National Bureau of Standards

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Foreword

When the Bureau was established more than 80 years ago, it was given the specific mission of aiding manufacturing, commerce, government, and academia. Today, NBS remains the only federal laboratory with the explicit goal of serving U.S. industry and science. This mission takes on special significance now as the country responds to serious challenges to its industry and manufacturing—challenges which call for industry, universities, and government to pool their resources in research and development. The U.S. Department of Commerce has made industrial competitiveness a cornerstone of its programs. As a Commerce Department agency, NBS provides the measurement foundation that our changing industrial economy needs, and thus is well-positioned to help the nation meet these challenges.

Each year over 500 university, industry, and government people work in our laboratories, side by side with NBS researchers. Most of these scientists and engineers work at their own expense. For example, 155 research associates from private companies, trade and professional associations, and other organizations are conducting cooperative research at NBS now on projects of mutual interest. The sponsoring organizations provide the salaries of these research associates, while NBS makes its facilities and staff available to the associates. These researchers are joined by 325 visiting faculty and students, 43 postdoctoral research associates, and 34 intergovernmental personnel in exchange programs.

This person-to-person interaction is just an indicator of our close ties with those who rely on NBS for assistance in laying the measurement groundwork for U.S. scientific and technological advancement. Each year we provide literally thousands of other opportunities for transferring the results of NBS research to those who need to use them. We do so by making technical presentations, issuing publications, sponsoring major conferences and workshops, answering numerous inquiries for assistance, and working with voluntary standards organizations. We also offer a range of services to ensure the reliability of measurements and improve quality control, including calibrations for equipment and Standard Reference Materials.

Our cooperative programs are very much in the spirit of today's National Science Policy. The President's Science Advisor has emphasized the need to support the U.S. economy by expanding and strengthening the partnerships among industry, government, and universities. Likewise, the Panel of the White House Science Council on Federal Laboratories, also known as the Packard Committee, called for new collaborative relationships. And Congress has many times expressed its desire to see closer relationships among industry, government, and universities.

While we at NBS have a record of cooperation that I am proud of, we intend to do more to pursue new avenues for joint research and services. For instance, the Bureau's research managers are encouraging even greater use of our research facilities by outside institutions in order to make the most out of this important national investment at NBS. For the first time, we will be making some of our facilities available for private companies and others to use in conducting proprietary research. By increasing industry's access to our advanced measurement capabilities, we hope to help industry improve its products and processes and thus its international competitiveness.

The NBS Automated Manufacturing Research Facility is an excellent example of the type of cooperative research we plan to encourage. NBS researchers have been joined by people from industry, universities, and other government agencies to develop the quality control techniques and the software interface standards needed for the unmanned factory of the future. In another case, we are taking steps to increase our cooperation with industry and universities in devising new approaches for providing evaluated data suitably formatted for the computer-based systems of the future.

We are continuing to expand our cooperative research efforts because it is clear that this nation must plan for the future now by developing the measurement foundations that are and will be needed by U.S. science and industry. This brochure describes some of the cooperative programs we have underway as well as other work we are doing to improve the nation's measurement capabilities.

E. Ambler.

Ernest Ambler
Director

Center for Materials Science

From ceramic tiles that shield the space shuttle to dental adhesives which replace metal fillings, new materials are revolutionizing technology and everyday life. NBS is at the forefront of materials technology with its broad-based research effort conducted by the Center for Materials Science (CMS). The Center provides measurements, data, standards, reference materials, and other technical information regarding materials to industry, government agencies, universities, and other scientific organizations. CMS research supports development of new and improved materials which can be used safely, efficiently, and economically.

Scientist Donald Hunston uses a mechanical testing instrument to study crack growth in advanced polymer matrix composites to improve the strength of resin materials.

As part of its general program, the Center for Materials Science operates several large facilities. One is a nuclear reactor dedicated to materials and radiation standards research. Another is a metals processing facility capable of modifying surfaces with electron beams and by laser melting, as well as providing measurements of sample quality and microstructure. Together with the Naval Research Laboratory, the Center is leading an effort to construct hard radiation branch lines at the National Synchrotron Light Source at Brookhaven National Laboratory. When completed, this facility will permit unique experimental work in materials characterization. These facilities are used extensively by guest scientists and research associates from academia and industrial research institutions from across the country.

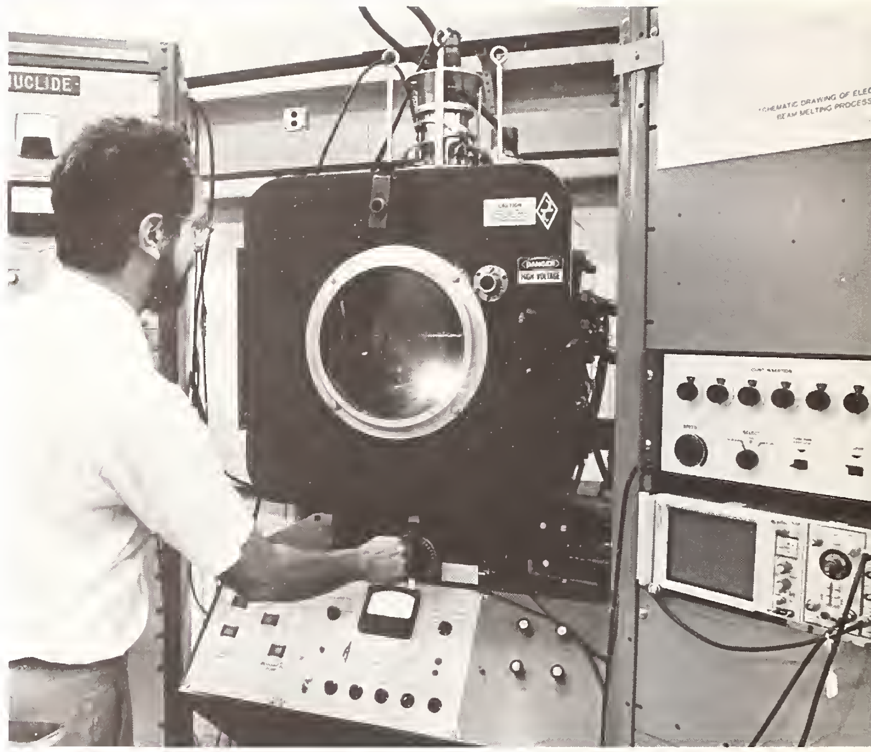
In addition to managing and carrying out these facilities and programs, the Center supports fundamental theoretical work in phase stability and materials fracture. This work is basic to all of the Center's technical programs and to materials science research throughout the United States.

The Center's research involves four technical "themes": materials processing, microstructure characterization, properties, and performance. Scientists from each Center division plan and coordinate activities in each of these areas.

For example, there is a coordinated effort within the Center to measure, collect, and evaluate phase diagram data for the processing of metal alloys, ceramics, and polymer blend materials. This information is used in the development of new materials and the design of new materials processes. The Center, in collaboration with professional societies, periodically publishes phase diagrams for alloys and ceramics and makes them available to researchers and industrial users. A large body of evaluated data is being converted into computerized files so that it will be available to users through on-line access. The Center's phase diagram work is supported cooperatively by the American Society for Metals, the American Ceramics Society, and the Society of Plastics Engineers. Experimental results are compiled and evaluated by authorities in 35 data centers throughout the world. In addition to providing phase diagram data, the Center carries out experimental and theoretical research in support of the data program.

An example of the Center's activity in microstructure characterization is the work carried out with the small-angle neutron scattering (SANS) apparatus at the research reactor. This apparatus is used to study microstructure and flaw development in new structural ceramics, to observe precipitation transformations in supersaturated metallic systems, and to characterize molecular structure and conformation in polymer blends. Similar work will be carried out with the NBS beam lines at the National Synchrotron Light Source at Brookhaven. Researchers will use real-time topography for kinetic studies of solidification; small-angle x-ray scattering for measurement of block copolymer structural features; and interface/inelastic spectroscopy for characterizing multilayer metal-metal oxide coatings.

Research on the properties of materials focuses on wear characterization, measurements, and standards for metals, ceramics, and polymer matrix composites. Researchers characterize metal-to-metal wear, under both clean and abrasive conditions, and the wear of lubricated surfaces. They develop measurement methods for wear-resistant materials and provide reference materials for calibration of wear tests. Center scientists are investigating the erosion of refractory materials by experimentally observing the effects of single particle indentation. Their research has also shown that



In the metals processing laboratory, physicist Robert Schaefer uses an electron beam surface melting technique to produce alloy coatings on metals for improved resistance to wear and corrosion. A close up shows the electron beam melting a metal surface (detail).

the wear of a polymer matrix composite is influenced by ambient liquids which soften the matrix.

Performance is a crucial characteristic of all materials. A major materials performance problem is environmentally induced cracking. For example, stress corrosion can cause cracking in engineering alloys; hydrogen embrittlement can crack high-strength steels; cracking in glasses and ceramics is often induced by water vapor; and environmental stresses can crack ethylene-based plastics. Toward the goal of reducing such damage, Center researchers establish the basic mechanisms of the cracking processes and develop test methods to determine the failure resistance of various materials.

In addition to these broad-based research activities, the Center conducts specific research projects such as development of a cold neutron source facility for advanced materials research. The facility is being designed to contain a low-background-radiation experimental hall and up to 15 new instrument stations. It will be managed and operated as a national research facility for industrial, university, and government scientists.

Cold neutron beams can augment research in virtually every branch of materials science. Some of the experiments planned for the new facility will focus on the magnetic properties of new advanced alloys; the growth of cracks and nature of voids in new advanced ceramics; the distribution of dopants in advanced semiconductor materials; development of new catalytic materials for petroleum refining; and measurement of the size and shape of engineered biomolecules.

Among the materials of the future are advanced high-performance ceramics. The Center has begun to investigate the relationships among the synthesis, microstructure, properties, and performance of these ceramic materials. In their initial work, researchers are emphasizing new chemical approaches to synthesizing the submicron, multicomponent powders needed by industry to produce such complex ceramics. They have established laboratory facilities to study the synthesis and characterization of ceramics which are important to industry. They are also studying various properties of finished ceramics and are developing a unique program to measure high-temperature wear characteristics of ceramics.

Another class of future materials is polymer composites. Polymers reinforced with high-strength fibers such as graphite or glass have outstanding strength and stiffness for their weight. They are being used extensively in aerospace applications and will be used increasingly in automobiles and construction. The Center is developing measurement methods to investigate and control composite processing in order to aid industry in controlling quality while increasing production efficiency. CMS is also investigating the mechanisms by which fiber-reinforced composites fail. The test methods and data being produced by this program should lead to improved composite materials and better ways to predict the materials' useful service lives.

One of the fastest growing segments of the polymer industry is the production of polymer blends, which are mixtures of two or more polymers. These materials are particularly useful as engineering plastics that can replace metals in products such as gears, pumps, and machine housings. When a polymer blend is processed, the component polymers phase separate, and the mechanical properties of the finished blend depend on the morphology of the phase-separated structure. The Center's program focusing on polymer blends will provide phase diagrams to industry. These diagrams will show the ranges of miscibility with respect to concentration and temperatures; measurement methods that will detect the degree of miscibility of two polymers; and data on the rates of diffusion of one polymer in another under processing conditions. Researchers also will study the mechanism by which polymers separate from each other, using the small-angle neutron scattering facility.

In addition to advanced ceramics and polymers, electro-optic materials help perform many of the dream feats of forward-thinking engineers. CMS has begun a program to measure the optical properties of thin film materials and to study their dependence on processing characteristics. This research will contribute scientific knowledge to the ongoing effort to improve the performance of materials in optical information processing devices and systems.

In the future, many products using advanced materials may be produced in automated manufacturing facilities. These facilities will use nondestructive evaluation (NDE) techniques to monitor product quality. Advanced NDE techniques can now monitor important material properties and product parameters. The Center's NDE program is developing the science base, measurement methods, and standards that will be needed to use

Here dental technician Karen Jennings places artificial teeth in wax on the frame of a partial plate in the NBS/ADAHF laboratories. The teeth will have cavities filled with composite materials for a study to improve the wear of dental fillings.

Physical scientist Robert L. Parke prepares a sample of rapidly solidified alloy powder in a vacuum dry box. The material will be tested in the metals processing laboratory.

NDE for process control in automated manufacturing plants. Work in this area also helps enhance product inspection methods which are now used in manufacturing.

The trend toward automated manufacturing is also expected to affect welding. NBS is collaborating with industry in establishment of the American Welding Technology Application Center (AWTAC), which will study advanced welding technology and disseminate information about it. One of AWTAC's programs will focus on automated welding. NBS will study how flaws are formed during this welding process by conducting controlled solidification experiments in model materials. The experiments will use acoustic emission and ultrasonic techniques to detect flaws as they are formed in the welded material. These experiments should lead to better control of defect formation, more effective feedback control for thick-section weld automation, and improved weld efficiencies for specific processes.

Many of the Center's prominent research activities are carried out in cooperation with industrial organizations, which support the work of research associates at the Bureau. For example, Exxon has supported research in characterizing polymer blends with small-angle neutron scattering; General Electric has used NBS' unique time domain dielectric spectrometer for polymer measurements; and Martin Marietta has cooperated in characterizing resins used on the space shuttle. Ongoing cooperative programs involve:

- The American Society for Metals—evaluation and dissemination of computerized alloy phase diagrams and bibliographic information worldwide with funding support from industry.
- The American Ceramic Society—establishment of computer access to phase diagrams and dissemination of phase diagrams of interest to ceramists. The American Ceramic Society will develop industry support and disseminate the phase diagrams and related information.
- The Society for Plastics Engineers—development and dissemination of data on thermodynamic behavior of polymer blends. This information will be published through the National Standard Reference Data System at NBS.
- The American Iron and Steel Institute—research aimed at development of process control sensors for the steel industry. The joint program concentrates on rapid on-line measurement of temperature distributions and automatic detection of porosity in hot steel.
- The National Association of Corrosion Engineers (NACE)—provision of evaluated corrosion data on alloys and other materials. NBS provides technical guidance and NACE develops program and funding support from industry.
- The American Dental Association—development of dramatically improved tooth restorative adhesives and more effective fluoridation treatments based on understanding of tooth mineral phase diagrams. This research is part of a 53-year-old cooperative program partly supported by the National Institute of Dental Research.
- The American Welding Technology Application Center (AWTAC)—establishment of the AWTAC/NBS Welding Data Bank for rapid dissemination of welding data to U.S. industry and improvement of narrow gap, thick-plate welding processes in order to increase industrial productivity.
- The Welding Research Council—development of improved weld procedure qualification methods.
- The Joint Committee on Powder Diffraction Standards-International Centre for Diffraction Data (JCPDS-ICDD)—critical evaluation of powder diffraction data, measurement of reference data, and dissemination of results. The JCPDS-ICDD provides funding support through sales of the Powder Diffraction File. They also disseminate publications and a computer file from the Crystal Data Center maintained by NBS.

National Engineering Laboratory

From basic studies of the subtle behavior of microelectronic circuits to their work in engineering standards, the staff of the National Engineering Laboratory (NEL) apply their expertise in engineering and scientific measurement to a broad spectrum of national concerns.

NEL scientists and engineers conduct research in engineering and the applied sciences. They study problems in electronics, automation and manufacturing, chemical engineering, the behavior (and prevention) of fires, and the design and construction of buildings. NEL researchers also provide the nation with state-of-the-art measurement and calibration services in these areas. Their research and services in applied mathematical and computer sciences support technical programs throughout the Bureau.

To provide a more precise voltage reference for maintaining the U.S. legal volt, NBS is exploring the use of superconducting microelectronic circuits. Here, electronics engineer Richard Kautz lowers a prototype into a liquid helium dewar for testing.

Center for Manufacturing Engineering

Despite tremendous changes that it has undergone during the last few decades, manufacturing remains a mainstay of the nation's economy. With the development and application of new technology, this sector can continue to compete with foreign producers and contribute to the country's new economic growth. The NBS Center for Manufacturing Engineering (CME) is supporting the U.S. mechanical manufacturing community in its drive to advance technologically.

Through its calibration services, the Center provides manufacturers with convenient access to national standards of mass, force, and length, as well as derived quantities such as acoustic pressure, acceleration, and sound power. The Center works to extend and improve the national standards applicable to mechanical manufacturing, and in doing so provides technical support to the voluntary standards community. Its research program encompasses measurement science, precision engineering, and software development. The goal of the program is to develop a base of knowledge and services which reflects state-of-the-art technology.

Much of the Center's research involves the advancement of measurement science in support of the Bureau's calibration services. Of particular interest in this field is surface characterization: the study of the mechanical roughness of surfaces. The degree of surface roughness is important in a wide variety of products. Roughness can affect the appearance of automobile bodies and the life of ball bearings. It can affect how vehicles move through air or water, and can even be a factor in maintaining the sterility of food processing equipment.

NBS has long provided industry with standard measures of the heights of peaks and depths of valleys of surfaces. Many surface properties, however, depend on the distance between peaks, which is difficult for scientists to describe and little understood. CME scientists are using lasers and computer modeling to devise new ways of describing and measuring surfaces. As a result of this work, NBS has issued some new transfer standards which are more highly characterized than their predecessors. For the first time, NBS is beginning to relate

Physicist Ted Vorburger uses a measurement system designed at NBS to evaluate the roughness of the surface of a test specimen. The specimen will become a new NBS Standard Reference Material for surface roughness and may be used by researchers in industries such as semiconductor manufacture and optics to improve the quality of their measurements.

Here researchers are at work on the control systems for an automated work station, part of the Automated Manufacturing Research Facility. This single work station, including an automated machine tool, industrial robot, and computer vision system, uses 16 computers.

an item's measured surface properties to its performance when the item is used as intended.

In a similar effort, the Center is using new technology to improve the usefulness of nondestructive evaluation techniques. Using ultrasonics, scientists can detect internal flaws in materials and structures with unprecedented accuracy. NBS has developed new standards that permit increased uniformity of measurements, resulting in enhanced quality. In order to develop both the nondestructive evaluation and the surface characterization techniques, Center scientists have undertaken a considerable amount of theoretical study aimed at understanding the physical phenomena on which the measurements are based.

While maintaining its traditional support and services for the manufacturing community, the Center has taken an unusual step to help industry and government cope with a revolutionary change in manufacturing technology: automated manufacturing. In cooperation with the Department of Defense, NBS is developing an Automated Manufacturing Research Facility (AMRF), scheduled to be fully operational in 1986. The ARMF, a unique research facility, is designed to emulate the factory of the future. It consists of a number of work stations, each of which has a numerically controlled machine tool and a robot. The work stations are organized into cells, which are supplied by a material handling system and controlled by a computer network.

The individual work stations will provide a realistic environment for testing new concepts, such as deterministic metrology, which could lead to more efficient and less costly manufacturing techniques. The deterministic metrology concept applies the idea of process control, long used in the chemical industry, to mechanical manufacturing. In an automated manufacturing environment, there is a fully deterministic cause-and-effect relationship between process parameters and product quality. In an automated facility, modern sensor and microprocessor technology can be used to monitor the process parameters, and adaptive control techniques can be applied to ensure that process parameters do not vary beyond assigned limits. Applying this process control technique to automated manufacturing should ensure that each finished product is of high quality. By automating quality control in this manner, manufacturers could eliminate the time-consuming and costly process of inspecting products as they come off the assembly line.

The AMRF uses control architecture that was developed by NBS. It permits a uniform set of interfaces between units. Its data-driven software allows the use of disparate machines and computers, as well as simple programming for a very diverse part mix. This control structure can be implemented either in hardware or in a computer emulation package which allows new configurations to be tested before the hardware is installed. The control structure uses artificial intelligence concepts of state-table programming and expert systems.

Even while it is still being built, the AMRF has become the focal point for joint research efforts involving a dozen industrial firms and several universities. These efforts concern various problems that are expected to rise as automated manufacturing becomes widely adopted. The Bureau faces the problem of fulfilling demands for readily accessible new national standards; the automated manufacturing environment will outdate current transfer standards and protocols. Industry and the Department of Defense will face difficulties in adopting the new automated technology, which will require transfer of control and status information among computer systems which currently share no uniform language, uniform format, or interface standards. Universities face the problem of teaching students about the new manufacturing technology. The subject straddles traditional departmental divisions, and the equipment needed for research and training is extremely expensive. The NBS facility will permit researchers from industry, government, and academia to work together in determining how to improve the use of automated technology.

To improve the design and control of chemical processes, to assure equity in domestic and international trade, and to strengthen the competitiveness of U.S. industry in the world market, the chemical process industry needs accurate measurements and reliable databases. The NBS Center for Chemical Engineering (CCE) is working to provide industry with the necessary measurements and databases through its research in chemical process metrology, thermophysical properties of fluids and solids, and chemical engineering science. The results of these efforts include calibration and other measurement services, measurement practices and standards, and engineering data.

The Center's current program is mainly aimed at the chemical, petrochemical, plastic, and petroleum industries. Its research is also useful in the manufacture of related products such as paper, rubber, metals, and glass.

Since the prices of natural gas and oil began to escalate, the industry has sought more precise ways to measure these fuels. NBS has developed a unique way to make precise gas flow measurements on a mass flow basis. The mass flow facility in Boulder has flow capability up to 15-cm-diameter test sections in cryogenic pipelines. A large heat exchanger is used to vaporize liquid nitrogen for gas flow tests at room temperature and high pressure. The gas is condensed into a liquid and is weighed as a liquid, providing better than normal accuracy. The Gas Research Institute is sponsoring testing of orifice meters with this technique. The American Petroleum Institute is supporting a companion program at NBS in Gaithersburg to improve liquid and gas flow measurements using orifice meters.

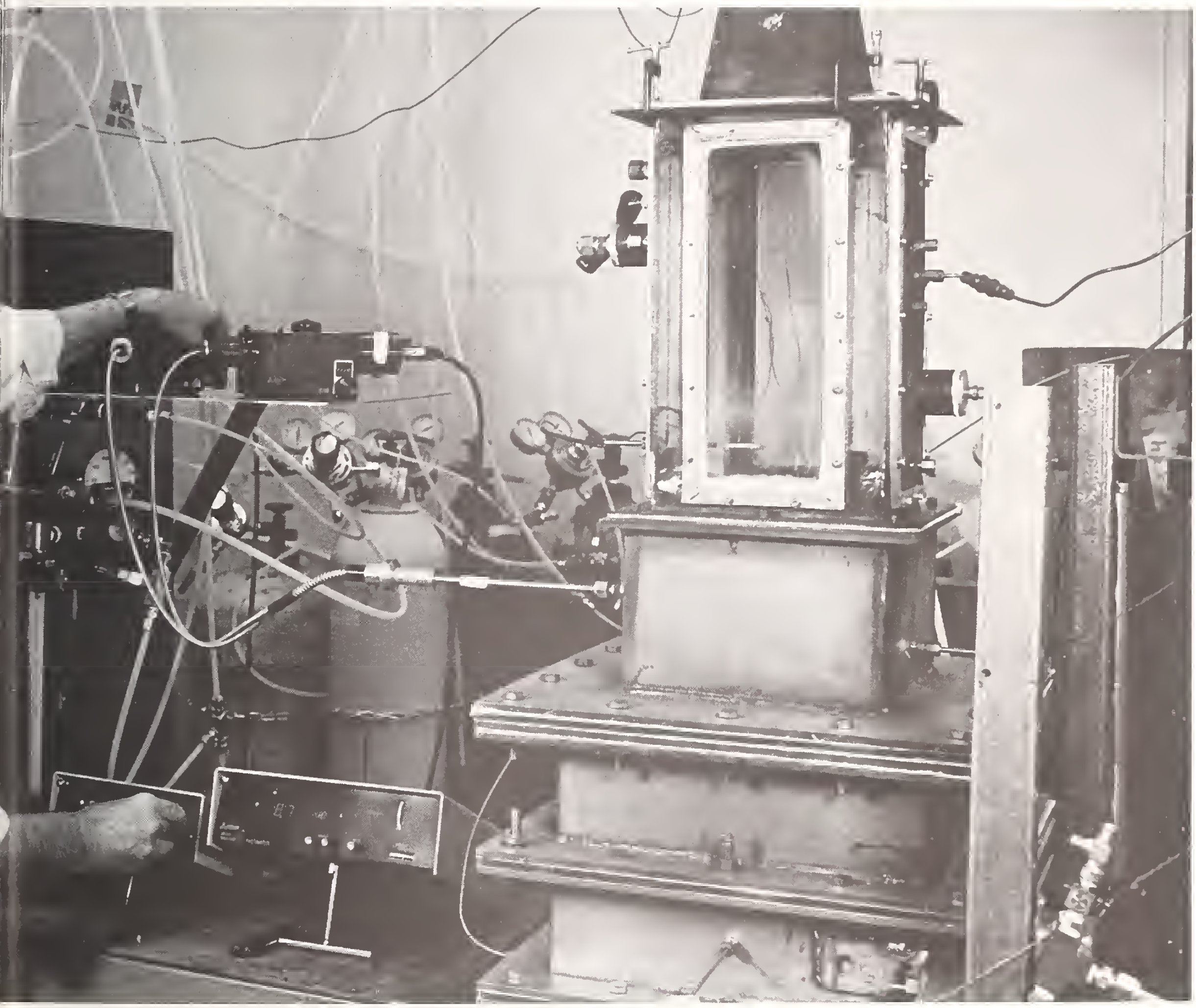
Another industrial trend to which CCE has responded is the increased use of slurries for the processing of various solids such as biomass, foods, paper pulp, coal, and shale. Coal slurries, made from pulverized coal mixed with water, can be used to make synthetic fuels and can also be used for electric power generation in fluidized bed combustion. The Center anticipates offering slurry flow calibration services to U.S. industry. As a step toward that goal, the Center recently commissioned a small research-grade slurry flow apparatus. The apparatus is being used to determine various aspects of slurry flows, such as pressure drop, critical settling velocity, packing, blockage, and flow modes.

To minimize expenditures on high-priced fuel, U.S. industry is interested in obtaining the maximum energy output from fuel combustion. Advanced methods of measuring and evaluating combustion are necessary for this effort to succeed. The Center is pursuing new ways to improve combustion efficiency by monitoring soot formation. Center researchers are using laser scattering, extinction, and Doppler velocimetry to determine the size of soot particles, their distribution, and their velocity. In soot formation studies, researchers want to know how to adjust the flame, oxygen, and fuel levels to form the optimum amount of soot and then allow the proper amount of time for the soot to burn out. These studies can lead to improved performance of boilers, dryers, and furnaces.

To optimize the performance of high-temperature industrial processes, engineers must have accurate ways to measure the high temperatures involved in such processes. To help meet this need, a Center researcher invented a new optical fiber thermometer. The invention won one of the prestigious IR-100 awards in 1983. The main part of the thermometer is a single-crystal sapphire fiber 20 cm long and 1/2 mm in diameter. The sapphire tip is coated with an iridium film, which is in turn coated with an aluminum oxide ablative film. The iridium forms a blackbody emitter and emits axially up the sapphire fiber. The axial radiance provides a reliable, repeatable, and accurate indication of temperature. This thermometer may extend the current NBS temperature standard scale from 1770 K to 2270 K, and could improve numerous industrial chemical process and manufacturing systems.

In other work, CCE recently correlated almost all of the existing quality data on water and steam with a wide-ranging equation of state now known as the Harr-Gallagher-Kell equation. It has been carefully checked and tentatively accepted by the International Association for the Properties of Steam.

Using an optical probe system, research scientist Andrej Maček measures the temperature in a laboratory fluidized-bed combustion chamber. The probe will permit industrial operators to monitor the interiors of full-size furnaces.



Liquid membranes are used to separate various components of mixtures. In this work, the membrane is in the form of tiny globules of an emulsion suspended in the mixture. The membrane selectivity transports the component of interest into the interior of the globule and the globules can later be physically separated from the remaining mixture. Shari Hanson, a chemical engineering co-op student from New Mexico State University, digitizes a photomicrograph of the suspension to determine the size distribution of the globules.

This information is used throughout industry to design process and power plants.

Other important data are being provided to industry through a new computer program called TRAPP, for Transport Properties Prediction. This program predicts the viscosity, density, and thermal conductivity of various fluid mixtures. NBS is making the program available to the public through the Office of Standard Reference Data.

The Center recently formed an industrial consortium of nine private firms and initiated its own laboratory work to investigate supercritical extraction. This program will investigate the properties of supercritical fluids, such as carbon dioxide, which can be used as a solvent to dissolve large amounts of other fluids such as crude oil (in oil recovery operations). By lowering the pressure of the mixture, the solute can be recovered (separated) and the solvent can be reclaimed to be used again. The use of supercritical fluids could reduce the cost of chemical separations in many other industrial processes.

The use of various types of membranes to separate mixtures could lead to improved energy and equipment efficiencies. The Center is conducting both theoretical and experimental studies to provide reference data and methods of measuring the performance of different types of membranes. Emulsion liquid membranes are being modeled to determine the effects of geometry, time, solubility constants, diffusion coefficients, and forward and reverse reaction rates on mass transfer rates.

Center for Fire Research

The United States has one of the worst fire loss records in the industrialized world.

The NBS Center for Fire Research (CFR) is committed to providing the scientific and engineering bases needed by manufacturers and standards and codes communities to reduce both these losses and the cost of fire protection.

By improving the understanding of the chemistry and physics that take place during combustion and by developing accurate computer models of fire hazards, the Center provides technical information to voluntary standards organizations, engineering and design communities, building industry, fire service and fire protection organizations, and materials manufacturers. The Center also helps these groups to translate the findings into new engineering practices, test methods, and proposals for improved standards or code provisions. NBS, however, does not promulgate or enforce standards or regulations.

One of the most complex and yet crucial phenomena affecting fire growth is soot formation. It is incandescent soot, radiating thermal energy to convert furnishings or construction materials into gaseous fuels, that drives fire growth. Soot also affects people's survivability in fires, both from inhalation and the obstruction of vision. Yet the same particles are the fire "signature" that activates the now-common smoke detectors. Center scientists are conducting a long-term study of the fundamental chemistry and physics of soot formation to provide the understanding necessary to improve sooting performance of burning materials. They have devised new, laser-based techniques for measuring key molecules in the chemical chain of soot growth. Using multiphoton ionization measurements researchers can detect certain organic species, such as butadiene, throughout the flame itself. They have also obtained profiles of polycyclic aromatic hydrocarbons using ultraviolet and visible fluorescence. Concurrent theoretical calculations on the "stickiness" of aromatic molecules have further clarified which chemistry is significant in building soot particles from small molecules.

Perhaps the topic of most concern in fire research today is that of fire gas toxicity. Most fire deaths are caused by the inhalation of smoke. Carbon monoxide, a combustion product of most burning materials, has been widely considered as the primary cause of these deaths. Recent laboratory tests and analyses of samples from some fire victims, however, have suggested that other toxicants or factors may contribute to some deaths. Building on a decade of leadership in measuring the lethal effects of fire-generated smoke, CFR researchers are now studying the extent to which the generation rates of a few principal toxic gases can be used to predict mortality. The results of experiments with carbon monoxide, carbon dioxide, hydrogen cyanide, hydrogen chloride, and reduced oxygen levels are well on their way to explaining the lethality of fire gases.

Center researchers are also creating ways to predict the precise contribution of materials to a fire's severity. Their recently developed oxygen consumption technique greatly simplifies the measurement of a burning sample's rate of energy release, a key factor in the rate of fire growth. This

Physical scientist Randall Lawson adjusts instrumentation on the Bureau's furniture calorimeter, part of an NBS-developed method to measure the rate at which heat is released by burning furnishings. The heat release rate in large part determines how a material will contribute to a room fire.

Barbara Levin, research biologist, prepares an experiment aimed at establishing in a measurable way the relative contribution of smoke toxicity to the overall hazards of fire.

method is now used to measure the heat given off by furniture and wall coverings during full-size room fires. A Center-designed instrument, the cone calorimeter, operates on the same principle and shows exceptional promise for predicting the large-scale rate of heat release using small samples. By including such factors as the mass, shape, and materials of upholstered furniture, researchers seem to be able to predict peak energy release values. The benefits of this capability to materials developers and building designers alike are significant.

Predicting fire growth requires a fundamental understanding of elemental fire processes, such as flame spread, and the characterization of fire-induced flows. Methods have been developed to correlate the speed at which flame spreads across and down a burning vertical surface with the basic thermal properties of the burning materials. Measurements of flame height and flame radiation are now providing key information in our understanding of upward flame spread, a faster and therefore more critical process. The buoyancy-driven flow of fire gases through doors and open windows and their replacement by ventilation air is now predictable. Ventilation and the rate of heat release of the fuel are the primary factors which determine if and when a room will "flashover," a term used to describe the total fire involvement of all items in a room.

Information obtained through tests like these is used in mathematical models designed to predict the vulnerability of a building and its occupants to fire. These computer-based models make it possible to replicate real fire situations within a limited budget. It is far less costly to "burn" a room or building using a computer. Center researchers are now designing a true general purpose model of fire hazard. It will include the burning behavior of a room, the movement of fire gases throughout a building, and the effect of those gases on people. By using such a model, fire professionals will be able to study "their fire" on a computer, varying each component as needed, and making quantitative decisions for improving fire safety.

One prediction model is already available. Termed ASET (Available Safe Egress Time), the computer code incorporates sound but simplified single-room fire growth. It calculates the time at which a smoke detector is activated and the time at which the room becomes uninhabitable. The difference between these two events is the time that the inhabitants of the room have to escape.

More widespread and proper use of sprinkler systems could significantly reduce fire losses. To assure their efficacy, better operational and design criteria are needed. The Center has recently produced a computer program for calculating the response time of heat-activated sprinklers. To the behavior of a small fire in a single room, the model adds the location and thermal properties of both heat detectors and sprinklers heads. The predicted temperatures at those sites agree well with steady-state laboratory tests. Large-scale tests with growing fires are planned to establish the range of applicability of the computer code.

The Center for Fire Research also sponsors a program of grants and, to a lesser degree, contracts for fire research in support of the internal research program of the Center. Approximately 30 grants are awarded to universities and research institutes annually.

Center for Building Technology

The safety and comfort of virtually all Americans depends on the design and performance of the buildings in which we live and work. The federal government helps advance building technology and improve building practices through the NBS Center for Building Technology (CBT), the nation's building research laboratory.

CBT performs field, laboratory, and analytical research to gain an understanding of the properties of building materials, components, systems, and practices, and develops measurement techniques to evaluate those properties. It assists the building community in the application of advanced computation and automation technology. Working with other private and public organizations, the Center provides technical support to groups which develop building standards, codes, and regulations.

One major focus of CBT's research is computer-aided design. Computers can be used to help design new buildings, assess the quality of new and existing buildings, diagnose problems, and monitor changes in building performance. CBT is developing measurements for building diagnostics and quality assurance using dedicated microprocessors to assess complex properties. The Center is also working on information interface standards to permit various manufacturers, trade associations, and professional organizations to cooperate in developing information systems used in computer-aided design, construction, and operation. As part of this effort, the Center is developing a standard analysis, synthesis, and expression (SASE) computer program which will help develop and test building standards and expert systems.

Failure to design buildings to meet structural loads can result in tragedy. When major building failures occur in the United States, NBS experts are often called upon to provide third party evaluations. These investigations provide the basis for improving future building practices.

NBS participated in the investigation of the 1981 collapse of two suspended walkways in the Kansas City, Missouri, Hyatt Regency Hotel which caused 114 deaths and 185 injuries. NBS also investigated a 1982 Indiana bridge collapse which killed 13 workers, and the 1981 Harbour Cay Condominium collapse which killed 12 workers in Cocoa Beach, Florida.

The Center's building structure and safety research has been incorporated in a new standard, American National Standard A58, Minimum Design Loads for Buildings and Other Structures, which is used as a basic resource by authorities in promulgating both model and actual building codes. The standard contains a new load reduction procedure based on survey data obtained and analyzed by NBS.

Not only must buildings be designed to withstand normal loads, but they must also be resistant to earthquake damage. In response to the Earthquake Hazards Reduction Act of 1977, NBS has established a national earthquake hazards reduction program. Center researchers are studying the strength and energy-absorption characteristics of structural and geotechnical materials and systems. The program aims to develop improved design criteria and standards for new and existing buildings.

Building quality can be enhanced not only through structural design but also through improvements in thermal, lighting, and acoustic design. These three areas are being investigated by CBT's building physics program. In the thermal design program, researchers have recently developed a guarded hotplate, which accurately characterizes thermal

Caroline Harner, a co-op student from the University of Maryland, inserts a sample of a cement component into an isothermal calorimeter to measure the rate at which heat is released during hydration reactions.

Kyle Woodward, a research structural engineer, studies data from a computer-directed test facility. The special tri-directional facility is part of the Bureau's earthquake hazards prevention research.

insulation to thicknesses of 300 mm. The NBS guarded hot-plate is used to measure precisely insulation materials that in turn are used to calibrate similar devices in other laboratories throughout the world. A new NBS calibrated hot-box facility provides precise thermal measurement on full-scale building walls.

Building acoustics researchers in the Center are developing test methods to measure the acoustic power emitted by sources and building components; propagation of acoustic energy in enclosed spaces; and the effects of boundary conditions on acoustic energy flow and reverberation time. Building illumination researchers are working toward development of cost-effective, energy-conserving lighting systems by identifying the physical characteristics of lighting which contribute to visual performance; conducting research on visual performance at suprathreshold levels; determining how daylight can be used for indoor illumination; and developing ways to predict and measure these parameters.

The CBT building equipment program focus on energy management and control systems will be highlighted with installation of such a system in a convenient test site location: the NBS Administration Building. Center researchers are working to predict the performance of energy management and control systems; measure the properties of components and systems; and develop guidelines for efficiently operating and maintaining these automated systems. The researchers in the building equipment program are also developing improved measurement techniques for characterizing refrigerants, as well as analytical and test procedures for evaluating the performance of active and passive solar heating and cooling systems, components, and materials.

One basic material used in a variety of building designs is cement. NBS is developing mathematical models to predict the reactions of cements in concrete, in order to predict how concrete may be strengthened as a function of starting material characteristics, mixture proportions, the nature and quantities of additives, and temperature and curing conditions.

Not only cements but also concretes, coating systems, and steel coatings are the subjects of CBT's research effort to enhance the quality of building materials. As part of this program, the Center operates two materials laboratories with sponsoring organizations. These laboratories provide proficiency samples, inspections, and field test methods to 580 other laboratories throughout the United States.

A number of years ago, CBT began investigating epoxy coatings for steel reinforcing bars to be used in concrete bridge decks. Uncoated reinforcing bars are often corroded by the deicing salts used on bridges. As a result of the NBS testing and evaluation effort, more than 1,000 bridge decks using the new reinforcing bar coatings have been constructed in the United States. These bridge decks are expected to last more than twice as long as their predecessors.

Center for Applied Mathematics

In nearly all the Bureau's research programs, and in laboratories throughout the United States, there is a substantial need for advanced mathematical, statistical, modeling, and computing techniques. It is the role of the NBS Center for Applied Mathematics (CAM) to provide the best available tools of modern applied mathematics and computing to the NBS staff. Such tools, developed at NBS, are often used widely by American and foreign researchers.

In providing its support service, the Center's professional staff interacts and collaborates with the scientific staff of NBS technical programs, and operates the NBS central computing facility. Center researchers are aided in their work by visiting specialists from industry, government, and universities.

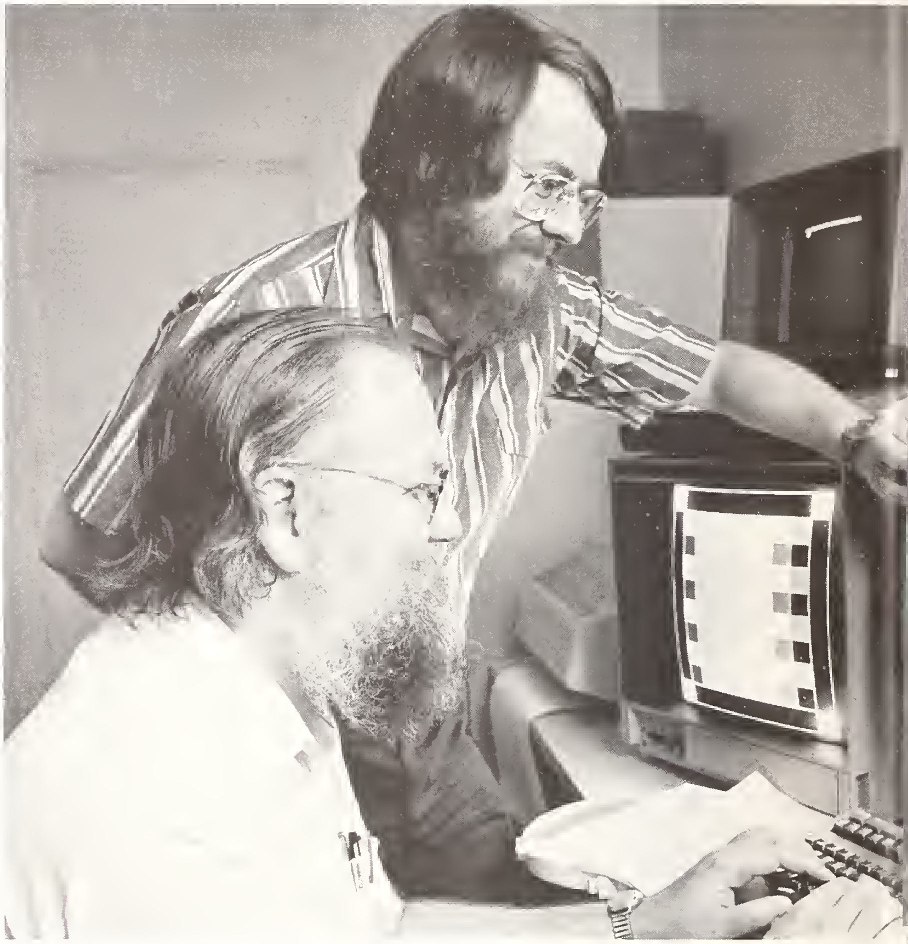
While schooled in theory, NBS mathematicians have their feet firmly planted on the ground of applications. They are concerned primarily with developing and adapting mathematical techniques for NBS research programs. Their work takes them into the areas of space science, robotics, fire research, economics, manufacturing, measurement, and development of new hardware and software for future computers.

One recently completed project helps fire researchers understand how indoor fires behave. The Center developed, tested, and validated a mathematical model of fluid motion and smoke evolution patterns for an indoor fire. Researchers tested calculations based on both two- and three-dimensional models. Using high-resolution dynamic graphics to display the particles, researchers achieved new insights into the dynamic features of the model.

The dynamic graphics display used in this project allowed researchers to observe the swirling motion of heated air on a computer display screen. The system, developed at the Center, allows users to cycle rapidly through any sequence of graphic figures stored in the computer, moving them around in almost any way and observing them from many angles. As the pictures appear to rotate three-dimensionally on the computer screen, new patterns can be perceived. The researcher can "zoom in" to study details, or "zoom away" to take in the larger view.

Soon after its recent introduction, the Center's new graphics display system became popular throughout NBS, providing new ways to study a variety of phenomena. The Center for Materials Science used it to develop dynamic displays of polymer chains and molecular structures. The Center for Chemical Engineering used it to observe time-dependent vibrations of a solid crystal from which energy is steadily drained.

The need for highly sophisticated "three-dimensional" dynamic computer graphics display is also present in the Bureau's robotics research. In order for robot-like machines to operate in an automated manufacturing facility, their grippers must be able to move through space without colliding. The Center is working with the Bureau's Center for Manufacturing Engineering to develop software algorithms and computer techniques which will describe, manipulate, and control objects in space. They are constructing methods for determining piecewise linear paths through regions without obstructions.



Mathematician James Blue (standing), CAM, and Charles Wilson, CEEE, developed a new computer model, CS 1, which brings sophisticated mathematical analysis techniques to a semiconductor model efficient enough to run on a minicomputer.

In performing this research, mathematicians are using the Voronoi diagram, which divides the available space into cells. Then the trajectory software searches adjacent cells to determine the path sequence. Using this tool, the researchers can construct trajectories with a minimum of computational effort and cost.

Another CAM project applicable to manufacturing concerns the production of high-quality metal alloys and semiconductors. In a manufacturing method known as unidirectional solidification, it is necessary to exert careful control over the degree of solute segregation at the liquid-solid interface. Under certain conditions, the planar interface can become unstable and deformed, causing production of a solid with non-uniform concentration.

Collaborating with scientists from the Center for Materials Science and Carnegie-Mellon University, NBS mathematicians developed a model that permits numerical calculation of curved interfaces, concentrations, and temperature fields relevant to this production method. Using this model, engineers can now study the dependence of the solute segregation on the processing variables in unprecedented detail.

CAM has also developed models which aid in a different area of manufacturing: the development of complex, custom integrated circuits for advanced computers and other electronics systems. This highly competitive field of endeavor depends on efficient computer-aided design tools. Cooperating with the Center for Electronics and Electrical Engineering, NBS mathematicians are developing a family of specialized computer packages which can be run on minicomputers. One package offers features which were previously available only in codes which required large mainframe computers. The CS 1 package has been provided to more than 80 users since 1982.

In addition to its important role in the development of advanced manufacturing techniques, applied mathematics plays a crucial role in space technology. Center researchers recently resolved a 25-year-old theoretical debate concerning satellite orbits. In cooperation with the Naval Research Laboratory and the State University of Utrecht, Holland, they have justified why a satellite at certain inclinations maintains its perigee stationary. The result will make it easier for engineers to control the trajectories of time and communications satellites.

In other recent work, the Center has:

- Streamlined the dissemination of alloy phase stability data to industrial users, through development of an interactive computer program which generates camera-ready diagrams.
- Helped implement four measurement assurance pilot programs at the Ford Motor Company Central Research Laboratory.
- Helped develop a method for selecting an optimal small set of artifacts to be used as Standard Reference Materials for estimating the systematic error of a user's linewidth measuring system, so that fabrication of a linewidth wafer standard could begin.
- Developed a model which helps state and local governments to evaluate the costs of proposed waste recovery facilities.
- Developed and distributed a graphics and statistics interactive language system called DATAPLOT, now used at more than 100 sites including major industrial firms.

Mathematician Sally Howe is developing algorithms and software for robot motion planning that will be used in the Bureau's Automated Manufacturing Research Facility.

Center for Electronics and Electrical Engineering

The scope of research in the Center for Electronics and Electrical Engineering (CEEE) extends quite literally from the sand to the stars. Grains of sand are the genesis of silicon-based integrated circuits, the "miracle chips" of the computer industry and one major focus of CEEE's work. Distant stars emitting radio signals are used by Center scientists to evaluate advanced telecommunications and satellite equipment, a second emphasis of the Center's research.

In these areas, and others, Center researchers are working to eliminate measurement-related barriers to the effective use of electrotechnology in a wide range of applications that are important to industrial productivity, national defense, safety, energy, and commerce. To fulfill this goal, they conduct research, develop measurement methods and physical standards, provide calibration and special test services, and develop models and data.

The Center's research is concentrated in four major areas:

- Metrological problems with semiconductor materials and processes, fabricated semiconductor devices, and advanced integrated circuitry.
- Improved techniques for measuring electric power and energy, fast high-energy transients, and the quality of electrical insulation.
- Fundamental metrology for fast signal acquisition, processing, and transmission, covering the analog and digital techniques and frequencies from direct current through microwave to lightwave.
- Methods for measuring and characterizing the electromagnetic environment, sources and reflectors of electromagnetic energy, and immunity of equipment to outside interference.

At the cutting edge of microprocessor technology development is the very large scale integrated circuit (VLSI), which could provide much more rapid computing and information processing at a lower cost per function. Before the full potential of VLSI can be realized, however, engineers must overcome significant technical barriers related to materials purity, demanding fabrication technology, and circuit complexity. To address these barriers, CEEE is developing measurements and standards for evaluating the quality of semiconductor materials and the performance of integrated circuit fabrication equipment, fabrication processes, and device circuit elements and packages.

As part of this effort, the Center has prepared four new Standard Reference Materials (SRM's) for calibrating the equipment used to make spreading resistance measurements on silicon specimens. Together with earlier-developed SRM's for four-probe measurements, these SRM's should help engineers obtain more accurate measurements of resistivity, which has been identified as the single most important parameter in fabricating circuits from silicon.

As computer technology spreads throughout the world, and international trade increases, the need for international standards becomes critical. NBS has played a key role in bringing together all five of the free-world organizations that write test-method standards for semiconductor materials so these methods may have a common basis in the United States, Europe, and Japan.

NBS has disseminated its technique for measuring linewidths on photomasks, which are an essential part of the fabrication of most integrated circuits, to virtually every U.S. manufacturer of integrated circuits and the optical equipment used to make photomasks. CEEE recently completed its sixth and seventh in a series of training seminars which have been attended by more than 400 representatives of more than 100 organizations.

In other work aimed at advancing knowledge of integrated circuits, the Center has developed and characterized integrated circuit test structures. These devices are widely used by the semiconductor industry and other government agencies to characterize fabrication processes, evaluate the effectiveness of processing equipment, and obtain crucial parameters for device and process models.

More than 90 organizations in industry, government, and academia have requested CEEE's recently developed computer code used to calculate the electrical characteristics of self-aligned, silicon-gate short-channel MOS (metal-oxide-semiconductor) transistors. This code is being used for the computer-aided design and analysis of the transistors required for developing VLSI circuits.

In a related area of semiconductor development, the Electronic Industries Association has adopted the NBS technique for measuring the operating temperature of power MOSFET's (metal-oxide-semiconductor field-effect-transistors) as a preferred

Technician Mike Thomas inspects a silicon specimen through the microscope of a spreading resistance instrument. A photomicrograph (detail) shows a pair of spreading resistance probes poised just above the surface of a silicon test specimen. Reflections of the probes may also be seen in the photo. The separation between the two probes is 25 micrometers, or about 1/3 the width of a human hair.

Physicist Gary Carver prepares to inspect a silicon wafer under a microscope in the Bureau's new semiconductor processing laboratory. Also called a "clean room," the laboratory is designed to allow no more than 10 dirt particles per cubic foot of air in critical working areas.

procedure, and has included it in a handbook on the subject.

Increasingly faster and more complex semiconductor integrated circuits have made the information age possible, and now technology needs correspondingly advanced systems to acquire, process, and transmit mind-boggling amounts of data. The systems responding to these new demands include test instrumentation and radar systems used in aerospace navigation and guidance, optical-fiber systems, and communications systems using microwave and millimeter-wave antennas. In all of these applications, digital techniques are providing the highest data rates.

To address the metrological needs involved in improving signal acquisition and processing systems, the Center is working on standard waveform generators and measurement systems which use superconducting electronics. To address signal transmission problems, CEEE is developing measurement methods for complex antennas, national measurement standards for millimeter-wave parameters, measurements for characterizing optical fibers, and measurements and standards for lasers.

A recent achievement in this area is the new microcomputer-based standard for measuring the average power contained in highly distorted electrical waveforms. This new standard provides an improved basis for comparing the performance of commercially available wideband wattmeters, and permits on-site power tests using an NBS standard. The instrument is expected to serve as a laboratory standard wattmeter for calibration of wideband power and energy standards in the frequency band from dc to about 50 kHz.

Many Center projects involve direct collaboration with industrial firms and laboratories. For instance, CEEE has completed a special study for a major domestic aerospace systems manufacturer, which is the prime contractor for an international communications satellite. The company wanted to know if near-field antenna testing could provide accuracies as good or better than far-field testing for a complete range of measurements. Based on the NBS study results, the company selected the Bureau's near-field antenna measurement methodology for performance testing of antennas to be flown on the new satellite. The indoor near-field technique, pioneered by NBS,

Electronics engineer Galen Koepke prepares a piece of electronic equipment for electromagnetic susceptibility tests in NBS' reverberation chamber.

offers higher resolution as well as savings in personnel, travel, and equipment costs over the conventional outdoor far-field technique. It is widely used by industry for performance testing and is now finding use in manufacturing process control for complex antennas.

Some projects involve international collaboration. In cooperation with scientists from a West German standards laboratory, NBS researchers have demonstrated constant voltage steps at 1.2 volts from a series array of 1,474 lead-alloy Josephson junctions operating with a 90-GHz signal. This major achievement demonstrates that no scientific barriers prevent the development of practical-level Josephson-junction voltage standards. The experiments also confirmed previous theoretical models.

While some of the Center's research is conducted primarily for a single purpose, much of it has a wide range of applications. For instance, planners at all levels of government are concerned with proper functioning of the nation's electrical power systems, communications networks, computers, and defense systems, all of which are vulnerable to disturbance by electromagnetic pulses. CEEE's study of electromagnetic pulses has additional applications; pulse-power systems are being developed, for instance, for fusion and industrial system processing. The Center is also working on more precise high-voltage measurement techniques, on diagnostic techniques for electrical insulation systems, and on critical current measurements to support the theory for high-yield, high-stress conditions in superconducting materials.

As part of this work, the Center has improved the sensitivity of electro-optical measurements of electric fields by one to two orders of magnitude, with a resolution of 1/1000 fringe. The Center also has developed the capability to characterize voltage sensors in the 1-nanosecond range—an order of magnitude improvement in the testing of high-voltage dividers used in pulse-power systems. In addition, the Center has established the capability to make quantitative measurements of chemical species produced in partial discharges in gases as a function of total energy dissipated or total charge transferred during the time of the partial discharge. This development provides information on the aging effects in gaseous insulation.

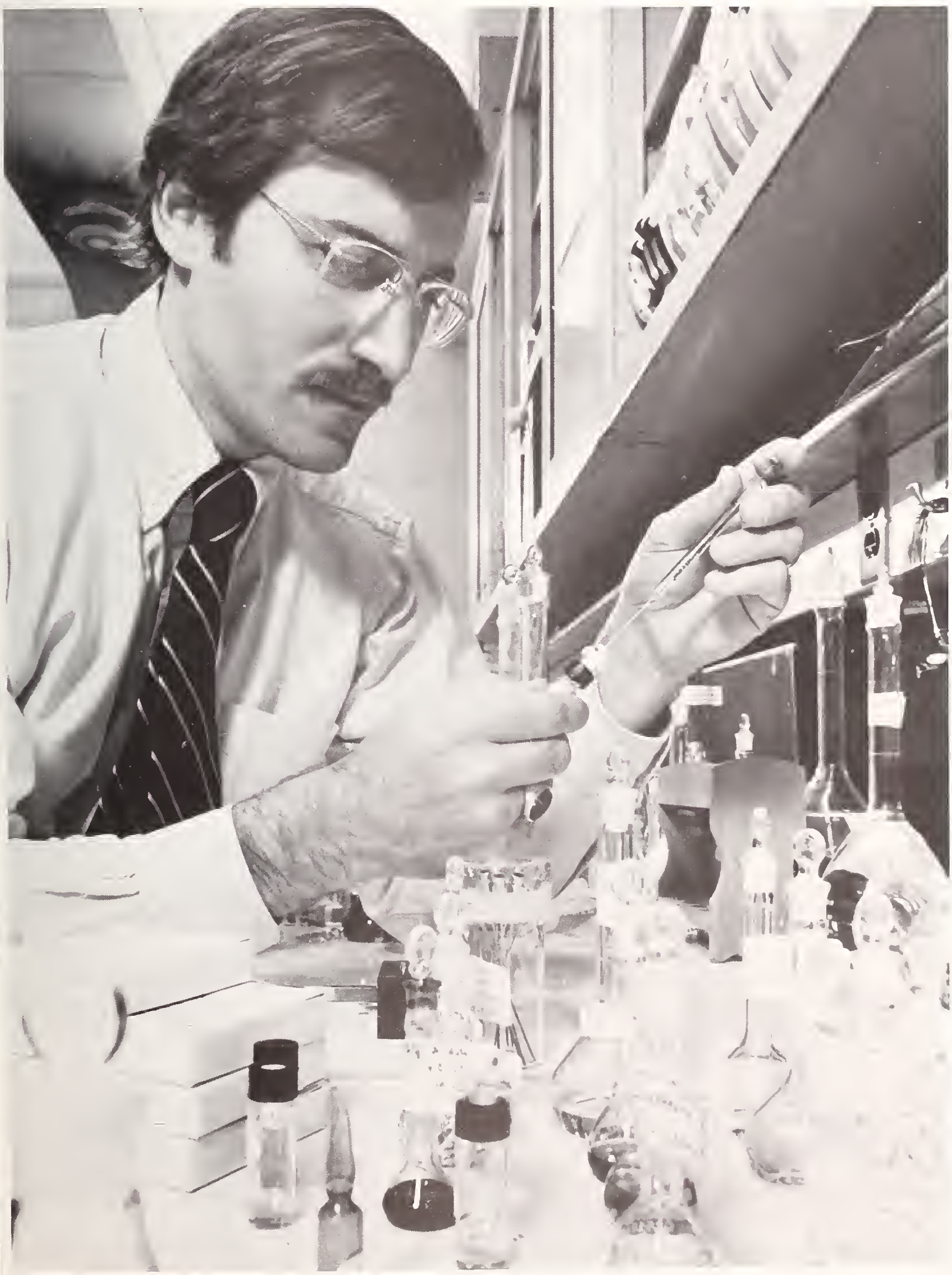
To resolve system performance problems caused by electromagnetic interference, scientists must be able to measure electromagnetic environmental conditions produced by complex signal patterns from multiple sources. To address this problem, the Center is focusing on measurements of complex, interfering electromagnetic fields and measurements of electromagnetic emissions and generations of standard fields for immunity testing.

The new isotropic magnetic-field meter designed by NBS, called MFM-10, measures the near magnetic fields of various high-power radio-frequency sources, including antennas and industrial equipment. Contained in a portable package and using a single probe head, the instrument offers wide frequency coverage, large dynamic range, and flat frequency and isotropic response. The MFM-10 was developed originally to survey worker exposure to industrial sources such as sealers, dryers, and induction heaters. As with its earlier electric-field instrument, EFM-5, NBS is providing detailed information regarding construction, operation, and calibration of the MFM-10 to potential manufacturers.

To aid the computer and communications industries in solving problems related to electromagnetic interference, CEEE is developing a number of measurements. The staff has carried out a theoretical analysis to prove the feasibility of near-field, phased-array EMI testing for integrated systems or whole-systems testing. They have developed a theoretical understanding of mode structures and mode distributions in reverberation chambers as a function of frequency. And they have validated the concept of the time-domain measurement approach for evaluating the shielding effectiveness of composite materials.

All of these projects apply some of the world's most advanced measurement techniques to the rapid development of the electrical and electronics technology which pervades almost every facet of life.

National Measurement Laboratory



Our highly technical society demands increasing measurement accuracy for the continued advancement of technology. And improvements in measurement science require an ever deepening understanding of the physical world. Scientists in the National Measurement Laboratory (NML) conduct research at the frontiers of physics which leads to improved realization of the basic physical quantities that underlie measurement science—mass, length, time, temperature, electric current, and radiant intensity. Their research also helps to improve understanding of fundamental atomic, molecular, and nuclear radiation processes. NML provides the nation with state-of-the-art measurement services in thermodynamics, transport properties, chemical kinetics, surface science, molecular spectroscopy, and chemical analysis.

Research chemist Laurence Hilpert prepares to analyze an environmental sample by gas chromatography/mass spectrometry, a sensitive analytical technique used to measure trace level toxic organic compounds at the parts per billion level.

Center for Basic Standards

As the inheritor of the government's nearly century-old attempts to standardize weights and measures, the NBS Center for Basic Standards (CBS) is responsible for the consistency of physical measurement standards in the United States. It develops and maintains the national standards for mass, length, time and frequency, temperature, pressure, vacuum, and electrical quantities. The Center's work ensures that these national standards are compatible with those of other nations, and the staff provides a variety of measurement services to the public. In addition, the Center conducts basic experimental and theoretical research to build a stronger and more accurate foundation for physical measurements and to improve our understanding of the phenomena on which physical measurements are based.

During 1983, two momentous occasions occurred in the world of basic standards: scientists redefined the meter, and the Bureau's 94-year-old platinum kilogram prototypes were recalibrated at the International Bureau of Weights and Measures (BIPM) near Paris, France.

Late in the eighteenth century, French scientists defined the meter as 1/10,000,000 of the length of the meridian through Paris between the North Pole and the Equator, and the kilogram as a cubic decimeter of water at the temperature of its maximum density. They produced metal prototypes of both the meter and kilogram. The meter-length artifact became especially useful since it proved impossible to measure the length of the meridian accurately.

In the search for greater accuracy, scientists redefined the meter in 1960 as 1,650,763.73 wavelengths of the light emitted by the atmospheric gas krypton 86. The krypton-based meter was accurate to 4 parts per billion, but even this small margin of error led to inaccurate measurement of distances in outer space.

Now, based on experiments conducted at NBS and other laboratories, scientists are able to measure length with unprecedented accuracy using advanced atomic clocks. As a result of these experiments, the meter was redefined by the General Conference on Weights and Measures, the international standards-setting body in Paris, in 1983, as the distance that it takes light to travel through space in 1/299,792,458 second.

Although scientists are working to develop an atomic standard for mass, they must still refer to the original French kilogram artifact, which is accurate by definition. In 1890, the United States received two kilogram mass standards, exact duplicates of the French standard. They are kept at NBS, but until 1983 only one had been recalibrated since its arrival in the United States. In December 1983, an NBS physicist carried both standards to BIPM in specially designed containers. There, they were cleaned and calibrated using the world's most accurate balance scale, built at NBS in 1970 and on indefinite loan to BIPM. Now that the NBS standards have been checked for accuracy, NBS scientists can continue to use them to calibrate other working standards.

Here physicist John Bollinger (left) and postdoctoral research associate John Prestige examine the laser set-up used to develop the first laser-cooled atomic ion clock.

While progressing toward more accurate measurement based on natural phenomena, CBS continues to emphasize its everyday research and service to the public. It is helping other scientific and technical organizations by providing faster and more accurate calibration services. The Center recently introduced new primary standards for the ac-dc difference and automated a large part of its resistance calibration facility, resulting in greater precision. Through automation and improved management over the past 2 years, the Center has reduced the average time required for each calibration from 3 months to 3 weeks.

In addition to providing calibration services, the Center seeks to aid industry by communicating the results of its metrology research and offering a variety of documentation and training services. As part of its recently expanded industrial outreach program, the Center is starting a series of electrical measurement assurance seminars and has begun publishing the *Industrial Measurement Series,* which contains papers written by NBS and industrial metrologists.

Serving industry in a different manner, the Center has expanded its time dissemination services. NBS broadcasts precise time and frequency signals from three radio stations and the Geostationary Operational Environmental Satellite. Until recently, the accuracy of time broadcasts ranged from 10 milliseconds to 30 microseconds. The new services, involving the Coast Guard's LORAN-C system and the Department of Defense's Global Positioning Satellite, cover the range from 3 nanoseconds to 1 microsecond. These new services feature highly automated equipment and extensive user interaction with NBS.

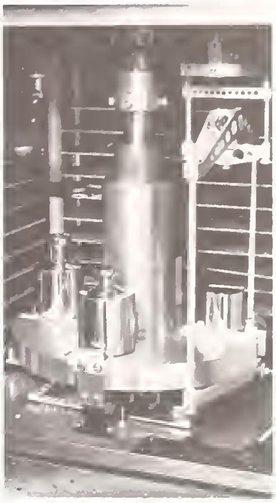
In another project designed to improve the accuracy of time and frequency measurement, the Center developed and evaluated the world's first cooled ion frequency standard. The use of laser cooling to reduce atomic velocity helps overcome the most serious limitation of all current atomic frequency standards—the Doppler effect. Center scientists are already experimenting with a second-generation device which should produce a hundredfold improvement in performance.

A related project is aimed toward developing measurement instruments with unprecedented accuracy, using ultra-high resolution laser spectroscopy. To produce the slow atoms needed for such studies, Center scientists recently used a laser beam to irradiate a beam of neutral sodium atoms, cooling the atoms to an effective temperature of 70 millikelvin.

Center researchers have joined scientists around the world in an intensive study of the "quantized Hall effect," which was first reported 4 years ago. This phenomenon, which describes an effect of an electric current flowing through a superconducting semiconductor in the presence of a strong magnetic field, may provide the basis for a new, more accurate standard of electrical resistance based solely on physical theory and basic natural constants. Although the NBS research is directed primarily at solving practical problems in the construction and use of such a standard, it also provides important information for theorists who are studying the quantized Hall effect. Recent experiments at NBS provided the most accurate measurements to date of a previously unrecognized temperature dependency in the Hall effect, and uncovered unexpected results in the local breakdown of the superconducting effect at certain critical current strengths.

Another recent achievement has been in developing an accurate basis for a method measuring the pressure and temperature of gases using a light source instead of a mechanical probe. The laser diagnostic technique being developed at NBS has the potential to provide dynamic temperature measurements of volumes as small as a few cubic millimeters almost instantly—within 10 nanoseconds. Center researchers have obtained basic information regarding the spectral response of gases. The project could provide the basis for a greater understanding of combustion processes in engines.

Through the Joint Institute for Laboratory Astrophysics, which NBS cosponsors with the University of Colorado, Center scientists also conduct research in precision measurements, geophysical measurement methods, chemical physics, atomic and molecular physics, and astrophysics. They have recently contributed to the development of stabilized lasers, the search for more efficient photovoltaic energy converters, and the measurement of fundamental molecular reaction processes. These researchers have also interpreted observations of stellar atmospheres obtained from ground-based and space-satellite experiments.



Kilogram Prototype K-20, one of two prototypes that define a kilogram of mass in the U.S., and hence the entire U.S. measurement system for mass, is the small platinum-iridium cylinder resting on the balance pan on the right-hand side of this photograph.

Center for Radiation Research

Through its research to understand and measure various forms of radiation, NBS produces information that is used to enhance industrial productivity, assure public health and safety, explore outer space, control pollution, conduct energy research, and design advanced telecommunications equipment.

In the NBS Center for Radiation Research (CRR), scientists examine both electromagnetic radiation, such as visible light and x-rays, and particle radiation, such as beams of electrons, ions, and neutrons. They study and measure ways in which such radiation interacts with matter, ranging from extended material surfaces to the molecular and subnuclear levels.

Much of this work results in accurate methods for measuring, characterizing, and producing radiation sources and standards. In recent years, radiation research has developed an important new relationship to health and medicine. For example, doctors are now trying to determine the long-range health effects of human exposure to low-level radiation sources. To do so, they need new measurement tools and data describing how radiation interacts with the human body.

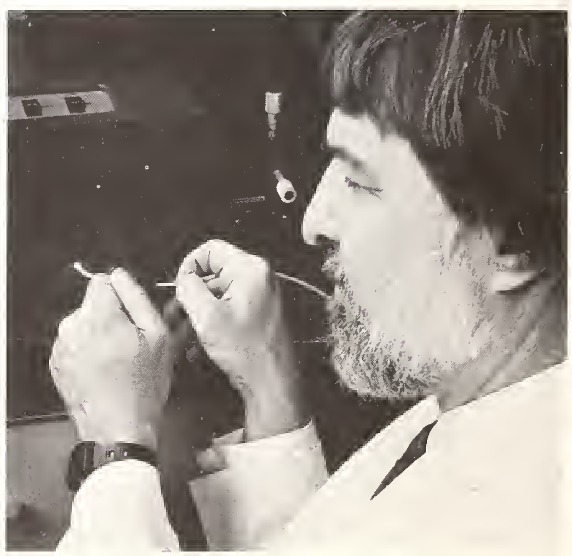
To aid in this effort, CRR is collaborating with researchers from local universities and the National Foundation for Cancer Research in a basic study of the chemical and physical effects of radiation on condensed materials, such as those found in biological systems. One recent accomplishment is the development of new techniques for separating and identifying new species of proteins produced by the action of ionizing radiation on natural proteins.

Radiation can have both long-term and short-term effects on humans. The immediate effects of human exposure to radiation can now be gauged more accurately with a new ionizing radiation measurement device designed by the Center with the U.S. Army and the Federal Emergency Management Agency. The optical waveguide dosimeter, now being produced commercially, is 100 times more sensitive than conventional chemical dosimeters. It can be used to measure radiation in industrial, medical, agricultural, space, and defense applications, as well as in the fast-growing radiation-processing industry.

One reason why the radiation-processing industry is growing by about 30 percent annually is that the use of several chemical decontaminants, recently found to be unsafe, is now limited by federal regulatory agencies. Ionizing radiation, for example, could be used instead of EDB (ethylene dibromide) to control pests in foodstuffs, as well as to sterilize medical devices instead of EO (ethylene oxide). Radiation-processing industries have installed more than 200 radiation sources to meet the new industrial demand. The Center has contributed to this technology by developing radiation standards and improved industrial quality control systems to monitor radiation doses, so that safely sterilized products are delivered to consumers.

Radiation research is not only meeting down-to-earth human needs, but is also reaching out into space. Research instruments routinely calibrated by CRR will be operated on the space shuttle and the orbiting space telescope.

In addition to studying radiation in space, scientists are interested in harnessing the energy of certain types of radiation. To aid those trying to develop nuclear fusion energy systems, NBS has developed the first completely consistent set of atomic physics codes producing theoretical data for dielectronic recombination rates encountered in fusion and x-ray laser plasmas. The NBS data can be used by physicists to develop computer models of Tokamak fusion reactors.



Physicist William L. McLaughlin studies the use of specially-tailored, radiation-sensitive dyes and fiber optics to make cheap, convenient industrial radiation dosimeters that can be read with a beam of light.

Miral Dizdaroglu (left), a research associate from the National Foundation for Cancer Research, works with NBS research chemist Michael Simic to study certain chemical reactions that can damage DNA and which may be an important step in the basic mechanism of cancer.

To produce radiation for experimental purposes, the Center builds and operates sophisticated accelerators and other radiation sources. The largest is the Synchrotron Ultraviolet Radiation Facility (SURF II), which is being upgraded to 300 MeV. With the installation of a high-resolution spectrometer on one of its beam lines, SURF II's resolving power will be 10 times better than that of any similar facility in the world.

SURF II is one of a few sources in the world which can provide continuous radiation in the ultraviolet and near x-ray region of the spectrum. The special properties of this radiation enable NBS to use this synchrotron as the only absolute national radiometric standard in the ultraviolet range of the light spectrum. It is used as a research and calibration tool by numerous visiting scientists, and for the study of optical properties of materials, molecular kinetics, ionization dynamics, and other fields of investigation.

Other ongoing CRR projects will aid a wide variety of theoretical and practical scientific and technological investigations. These projects involve:

□ The use of polarized electron beams to investigate surface magnetism, determine surface potentials of metals, study inverse photoemission from metals, and characterize ferromagnetic glasses.

□ Development of advanced radiographic measurement tools, including work on combining multi-channel photoelectronic detection, digital image processing, and tomographic analysis. The result is improved diagnostic methods and standards for medical, dental, and industrial radiographic applications.

□ New wavelength measurement of the atomic transition in helium, measured by Doppler-free intermodulated fluorescence spectroscopy and Doppler-limited spectra.

□ Production of computer-readable data files to supplement the traditional printed compilations of radiation data.

□ Development of calibrated radionuclide solutions to be used as standards in a government-sponsored bioassay measurement quality assurance program.

□ Establishment of a new high-accuracy calibration capability in the near infrared, achieved by improving spectrophotometry design.

□ Development of a new absolute neutron detector for measurements in the neutron energy region from 1 to 20 million electron volts.

□ Work with other scientists to build and test large accelerators, such as the 200-million electron volt, continuous-wave electron accelerator being developed jointly with Los Alamos National Laboratory, to ensure development of state-of-the art radiation sources.

Center for Chemical Physics

Environmental monitoring, fossil fuel combustion, and biotechnology are among the applications of research conducted by the NBS Center for Chemical Physics (CCP). Center researchers develop advanced measurement techniques in surface science, chemical kinetics, thermodynamics, and molecular spectroscopy. Using these techniques, scientists can achieve greater understanding of the molecular foundations of complex physicochemical systems.

Many rapidly growing areas of technology, including the development of high performance materials, computers, and semiconductors, involve surface characterization. One thrust of NBS surface science research is to develop measurement techniques for surface characterization. A second major goal of NBS surface science research is to determine the structure and reactivity of molecules adsorbed on surfaces, especially those important in catalysis. To conduct this research, the Center has established some unique experimental facilities.

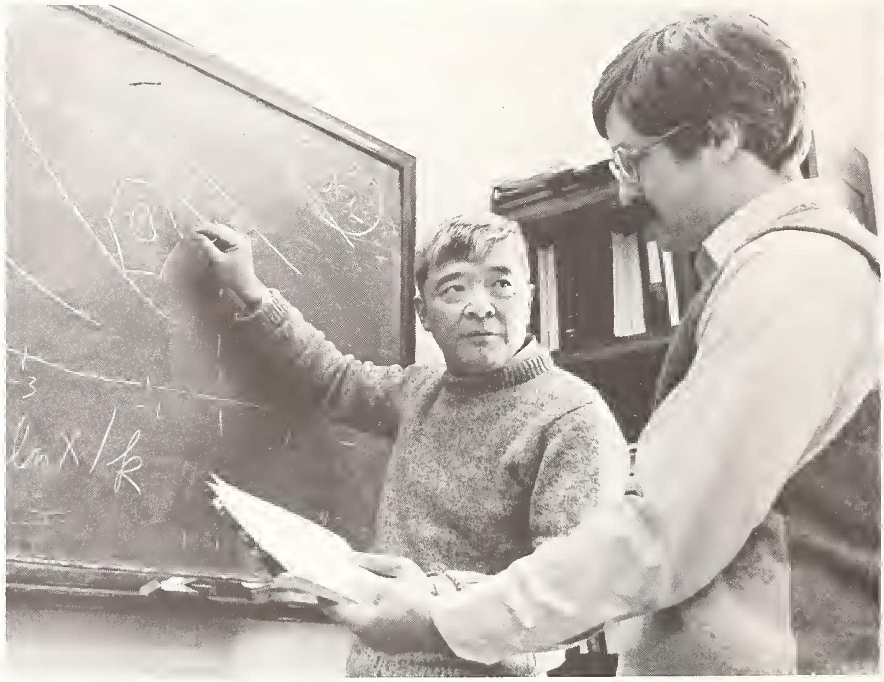
Center researchers recently constructed a new atom probe field ion microscope which has several novel features. It combines principles of field ion microscopy–which provides images of a crystal structure's individual atoms at magnifications up to several million times–and a time-of-flight mass spectrometer. The new microscope, a powerful tool in materials analysis, can detect the locations and mass of individual atoms in a crystal structure. With it scientists can probe regions ranging from only 5 angstroms in diameter to areas 800 times as wide. Researchers from NBS, the University of Illinois, and industry are now using this microscope to analyze rapidly solidified alloys.

The NBS synchrotron (SURF II) and an x-ray light source at the Brookhaven National Laboratory are being used to study the bonding of atoms and molecules to surfaces of metals and oxides. Combined with other surface-sensitive methods, this research is providing new insights into the geometrical and electronic structures of molecules on surfaces and the electronic properties of the substrate. The results of this research could help to improve materials used in electronics and other high-technology industries.

The study of chemical kinetics at NBS has numerous near-term applications, particularly in controlling and monitoring environmental pollution. Center researchers have proposed a new way to monitor the effectiveness of the burning of hazardous waste. A major problem in burning hazardous waste mixtures has been verifying that the hazardous components of the mixture are actually being destroyed. NBS has suggested using tracer compounds which are known to be more difficult to destroy than the hazardous components of the waste mixture. The tracer, added to the waste mixture in small quantities, could be used to determine the incinerator's efficiency. Use of such tracers could be cheaper, simpler, and more accurate than present methods of checking the operation of waste incinerators, heat-recovery plants, and similar installations. NBS has identified candidate tracers, which are being tested in California. This project has attracted the interest of industry, energy, defense, and standards experts.

Industry is also interested in the Center's recently patented idea which could help solve the nation's acid rain problem. Center scientists proposed a new chemical process for removing the noxious pollutant sulfur dioxide from industrial gas streams, such as the flue gas emitted from coal-burning power plants. The proposed reaction scheme converts sulfur and nitrogen to acids which can be removed easily from the gas. It could prove more efficient and reliable than the slurry systems which are presently in use.

The nationwide effort to develop more efficient and less polluting combustion systems has cre-



Using chemical kinetics, Wing Tsang (left) and Walter Shaub, research chemists, work to identify "tracer" compounds that could be used to monitor the performance of hazardous waste incinerators.

ated a growing need for chemical kinetics data and models. NBS is working to provide the scientific database for the design, modeling, and optimization of high-temperature processes. With the Department of Energy, NBS is asking research groups throughout the United States to cooperate in preparing an evaluated chemical kinetics database of elementary single step reactions for use in combustion modeling.

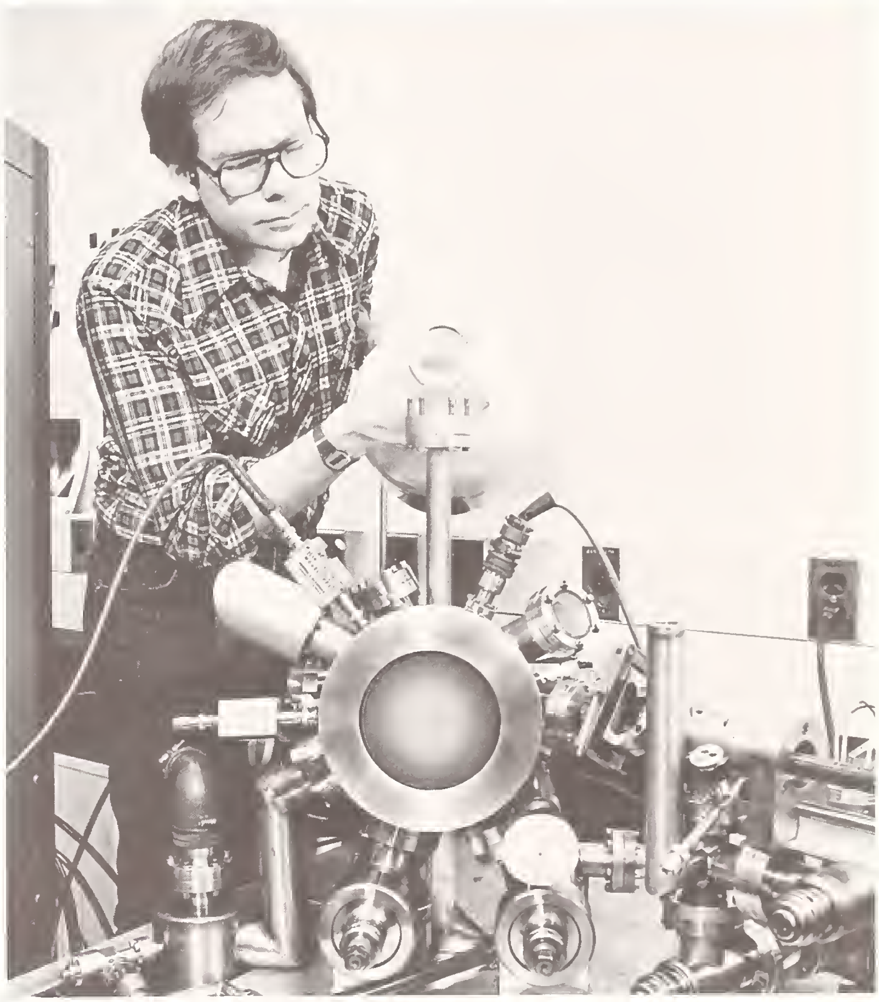
In addition to such databases, CCP provides data evaluation services and determination of benchmark values. The Center, in conjunction with the Standard Reference Data Program, recently completed a new set of tables of chemical thermodynamic properties. More than 60,000 references were used to compile the original data, which were then carefully evaluated and checked for thermodynamic consistency using specially developed computer programs. The tables have been published by the American Chemical Society and the American Physical Society.

In the NBS tradition of providing the measurement base for new and growing industries, the Center has begun to develop a new focus in biothermodynamics. CCP is evaluating existing thermodynamic data to estimate the properties of important biological building blocks. They are examining enzyme-catalyzed reactions in order to obtain data on product formation under varying process conditions. They are also measuring the energetics of nucleic acids by combustion bomb calorimetry. NBS-designed microcalorimeters and a high-performance liquid chromatography technique developed and validated at NBS were recently used to investigate the thermodynamics of the isomerization of glucose to fructose.

In a related area, CCP and the National Foundation for Cancer Research have initiated a cooperative research program to study the chemical behavior of metalloenzymes. These proteins are important in DNA replication and may play a role in the growth of tumors. NBS researchers have developed quantum chemical computation techniques to calculate complex systems of organic molecules interacting with metal ions. These calculations will enable them to predict important chemical properties.

Another major effort in the Center is a study of the properties of weakly bonded molecules. Center scientists are presently interested in hydrogen bonding in condensed phase systems. Hydrogen bonding is well understood on a macroscopic level. It is what makes water expand when it freezes, so that ice floats on the oceans instead of sinking. At the molecular level, however, hydrogen bonding is poorly understood. Only recently has spectroscopic instrumentation made it possible to resolve the rotational-vibrational fine structure of hydrogen-bonded complexes in gas phase systems.

NBS researchers are coupling theoretical spectroscopy with their infrared and microwave experimental results to explain the first resolved rotation-vibration spectrum of a hydrogen-bonded dimer molecule. From this spectroscopic data, scientists can obtain bond strengths and potential energies of the hydrogen-bonded systems.



Physicist Mark Twigg uses a specially designed atom probe field ion microscope that can detect the locations and relative mass of individual atoms in crystals under study. The instrument allows researchers to make detailed studies of the crystal structure of experimental alloys.

Center for Analytical Chemistry

More than 30 billion chemical analyses are performed each year in the United States by researchers in government, industry, academia, and private and public testing laboratories. Helping to ensure the accuracy of these analyses is the NBS Center for Analytical Chemistry (CAC). The Center serves as the nation's reference laboratory for chemical compositional measurements of inorganic, organic, gaseous, and particulate materials.

To help solve national problems that involve analytical chemistry, the Center develops accurate testing methods and Standard Reference Materials (SRM's) by: (1) investigating fundamental chemical and physical principles and concepts to develop new analytical procedures; (2) developing definitive test methods, which have been investigated exhaustively to remove bias and obtain high degrees of accuracy and precision; (3) modifying existing analytical methods to include new sample types and to permit accurate testing of samples with lower concentrations of important chemical constituents; and (4) standardization research, including certification of chemical compositions in SRM's.

Much of the Center's work has important applications in technology development. To design new high-technology machines and instruments, engineers must be able to predict the performance of materials such as alloys, composites, and electronic components. The performance of these materials is linked to their chemical composition and structure on a micrometer scale. In collaboration with scientists from the aerospace and electronics industries, academia, and other national laboratories, Center scientists are using beams of neutrons to measure elemental compositional profiles in materials important in high-technology industries. This technique is called neutron depth profiling (NDP). Using measurements obtained by NDP, they developed three-dimensional chemical maps for specific constituents in the sample. These maps, with resolution at the tens of nanometer level, can play a major role in establishing relationships between the chemical composition of materials and their performance.

With another technique, called resonance ionization mass spectrometry (RIMS), Center scientists hope to detect single atoms within chemical samples and measure and analyze accurately a sample with as few as 10,000 atoms. This technique will provide scientists with additional capability to measure ultra-low concentrations of elements and molecules in a variety of matrices (sample types). RIMS is expected to aid scientists in their efforts to follow the pathways of natural and manmade environmental contamination, to measure nutritionally and biologically important trace elements, and to study a variety of nuclear decay processes.

In addition to developing new measurement techniques which are at the cutting edge of technology, the Center has developed definitive methods which are the cornerstones of quantitative analytical chemistry. Using these methods, the Center determines chemical values for a variety of test samples and SRM's. Scientists in both the private and public sectors use these SRM's to assess the accuracy of their own analytical methods. The Center has developed highly accurate analytical methods for inorganic and/or organic constituents in a variety of matrices, including human serum, metals, nuclear materials, biologicals, and glasses.

Scientists in CAC have certified the chemical composition of more than 700 SRM's. They also perform research to develop new SRM's. In a recently completed SRM project, Center scientists developed

Chemist Gwen Marbury adjusts an electrochemical cell before testing a new polymer-modified electrode for analysis of organohalogen pesticides such as ethylene dibromide (EDB).

Analytical chemist Paul Paulsen loads an arsenic sulfide sample into the source of a mass spectrometer to measure sulfur isotopic rations. Researchers are determining sulfur concentration by stable isotopic dilution for certification of Standard Reference Materials at concentration levels from a few parts per million to several percent.

analytical methods to certify a unique SRM for measuring asbestos in the non-working environment. This effort used analytical electron microscopy to count micrometer-size asbestos fibers on membrane filter samples.

While SRM's are used in a broad range of applications, much of the Center's work has near-term use in specific areas of research. Recently, Center scientists analyzed cholesterol and other constituents of human serum in collaboration with the College of American Pathologists, determined levels of phenols in fuel in cooperation with the Department of Energy, and cooperated with industry and the Food and Drug Administration to determine ethylene oxide residues in surgical materials.

All three of the above analyses were done to respond to new requirements in organic analytical chemistry. Until the mid-1970's, the typical analysis for organic constituents was performed by isolating and quantifying fairly high concentrations of a single component in a simple matrix. In such an analysis, other chemicals in the matrix can affect the detection and quantitation of a specific compound. To overcome this problem, scientists have been investigating the chromatographic separation of chemical compounds. Using the results of this investigation, NBS scientists are now able to separate and analyze specific organic compounds from complex samples containing thousands of chemicals.

In other work that has near- and long-term applications, the Center has cooperated with the Environmental Protection Agency to establish a pilot environmental specimen bank program. The bank contains well-characterized biological samples for analysis of chemicals present in the environment. These samples can be used in the future to evaluate environmental changes which may occur over a given period of time and also to distinguish man-made changes from natural ones. The program to date has involved developing analytical protocols for sampling, processing, and storing samples; evaluating analytical methods for determining trace elements and organic pollutants in biological samples; establishing baseline data on selected environmental specimens; and evaluating the feasibility of long-term sample storage under various conditions.

In a related project, scientists are investigating isotopic and chemical compound distributions in natural samples. They are using mathematical modeling and chemometrics to identify sources of environmental pollutants. These procedures can be used for other chemical analyses as well.

Along with the rest of the National Measurement Laboratory, the Center has programs to ensure that its measurement technology is transferred to outside users. It has provided quality assurance courses to more than 2,000 people, and is producing a generic quality assurance document for a broad range of users in cooperation with six other government agencies.

Office of Measurement Services

Reliable measurements can help avoid costly manufacturing mistakes and unnecessary use of products and systems. They can provide the basis for sound and economical environmental and safety regulations. Good measurements can also improve health care by ensuring the validity of clinical tests and procedures.

At the heart of the NBS mission are services which ensure the accuracy and compatibility of measurements on a national and international scale. These services also disseminate NBS-developed measurement technology to users throughout the world. Three such programs are directed by the Office of Measurement Services: the Standard Reference Materials (SRM) Program, the Calibration Service Program, and the Measurement Assurance Program (MAP).

SRM's, produced by NBS since 1906, are homogeneous and stable materials, which have one or more physical and/or chemical properties accurately measured and certified by NBS. They are used throughout the world to calibrate instruments and evaluate test methods used in industrial quality control, medical diagnostics, environmental monitoring, and basic metrology. NBS currently maintains an inventory of about 900 different SRM's, which are described in the *Catalog of Standard Reference Materials,* NBS Special Publication 260. Each year, NBS sells more than 35,000 SRM units to over 10,000 customers, including 2,500 foreign customers.

Although NBS has been providing basic measurement services such as SRM's for nearly 80 years, the accelerated pace of technology development has called for new and more accurate SRM's. Some of the most recently developed SRM's are in dimensional metrology, ferrous metals, and biotechnology.

Scientists working in the early 1900's would have had little use for microdimensional SRM's with an average diameter of 0.895 micrometers. That is the size of the tiny polystyrene spheres in the new SRM 1690. Developed in cooperation with the American Society for Testing and Materials, this SRM can be used to calibrate optical and electron microscopes, flowthrough counters, and other instruments which measure the size of small particles. Such particle size measurements are vital in a variety of fields, including metallurgy, clinical chemistry, environmental monitoring, and food technology, as well as in the production of printing inks, explosive powders, and cement.

The steel industry uses more than 100 different NBS steel reference materials to assure quality production and to calibrate automated measurement systems. The 1200 series of low-alloy steels, prepared to NBS specifications, has been the standard for the entire low-alloy steel industry for more than a decade. Some newer SRM's are helping the industry produce high-strength, temperature-resistant stainless steels for a variety of applications. One new SRM series with a high nickel and chromium content prepared in cooperation with industry and technical standards groups, is vital to this effort.

SRM's are used not only in America's most basic industries but also in the rapidly expanding biotechnology sector. NBS now has more than 30 SRM's to support measurements in biotechnology and clinical chemistry. One such SRM, Human Serum (SRM 909), was recently updated to include measurement of enzymatic activity for 7 important enzymes involved in medical diagnoses. This improvement, which drew worldwide attention from clinical chemists, constituted an important step toward standardization in the clinical area of enzymatic activity.

As essential as the SRM service are the calibration and physical measurement services provided

Metrologist Ralph Veale demonstrates the use of a socketed ball bar to test coordinate measuring machines, which are used in the aerospace and automotive industries and in the manufacture of farm and construction equipment.

NBS measurement assurance seminars, like this one by researcher John Taylor, CAC, help train participants to establish and maintain vigorous quality control programs in their laboratories.

by NBS. By calibrating a variety of standards and measurement equipment, these services provide the basis for a complete and consistent national system of physical measurements. During 1983, NBS calibrated more than 8,000 instruments and transfer standards—up from 6,800 in 1982—for more than 1,500 customers. Calibrations are provided for a variety of important parameters including fundamental quantities (mass, length, time, electrical current, and temperature) and derived quantities (such as fluid flow rate, electrical resistance, spectral radiance, laser power, and microwave attenuation).

In addition to developing new SRM's to meet the demands of technology, NBS is also continuing its search for new ways to enhance the accuracy of its calibration services. When customers properly use instruments calibrated by NBS, they can be reasonably assured of accurate measurement in their laboratories. Inaccuracy can occur, however, if the device is damaged in shipment, or if other factors (such as unskilled operators or environmental conditions) hamper accurate measurement. For customers whose measurements must be of the highest accuracy and traceable to national measurement standards, NBS has developed its Measurement Assurance Program (MAP).

The NBS MAP service comprises multilaboratory testing programs, which enable participants to evaluate the performance of their total measurement systems relative to national standards and to the performance of other laboratories. During the past 5 years, NBS has provided MAP services for electrical resistance, electrical capacitance, dc voltage, platinum resistance thermometers, mass, gage blocks, watt-hour meters, laser power and energy, and optical retroreflectance.

In a MAP, NBS carefully measures a stable artifact, referred to as a transfer standard, which is then measured by the participating laboratory and again by NBS to assure stability during shipment. The transfer standard is then sent to another participating laboratory and again back to NBS for measurement. After analyzing all the data from the participating laboratories, NBS prepares a test report stating how much each the participating laboratory's measured value deviates from the NBS standard and from the mean values of the other participants. All parties measure the transport standard again periodically. Participating laboratories must have ongoing measurement quality control programs to monitor their own check standards.

MAP's have been shown to improve participants' precision and accuracy substantially. Participating laboratories that are located in the same region of the country can form interlaboratory testing groups known as regional MAP's. In such arrangements, one laboratory provides the principal point of contact with NBS to help ensure the stability of the transfer standard.

To enhance the use of accurate measurements throughout the scientific community, NBS holds measurement assurance seminars. These seminars provide in-depth training in both measurement techniques and statistical evaluation of measurement processes. These seminars, given at locations throughout the country, help train participants to establish and maintain vigorous quality control programs in their laboratories.

Office of Standard Reference Data

More than a million scientific papers are published each year, a production rate that is beginning to overwhelm scientists and others who are finding it more difficult than ever to be sure about the reliability of the data in those papers. Yet decisions based on inadequate or outdated information may result in the costly overdesign of industrial facilities or possible failure of products.

Researchers at all levels of industry, government, and academia depend on the evaluated physical and chemical databases developed and distributed by the NBS Office of Standard Reference Data. This program, mandated by the Standard Reference Data Act (Public Law 90-396), coordinates the activities of 23 continuing data centers and 31 other data evaluation projects. Each data center monitors an important disciplinary area and develops and maintains one or several databases. The Office's database is then made available to the technical community in several formats: published, computer-readable, and on-line. The data projects often answer the need for specialized databases in particularly important areas of science and technology.

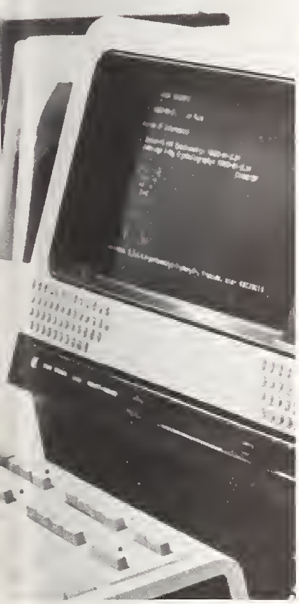
The Office now distributes six major databases in computer-readable format on magnetic tapes. In this way, the databases are more accessible to a variety of users and can be updated more easily. These databases have numerous uses, such as identifying chemical unknowns encountered in different environments, predicting chemical reaction equilibria, and designing industrial processes. The six databases presently available on magnetic tape are: NBS/NIH/EPA/MSDC Mass Spectral Database, NBS Chemical Thermodynamics Database, NBS Thermophysical Properties of Hydrocarbon Mixtures Database, NBS Crystal Data Identification File, Thermophysical Properties of Helium, and Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids.

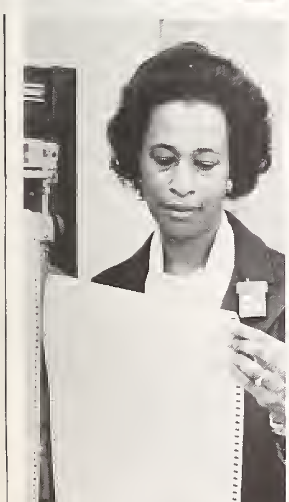
Additional efforts are underway to provide more needed data in computer-readable format. For example, the Photon and Charged Particle Data Center is preparing computer-readable files of accurate cross section data for the interaction of photons and electrons with matter. These data are needed by many scientists working in energy research, medical physics, space science, radiation sterilization, and materials processing. Two data files are being prepared. The first is XGAM, which will contain data pertaining to the interaction of x-rays and gamma rays with elemental substances in the energy region 1 keV to 100 GeV. The second, EPSTAR, will consist of stopping powers for electrons in 285 materials and for positrons in 29 materials of dosimetric interest.

Some of the Office's recent data evaluation and database development work involves the use of prediction and correlation techniques. These techniques help determine hard-to-measure data and

Chemist Bettijoyce Molino develops an evaluated database for the chemical processes industry.

Research chemist Marlene Morris, an NBS research associate with the JCPDS International Centre for Diffraction Data, studies an x-ray powder diffraction pattern that was recorded on a laboratory diffractometer.





provide internal checks to assure that a particular database is scientifically self-consistent. An example of this effort is the NBS Chemical Thermodynamics Database that contains data on the thermodynamic properties of 15,000 substances which are totally consistent with the laws of thermodynamics.

Researchers in the Fluid Mixtures Data Center are developing techniques which will enable scientists to predict transport properties of pure fluids from thermodynamic and molecular data, to predict properties of mixtures from the properties of pure fluids, and to interpolate and extrapolate data over a range of temperature, pressure, and relative concentrations (in mixtures). With such capabilities, researchers can generate needed thermophysical data on-line for specific multi-component mixtures. It would be impossible to provide such information on all possible mixtures in printed tabular form.

To make the Standard Reference Data program successful, its managers must be aware of data requirements in the U.S. technical community and obtain that community's assistance in the job of providing needed data. For this reason, program managers collaborate with a variety of industrial and professional groups. These cooperative activities provide considerable assistance-in-kind to the program, as well as highly effective routes for dissemination of data.

For example, the National Association of Corrosion Engineers and NBS have established a joint program to provide evaluated corrosion data on alloys and other materials. Corrosion of materials, such as in machinery and bridges, cost the United States an estimated $126 billion in 1982. The new cooperative effort is aimed at reducing these costs through improved utilization of materials and application of good anti-corrosion practices. The Office of Standard Reference Data has established a new Corrosion Data Center within the NBS Center for Materials Science. The data center will provide overall guidance of the technical aspects of the program and will assure reliability of the data evaluations.

The Office of Standard Reference Data also collaborates with the Design Institute for Physical Properties Data (DIPPR), sponsored through the American Institute of Chemical Engineers. DIPPR's purpose is to provide reference data to the chemical industry by a combination of critical data evaluation and experimental measurement. The more than 40 organizations that support DIPPR include companies which manufacture chemicals, design processes, and plants and provide a variety of services to the chemical industry.

Through the Standard Reference Data program, NBS played an active role in helping the industry establish DIPPR and the research agreement which spells out the cooperative activities between the two organizations. These activities include direct support of DIPPR projects by NBS, and carrying out of certain types of work for DIPPR at NBS.

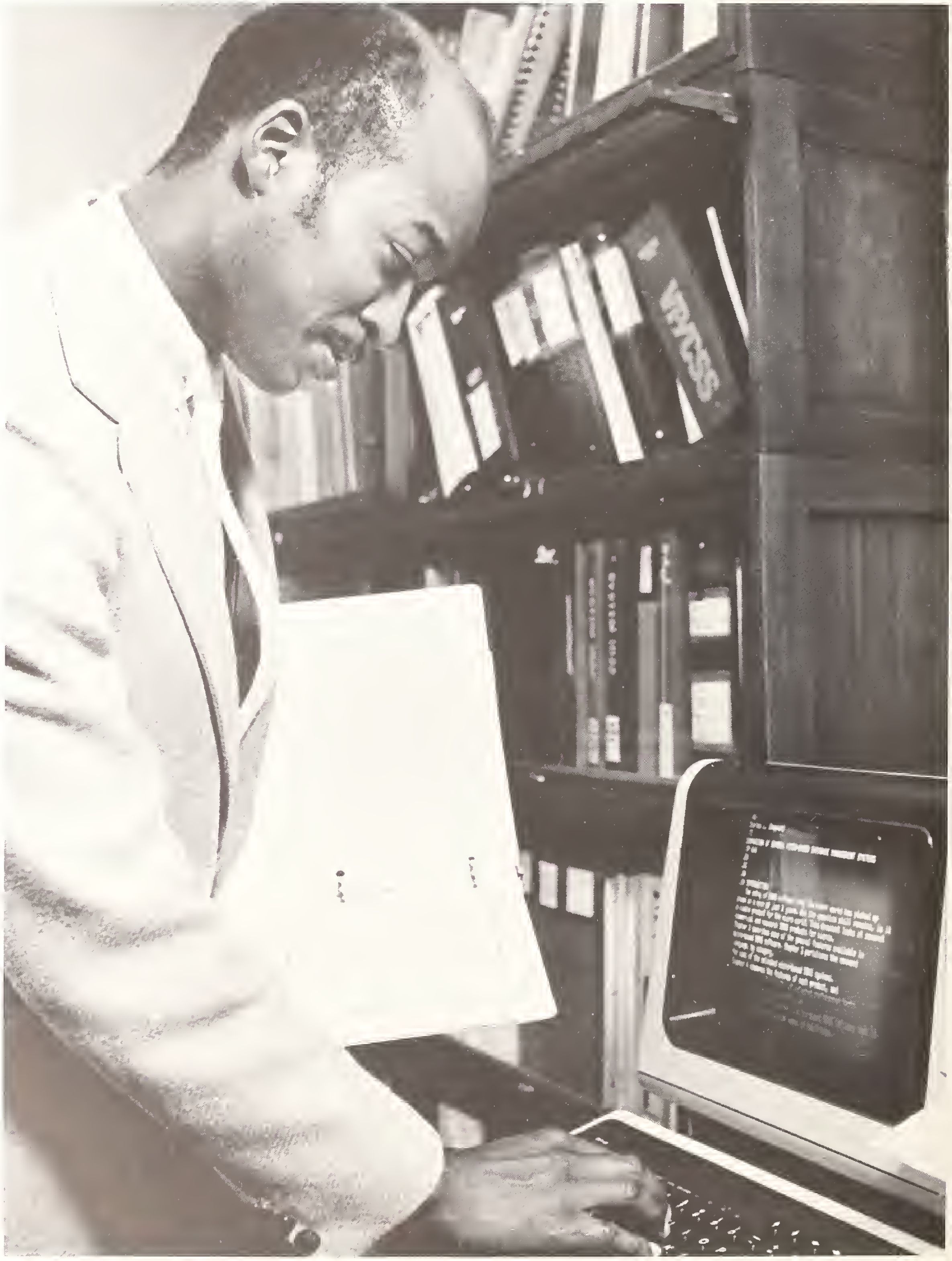
In addition to new activities, the Office of Standard Reference Data enjoys a number of long-standing cooperative arrangements. One is its 12-year collaboration with the American Chemical Society and the American Institute of Physics to publish the *Journal of Physical and Chemical Reference Data*, the major printed output channel for the National Standard Reference Data System. The journal presents compilations of physical and chemical property data which have been evaluated by scientists knowledgeable in the pertinent field of research.

The American Chemical Society handles promotion and subscriptions as well as a unique service: selling bound offprints of articles. The American Institute of Physics is responsible for composition, printing, and mailing, while NBS provides technical and editorial control. By sponsoring this effort and actively disseminating the results to their membership, these two professional societies demonstrate their recognition of the data's importance.

These database development and cooperative activities are merely representative of the large and comprehensive efforts through which the Office of Standard Reference Data provides up-to-date evaluated scientific information to the technical community.

Institute for Computer Sciences and Technology

No device symbolizes the ongoing technological revolution more effectively than the computer, a ubiquitous feature of business life, now commonly used in homes and schools. The rapid growth of computer technology has caused some problems and confusion, however. Computer users have encountered systems which don't "talk" to each other, which provide inadequate security, and which otherwise fail to meet their needs. The Bureau's Institute for Computer Sciences and Technology (ICST) helps organizations manage and use computers and information technologies effectively by providing a range of technical products and support.



Charles Sheppard, a computer scientist, develops guidance for selecting and using off-the-shelf database management packages.

The staff of the Institute for Computer Sciences and Technology collect, analyze, and transfer information about new technology, develop guidelines and standards for the federal government, and provide technical advice and assistance. The Institute also conducts applied research and development, such as test methods, description techniques, design specifications, and performance measures.

To carry out this program, ICST works with many other groups, including computer users in government and industry, computer manufacturers and service providers, national and international voluntary standards organizations, and a variety of research organizations.

As their costs go down and their capabilities increase, computers are attracting new users in business, government, and households. Small computer systems are being purchased by organizations of all sizes. As computer technology reaches into new areas, computer applications are becoming more complex. Distinctions among computers, communications, and information management are becoming blurred.

With this growing complexity, there is an increasing need to coordinate the development, implementation, and management of computer technology and new computer applications. And as more computer functions become automated, users are becoming more concerned with the protection of data and processing resources.

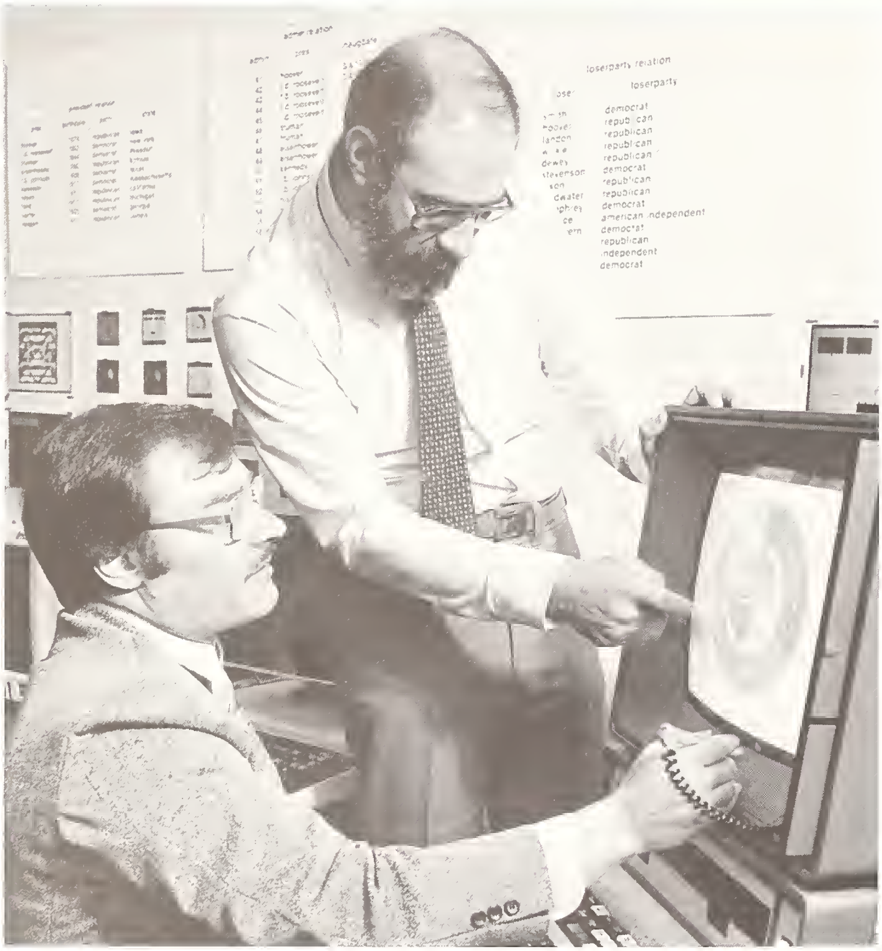
To help organizations keep up with new developments and plan effectively for the future, ICST programs focus on three major areas: compatibility and interconnection of components, systems, and networks; efficient management and use of computer resources throughout the system life cycle; and the integrity, reliability, and availability of computer resources.

Without commonly accepted methods of transmitting and receiving information, equipment cannot be linked together into compatible systems, and networks cannot be developed from commercially available products. ICST helps develop voluntary industry standards to achieve compatibility of components, systems, and processes. Providing both technical leadership and support, ICST contributes to the development of standards that meet both user and vendor requirements. These standards help stimulate development of high-quality, reliable, off-the-shelf products and enable the U.S. computer industry to compete in world markets.

ICST scientists are researching ways to make it possible to form resource-sharing networks from different manufacturers' equipment. Shown here in the Network Protocol Lab are (left to right standing) Jerry Linn, Ken Diamond, Wayne McCoy, and Fran Nielson and (left to right seated) Dan Rorrer and Stephan Nightingale.

In supporting the development of voluntary standards, ICST works with a variety of user organizations, such as the Network Users Association and the Association of Data Communications Users, as well as users in federal, state, and local government groups. ICST also works with hardware and software manufacturers, the American National Standards Institute (ANSI), the International Organization for Standardization (ISO), and the Institute of Electrical and Electronics Engineers (IEEE). ICST staff members participate in more than 60 standards-writing committees to which they contribute specifications, test methods, and ICST research findings. When standards are implemented in products, ICST works with industry and users to test the standards' performance.

When new voluntary computer standards are developed, they are often adopted for federal government use as Federal Information Processing Standards (FIPS). ICST helps federal agencies analyze the impact of proposed standards before they are



Computer scientists Mark Skall and Joseph Collica look at ways to integrate database management systems with computer graphics systems, thus making both easier to use and more efficient.

adopted. The federal government has issued more than 100 FIPS, including guidelines for managing and using computers. Once issued by the government, FIPS are often widely used in the private sector.

Standardization and compatibility are also important issues in the drive to link together equipment used for different applications into resource-sharing networks. Such networks can be difficult to form, however, because different manufacturers' systems do not communicate with each other. To achieve compatible communication, a special type of software called "protocols" can be developed. ICST is working on international network protocol standards with ISO, ANSI, and other groups. The goal of this effort is to develop standard protocols for the various data communication functions in networks—from physical connections, routing, and switching functions through the structuring and organizing of data. When implemented in commercial products, the standard protocols will enable users to develop and expand their own computer networks for a variety of applications.

One of ICST's major accomplishments in the network standards area has been developing technical specifications and test methods for prototype implementations. Because there are currently no standard products in widespread use, testing implementations is a critical step in the process of developing international standards. The testing program involves satellite networks, local area networks, office system networks, and videotex applications. Computer manufacturers, users, and network research organizations in other countries are participating in this program with ICST.

In related work, ICST is also developing specifications and test methods for data formats, coding systems, and computer storage media. Common formats and codes permit different computer-based office systems to exchange documents and messages. Computer components and systems must also have compatible storage media to exchange information. ICST has developed Standard Reference Materials which help computer manufacturers and users test the quality and performance of their storage media and associated equipment.

Before computers can transmit and store data, the data must be made computer-readable. ICST is investigating data entry techniques that can reduce costs to users. These techniques include optical character recognition and speech technology.

As personal computers become more widely used in the office workplace, many organizations are increasingly concerned with managing end-user computer applications. ICST's technical support program helps organizations understand and manage such applications. The program investigates the features of small computers and software packages and provides guidance for users based on laboratory findings and user experiences.

One of the most costly, labor-intensive activities for computer users is development and maintenance of software. ICST conducts programs designed to help manage information resources, improve programmer productivity, and enhance software quality. Toward this goal, ICST is investigating new technologies such as software development tools, user-oriented programming languages, and knowledge-based systems.

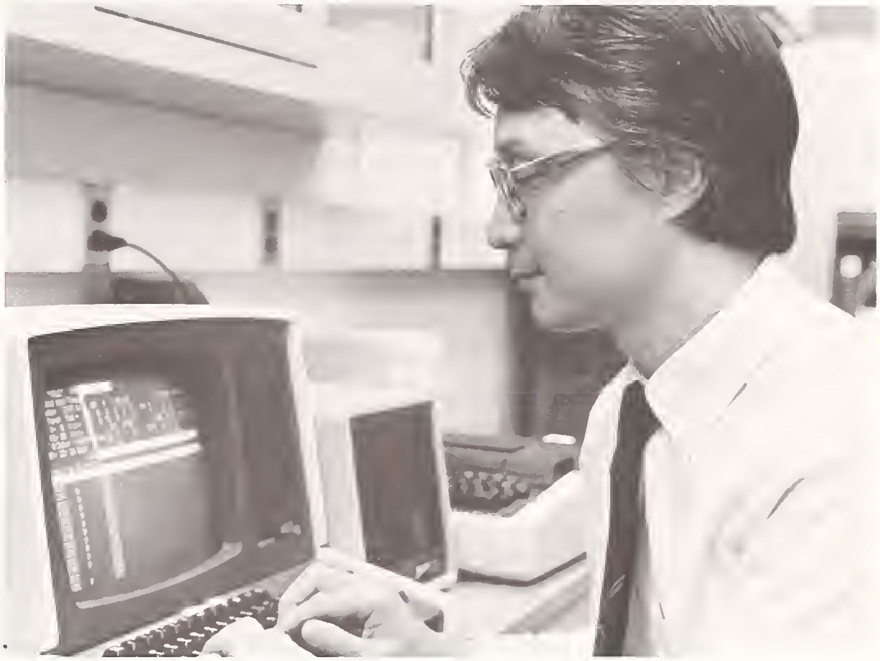
To enhance the efficiency of storing, retrieving, and manipulating data, ICST is developing standards and guidelines for data dictionary systems, database management systems, and graphics systems. Working with users and software vendors, ICST is preparing functional specifications for data dictionary systems. This work has been adopted by voluntary standards groups as the basis for an international standard.

With increasing numbers of organizations depending on computers to carry out their programs and deliver their services, computer security is a growing concern. The confidentiality, integrity, and availability of computer data and processing resources must be protected from threat and loss. While much public attention has been focused on deliberate breaches of computer security, most experts agree that accidental events cause greater loss than do computer-related crimes and mischief.

ICST is investigating safeguards that protect systems against accidental events as well as intentional acts. These safeguards include both management and technical computer security methods such as risk analysis, contingency planning, personal identification, applications and database security, and procedures for certification and accreditation. ICST works with federal and private sector computer users, computer security professionals, and auditors to develop methods and techniques that will help organizations of all sizes protect their computers and data.

An example of a technical safeguard under investigation is the use of computer cryptography to protect data transmitted in networks. The Institute has developed a Data Encryption Standard (DES), which has been adopted to protect sensitive but unclassified data in federal government computers. The DES has also been adopted as a voluntary industry standard.

To use the DES, computer operators must protect the secret keys that are used to encrypt and decrypt data. To protect these keys, ICST staff members developed a Key Notarization Sytem (KNS), for which they were awarded a U.S. patent. Notarization is the electronic equivalent of using a notary public to certify and authenticate legal documents. The KNS generates cryptographic keys used to encode and decode data. When the key is to be used in transmitting a secure message, the KNS "seals" the key with the identities of the transmitter and the receiver. Once the key has been "sealed," only the authorized transmitter can encrypt the message, and only the intended receiver can decrypt it. Neither party can create a fake message nor deny an authentic message. Using the KNS, the message receiver can prove to a third party that the message was in fact sent by the authorized transmitter.



▲ **To help assure that standards for linking computer terminals to packet-switched data communications networks work, electronics engineer Michael Wong has developed test methods and equipment.**

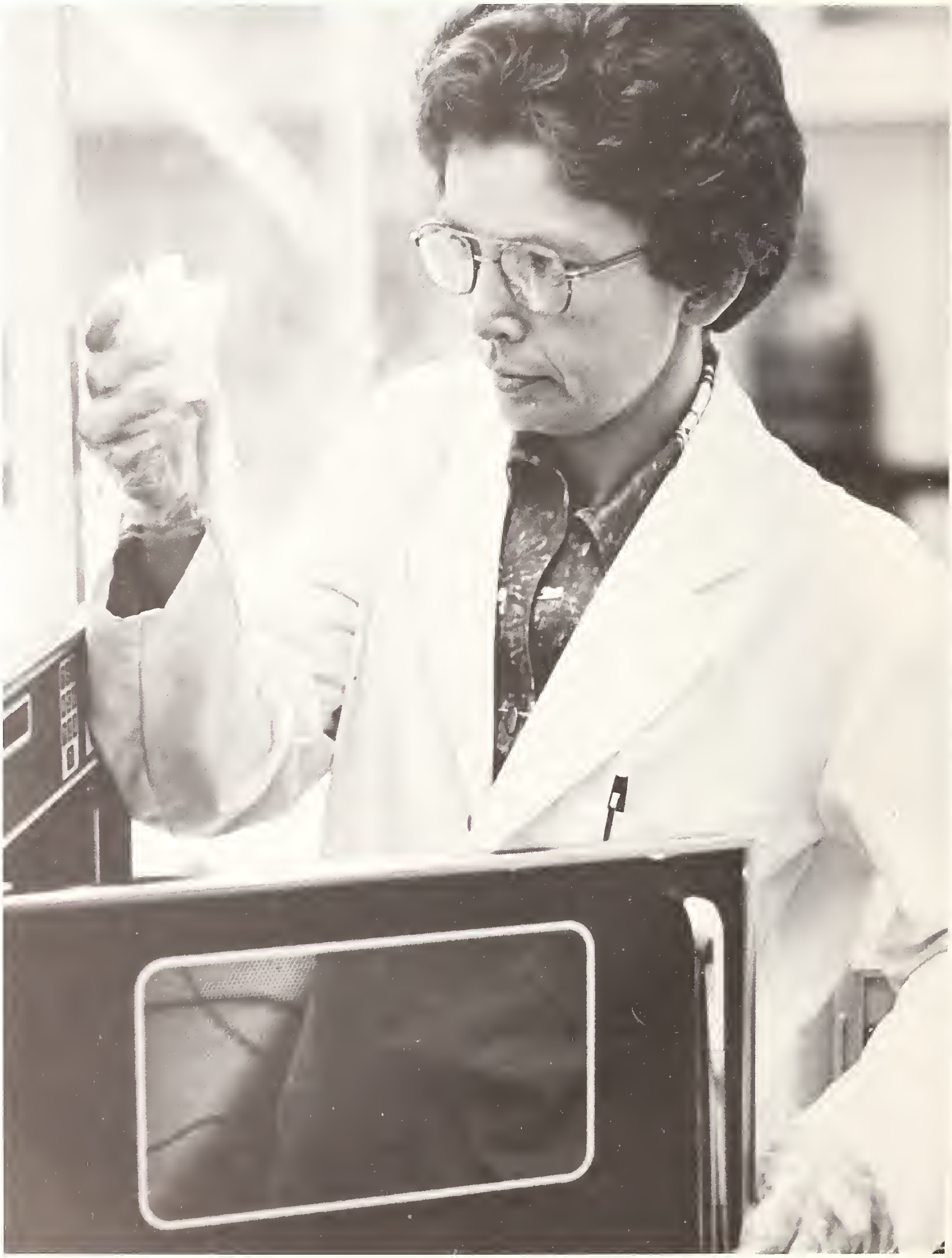
The KNS has been implemented in ICST's laboratories and is being used experimentally at several Department of Energy national laboratories. The banking community is considering using the KNS as a voluntary industry standard to protect financial data transmitted between banks.

In addition to providing general technical support to computer users, ICST carries out specific projects on a reimbursable basis for federal agencies. Typical projects include: assistance in establishing and maintaining software development policies, standards, and guidelines; evaluation of the data management capabilities of software; assistance in developing and implementing computer modernization plans; and development of prototype network systems to meet special agency requirements.

The results of ICST research are disseminated through guides, forecasts, analyses, workshops, and symposia. ICST publishes a computer science and technology series that covers applications of new technology. In addition, ICST is experimenting with information exchange services that computer users can reach by phone using computer terminals and small computers. Another method used to exchange information is teleconferences with state and local governments and with industry users.

Special Programs

The planning, organizing, and executing of NBS research programs require extensive interaction with numerous groups to assure that NBS is developing the measurement technology needed by the country and that it is reaching the Bureau's clients. Many of these interactions are coordinated through the Associate Director for International Affairs, responsible for cooperative work with other countries; the Office of Research and Technology Applications, which disseminates the results of NBS research to industry and state and local governments; and the Office of Product Standards Policy, which, among other activities, provides guidance and services to state and local weights and measures officials.



Lois Jassie, research associate from CEM Corporation, places a Teflon vessel containing a biological sample into a microwave oven. She is experimenting with the use of microwaves to dissolve samples for analyzing elements at the trace (parts per million) level.

The laws of science and the art of measurement know no international boundaries. To achieve its goals, NBS must interact with scientists and institutions of other nations whose objectives are related to those of NBS. The Bureau's international activities include:

□ Representation of the United States in international governmental bodies such as the International Bureau of Weights and Measures, which was created by the Treaty of the Meter, and the International Organization of Legal Metrology.

□ Participation in bilateral agreements for cooperation in science and technology. NBS currently is participating in cooperative programs with Canada, the United Kingdom, Japan, Korea, China, Yugoslavia, Egypt, and other countries.

□ Provision of training and technical assistance to developing countries.

□ Interchange of guest scientists with foreign countries. In 1983, NBS hosted several hundred short-term foreign visitors, plus 171 foreign guest scientists working at the Bureau, of whom 101 persons received partial NBS support. The number of foreign scientists working at the Bureau has increased since 1980, as has the number of NBS personnel visiting or working at foreign institutions. A dramatic increase was in the number of NBS personnel traveling abroad with partial funding assistance from foreign sources: from less than 10 in 1980 to 143 in 1983.

The United States' participation in international standards organizations dates from 1875, when the United States joined other countries in signing the Treaty of the Meter. From the time of the Bureau's birth in 1901, NBS has been assigned the responsibility of representing the U.S. government in technical activities associated with this treaty. The NBS Director serves as the U.S. delegate to the quadrennial General Conference on Weights and Measures, and is a member of the International Committee of Weights and Measures, which sets policy and guides the technical work of the General Conference. NBS staff members serve on the eight technical subcommittees of this parent body.

In a similar vein, NBS cooperates with related institutions in the major industrialized countries of the world, including Japan, Germany, the United Kingdom, France, and Canada. An example of this cooperative effort is the U.S.-Japan Panel on Wind and Seismic Effects, for which NBS serves as co-chair for the United States. By sharing research results in an annual joint seminar, and by jointly determining objectives for future research, the two countries are able to work together to minimize future damage by earthquakes, hurricanes, and typhoons.

An example of the Bureau's work with developing countries is its program of providing technical assistance to Egyptian standards organizations. Sponsored and funded by the U.S. Agency for International Development, Egyptian scientists are trained at NBS, and NBS specialists are sent to Egypt to provide consultation and assistance in procuring special equipment.

A Literally hundreds of guest workers from other countries visit or work at NBS each year. Tao Guang-Yi of the People's Republic of China (PRC) works with researchers in the NBS Center for Analytical Chemistry. The Bureau has formal exchange agreements with the PRC.

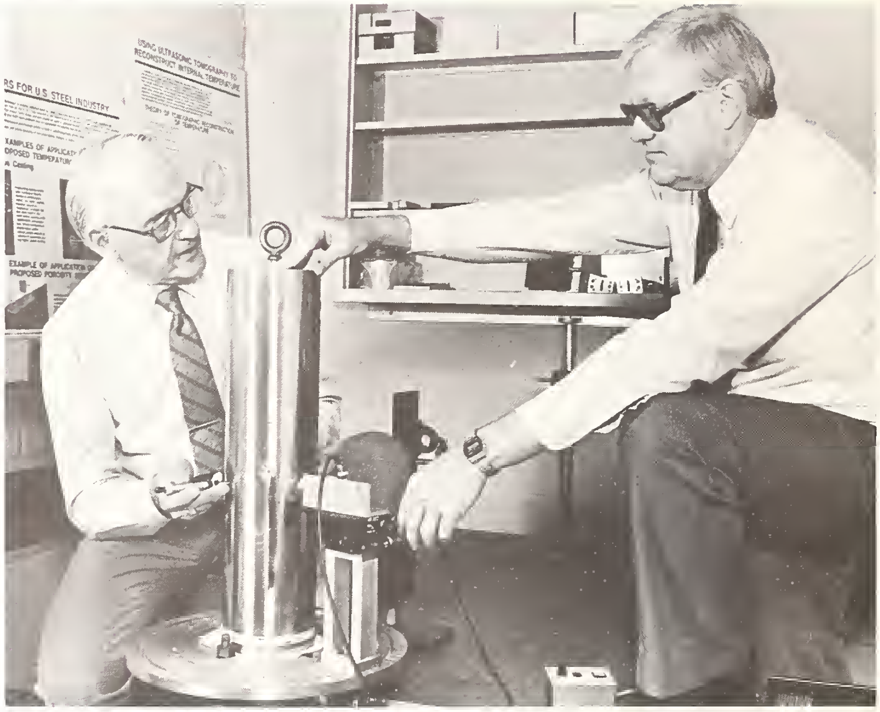
Office of Research and Technology Applications

The amount of research done by federal laboratories is significant: about $11 billion in 1984. For the nation to gain the maximum benefit from this research and technology development, the results must be actively made available to users and interested members of the public. This is the goal of the Stevenson-Wydler Technology Innovation Act of 1980, which emphasizes the active transfer of technology to solve specific problems. In response to this Act, NBS established the Office of Research and Technology Applications (ORTA) in March 1981. ORTA's program is dedicated to improving accessibility of federal technology, in particular that done by NBS laboratories, to U.S. industry and state and local governments.

ORTA joined in the formation of a Federal Laboratory Consortium (FLC), which has become a network of more than 300 of the federal laboratories dedicated to improving the availability of federal technology. In collaboration with the FLC, ORTA developed a "how to primer" as guidance for the transfer of federal technology and a *Directory for Federal Laboratories,* which has been a "best seller" among private industry and government.

To improve industrial access to the Bureau's research and services, ORTA surveyed the members of the Industrial Research Institute and the Commercial Development Association to determine the level of industrial interest in federal technology, the manner in which industry acquires federal technology, and the ways in which U.S. industry prefers to be informed of technological opportunities in federal laboratories. The findings were disseminated among federal and industrial laboratories, and NBS is using the results to better focus its communications.

One of the most popular ways to make NBS research and facilities accessible to U.S. industry is through the Industrial Research Associate program, which NBS has run since the 1920's. Under this program, industrial scientists and engineers join their NBS peers in solving technical problems which interest industry and help implement the NBS mission. Industrial interest in this program is at an all-time high: industry is currently sponsoring 155 research associates in 55 separate programs at the Bureau.



In a cooperative industry-government effort to develop process control sensors for the steel industry, NBS metallurgist Floyd A. Mauer (left) and David Rogers, American Iron and Steel Institute research associate from U.S. Steel Corporation, set up a cylindrical steel billet for ultrasonic tomographic temperature imaging measurements.

In keeping with the growing national interest in industry/government interaction, ORTA has participated in a wide range of jointly sponsored activities. The Office has arranged and participated in industry/government workshops to advise private U.S. companies of technology developments in federal laboratories that are of possible commercial interest. The Office also helped state officials to organize regional technology fairs. ORTA staff members have given speeches on subjects such as the commercialization of federal research and development at national conferences. The Office has arranged for NBS managers to brief business leaders through the Department of Commerce's Office of Business Liaison.

Through ORTA, city, county, and state government officials regularly receive information at meetings, exhibits, panels, and workshops on how the Bureau can help to solve technical problems faced by state and local governments. Subjects of particular interest which have received such attention are law enforcement product standards, fire research, building technology, and developments in computer technology.

Office of Product Standards Policy

Each year, the Bureau receives more than 6,000 requests for information regarding standards and certification and 10,000 concerning weights and measures. These requests are handled by the Office of Product Standards Policy (OPSP). Providing such information is just one of the functions of OPSP, however, which formulates and implements federal policy relating to national and international standardization, laboratory accreditation, and legal metrology. As part of this effort, the Office works with domestic, foreign, and international organizations concerned with standardization and related measurement activities. It provides guidance and services to state and local weights and measures jurisdictions and manages U.S. international legal metrology obligations.

One of the Office's ongoing activities is administration of the Federal Interagency Committee on Standards Policy. This committee produces guidelines for federal agency use of private sector standards and certification programs and for employee participation in standards activities.

Because standards are crucial to the success of international trade, OPSP provides technical analysis of trade issues and carries out U.S. notification responsibilities specified by the Standards Code of the General Agreement on Tariffs and Trade.

The Office participates in national and international activities to improve the reliability of standards-related results produced by testing laboratories. It conducts workshops on testing methods, develops proficiency testing techniques, and gathers information on laboratory performance evaluation methods. It serves as the clearinghouse on laboratory accreditation programs, and operates national voluntary programs accrediting more than 100 laboratories for testing of carpets, insulation, and a variety of other products.

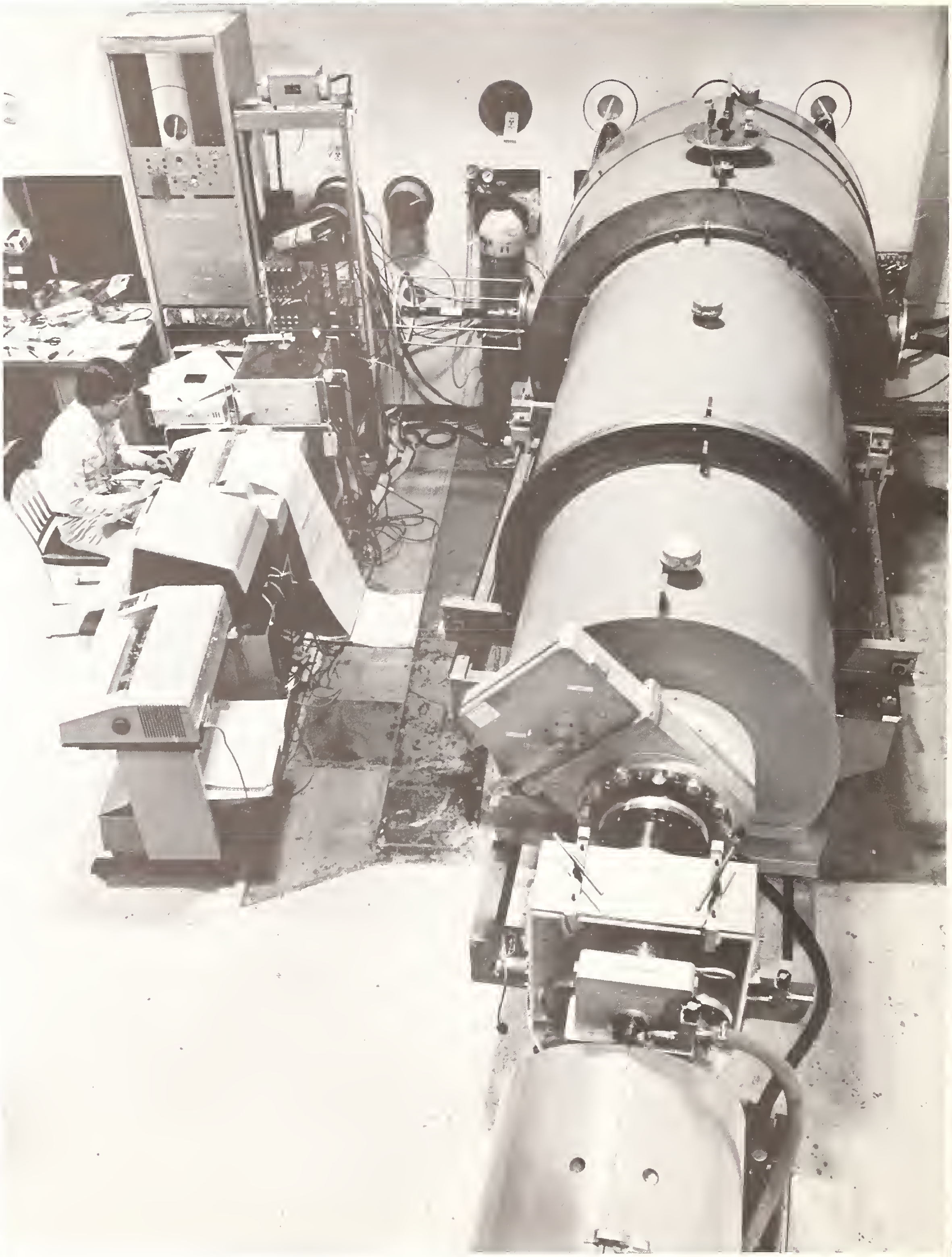
Since 1905, the National Conference on Weights and Measures has promoted uniformity of state and local requirements pertaining to retail marketplace measurements. OPSP sponsors this conference, develops procedures for evaluating the adequacy of measuring instruments used in the marketplace, coordinates training programs for measuring equipment inspectors, and supports state metrology laboratories.

The Office also manages U.S. participation in the International Organization of Legal Metrology (OIML), which aims for international uniformity of legal metrology requirements. In recent years, the United States has chaired some 24 OIML committees of interest to industry as a means of increasing U.S. exports and ensuring international recognition of U.S. measurement practices. The Office presently manages U.S. participation in more than 100 OIML committees in areas vital to the nation's trade and legal metrology interests.

Sound engineer Thomas Bartel (left) and physical engineer Douglas Thomas inspect instruments in the NBS anechoic chamber for use in an acoustical testing services laboratory accreditation program.

The Bureau's work is carried out by highly skilled staff who are often recognized as national or international leaders in their specialities. In Gaithersburg, Maryland, located north of Washington, D.C., NBS has about 2,300 full-time employees working in 26 buildings on 230 hectares (575 acres).

The Bureau also has nearly 380 full-time staffers who work in 14 buildings on 83 hectares (208 acres) in Boulder, Colorado. The Joint Institute for Laboratory Astrophysics, cosponsored by NBS and the University of Colorado, is located in Boulder, where scientists study atomic and molecular physics and astrophysics. At Ft. Collins, Colorado, NBS operates radio stations WWV and WWVB, which broadcast standard time and frequency information. Another station, WWVH, broadcasts from Kauai, Hawaii.



In an overhead view of the small angle neutron scattering (SANS) spectrometer, physicist Charles Glinka analyzes data at a computerized color-display terminal linked to a two-dimensional neutron detector located inside the 3.5-meter flight path tube behind the sample chamber.

As the nation's central reference laboratory, the Bureau houses a number of special facilities and equipment, many of which are available for use by the scientific and engineering communities—some for conducting proprietary research. For example, the NBS research reactor is a major national facility for cooperative research in materials characterization. In the past year, over 150 scientists from 15 industrial firms, 22 universities, and 18 federal agencies used the NBS reactor in projects ranging from nuclear theory to analyses of food contaminants.

An electron accelerator, capable of producing well-focused electron beams at energies between 14 and 140 million volts, is used to produce high-energy electrons, positrons, photons, and neutrons for nuclear physics research, neutron measurements and standards, analytical chemistry, and dosimetry research. As part of this facility, a 200-million-volt microtron, which will be a user facility for research in nuclear physics, is now being installed. From 1985-1990, this will be the only U.S. accelerator available for high-current, forefront nuclear coincidence experiments in the 200-million-volt energy range.

The Bureau's Synchrotron Ultraviolet Radiation Facility (SURF II) is a 280-million-volt electron storage ring that radiates synchrotron radiation which is highly collimated, nearly linearly polarized, and of calculable intensity. SURF II is used in studies in atomic, molecular, biomolecular, and solid state physics; surface and materials science; electro-optics; and chemistry and radiation effects on matter.

Among other NBS facilities are an Automated Manufacturing Research Facility, several environmental chambers, a tri-directional structural testing facility, a fire research laboratory which includes a facility for smoke movement studies, a 2-story structural steel test facility, and a network protocol testing and evaluation laboratory. In addition, an extensive instrument shops group answers specialized research needs. Shop capabilities include glass blowing, optics, and metalworking.

In fiscal year 1982, the Bureau operated on a budget of $172.9 million. Direct Congressional appropriations accounted for about 61 percent of NBS' fiscal year 1983 budget of $186.5 million, with an additional 31 percent resulting from work performed by NBS for other government agencies. The sale of NBS goods and services, such as Standard Reference Materials and calibrations, provided the final 8 percent.

Total NBS Operating Funds—All Sources
(in millions of dollars)

	FY 1983 (actual)	FY 1984 (estimate)	FY 1985 (estimate)
Measurement and engineering research and standards:	**$168.9**	**$174.6**	**$170.3**
Measurement research and standards	82.3	83.5	91.0
Engineering measurements and standards	47.3	48.4	47.2
Computer sciences and technology	12.1	14.0	8.5
Core measurement research for new technologies	18.2	19.6	20.2
Fire research	9.0	9.1	3.4
Competence and central technical support:	**17.6**	**26.1**	**30.8**
Technical competence fund	7.2	8.1	8.7
Central technical support	10.4	18.0	22.1
Total NBS	**$186.5**	**$200.7**	**$201.1**

Directory

Director
Deputy Director

Office of the Legal Adviser

Office of Congressional and Legislative Affairs

Office of Research and Technology Applications

Associate Director for International Affairs

Associate Director for Programs, Budget, & Finance

Program Office

Budget Office

Office of the Comptroller

Office of Product Standards Policy

Office of the Director NBS Boulder Laboratories

Director of Administration

EEO Support

Information Resources & Services

Public Information

Management Systems

Plant

Facilities Services

Occupational Health & Safety

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National Measurement Laboratory

Office of Standard Reference Data

Office of Measurement Services

Center for Basic Standards

Center for Radiation Research

Center for Chemical Physics

Center for Analytical Chemistry

National Engineering Laboratory

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Center for Manufacturing Engineering

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Center for Fire Research

Center for Chemical Engineering

Institute for Computer Sciences & Technology

Center for Programming Science & Technology

Center for Computer Systems Engineering

Center for Materials Science

Inorganic Materials

Fracture and Deformation

Polymers

Metallurgy

Reactor Radiation

Nondestructive Evaluation

Technical work is carried out in the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Computer Sciences and Technology, and the Center for Materials Science. These groups are supported by the Office of the Director of Administration; the Office of the Director, NBS/Boulder Laboratories; and the Office of the Associate Director for Programs, Budget, and Finance. This amalgam of people and programs forms a community dedicated to service. An interdisciplinary approach allows NBS to provide the nation with scientific measurements of high precision and accuracy, coupled with solutions for current and future technological problems.

This brochure highlights only some of the Bureau's programs. For more information on specific projects, contact the people listed in this directory. To reach members of the Gaithersburg, MD staff, dial (301) 921 + extension or write to the National Bureau of Standards, Gaithersburg, MD 20899. Bureau staff located in Boulder, CO, can be contacted on (303) 497 + extension noted in the directory, or write to the National Bureau of Standards, Boulder, CO 80303. Boulder staff members are designated in the directory with asterisks.

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Office of the Director, NBS/Boulder Laboratories

The Office of the Director, NBS/Boulder Laboratories, which is located in Boulder, CO, oversees the technical programs of the NBS/Boulder Laboratories. These laboratories conduct research in time and frequency, quantum physics, and thermodynamics for the National Measurement Laboratory and in materials science for the Center for Materials Science. The laboratories also carry out programs for the National Engineering Laboratory in electromagnetics, thermophysical properties, and fluid dynamics.

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Office of the Associate Director for Programs, Budget, and Finance

The Office of the Associate Director for Programs, Budget, and Finance plans, develops, and evaluates Bureau-level programs and formulates and carries out policies and strategies for programmatic, budgetary, and financial matters. It develops techniques for and coordinates the review of technical and overhead programs; serves as the NBS Director's staff for Bureau-level, programmatic budget formulation and execution and finance matters; and develops and maintains mechanisms to monitor planned and actual uses of resources by providing integrated, evaluated information on program progress, opportunities, and resources to the NBS Director. In addition, the Office advises management on significant changes and deviations and recommends program, budget, finance, and accounting priorities to the NBS Director.

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Office of the Comptroller
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The Office of the Director of Administration directs the management of Bureau-wide facilities, information systems, and management and administrative services including library and publications services; procurement, administrative computing, technical and public information functions; personnel, management analysis, health, safety, and security services as well as physical plant, facilities, and space management. The Office also decides on policies and plans and directs actions to assure that these services are responsive to the needs of the technical programs.

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The Center for Materials Science (CMS) provides the nation with a central basis for uniform physical measurements, measurement methods, and measurement services basic to the processing, microstructural characterization, properties, and performance of materials. It provides government, industry, universities, and consumers with standards, measurement methods, data, and quantitative understanding concerning metals, polymers, ceramics, composites, and glasses. CMS also obtains accurate experimental data on the behavior and properties of materials under service conditions to assure effective use of materials.

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National Measurement Laboratory

The National Measurement Laboratory (NML) provides the national system of physical and chemical measurements; coordinates the system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical and chemical measurements throughout the nation's scientific community, industry, and commerce. NML also furnishes advisory and research services to other government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides standard reference data and calibration services.

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The Institute for Computer Sciences and Technology (ICST) develops computer standards, conducts research, and provides scientific and technical services to aid federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in government operations in accordance with Public Law 89-306, relevant Executive Orders, and other directives. ICST manages a government-wide program for standards development and use, including management of federal participation in ADP voluntary standardization activities. In addition, ICST provides technical support in: the development of federal ADP management and procurement policies, the selection and direction of federally sponsored computer research and development, and the resolution of computer utilization issues.

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The National Engineering Laboratory (NEL) furnishes technology and technical services to users in the public and private sectors to help to solve national problems in the public interest. NEL conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical services; and develops engineering data and measurement capabilities. NEL also provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user.

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