurmer,** scholarly and professional articles.

Recipients of awards of merit were **David E. Fowler, Lydia S. Corrill, Michael P. Farrell, Thomas Gross,** and **Larry Davis,** newsletters; **Carolyn Krause, Luci Bell,** and **Vickie Conner,** house organs; **Cynthia A. Chance, Brenda J. Smith,** and **Evelyn Carver,** promotional materials; **Felicia M. Foust, Vic Tennery,** and **John V. Cathcart,** promotional materials; **F. J. Barber** and **Sharon McConathy,** scholarly and professional articles; **W. B. Dress, Shirley Hendrix,** and **LaWanda E. Klobe,** technical reports; **J. William Roddy, James C. Mailen,** and **Cindy S. Robinson,** technical reports; **E. Charles Crume, Jr.,** and **Margaret Boone Nestor,** technical reports.

Entries and winners who earned awards of achievement were **Marilyn E. Langston, Carol J. Oen,** and **Lola M. Roseberry,** hardware reference guides; **Judy Wyrick** and **Gloria M. Caton,** house organs; **Don Jared, Walter Koncinski, Jr.,** and **Vickie Conner,** promotional materials; **Wanda Jackson, Larry Davis,** and **Vickie Conner,** periodic activity reports; **Braulio D. Jimenez, B. Z. Egan, Norman E. Lee, J. J. Beauchamp,** and **John F. McCarthy,** scholarly and professional articles; **Linda Mann, Dale W. Johnson,** and **Darrell C. West,** scholarly and professional articles; **Larry Dresner** and **Margaret Boone Nestor,** technical reports.

ORNL and Energy Systems employees who received awards in the 1988–89 Technical Art Competition sponsored by STC's East Tennessee Chapter included **Vickie Conner, Carolyn Krause,** and **Luci Bell,** design graphics: publications design, award of merit; **Danny K. Cochran** and **Joe Beaver,** design graphics: posters, award of merit; **Judy C. Neeley** and **Dan J. Hoffman,** interpretive illustration: line art, one color, award of merit; **Rosemary Adams** and **Richard Booker** (designers), Environmental Sciences Division staff (author), design graphics: exhibits, award of merit; and *FY 1988–1993 Institutional Plan, Oak Ridge National Laboratory*, **Vickie Conner, Mark Sollenberger,** and **Wanda G. Jackson** (editor), design graphics: publications design, award of achievement.

The Chemical Technology Division (CTD) has made several organizational changes partly because of the transfer of the Isotope Section of the Operations Division to CTD. **J. Robert Hightower** has been appointed associate division director for Radiochemical Processing Programs; **Allen G. Croff,** associate division director for Waste Management R&D Programs; **Charles D. Scott,** head of CTD Energy Research Programs; **Jim T. Bell,** head of the Chemical Development Section; **E. Kaye Johnson,** head of the newly formed Resource Systems Management Section; **Brad Patton,** head of the newly formed Isotopes Section; and **Robert L. Jolley,** acting director of the Waste Management Technology Center.

Bob Hightower

Jim Bell

E. Kaye Johnson

Brad Patton

Elizabeth S. McDougald has been named coordinator for Radioactive Waste in the Energy Systems Environmental and Safety Activities Organization.

Dale D. Huff has been named head of the Environmental Engineering and Hydrology Section in ORNL's Environmental Sciences Division.

Daniel W. McDonald is now head of the Measurement and Controls Engineering Section in ORNL's Instrumentation and Controls Division.

Harold A. Glovier has been appointed associate director of the Research Reactors Division, and **Jane Eggers** has been named head of the division's Training and Procedures Section.

Strategic Defense and Arms Control

Alvin Weinberg and Jack Barkenbus, eds., Paragon House Publishers, New York, 1988 (263 pages)

Reviewed by David J. Bjornstad, ORNL's Energy Division

"Rather than the current strategic domination by offensive weapons, DPB would lead to domination by defensive means and weapons."

This volume of ten essays by a diverse group of knowledgeable writers, all veterans of nuclear politics, is a potentially important contribution to arms control literature. It addresses a traditional concern—arms control—from the perspective of the defense-protected build-down (DPB) concept, proposed by the editors in 1984.

Alvin Weinberg, former ORNL director, and Jack Barkenbus of the University of Tennessee, argue that defenses against offensive nuclear weapons can meet the twin tests of arms reduction and bilateral arms stabilization. This DPB idea, they say, flies in the face of conventional cold-war wisdom. Deterrence by offensive buildup implies that even following a first strike by the other side, the attacked country can retaliate against the aggressor's cities. Cities and populations are held hostage by the perception of mutually assured destruction (MAD), and war is averted by the certainty of destruction. Rather than the current strategic domination by offensive weapons, DPB would lead to domination by defensive means and weapons.

Weinberg and Barkenbus asked their contributors to assume that defense is technically possible; to look beyond the Reagan Administration's Strategic Defense Initiative (SDI) and view defenses more generically; and to focus on the worth, desirability, political feasibility, and practical achievement of DPB under current institutions. They stress that the goal is not to underwrite a new "technical fix."

The editors state that there are no experts in nuclear war, only specialists in its various aspects. The diligent reader will become quickly aware that this specialization is not only real but adds layer upon layer of complexity to the DPB issue. Indeed, the authors are not a group of proselytes asked to restate a commonly held truth. The contributors treat DPB in terms of their own well-reasoned beliefs and arrive at conclusions that sometimes support and sometimes refute the DPB notion. The result is a wide-ranging discussion of nuclear politics that spans the intellectual and practical accumulation from 40 years of life with the bomb, focusing on current events, but cognizant of the past. The conclusions are much less settled than the editors might have hoped and, in the end, succeed mostly in making a case for the moral superiority of defense domination over offensive weapon domination.

The book is introduced and concluded by Weinberg and Barkenbus, and the body is divided into three parts. The first describes the stages by which one might operationally move from an offense-dominated theater to a defense-dominated one. Weinberg and Barkenbus introduce this section by elaborating on the point that DPB can proceed either unilaterally (with defense exchanges for offense) or bilaterally. They tacitly assume that the opposing superpowers would be anxious for such an opportunity because each prefers having fewer, rather than more, intercontinental ballistic missiles.

Next, Sanford Lakoff discusses the practical process of transition, noting that past treaties and the current arms negotiation process set the stage for DPB. Because the book was published just slightly before the initial U.S.–U.S.S.R. breakthrough in negotiated missile reductions in Europe, the authors seem less sanguine about negotiated success than current events might dictate. Weinberg concludes the section with a description of Freeman Dyson's "live and let live" (LLL) concept. Dyson pictures nirvana, a world in which offensive weapons are reduced to very low levels, effective defensive weapons are in place, and the time required to actually begin a nuclear conflict has been substantively lengthened—goals that DPB seeks to achieve.

The second section, "Enhancing Deterrence Through Defense," is a collection of three well-written papers. Roy Radner develops a rigorous model-based description of deterrence, and E. William Colglazier examines more traditional "hard-point" defense that emphasizes making land-based ICBMs more survivable through hardening and basing. Colglazier argues that the three most valuable approaches would be a mobile Midgetman, a superhard MX silo, and a hard-canister mobile MX. The last essay in the group, by Conrad Chester of ORNL, discusses passive defense by the population (i.e., civil defense). Chester makes an impressive, if somewhat unsettling, case for the revival of civil defense in this country.

Donald Snow argues in the book's final section that much of the support for SDI and DPB stems from the axiom that they reduce the number of nuclear weapons, which are believed to have made the world a worse place to live. But have they? He believes that MAD has permitted survival as societies mature and has bought time to allow differences to be settled. The logic is draconian, but the evidence is convincing.

Steven E. Miller offers a similar thesis, concluding that in a dynamic world, each perfect defense would be rendered vulnerable by technological change. Hence, the superpowers could exchange temporary vulnerability and invulnerability over time, inviting a strategic first strike.

In the conclusion, Weinberg and Barkenbus provide a remarkably evenhanded review of the evidence presented and its relevance to DPB. Their bottom line is that defensive dominance, despite its problems, remains the desired end, if only because of its moral superiority. Although the book has the redundancies and gaps inevitable in a collection of essays, it is quite readable and should prove interesting to a variety of audiences. The compelling and singular conclusion desired by the editors is lacking, but this book illustrates very well the complexity of the issues and the diversity of opinion characterizing defense and arms control questions.

Books by ORNL Employees

The following books were recently authored or edited by ORNL staff members (whose names are in boldface).

Fusion Reactor Materials (Proceedings of the Third International Conference on Fusion Reactor Materials at Karlsruhe, Federal Republic of Germany, October 1987), eds. K. Anderko, C. A. English, H. Kleykamp, H. Matzke, H. Ullmaier, and **F. W. Wiffen,** North-Holland, Amsterdam, 1988, 1379 pages.

Properties of Estimators for the Gamma Distribution, **K. O. Bowman** and L. R. Shenton, Marcel Dekker, Inc., 1988, 261 pages.

Report of the Advanced Neutron Source (ANS) Safety Workshop, **J. R. Buchanan, J. N. Dumont, R. M. Harrington, C. M. Kendrick, T. H. Row, C. D. West,** J. F. Marchaterre, and M. D. Muhlheim, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1988, 328 pages.

Proceedings of Neurocon-1, San Jose, California, July 1986, ed. **W. B. Dress,** Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1988, 44 pages.

Research and Development on Heat Pumps for Space Conditioning Applications (Proceedings of the Second DOE/ORNL Heat Pump Conference), ed. **P. J. Lewis,** U. S. Department of Energy, Washington, D. C. , 1988, 230 pages.

Advances in Molten Salt Chemistry, eds. G. Mamantov, C. B. Mamantov, and **J. Braunstein,** Elsevier Science Publishing Co., Inc., New York, 1987, 350 pages

Proceedings of the Third International Workshop on Quantitative Structure-Activity Relationships in Environmental Toxicology, held May 1988 in Knoxville, Tennessee, eds. **J. E. Turner,** M. W. Williams, T. W. Schultz, and **N. J. Kwaak,** Scientific and Technical Information Center, U. S. Department of Energy, 1988, 255 pages

Problems and Solutions in Radiation Protection, **J. E. Turner, J. S. Bogard, J. B. Hunt,** and **T. A. Rhea,** Pergamon Press, Inc., New York, 1988, 336 pages.

Science, Law, and Hudson River Power Plants, eds. **Lawrence W. Barnthouse,** Ronald J. Klauda, **Douglas S. Vaughan,** Robert L. Kendall, monograph for the American Fisheries Society, Bethesda, Maryland, 1988, 347 pages.

HFIR Restarted April 18

ORNL's High Flux Isotope Reactor (HFIR), which had been inactive for 29 months, was restarted on April 18, 1989, a week after ORO Manager Joe La Grone authorized Energy Systems President Clyde Hopkins to initiate the restart process. That day at 5:06 p.m., sustained fissioning of the uranium fuel was achieved for the first time since November 1986, when the reactor was shut down because of concerns about possible embrittlement of the pressure vessel.

Three other ORNL reactors remain idle after being shut down by DOE in March 1987 because of concerns about their management. They are the Bulk Shielding Reactor, the Health Physics Research Reactor, and the Tower Shielding Reactor.

Comprehensive reviews of the Tower Shielding Reactor have been conducted. As a result of these reviews, quality assurance, safety documentation, reactor operator training, and emergency planning have all been upgraded. Improvements have also been made to various systems. Reactor operation is expected to be resumed, pending resolution of final questions and approval by DOE.

Because the HFIR is the western world's only production source of at least ten of the transuranic elements most needed for research, medical, military, and industrial applications, its restart has been anxiously awaited by the scientific community. Depletion of the californium-252 isotope stockpile has been of particular concern to medical facilities, which use the isotope for cancer research and therapy.

The reactor is also used for materials irradiation testing and neutron scattering experiments. ORNL capabilities in neutron scattering research have been improved by a new high-resolution powder diffractometer, one of the many upgrades installed during the HFIR shutdown.

Restart plans called for extended low-power testing and evaluation of all HFIR components, with "hold-points" in the restart protocol at power levels of about 2.5 MW and 11 MW. Full-power operation at 85 MW was to be resumed after DOE had determined that low-power tests were successful and after operator qualification and training requirements at the low-power levels were completed. The entire restart process was expected to be completed by mid-July.

Research Reactors Division personnel involved in the HFIR restart are, from left, Ken Belitz, Mike Farrar, and Bernie Corbett.

Environmental Park a "Biosphere Reserve"

The Oak Ridge National Environmental Research Park (NERP), set aside in 1980 as a protected area on DOE's Oak Ridge Reservation, has been designated a unit of the Southern Appalachian Biosphere Reserve. The selection, made by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), makes the NERP part of a global network of sites for cooperative environmental research. Nominations for biosphere reserve sites are made by more than 100 countries participating in UNESCO's international "Man and Biosphere" program.

The Southern Appalachian Biosphere Reserve also includes the Great Smoky Mountains National Park and the Coweeta (North Carolina) Hydrologic Laboratory. These areas, along with others to be added, are considered representative of the "temperate broadleaf forest biogeographical region" of the Southern Appalachians. The biosphere reserve designation is expected to attract additional research interest in the 12,400-acre NERP, which serves as an "outdoor laboratory," open to visiting students and scientists.

Fission Product Lab in Safe Standby

On April 4, 1989, DOE's Oak Ridge Operations directed ORNL to place its Fission Product Development Laboratory (FPDL) in a "safe standby condition." Normal operations were temporarily discontinued in the nuclear processing facility because of concerns about the possibility of radioactivity releases from the FPDL in the event of damage during a severe earthquake.

A recent DOE review of a 1984 preliminary safety analysis report on the FPDL raised questions about the seismic integrity of the facility. In response to a subsequent DOE order, ORNL is reevaluating the impact of such natural events on the FPDL. Based on this reassessment, a decision will be made on future operations of the facility.

Built in the late 1950s, the FPDL consists of a series of shielded "hot cells"—with massive concrete walls—designed to safely process and encapsulate highly radioactive materials. From 1958 until 1975, the facility processed aqueous wastes to remove fission products.

Since then, the FPDL has been used primarily to process strontium-90 sources for thermoelectric generators and cesium-137 sources for medical research and cancer treatment. ORNL is the sole U.S. fabricator of cesium-137 sources and strontium-90 sources, which account for nearly $2 million in isotope sales. If the FPDL standby period is lengthy, ORNL will have to move the processing work to another ORNL facility or send its customers to foreign cesium suppliers.

"The FPDL is designed to safely process and encapsulate highly radioactive materials."

Off-Site Wells Being Sampled

Energy Systems has announced plans to expand sampling and analysis of water taken from existing private wells in areas surrounding DOE's Oak Ridge Reservation. Since 1949, off-site groundwater obtained from private wells has been sampled and analyzed randomly. So far, no off-site contamination has been found.

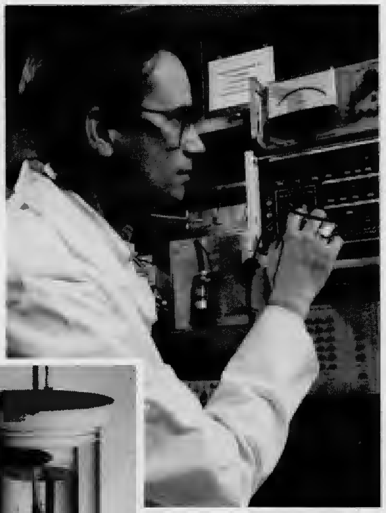
This new program marks the first time that off-site drinking water supplies will be sampled on a regular basis. The sampling will become part of an existing comprehensive year-round program to monitor the region's ground and surface waters, soil, air quality, vegetation, and wildlife. Data from the expanded sampling will provide additional verification and will be included in the annual environmental surveillance report issued each spring.

Some 20 to 30 representative wells located in close proximity to the reservation will be sampled twice a year at the point where local property owners draw their drinking water. The samples will be taken before the water undergoes any filtration or treatment process.

Preliminary plans call for initial samples to be analyzed for most of the primary and secondary drinking water standards and for the presence of heavy metals, radioactivity, strontium, tritium, uranium, technetium, and total suspended solids. Field measurements will include temperature, acidity, and specific conductance.

ORNL Researchers Test Claims of "Cold Fusion"

In April 1989, Secretary of Energy James D. Watkins directed DOE national laboratories—including ORNL—to intensify their research efforts to more clearly understand the reported



Bob Smithwick, a Y-12 Plant employee working with Loren Fuller at ORNL, adjusts the electrochemical controls of an experimental "cold fusion" cell (inset), to test the claims of Pons and Fleischmann.

phenomenon of "cold fusion in metals." He also requested DOE's Energy Research Advisory Board to establish a panel to conduct an independent review of the entire fusion research situation.

On March 23, a group led by chemists Martin Fleischmann of the University of Southampton in England and B. Stanley Pons of the University of Utah claimed they had observed fusion reactions in an electrochemical cell containing palladium and platinum electrodes, heavy water, and lithium deuteroxide. As a result of electrolysis in the "jar of heavy water," the heavy water was split into oxygen, which migrated to the platinum anode, and deuterium, which was absorbed by the palladium cathode.

The two chemists reported a heat output from the palladium cathode greater than the energy input and claimed to have measured by-products of fusion reactions, neutrons and tritium, although at levels a billion times too low to explain the excess heat. In a related experiment using an electrochemical cell with different electrolyte and cathode materials, Steven Jones and his colleagues at Brigham Young University (BYU) reported a low neutron rate (few hundred per hour), implying evidence for cold fusion reactions at a rate much smaller than the rate claimed by Utah but nevertheless far higher than the rate predicted by existing theory.

With the strong support of ORNL Director Alvin Trivelpiece, ORNL researchers began cold fusion experiments on March 29, a few days after the University of Utah news release was distributed. In April through June, ORNL groups from the Physics, Engineering Physics and Mathematics, Chemical Technology, and Metals and Ceramics divisions set up and operated more than a dozen electrochemical cells to test the University of Utah and BYU claims.

The groups, which included some researchers from the Oak Ridge Y-12 Plant, are led by E. Loren Fuller of the Metals and Ceramics Division, Don Hutchinson of the Physics Division, Mike Naney of the Chemistry Division, and Chuck Scott of the Chemical Technology Division. To facilitate exchange of information among the ORNL researchers, an ad hoc committee on cold fusion was organized by Michael Saltmarsh of the Fusion Energy Division.

The ORNL groups set up calorimeters to measure heat output and neutron detectors and spectrometers to detect neutrons and measure their energies. According to Saltmarsh, ORNL's neutron detection equipment is considered among the best in the world and is three to five times more sensitive than that at BYU.

In testimony on April 26 before the Committee on Science, Space, and Technology, U.S. House of Representatives, Saltmarsh said, "To date, no observations of excess heat or fusion radiation have been recorded. However, we are still not sure that we have replicated all the relevant features of either of the original experiments, nor do we understand which are the relevant features."

Saltmarsh recommended that the national laboratories collaborate with the Utah and BYU groups "by bringing a range of different diagnostic equipment to bear on an already working experiment." Since that time, DOE's Los Alamos National Laboratory (LANL) and the University of Utah group announced plans to begin collaborative research on cold fusion.

At a LANL-sponsored workshop on cold fusion May 23 through May 25 in Santa Fe, New Mexico, it was concluded that, if cold fusion exists, it is extremely complex and elusive.

The cold fusion claims, said Saltmarsh, are "stimulating" and require "careful scientific scrutiny" to determine whether the reported results are valid. "Whatever the final outcome," he stated, "the renewed discussion of the potential promise of controlled fusion power has been very healthy." ornl

Take a Number

By V. R. R. Uppuluri

Last Digit to First Place

Several integers have an interesting property whereby transposing the last digit to the first place of each produces a new integer that is a multiple of the original.

Take the integer 102,564 and transpose the last digit (4) to the first place (to the left of 1). The result is 410,256. This second integer is *four times* the first integer:

$$410{,}256 = 4 \times 102{,}564\,.$$

102,564 is the smallest integer having this property in which the new integer produced by transposing the last digit to the first place is quadruple the original integer.

The large integer 1,034,482,758,620,689,655,172,413,793 has a similar property. Transpose the last digit to the first place, and the new number is *three times* the original.

Try transposing the last digit to the first place in the integer 105,263,157,894,736,842. You will find the new integer has *twice* the value of the original, which is the smallest integer having this property.

Responses to the Previous Column

Lee M. Hively, a research staff member of ORNL's Fusion Energy Division, has resolved a question raised in the previous "Take a Number" column (Volume 21, Number Four, 1988, p. 97). There I stated the following: "It has been shown that the mean and standard deviation of any set of *seven* consecutive integers are both integers. Recently, Jim Delany, of San Luis Obispo, California, asked whether this property is shared by any other sets of consecutive integers. Home computer hobbyists are invited to try to answer Delany's question."

Hively has shown that the mean and standard deviation of any 7; 97; 1351; 18,817; 262,087, or 3,650,401 consecutive integers are also integers. To obtain this information, he derived and used the quadratic equation

$$n^2 = 12k^2+1$$

with integer solutions. The same answers were also obtained by W. G. McMillan, professor of chemistry at the University of California at Los Angeles.

ORNL Helps Develop a "Smart House" System

"ORNL is leading the effort to test the workability of the Smart House communication system."

ORNL is playing a key role in the development of a "Smart House" wiring and control system that will increase the convenience, comfort, safety, security, and energy efficiency of the home. ORNL is one of many organizations involved in this five-year-old research and development (R&D) project. Participants include home builders; manufacturers of electrical, electronic, and gas-powered home products; independent R&D institutions; industry trade organizations; and U.S. government agencies.

Robert G. Edwards, of ORNL's Energy Division, has been technical director for the development of the overall system concept for the Smart House Project of the National Association of Home Builders (NAHB) and the Gas Research Institute. Edwards helped win approval of a new electric cabling technology for Smart House systems in the recently revised National Electrical Code. This was a key step in moving the project forward. The hybrid power-signal cable will eliminate the unwieldy, spaghetti-like circuitry typical of homes built in the past 100 years. Using a hybrid cable bundle and mass termination techniques, an electrician will be able to install the Smart House wiring more quickly, simply, and inexpensively than is possible with conventional wiring techniques and materials.

The innovative cabling will link sensors, microchips, outlets, and switches, with a backup power supply for electronic components and computerized microcontrollers to monitor and regulate a home's communication and energy-distribution systems. The cable will carry audio, video, and telephone transmissions, as well as electrical power, and will allow appliances to "talk" electronically with each other.

ORNL's continuing work on the Smart House Project now involves Edwards, Reid Gryder, and Mark Spears of the Energy Division. Helping them are Patricia Daughtery, of the Tennessee Valley Authority, and Grimes Slaughter, a retired ORNL physicist who is serving as a consultant to the project.

"We provide technical advice and consulting services to the NAHB," says Edwards. "As an independent group with no vested interest in a particular product, we are able to stimulate new ideas and logical decisions, merge the best concepts of team members, and move the project forward."

ORNL is leading the effort to test the workability of the Smart House communication system. This system will allow sensors to communicate with appliances; for example, a sensor detecting the presence of an occupant could signal the heating system to warm up the previously unused room and the entertainment system to turn on some music. The communication system will also incorporate many microcontrollers, each the size of a postage stamp, which respond to signals and manage power use. They will give homeowners useful information through video displays of energy usage data and helpful warnings such as "Back left stove burner on."

"We have been promoting rapid prototyping of Smart House products," says Edwards. "This enables designers to rapidly cycle through the concept development, testing, and review phases of product development and should speed the availability of devices having the proper forms and functions for Smart House uses."

The ORNL team is now developing prototype testing equipment that will determine whether manufacturers' products actually work according to Smart House specifications. The equipment is designed for use in the project's Integrated Test and Certification Facility near Bowie, Maryland.

Energy-Saving Audit Developed

An ORNL-developed audit for selecting the most effective combination of conservation measures for individual homes shows promise for reducing energy consumption nationwide. ORNL's audit-directed weatherization procedure, which has been improved by the Wisconsin Energy Conservation Corporation (WECC) and

Mark Spears helped develop prototype testing equipment to determine whether manufacturers' products actually work according to Smart House specifications.

the state of Wisconsin, was tested by ORNL in 20 gas-heated homes in Madison, Wisconsin, and is now being tested in 50 gas-heated homes in Buffalo, New York.

The state of Wisconsin is using the procedure in their program to weatherize homes of low-income families, and several other states have expressed interest in using it. An audit service based on the procedure has also been sold by WECC to several utility companies.

In the Wisconsin test homes, the audit-directed procedure replaced the "priority list" commonly used by state programs to weatherize eligible homes under the Department of Energy's Weatherization Assistance Program. To keep heat within the home on cool days, the priority list typically calls for three measures: (1) caulking windows and weatherstripping windows and doors; (2) adding attic insulation to achieve an R-30 level of resistance to heat flow; and (3) installing storm windows.

"We thought that envelope-tightening measures combined with mechanical measures would save more energy for the money spent than just the ones in the priority list. We wanted to try a combination of these measures in people's homes and evaluate their effectiveness in reducing energy use," said Mark Ternes, one of the evaluators of the procedure and a member of the Efficiency and Renewables Research Section of ORNL's Energy Division. "So we began a research project in Wisconsin in 1985 that was supported by DOE's Office of Buildings and Community Systems and of great interest to DOE's Weatherization Assistance Program for low-income families."

The ORNL audit, developed primarily by Lance McCold of the Energy Division, determines the cost-effectiveness of various weatherization measures for individual homes, based on the installation price and the expected energy savings over the life of the measure. Fred Boercker and Michael B. Gettings, both of the Energy Division, also helped Ternes and McCold carry out the Wisconsin study.

As a result of adopting the ORNL procedure, most of the 20 homes in the Wisconsin study were provided with either wall insulation or a high-efficiency gas furnace. These measures were found to be most economical in improving energy efficiency, since many test homes already had a significant level of attic insulation.

By using the ORNL audit-directed weatherization procedure, the 20 Wisconsin homes saved 12.6 therms per year for every $100 invested in labor, materials, and program administration. (A therm is a unit of energy used by the natural gas industry.) Priority-list weatherization measures used in similar homes resulted in a savings of only 4.8 therms per year per $100 spent.

"In the Buffalo test," says Ternes, "we expect each home to save 22 therms per year per $100 spent. In nine years, the energy savings should cover the installation cost of the conservation measures. Final test results will be available in late 1989." In this test, ORNL is also working with a utility company, National Fuel, to compare the energy use in 50 weatherized homes with that in 50 standard houses.

"ORNL's bioreactor process is potentially simpler and more cost effective than competing cleanup tech-nologies."

ORNL Bioreactor Treats Tainted Groundwater

A device for destroying two of the most common organic contaminants in groundwater has been developed at ORNL.

Called a "methanotrophic bioreactor," the device uses microorganisms, supplied with methane and air, to convert two chlorinated alkenes into harmless substances—carbon dioxide, water, and trace amounts of chloride ion. The potentially toxic chlorinated alkenes degraded by this method are trichloroethylene (TCE) and 1,2 *trans*-dichloroethylene (DCE).

The naturally occurring microorganisms, originally isolated on the Oak Ridge Reservation, are immobilized as "biofilms" attached to a support material in the bioreactor. The water to be treated is injected into the top of the bioreactor and allowed to trickle down over the biofilms.

The microorganisms use carbon from the methane, oxygen from the air, and their own enzyme (methane monooxygenase) to stimulate the biochemical oxidation reaction that degrades the chlorinated alkenes. The bioreactor maintains a high concentration of the microorganisms and the best possible physical and chemical conditions to achieve high reaction rates.

In a single pass through a prototype bioreactor, more than 50% of the TCE and more than 90% of the DCE can be removed biologically from water samples containing 1 mg/L of each contaminant. About 95% of the TCE can be destroyed by recycling the water several times through the bioreactor.

Treated groundwater from the bioreactor can be discharged to a conventional wastewater treatment plant or reinjected into the groundwater aquifer, if permitted by local regulations.

ORNL's bioreactor process is potentially simpler and more cost effective than competing cleanup technologies, such as the combined ultraviolet radiation and ozonation process or air stripping followed by catalytic oxidation of the off-gas.

Developers of the methanotropic bioreactor are Terrence L. Donaldson, group leader, Gerald W. Strandberg, staff scientist, and L. L. Farr, all of ORNL's Chemical Technology Division; A. V. Palumbo, staff scientist of ORNL's Environmental Sciences Division; C. D. Little, visiting scientist from Florida State University (now with the Environmental Protection Agency, Gulf Breeze, Florida), and W. Eng, visiting scientist from St. Cloud State University in Minnesota (now with the University of Tennessee, Knoxville).

Radiation Detector for Groundwater Devised

ORNL researchers have invented a submersible device for detecting radioactivity in groundwater and shallow water.

The "in situ Cerenkov radiation detector" was developed for field surveillance of groundwater. However, it can be adapted for on-line monitoring of industrial waste effluents, municipal water treatment plants, and discharges from facilities processing nuclear materials.

The detector uses a conventional technique for measuring the bright blue "Cerenkov" radiation emitted from high-energy beta particles as they travel through the water sample. The Cerenkov scintillations are detected by two photomultiplier tubes, which are operated in coincidence and supply an electron pulse from each event for counting.

An alternative sampling scheme is to pump a test sample from a remote source supply into the sample cell of the detector. Developers of the detector are I. Lauren Larsen of the Environmental Sciences Division and Marion M. Chiles and Clint Miller, both of the Instrumentation and Controls Division.

Motion Sickness Predictor Improves Flight Simulators

Researchers at ORNL have invented a device that measures the dynamics of flight simulators and, using a behavioral data base, predicts the suceptibility of pilots to simulator sickness.

The SIMSICK biocybernetic device, which was developed for the U.S. Navy, was designed to determine the training effectiveness of various flight simulators for Navy pilots. This portable self-contained system includes built-in software to analyze flight simulator motion and predict its effects on humans.

Training pilots on flight simulators rather than actual aircraft can reduce training costs by at least 90%. However, motion sickness from simulators can affect from 5% to 60% of users, thus lowering the quality of the training, reducing pilot operational readiness, jeopardizing pilot safety, and raising training costs.

The SIMSICK device can measure angular and linear accelerations of individual simulators, and, by taking into account certain human physiological traits, it can anticipate and display conditions that may cause simulator sickness. It can also help identify the simulators that are least likely to make pilots ill.

Because the device can measure the operating characteristics of simulators and compare them with those of actual aircraft, it can be used to modify simulator design to improve ride comfort. In addition, it can be employed as a quality assurance device to determine whether a simulator works well enough to be certified for human use. The device also can be used for the design and testing of other motion platforms, such as tanks and ships.

Developers are Glenn O. Allgood and Richard Muller, both of the Instrumentation and Controls Division, and Blake W. Van Hoy of the Engineering Organization of Martin Marietta Energy Systems, Inc.

Laser Instrument Monitors Superconducting Films

ORNL researchers have developed a laser-based instrument that can monitor the composition of high-temperature metal oxide superconducting films for uniformity as they are being deposited on substrate materials.

High-temperature superconducting materials prepared as thin films could have applications in the electronics, computer, and utility industries. However, superconductor film deposition by several techniques (including laser ablation at ORNL) has covered only small areas. Solving the difficult problem of preparing homogeneous large-area superconducting films that can withstand high current depends partly on ensuring that the entire film has the correct ratio of metal constituents.

"High-temperature super-conducting materials prepared as thin films could have applications in the electronics, computer, and utility industries."

ORNL's "real-time" monitor can obtain both laser-induced fluorescence spectra and resonance ionization mass spectra of metal-oxide species while they are being deposited to form superconductor films. Both types of data are needed to guide scientists in attaining the most favorable deposition ratio of metals in the films to achieve maximum superconductivity.

Fluorescence spectra are useful for identifying and quantifying metals such as yttrium, barium, and calcium, but are difficult to obtain for thallium and bismuth. Resonance ionization mass spectroscopy, based on a technique originally developed at ORNL, can be used to detect and measure nearly all metallic elements and some metal oxides without affecting the structure of the superconducting film or the substrate.

In the highly sensitive ORNL monitoring device, laser light of a selected frequency specific to a particular metal or metal oxide resonantly excites the atoms (or molecules) of interest, ionizing them by removing an electron from each atom. The released electrons are detected and counted to determine the number of atoms present.

Developers of this technique and the laser-based instrument are C. H. Chen, senior research staff member, R. C. Phillips, technician, and M. P. McCann, postdoctoral fellow from the University of Tennessee, all in ORNL's Health and Safety Research Division. ornl

New Office Aids ORNL Guest Researchers

By Barry Burks

For many years, Oak Ridge National Laboratory and other national laboratories have served as stewards of sophisticated and costly research facilities. Through informal collaborative arrangements, many of these facilities have been made available to qualified researchers at other government laboratories, universities, and industries.

In recent years, the Department of Energy has taken steps to promote this sharing of unique and costly equipment by establishing a series of officially designated "user facilities." The program helps minimize duplication of expensive instrumentation, promotes beneficial scientific interaction, and assures taxpayers that their investment in these facilities is being used most effectively.

Thirteen user facilities have been established at ORNL, and the uses range from atomic physics research to bioprocessing and roof testing. The number of individual outside users has grown from 89 in 1980 to nearly 600 in 1986 (before the shutdown of the research reactors). Most of the visiting scientists are from academic institutions, but stronger ties with industry and a relaxation of patent regulations have prompted greater interest and collaboration by industrial users.

DOE and ORNL officials believe that sharing user facilities with industries can contribute significantly to U.S. efforts to regain our competitive edge in world trade. Visiting scientists may pursue proprietary research on a full cost-recovery basis and retain the title to patented inventions developed through use of an ORNL user facility.

All of the user facilities are equipped with extensive support and computer services and are located in accessible, unclassified areas. Access is determined on the basis of scientific merit, technical feasibility, and compatibility of proposed research with the equipment and operational priorities, which vary for each site. Through this newly established department, the *ORNL Review* will feature information about user facilities in each issue.

Oak Ridge, a former "secret city," has become a bustling hub of scientific cooperation and exchange in the Southeast, with ties stretching across the country and around the globe. There is now a constant stream of visitors and guests at ORNL, ranging from college students to professors and industrial researchers. The interactions are beneficial to both ORNL and the visitors for the exchange of information and fresh ideas. Student researchers gain valuable experience at ORNL facilities and guidance from ORNL mentors. Both academic and industrial scientists use ORNL's expensive, sophisticated, and sometimes unique equipment free of charge for research that might otherwise not be possible. Although there are many mechanisms for cooperation with external researchers, one of the most effective means of interfacing with the academic and industrial communities is through on-site visits and guest research assignments, either within a division or at one of our DOE-designated user facilities.

In response to the growing role in hosting collaborative research, ORNL has recently reorganized some functions to streamline the administrative aspects of interactions among the Laboratory, ORNL staff, DOE-ORO, and outside researchers and institutions. The new Office of Guest and User Interactions (OGUI), reporting to Bill Appleton, associate director for the Physical Sciences, was set up to simplify access to ORNL facilities and staff by external scientists and organizations and create a more user-friendly environment that will encourage additional collaborative R&D. The role of the OGUI will be to eliminate the barriers, smooth the pathway, and simplify the sometimes formidable paperwork involved when a student or scientist wants to conduct research at ORNL facilities.

In 1988, ORNL hosted more than 30,000 visitors and over 2300 guest researchers—but the Laboratory would like to increase those numbers. The goals of the OGUI are to work more effectively with DOE-ORO to streamline procedures for external access to ORNL facilities, develop and implement simplified user and guest agreements, provide more on-site guest services, and increase external use of ORNL facilities by widely promoting the available guest and user opportunities.

Thirteen major ORNL experimental facilities have been designated by DOE as national user facilities or collaborative research centers. Over the past five years, the Laboratory has averaged nearly 500 outside users per year, even though three of the facilities are temporarily shut down and another is severely restricted by the unavailability of the research reactors since November 1986. During the last decade, guests and users of ORNL facilities have increased at the rate of about 150 per year. Even greater growth is expected as the research reactors resume operation and other user facilities are developed (e.g., the proposed Advanced Neutron Source and cooperative R&D initiatives such as the Superconductivity Pilot Center).

In the OGUI, personnel from the Foreign Nationals Office, Guest Services Office, a member of the Contract Administration Office, and a member of the Office of General Counsel, along with additional support staff, have joined forces to operate in a central location at ORNL. Visitors and guest researchers will be able to contact this one office, rather than many, to complete the necessary applications and agreements. The office will now serve as the point of contact for the administration of foreign national assignments at all of the DOE plants operated by Martin Marietta Energy Systems, Inc. The OGUI will also help facilitate assignments of ORNL staff to other organizations, especially foreign assignments.

As director of the OGUI, I look forward to coordinating its various functions and, in particular, to the planning and organization of additional user facilities in the future. As a former staff researcher at ORNL and guest researcher at other user facilities in this country and abroad, I appreciate the enormous technical value of these resources and the progress made possible by their collaborative use in research. By relieving much of the administrative stress associated with accessing ORNL facilities, we expect to achieve even greater success in attracting industrial and academic research collaborators, make increasingly productive use of our facilities, and ensure a more rewarding research experience for both our guests and the ORNL staff. ornl

Barry Burks, a native of Monroe, Virginia, holds a Ph.D. degree in experimental nuclear physics from the University of North Carolina at Chapel Hill. He joined ORNL's Physics Division in 1983, transferred to the Engineering Physics and Mathematics Division in 1987, and became technical assistant to Associate Director Bill Appleton in 1988. In June 1989, Burks was appointed director of the newly created Office of Guest and User Interactions.

User Facilities and Collaborative Research Resources[a]

EN-Tandem Van De Graaff	(1962)
Oak Ridge Electron Linear Accelerator	(1969)
Shared Research Equipment Collaborative Research Program	(1978)
Oak Ridge National Environmental Research Park	(1980)
National Center For Small-Angle Scattering Research[b]	(1980)
Holifield Heavy Ion Research Facility	(1980)
Surface Modification And Characterization Collaborative Research Center	(1980)
Neutron Scattering Facilities[b]	(1980)
Health Physics Research Reactor[b]	(1982)
Bioprocessing Research Facility	(1984)
Roof Research Center	(1985)
High Temperature Materials Laboratory	(1987)
Low Temperature Neutron Irradiation Facility[b]	(1987)

[a]Year facility opened for use is given in parentheses.
[b]Neutron scattering and irradiation experiments at these facilities are temporarily suspended pending restart of the research reactors.

University and Educational Programs at ORNL

By David R. Rupert

Staff members of the ORNL Office of University and Educational Programs include, from left, Dave Rupert, Tina Coatney, Cheryll Dyer (standing), Brenda Bradburn, and Helen Payne. Absent from the photograph is Linda Cain.

Secretary of Energy Admiral James Watkins has stated that the national laboratories will have a "growing role in helping high schools and universities motivate young people to seek vocations as the scientists, mathematicians, and engineers of tomorrow." ORNL's University and Educational Programs Office is helping fill that role by encouraging both students and educators, particularly those from minority backgrounds, to become involved in science and engineering activities at ORNL. Recognizing the growing importance of these educational activities at ORNL, this issue of the *ORNL Review* introduces a new Education Department with the following article.

ORNL has a long and distinguished tradition of cooperation with schools and universities in education and research activities. Our main objective in these cooperative programs is to ensure an adequate supply of trained engineers and scientists for the nation's future energy-related research and development activities.

The interactions of ORNL with the academic community are an important means for increasing our transfer of science and technology developments into the private sector. Both the universities and ORNL gain from the visits and research participation by faculty members and by ORNL staff visits and lectures at the participating colleges and universities. Collaborative research programs involving ORNL staff and university personnel and students are also a cost-effective method for the Laboratory to receive quality assistance in fulfilling its missions.

How Does It Work?

The answer is that it works very well! The number and variety of educational programs at the Laboratory and the growing participation on both the local and national levels are testimony to our success (see table on p. 50). In recent years, special efforts have been made to involve minority students and faculty members in our science education and research programs at ORNL. To extend our interactions with historically black colleges and universities and other minority educational institutions, these programs will now be administered through the ORNL Office of University and Educational Programs (they were previously part of the Office of Equal Employment Opportunity and Minority Program Development).

The Department of Energy's University/Laboratory Cooperative Program (ULCP) supports local research participation and training of students and faculty at both ORNL and Oak Ridge Associated Universities (ORAU). Many of the research and education opportunities here are administered through ORAU, a university-sponsored cooperative organization of 49 colleges and universities that conducts a variety of education, information, research, and human resource development programs. Two of the programs sponsored jointly by ORNL and ORAU and administered by ORAU are the Oak Ridge Science and Engineering Research Semesters and the Nuclear Engineering and Health Physics Internships. Through the ULCP funding, we were able to provide a variety of opportunities for minorities and to expand our precollege educational activities at ORNL in 1988. More than 30 summer appointments were made through the program to faculty and students from minority institutions.

The ULCP funding also helps support the operation of the Ecological and Physical Sciences Study Center at ORNL, which offers field-study modules for students in grades 4 through 12. In a variety of hands-on experiences, youngsters learn that science can be both challenging and fun. During 1988, Pat Parr, head of the Environmental Sciences Division's National Environmental Research Park, directed activities at the Center serving more than 9000 students and teachers. Linda Cain, Precollege Program Administrator at ORNL, reports that the number of applicants continues to surpass the Center's available resources.

More Users and Guests at ORNL

As the educational assistance programs and user facilities at ORNL have become more widely known, the number of industrial and academic users and guest researchers has increased (see table). Most of our guests participate in short-term research projects lasting from a few days to a few months. However, nearly one-third of our visiting researchers receive full-time assignments in ORNL divisions to perform work that may last as long as two years. Of the more than 1000 university-based guest researchers working at ORNL annually, fewer than 300 are supported by the ULCP; other research participation opportunities are made available through programmatic funds specific to the Laboratory's divisions, and some guest researchers are supported through academic fellowships or grants from the participating institutions.

ORNL also interacts with university guests by awarding research and development subcontracts, encouraging short-term use of our DOE user facilities and other resources, supervising students, establishing collaborative research projects, and lending ORNL personnel and equipment to meet special research needs. According to Helen Payne, our University Programs Administrator, both the number of academically oriented programs at ORNL and the number of participants in these programs are increasing. ornl

David R. Rupert, who came to ORNL in April 1987, holds a B.S. degree in social science education from Culver-Stockton College and an M.A. degree in social science from Northeast Missouri State University. After serving as manager of the Minority Educational Institutions Program, he became manager of the Office of University and Educational Programs at ORNL in December 1988.

Educational Programs* at ORNL For Precollege and University Participants (FY 1988)

Program	Participants	Program	Participants
Sponsored/Administered by ORNL			
GLCA/ACM Science Semester	25	Residence in Science and Technology	2
SCUU Science Semester	8	VISITS Program	15
Service Academy Research Associates	12	Science Alliance Summer Research Participation	13
Summer Research Internship	59	Cooperative Education	74
Health Physics Internship	0	Precooperative Education	5
Summer Forestry	2	Graduate School of Biomedical Science	42
Special Summer Program	9	Graduate School of Ecology	15
Summer Faculty Program	1	Wigner Postdoctoral Fellowships	4
Special Honors Study	6	Project Seed	1
Honors Workshop	55		
Sponsored by ORNL/Administered by ORAU			
Technology Internship Program	15	Postgraduate Research Appointment	8
Professional Internship Program	19	OHER Postgraduate Appointment	3
Graduate Student Research Participation	21		
Sponsored Jointly by ORNL and ORAU/Administered by ORAU			
Science and Engineering Research Semester	36	Postgraduate Research Training	32
Student Research Participation	36	Faculty Research Participation	26
Laboratory Graduate Participation	12	OHER HBCU Faculty	4
Sponsored and Administered by ORAU			
Research Travel Contract	152	Hollaender Postdoctoral	1
NET HBCU	11	Fusion Energy Postdoctoral	0
DOE Fellowships	1	Fusion Energy Professional Development	0
STRIVE	14	Minority Institution Research Travel	3
Total Program Participants	**742**		
Ecol. & Physical Sciences Study Center	**9,000**		
R&D Subcontracts/Other	**693**		
Total	**10,435**		

*Not including most visit/tour programs, such as Traveling Lecture, Speaker's Bureau, Junior Science and Humanities Symposium, etc., coordinated through Public Relations and University and Educational Programs Offices.

Bee Detector Licensed

ORNL inventors Howard Kerr and Mike Buchanan have formed a company to manufacture and market portable Africanized-bee detectors under a license from Energy Systems.

B-Tec of Maryville will produce the devices to help beekeepers detect the presence of Africanized honeybees, which are expected to reach the United States during 1990.

ORNL researchers discovered that Africanized bees and domestic species move their wings at different speeds. The difference can be detected electronically as a difference in frequency through noise-analysis techniques pioneered by ORNL scientists to study abnormalities in nuclear reactor operations.

B-Tec has modified the detector system, which originally used colored lights to indicate differences in frequency, to produce a commercial "buzz buster" that emits sounds to alert beekeepers to the presence of Africanized bees.

The license with B-Tec is the 30th issued by Energy Systems in its technology transfer program.

Commerce Park Tenant

The ORNL-developed technology for making whisker-toughened alumina will be used by the first tenant of Martin Marietta Corporation's Commerce Park in Oak Ridge. Hertel AG, a manufacturer of cutting tool inserts from the Federal Republic of Germany, has been licensed by Energy Systems to use the ORNL technology to fabricate this product in the Oak Ridge facility. The firm broke ground in the industrial park on January 11, 1989, for its 95,000 ft^2 manufacturing plant.

ORNL-Industry Agreements

ORNL's High Temperature Materials Laboratory has user agreements with 17 private companies as well as 24 universities. Industrial users include Allied Signal, American Matrix, Dow Corning, Great Lakes Research Corporation, Norton Company, and Selee Corporation.

ORNL's High Temperature Superconductivity Pilot Center has signed cooperative agreements with General Electric Company, Westinghouse Electric Corporation, and Corning Inc. In May, the pilot center and Westinghouse began a joint effort to increase the current capacity of high-temperaure superconductors, combining ORNL's expertise in materials processing and characterization with Westinghouse's experience in powder chemistry and superconductor fabrication.

The center is negotiating agreements with several additional firms, including American Superconductor, Inc., and IBM Corporation; American Magnetics; Consultec; Scientific, Inc.; E. I. du Pont de Nemours & Company; Avco-TEXTRON, and the Electric Power Research Institute. In addition, the pilot center has attracted several companies and universities for user agreements. Research is in progress under the first of these, a proprietary user agreement with American Superconductor.

ORNL Motor Design Source of Patent

The Electric Power Research Institute has filed for a patent on a superconducting electric motor that was designed at ORNL under a joint program. The invention could significantly reduce electricity consumption for motors rated at 20 horsepower or above. The device is also the first known superconducting motor having fully adjustable speed.

By reducing weight and size and increasing efficiency, superconductors offer the potential for improved motor performance. Because the magnetic field of the superconducting magnet is stronger than that of a conventional magnet, the motor can be smaller yet just as powerful as conventional motors. Superconductors are materials that lose all resistance to direct electric current flow if chilled to a critical temperature.

A 180-horsepower operating prototype of the new motor that uses a standard low-temperature (niobium-titanium) superconducting magnet is scheduled for testing this fall at ORNL. ornl

"B-Tec plans to modify the detector system so that it will emit audible signals to alert beekeepers to the presence of Africanized bees."

36 ENERGY SYSTEMS PATENTEES HONORED

At an awards ceremony held in Oak Ridge on April 14, 1989, Martin Marietta Energy Systems, Inc., honored 36 of its employees who shared in receiving 31 U.S. patents during 1988 for their work-related inventions. Four retired employees, one University of Tennessee scientist, two former employees, and one subcontractor also shared in the patent awards. The ceremonies honored 18 first-time recipients, who received "silver acorn" pins signifying membership in the Inventors' Forum. This organization represents more than 500 U.S. patent holders among the company's 16,000 employees.

Loucas G. Christophorou of ORNL's Health and Safety Research Division (HASRD) received a "golden acorn" pin to denote receipt of his 10th patent award. He becomes the 20th Energy Systems staff member to have been awarded 10 or more patents. Christophorou is one of two Energy Systems employees who were named on three patents in 1988. The other is **F. F. (Russ) Knapp, Jr.**, also of HASRD.

Six employees were named on two patents. In addition to **Cressie E. Holcombe, Jr.**, of the Y-12 Plant's Development Division, who now has more than 25 patent awards, they are ORNL researchers **C.T. Liu, Leon Maya, Prem C. Srivastava, George E. Wrenn, Jr.**, and former employee **Scott Hunter**.

The 1988 patentees from ORNL are: **Michelle V. Buchanan*** and **Marcus Wise***, for "Variable-Pressure Ionization Detector for Gas Chromatography";

Chain T. Liu, for "High-Temperature Fabricable Nickel-Iron Aluminides";

C. Thomas Wilson, Jr.*, for "Transformer Current Sensor for Superconducting Magnetic Coils";

Robert C. DeVault*, for "Triple-Effect Absorption Chiller Utilizing Two Refrigeration Circuits";

Jeffrey H. Harris*, Benjamin A. Carreras*, Robert N. Morris, and **Jack L. Cantrell,** for "Flexible Helical-Axis Stellarator";

Prem C. Srivastava*, for "Radioiodinated Maleimides and Use as Agents for Radiolabeling Antibodies";

Arthur J. Moorhead, for "Copper-Silver-Titanium-Tin Filler Metal for Direct Brazing of Structural Ceramics";

Carl A. Burtis Jr., Wayne F. Johnson, and **William A. Walker,** for "Method and Apparatus for Automated Processing and Aliquoting of Blood Samples for Analysis in a Centrifugal Fast Analyzer";

Loucas G. Christophorou and **Scott Hunter,** for "Laser-Activated Diffuse Discharge Switch" and for "Ternary Gas Mixture for Diffuse Discharge Switch";

Loucas G. Christophorou** and **Dennis L. McCorkle,** University of Tennessee, for "Gas Mixtures for Spark Gap Closing Switches";

Leon Maya*, for "Process for Preparing Transition Metal Nitrides and Transition Metal Carbonitrides and Their Reaction Intermediates";

Manfred L. Kopp (retired), for "Radiation Dose-Rate Meter Using an Energy-Sensitive Counter";

F. Wallace Baity, Jr., and **Daniel J. Hoffman,** for "Impedance-Matched, High-Power RF Antenna for Ion Cyclotron Resonance Heating of a Plasma";

Gilbert M. Brown and **Leon Maya,** for "Process for Producing Ceramic Nitrides and Carbonitrides and Their Precursors";

Gene M. Goodwin* and **J. D. Hudson***, for "Method and Apparatus for Determining Weldability of Thin Sheet Metal";

F. F. (Russ) Knapp, Jr., for "Radiolabeled Dimethyl-Branched Long-Chain Fatty Acid for Heart Imaging," for "Radioiodinated Glucose Analogues for Use as Imaging Agents," and, with **Prem C. Srivastava,** for "Precursors to Radiopharmaceutical Agents for Tissue Imaging";

Timothy C. Scott* and **Robert M. Wham***, for "Surface Area Generation and Droplet Size Control in Solvent Extraction Systems Utilizing High-Intensity Electric Fields";

Dan P. Kuban*, for "Advanced Servo-Manipulator";

David O. Hobson* and **Vinod K. Sikka,** for "Method and Apparatus for Removal of Gaseous, Liquid, and Particulate Contaminants from Molten Metals"; and

Elias Greenbaum, for "Method and Apparatus for Nondestructive In Vivo Measurement of Photosynthesis."

*Silver Acorn award (first patent)
**Golden Acorn award (10th patent)

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