National Bureau of Standards

U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Bureau of Standards
Ernest Ambler, Director

National Bureau of Standards
Gaithersburg, MD 20899
(301) 921-1000

National Bureau of Standards
Boulder, CO 80303
(303) 497-3000

NBS Special Publication 679
Revised April 1986

Supersedes NBS Special Publication 679
July 1984 Edition

Library of Congress
Catalog Card Number:
84-601089

CODEN: XNBSAV

Prepared by the
Public Information Division
A903 Administration Building
National Bureau of Standards
Gaithersburg, MD 20899
301/921-3181

Contents

NBS Gaithersburg laboratories.

NBS Boulder laboratories.

Foreword

Looking at where we are today and where we want to be—both for the National Bureau of Standards as an institution and the nation as a whole—one basic fact keeps coming to mind. Our knowledge and technology are this country's major asset and advantage, both in ensuring domestic strength and health and in competing with other nations. That means we must make the most of our research resources—our equipment as well as our people. Cooperation in research and development is one obvious answer. This is something that we have been doing since NBS was established in 1901 as the nation's physical sciences, measurement, and engineering laboratory. As an agency of the Department of Commerce, NBS has made cooperation with industry a way of doing business, and it has served as a model for cooperative arrangements which are becoming more popular today as industry, universities, and government form research partnerships all across the country. We are using cost-sharing arrangements with others whenever and wherever possible, and this brochure provides a number of examples of our cooperative endeavors.

But cooperation in research and development will not be enough. Doing the research is only half the battle. The results of this research must be incorporated into new ideas, new processes, and new products. New technology must diffuse throughout our industries, and diffuse more rapidly than it does now. We need to think about cooperation in the transfer and diffusion of technology in the same way that we have addressed cooperation in research and development.

NBS is taking a lead here, too. We spend a good deal of time with visiting scientists, engineers, and managers from industrial firms. About 200 of these specialists work at NBS each year as research associates, with their sponsoring organizations paying their salaries. They come to NBS to conduct research, but they also come to learn how they can put our work to use.

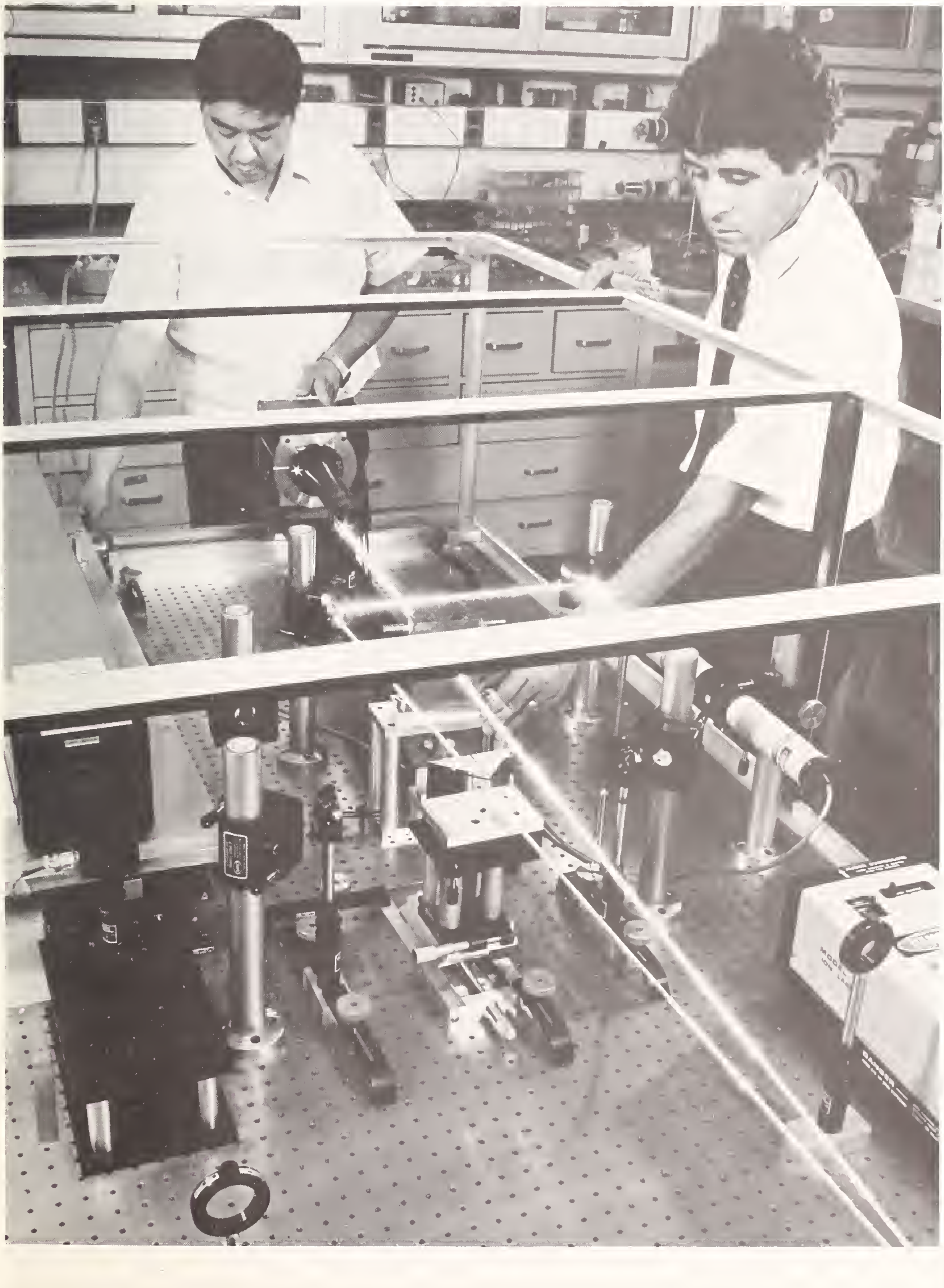
We have taken other steps to encourage technology transfer, by holding literally hundreds of conferences, workshops, and seminars each year, by encouraging our staff to publish results of their work as broadly as possible, and by working actively with professional and technical societies and standards organizations. We are using videotapes to explain our research so that others can take advantage of our work. We now are making many of our databases and experts available through computer networks, and we are considering expanding this service so that industry will be able to tap into even more of our information.

We will continue to look for new outlets, new ways to disseminate our research results and services throughout the U.S. economy. I am convinced that as a nation we must all join together to develop creative ways to transfer technology, just as we now seem to be developing the capacity to conduct research together. There is not much choice if we want this country to be competitive in a changing world economy.

Ernest Ambler.

Ernest Ambler
Director

Institute for Materials Science and Engineering



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 NBS Institute for Materials Science and Engineering (IMSE). The Institute provides measurements, data, standards, reference materials, and other technical information regarding materials to industry, government agencies, universities, and other scientific organizations. IMSE research supports development of new and improved materials which can be used safely, efficiently, and economically.

To determine how polymers behave during processing, polymer scientists Charles Han (left) and Isaac Sanchez use a forced Rayleigh scattering instrument to study phase separations in polymer blends.

Among the materials of the future are advanced high-performance ceramics, which have unique properties that make them well-suited for use in electronics, sensors, cutting tools, biomedical devices, and advanced heat engines. The Institute for Materials Science and Engineering 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 advanced ceramics. Other researchers are examining various properties of finished ceramics and developing a unique program to measure their high-temperature wear characteristics.

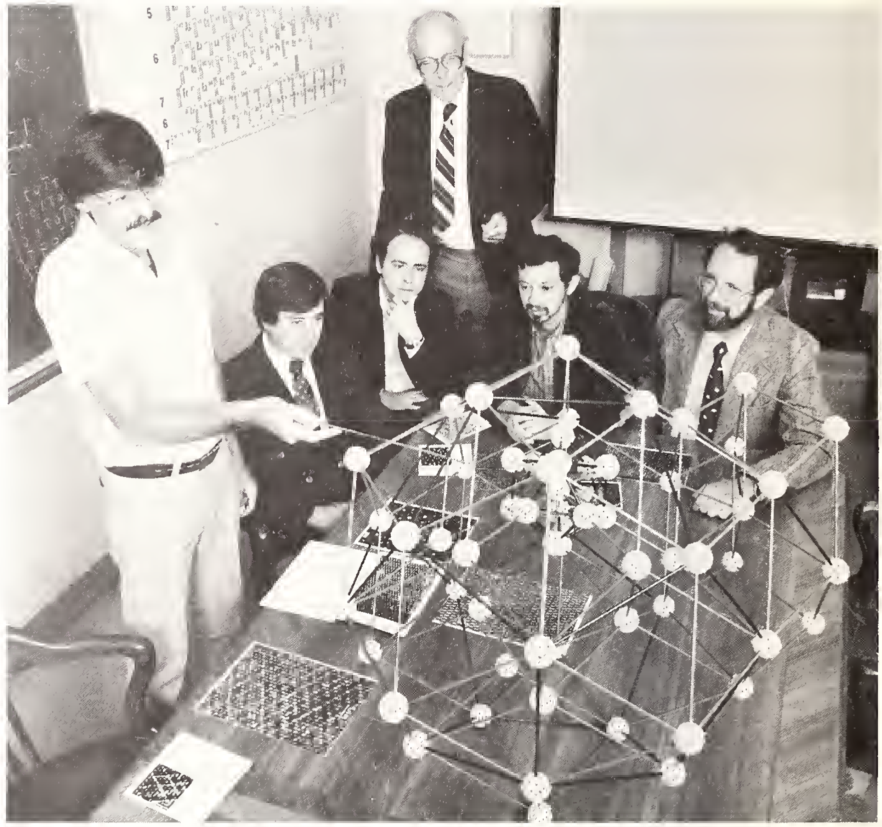
Another class of advanced materials is polymer-matrix composites. Polymers reinforced with high-strength fibers such as graphite or glass have outstanding strength and stiffness for their weight. They are now found extensively in aerospace applications and will be used increasingly in automobiles and construction. The Institute is developing measurement methods to investigate and control composite processing to aid industry in controlling product quality while increasing production efficiency. IMSE is also investigating the mechanisms by which fiber-reinforced composites fail. The test methods and data 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 U.S. synthetic polymer industry is the production of polymer blends, which are mixtures of two or more polymers. These materials are particularly useful as engineering plastics designed to replace metals in products such as gears, pumps, and machine housings. When a polymer blend is processed, the component polymers separate into phases of different compositions, affecting many of its useful properties. The Institute's polymer blends processing program is focused on measurement methods, data, predictive models, and general theoretical descriptions that will form a scientific basis for optimizing control of blend processing. Researchers will use the small-angle neutron scattering (SANS) facility at the NBS research reactor to study the mechanism by which polymers separate from each other.

In addition to advanced ceramics and polymers, electro-optic materials help perform many of the dream feats of forward-thinking engineers. IMSE 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 made of advanced materials will 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 Institute's NDE program is developing the science base, measurement methods, and standards that will be needed to use NDE for process control in automated manufacturing plants.

The trend toward automated manufacturing is also expected to affect welding. NBS collaborated with industry to establish the American Welding Institute (AWI), which will study and disseminate information about advanced welding technology. One of AWI's high-priority programs will focus on automated welding. NBS will study how flaws are formed during this welding process by conducting controlled solidification experiments in



Discussing quasicrystal structures in alloys are (l. to r.) Daniel Shechtman, Israel Institute of Technology; Frank Biancaniello, NBS; Denis Gratias, National Science Research Center, France; John Cahn, NBS; Leonid Bendersky, Johns Hopkins University; and Robert Schaefer, NBS. The discovery of quasicrystal structures in materials challenges a 100-year-old theory of crystallography, and the existence of quasicrystals may make it possible to produce materials with radically different properties.

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.

To provide the science base for the materials of the future, the Institute organizes its research around four technical "themes": materials processing, microstructure characterization, properties, and performance. Scientists from each IMSE division plan and coordinate activities in each of these areas.

For example, there is a coordinated effort within the Institute 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 Institute, 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 Institute's phase diagram work is carried out cooperatively with the American Society for Metals, the American Ceramics Society, and the Society of Plastics Engineers. Experimental results for metals, ceramics, and plastics are compiled and evaluated by authorities in 35 data centers throughout the world. In addition to providing phase diagram data, the Institute carries out experimental and theoretical research in support of the data program.

An example of the Institute's activity in microstructure characterization is the work carried out at the SANS facility. This facility 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/Naval Research Laboratory beam lines at the National Synchrotron Light Source at Brookhaven National Laboratory. Researchers will use real-time topography for kinetic studies of solidification; small-angle x-ray scattering to measure 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 as well as the wear of lubricated surfaces. They develop measurement methods for wear-resistant materials and provide reference materials for calibrating wear test equipment. Institute scientists are investigating the erosion of refractory materials by experimentally observing the effects of single-particle indentation. Their research has also shown that the wear of a polymer-matrix composite is influenced by ambient liquids which soften the matrix.

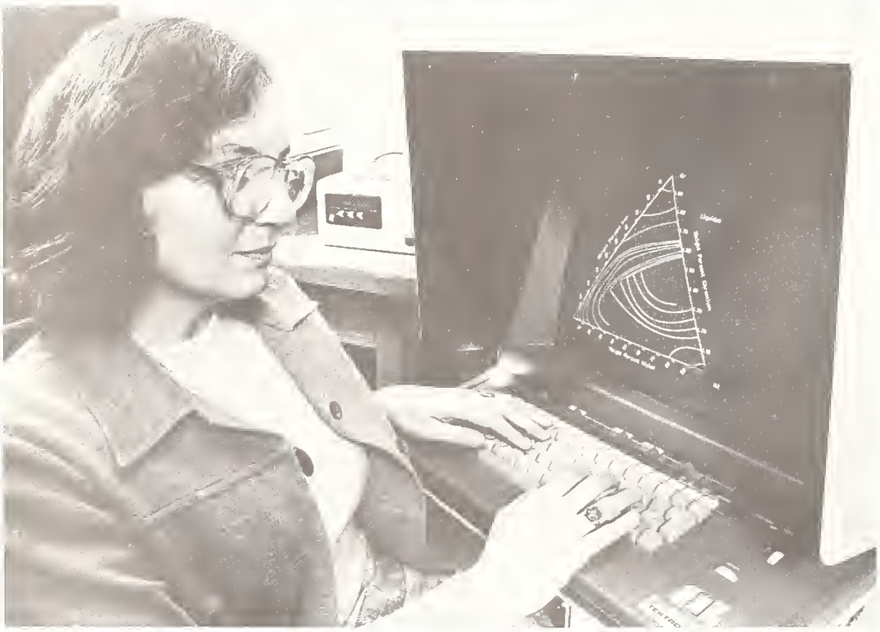
Performance is a crucial characteristic of all materials. A major materials performance problem is environmentally induced cracking. For example, stress corrosion can cause cracking in engineering alloys; hydrogen embrittlement can crack high-strength steels; cracking in glasses and ceramics is often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

As part of its general program, the Institute operates several large facilities, which are used extensively by guest scientists and research associates from academia and industrial research institutions from across the country. 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 Institute has led an effort to construct hard radiation branch lines at the National Synchrotron Light Source. This facility permits unique experimental work in materials characterization.

The Institute is also developing 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

Chemist Kay Hardman-Rhyne conducts small-angle neutron scattering experiments at the 20-megawatt NBS research reactor to observe crystal structure and microdefects in ceramics.



Metallurgist Joanne Murray displays a typical alloy phase diagram. Such diagrams are used in the development of new materials and the design of new materials processes.

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.

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

Many of the Institute's prominent research activities are carried out in cooperation with industrial organizations, which fund 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; 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 supplies 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 58-year-old cooperative program partly supported by the National Institute of Dental Research.

☐ The American Welding Institute (AWI)—establishment of the AWI/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 NBS 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.

For over a century U.S. factories have led the world in production of material goods. From appliances to aircraft, the domestic manufacture of products having discrete parts annually adds $200 billion to the gross national product. This keystone of the U.S. economy, under major challenge from foreign competitors, operates on a system of measurements and standards supported by the NBS Center for Manufacturing Engineering (CME).

Through its measurement services, the Center provides manufacturers with access to the national standards of length, force, and related quantities such as surface texture, acceleration, and acoustical power. The Center's standards activities give industry the technical support it needs to develop voluntary standards for mechanical manufacturing. To extend and improve measurements and the technical basis for standards in these areas, CME conducts research in measurement science, precision engineering, robotics, and software for automated manufacturing systems.

A focal point for the Center's measurement and standards work for the "factory of the future" is the Automated Manufacturing Research Facility (AMRF). Scheduled to be fully operational by the end of 1986, the AMRF is a research form of an advanced flexible manufacturing system made up of robots and machine tools working together under computer control.

A cooperative industry-university-government project, the AMRF has received substantial funding from the U.S. Navy, and $3.5 million in equipment has been loaned or donated by industry. Thirty-eight research associates from industry and researchers from 20 universities work collaboratively with NBS staff on various aspects of the AMRF.

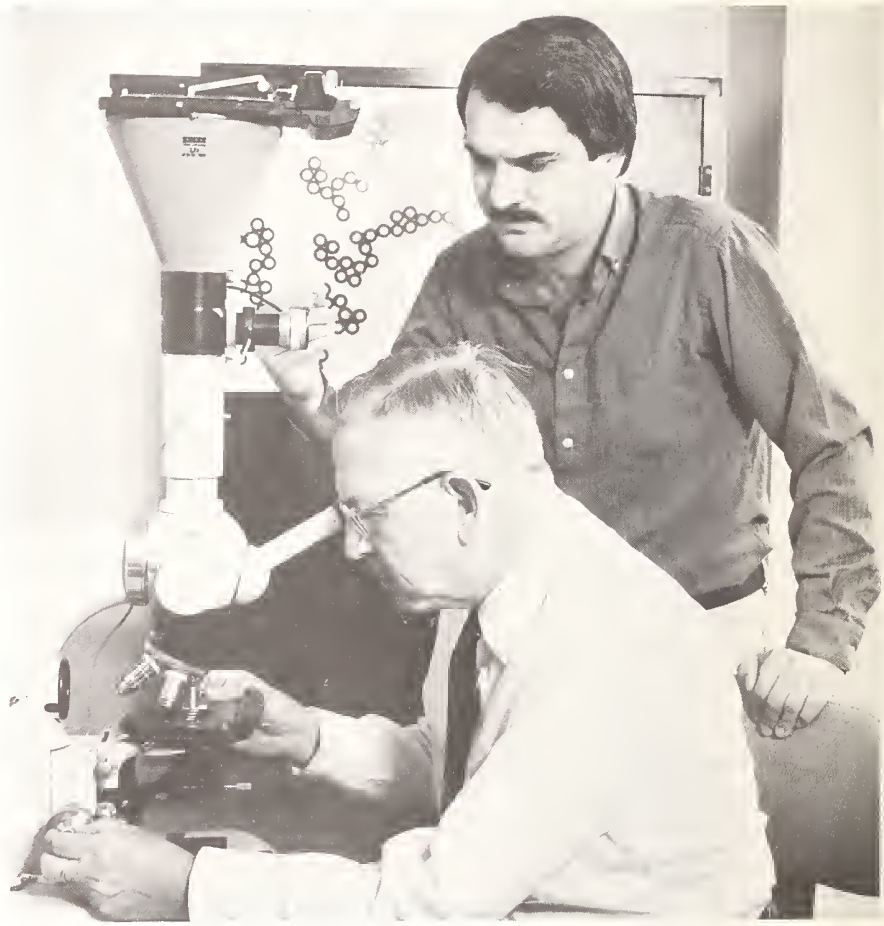
The AMRF consists of a number of work stations, which typically have a numerically controlled machine tool, a robot, and a computer controller. The work stations are organized into cells, which are supplied by a materials handling system and controlled through a computer network. Upon completion, the AMRF will be capable of carrying raw metal material through a series of machining operations to produce a finished, inspected part from a computer design of that part, all under automatic computer control.

In the AMRF, the Center is addressing two critical problems in computer-integrated manufacturing, the basis of the factory of the future. The first problem is to get robots, computers, and machine tools from different manufacturers to communicate and work together in an integrated system. The second is to find a means for carrying out quality control in a fully automated factory environment.

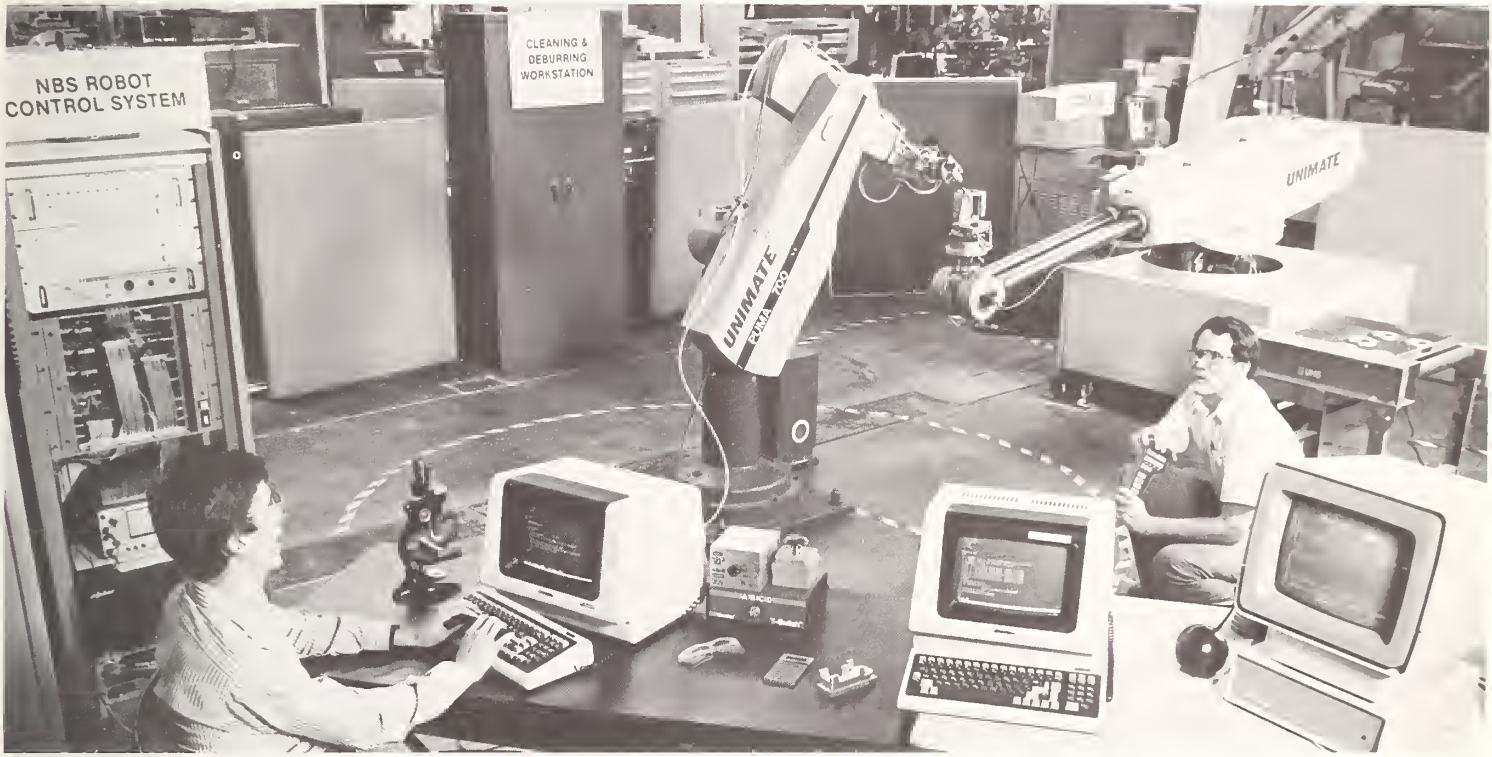
A solution to the first problem is the development of interface standards for the many devices, including the robots, machine tools, sensors, controllers, and computers, which make up an automated factory system. Such standards permit manufacturers of automated equipment to design and build interfaces for their products that protect the proprietary aspects of these products while allowing them to work with those of other manufacturers.

An important example of such an interface standard is the Initial Graphics Exchange Specification (IGES), which was developed by an industry-government coalition led by NBS and adopted by the American National Standards Institute, a private voluntary standards organization. IGES allows the transfer of part-design data between computer-aided design (CAD) systems from different vendors. Every major producer of CAD systems is now using IGES, and organizations such as the U.S. Navy, the National Aeronautics and Space Administration (NASA), and General Motors are writing IGES into procurement specifications.

Within the AMRF, NBS has developed and implemented a hierarchical control system with associated software and database systems as a basis for an entire family of standard interfaces. In such a computer control scheme,



A The first space-made product to be offered for sale was NBS Standard Reference Material 1960, 10-micrometer polystyrene spheres that can be used to improve microscopic measurements made in electronics, medicine, and other high-technology areas. Physicists Thomas Lettieri and Arie Hartman (seated) used a technique called "center distance finding" to make very accurate measurements of the spheres.



Research engineers Karl Murphy (foreground) and Rick Norcross study the performance of an experimental parts-deburring station at the NBS Automated Manufacturing Research Facility.

the data processing and computation necessary to accomplish a task is split into discrete levels, with the output of higher levels being used as input commands for lower levels, and lower levels furnishing status reports for higher levels. Each level in the hierarchy accepts tasks from the level above it and splits those tasks into subtasks that are parceled out to the levels below it. Such systems tend to be fast and efficient, because they can be designed so that decisions are made no higher in the architecture than necessary.

Center researchers also are working on a solution to the second problem, how to carry out quality control in a fully automated factory. They are devising the means to automatically monitor and control the manufacturing process so parts are made right the first time. Within the AMRF, researchers have designed and implemented measurement techniques for such process control.

The turning center workstation in the AMRF, for example, employs a microcomputer-based error compensation system for real-time control of the machining process. This system calculates the positioning error associated with a particular location of the cutting tool based on prerecorded data, monitors the temperature of various parts of the machine tool, and, through its automatic tool-setting station, checks the position of the tool's cutting edge relative to the machine's coordinate system. All three elements are used by the system to achieve high-accuracy in part diameters without dependence on post-production inspection.

At the same time that it gives measurement and standards support for industry's development of computer-integrated manufacturing to meet a major foreign challenge, the Center also provides 27 percent of the total volume of NBS calibration services and conducts advanced measurement research in all its areas of responsibility.

For example, Center scientists have developed high-resolution electron and optical techniques for the calibration of the dimensions of industrially important microscopic objects. They are using these techniques to calibrate billions of tiny polystyrene spheres made aboard a NASA space shuttle flight and now being sold as an NBS Standard Reference Material. The spheres, the first product manufactured in space to be offered for sale, will be used to improve microscopic measurements made throughout the economy in electronics, medicine, and other high-technology areas.

In another project, researchers from CME and the Center for Radiation Research have developed a technique for observing simultaneously the magnetic character of a surface and its physical structure over dimensions as small as 100 angstroms. Combining scanning electron microscopy with polarization analysis, the technique can be used to study important magnetic materials such as high-density magnetic media for computers. Collaborative studies with industrial researchers are planned.

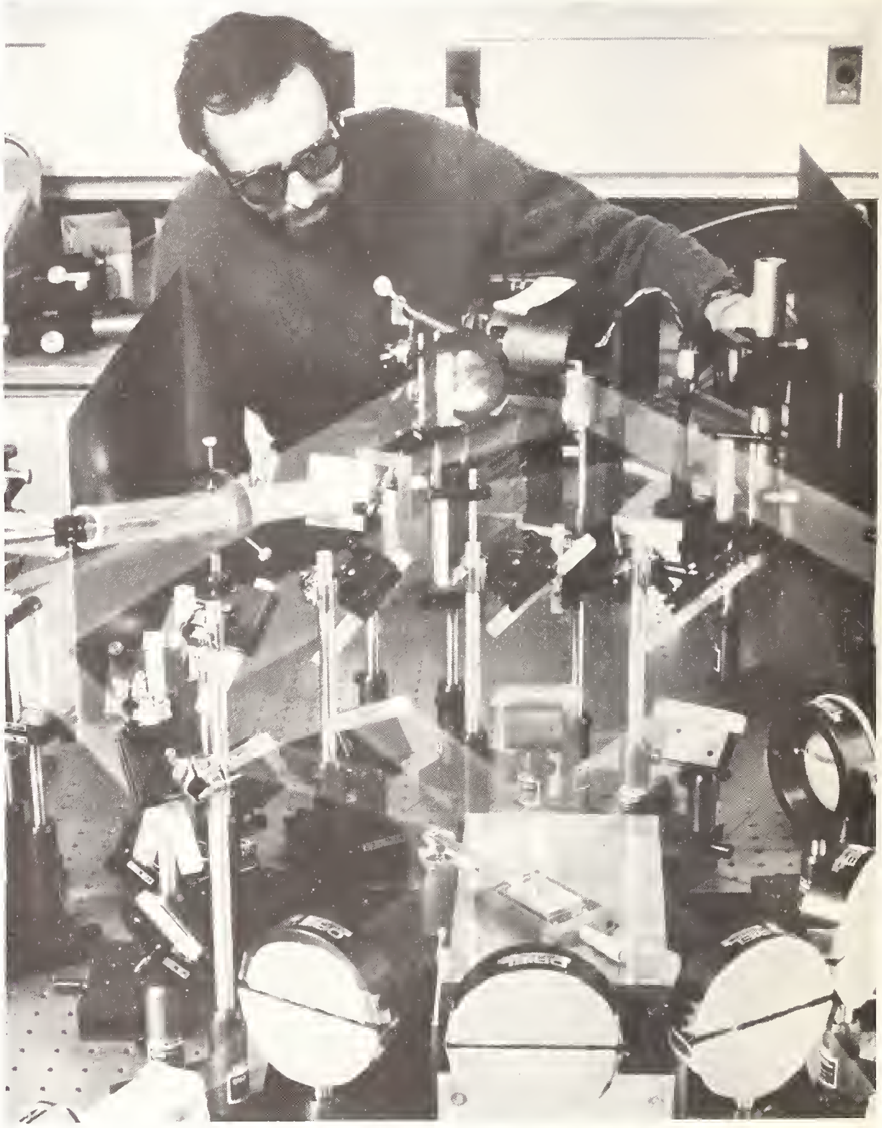
Center for Chemical Engineering

The NBS Center for Chemical Engineering (CCE) provides measurement methods, traceability to national measurement standards, fundamental chemical engineering science, and reliable evaluated data and databases. This work helps to strengthen the competitiveness of U.S. industry in the world market, to assure equity in domestic and international trade, and to provide industry with the engineering basis for improved design and control of chemical processes. Through research programs in chemical process metrology, thermophysical properties of fluids and solids, and chemical engineering science, Center researchers develop experimental and theoretical techniques to provide needed measurements and databases. The results of these efforts include calibration and other measurement services, measurement practices and standards, and engineering data.

The CCE staff work closely with trade associations, steering committees, and consortia of the chemical, petrochemical, plastic, gas, petroleum, and paper industries. Their research also contributes to the science base of the rubber, metals, glass, food, pharmaceutical, and related industries as well as the chemical engineering science programs of other government agencies.

As the prices of natural gas and oil have risen, 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. CCE's mass flow facility in Boulder, Colo., has the capability to test measurement systems with pipelines up to 15 centimeters in diameter. A large heat exchanger is used to vaporize liquid nitrogen for gas flow tests at room temperature and high pressure. The gas is recondensed and weighed as a liquid, providing better than normal accuracy. The Gas Research Institute is sponsoring evaluation of orifice meters using this reference measurement technique. In a companion program supported by the American Petroleum Institute, CCE researchers at NBS in Gaithersburg, Md., are using a water test fluid to improve liquid and gas flow measurements made by orifice meters.

An industry-government consortium of users and manufacturers is sponsoring research at the Center on vortex shedding flowmeters, a device that measures a wide range of flow rates. Researchers are designing computer flow models as well as advanced laser techniques to define the meter flow field. Their work will lead to a fundamental understanding of this type of flowmeter and will give industry the basis for designing and using improved vortex flowmeters.



Laser tomography is used by mechanical engineer Steven Ray to observe high-temperature reactions important in a number of industrial processes such as power and steam generation, recovery of materials, and materials processing.

In response to the long-range needs of the biotechnology industry, the Center has initiated and sponsored workshops in collaboration with Lehigh University on "Process Measurement for Biotechnology" and "Standardization Problems in the Design and Scale Translation of Bioreactors." These workshops complement a small focused program in the Center on bioreactor measurement and bioseparations.

Center researchers are collaborating with an industrial consortium of 13 private firms to develop the properties needed to exploit supercritical extraction separation techniques. They are working to develop the equations-of-state and phase equilibria properties of supercritical

Using an ellipsometer, physicist James Schmidt measures the thickness of extremely thin liquid layers adsorbed or flowing on solid surfaces. The thickness data are then used in the design of more efficient heat exchangers and methods of oil extraction.

fluids (such as carbon dioxide) which can be used as solvents 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 may reduce significantly the cost of chemical separations in many future industrial processes.

Improved energy and equipment efficiencies could result from the use of various types of membranes to separate and recover desired products from fluid chemical mixtures. The Center is conducting both theoretical and experimental studies to provide reference data and methods of measuring the performance of different types of membranes. CCE researchers are modeling immobilized liquid membranes, ion exchange membranes, and emulsion liquid membranes to determine the effects of such factors as geometry, time, solubility constants, diffusion coefficients, and forward and reverse reaction rates on mass transfer rates.

To minimize expenditure on high-price fuel, U.S. industry wants to obtain 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 studying particle formation and growth at high temperatures. For example, 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 are aimed at improving the performance of boilers, dryers, and furnaces.

The International Association for the Properties of Steam has endorsed steam tables developed by NBS and the National Research Council of Canada. The tables offer an unprecedented range of temperatures and pressures for scientific and general use. The revised steam tables will help scientists and engineers in designing industrial and chemical processes; exploring for petroleum and minerals; designing heat transfer systems, boilers, and turbines; and in harnessing geothermal energy.

CCE researchers correlated all existing quality thermodynamic data on water and steam with a wide-ranging equation of state now known as the Haar-Gallagher-Kell equation, on which the steam tables are based. The equation establishes a formulation that provides scientists and engineers with thermodynamically consistent data on the properties and density of water from the triple point to 2500 °C and from zero pressure of an ideal gas to more than 20 kilobars.

Other important thermophysical properties data are being provided to industry through new correlations, equations, models, and transportable computer programs. These programs predict the viscosity, density, and thermal conductivity of various pure fluids and fluid mixtures. Additional work is in progress to extend the range of these predictive codes to fluid mixtures of over 100 components and to include phase equilibria properties. NBS is making these evaluated properties-predictive computer codes available to the public through the NBS Office of Standard Reference Data.

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 the fire protection community to reduce both these losses and the cost of fire protection.

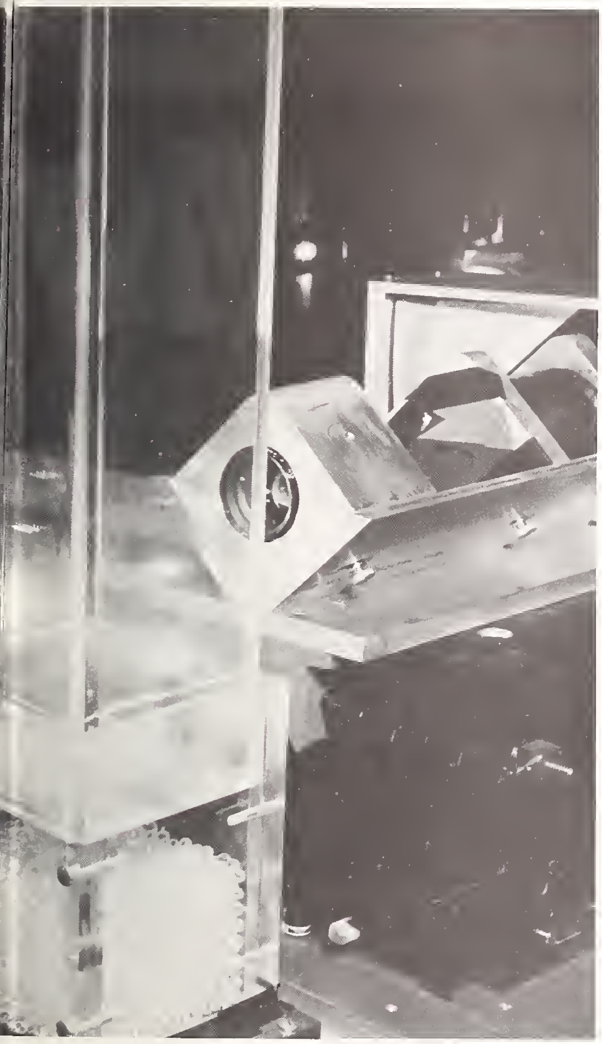
By improving the understanding of the chemistry and physics that take place during combustion and by developing accurate computer models of fire hazards, the Center provides technical information to voluntary standards organizations, engineering and design communities, building industry, fire service 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 that converts 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 form 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. 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, Center 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 helping to explain the lethality of fire gases.

Center researchers are also creating ways to predict the precise contribution of materials to a fire's severity. Their 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 method is now used to measure the heat given off by furniture and wall coverings during full-sized room fires. A Center-designed instrument, the cone calorimeter, operates on the same principle and shows exceptional

To study how turbulence mixes fuel gases with air, thereby feeding a fire, research chemist William Pitts designed a unique camera that works with other technologies, including a laser, to help in the research.



promise for predicting the large-scale rate of heat release using small samples.

Predicting fire growth requires a fundamental understanding of elemental fire processes, such as flame spread, and the characterization of fire-induced flows. Researchers have developed methods 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 ventilated air is also predictable. Ventilation and the rate of heat release of the burning materials 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 in experimental work 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 simulate 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.

Several prediction models are already available. In one model, 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 occupants of the room have to escape.

Another model, called FAST (Fire and Smoke Transport Model), can be used to determine the smoke level and temperature in a multiroom building with a fire in one room.

The Center recently set up a Fire Simulation Laboratory where scientists and engineers from the fire protection community can see demonstrations and obtain "hands on" experience with various fire models. Researchers also use the laboratory to modify models for particular applications.

More widespread and proper use of sprinkler systems also 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. It predicts the response time based on characteristics of the fire and the location and thermal properties of the sprinkler 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 25 grants are awarded to universities and research institutes annually.

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.

Center for Building Technology

Over two-thirds of the nation's fixed reproducible wealth is invested in constructed facilities. Moreover, the construction industry is one of the nation's largest, and constructed facilities shelter and support most human activities. The quality of these facilities affects the safety and quality of life of the American people as well as the productivity of U.S. industry.

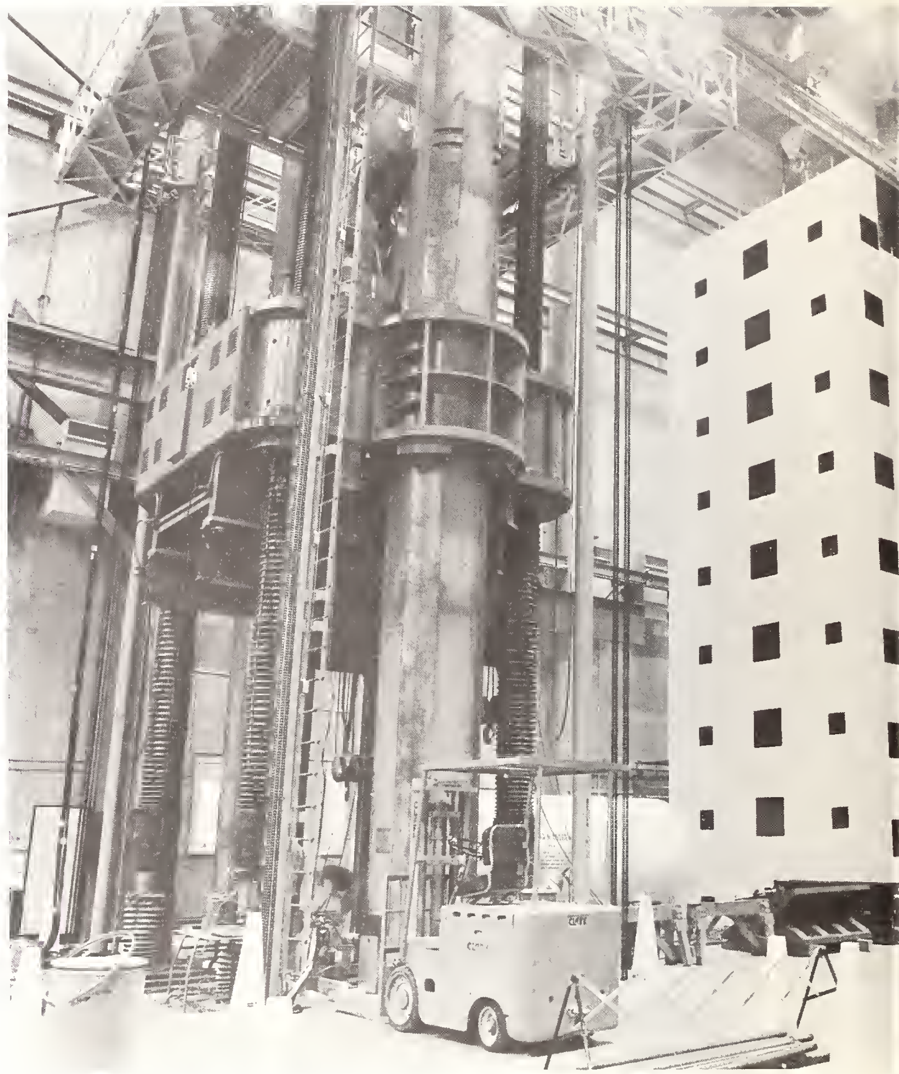
The NBS Center for Building Technology (CBT) increases the usefulness, safety, and economy of buildings through the advancement of building technology and its application to the improvement of building practices. CBT conducts laboratory, field, and analytical research to develop technologies for the prediction, measurement, and testing of the performance of building materials, components, systems, and practices.

Center researchers concentrate their efforts in computer-integrated construction, structural engineering, earthquake hazard reduction, building physics, building materials, and building equipment. They carry out their work in sophisticated and comprehensive laboratory facilities, which include: a six-degree-of-freedom structural testing facility, a large-scale structures testing facility, environmental chambers, a guarded hot plate, a calibrated hot box, a five-story plumbing tower, and anechoic and reverberation chambers.

CBT provides technical support and information to a number of voluntary standards groups such as ASTM; the American Concrete Institute; the American Society of Heating, Refrigerating and Air Conditioning Engineers; the American Society of Civil Engineers; and building code organizations. While it contributes to the development of voluntary product standards, the Center does not promulgate or enforce standards or regulations. Through this work, the Center helps eliminate technological market barriers of the construction industry and reduces the burdens of unnecessary or ineffective building regulations while maintaining safety.

CBT represents the United States in several international building research and standards organizations including the International Council for Building Research, Studies and Documentation; the International Union of Testing and Research Laboratories for Materials and Structures; and the U.S.-Japan Panel on Wind and Seismic Effects. These efforts contribute to U.S. use of foreign research accomplishments and the international competitiveness of U.S. building technology.

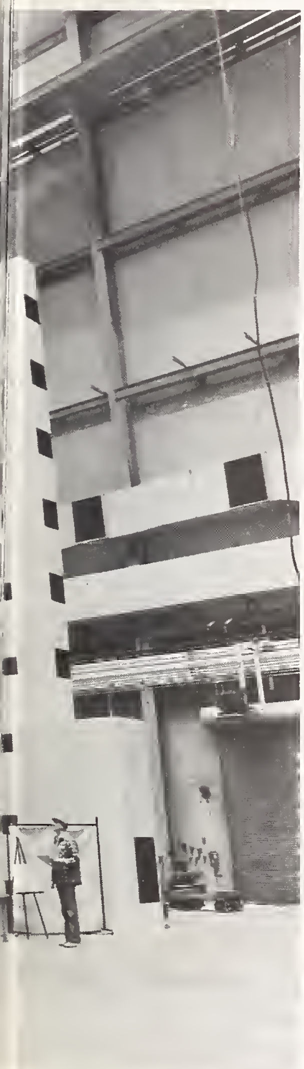
Much of the Center's research is done in cooperation with, or for, other federal agencies such as the Department of Energy, the General Services Administration, the Federal Emergency Management Agency, the Occupational Safety and Health Administration, and the White House. In addition, each year about 70 researchers from international and U.S. universities and industries join CBT staffers in cooperative programs.



This computerized, large-scale structural test facility is being used by NBS researchers to test how full-scale bridge and building components perform during earthquakes.

As an impartial third party, the Center is called upon to investigate the physical causes of major building and construction failures, such as the walkway collapse in the Kansas City Hyatt Regency in 1981 and the East Chicago, Indiana, ramp collapse in 1982. The results of the Center's investigations are promptly and publicly reported to help preclude recurrences.

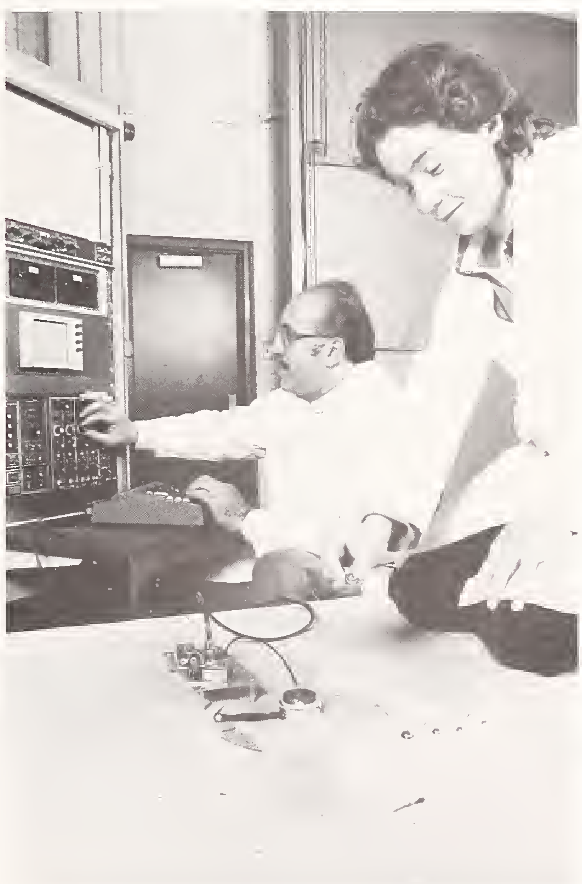
More of the Center's research, however, is aimed at developing improved building practices so that such tragedies do not occur. For example, Center engineers are working on ways to determine when poured concrete is strong enough for construction formwork to be removed. They have developed a standardized test for determining



Civil engineer Nicholas J. Carino and co-op student Mary Sansalone from Cornell University are studying a technique known as pulse-echo detection to determine whether it can be used reliably to detect flaws in concrete structures such as buildings or bridge columns.

concrete strength and a computerized method of analysis, both of which are being considered by ASTM for adoption as voluntary standards. Important from both safety and economic standpoints, these tools will help a builder remove the formwork as soon as possible, without risking the workers' safety.

Center researchers have designed and constructed a computerized facility to test how full-scale bridge and building components will perform during earthquakes. In a project sponsored by the National Science Foundation, the Federal Highway Administration, and the California Department of Transportation, CBT researchers are testing 30-foot-high bridge columns under conditions simulating earthquake forces. They are also running tests on columns one-third and one-sixth that size. By comparing the results of both tests, the researchers will be able to determine whether the behavior of small-scale



bridge columns can be used to predict that of full-scale columns. They will use this information to evaluate and refine computer models that predict how structures perform during earthquakes, enabling the building community to design safer buildings and bridges with fewer expensive physical tests.

To help the construction industry respond effectively to the opportunities and challenges offered by advanced computation and automation, CBT is investigating their application to performance prediction and measurement technology. For example, increases in computer power and reductions in computing costs will lead to "smart buildings" with integrated, automated control systems for greater usefulness, safety, and economy in operation. Center researchers are developing and verifying minute-by-minute simulations of the performance of building control systems to help owners, designers, manufacturers, and contractors set up economical and reliable automated control systems for buildings.

Computer technologies will make possible measurement advances in building diagnostics, quality assurance, and prediction of building behavior. CBT is, for example, developing modeling techniques for the microstructure of cements that will allow prediction of how cement ingredients, mixing, placement, and curing will affect the strength and durability of concrete structures.

Center researchers are formulating three-dimensional, dynamic computer simulations that will predict heat, air, moisture, and pollutant movements in buildings. These techniques will help improve energy conservation, use of solar energy and natural ventilation, smoke control for fire safety, and indoor air quality.

Other computer simulations are being developed and verified for dynamic tests of the thermal performance of walls. Improved test methods will provide more accurate assessments of effects of wall mass, air and moisture movements, and multi-dimensional heat, air, and moisture flow at junctions of building elements on thermal comfort and energy efficiency.

To provide the technical bases for substantial increases in the efficiency of innovative heat pumps and air conditioners, Center researchers are developing and verifying computer simulations of heat transfer properties of mixed refrigerants and refrigeration cycles.

Center researchers are also working with leading construction standards organizations to adapt artificial intelligence technologies to the needs of the building community and to supply the advanced performance prediction and measurement technologies that will be needed to realize the potential of expert systems for construction.

Center for Applied Mathematics

In virtually 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.

While schooled in theory, NBS mathematicians have their feet firmly planted on the ground of application. 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. Center researchers are aided in their work by visiting scientists from industry, government, and universities.

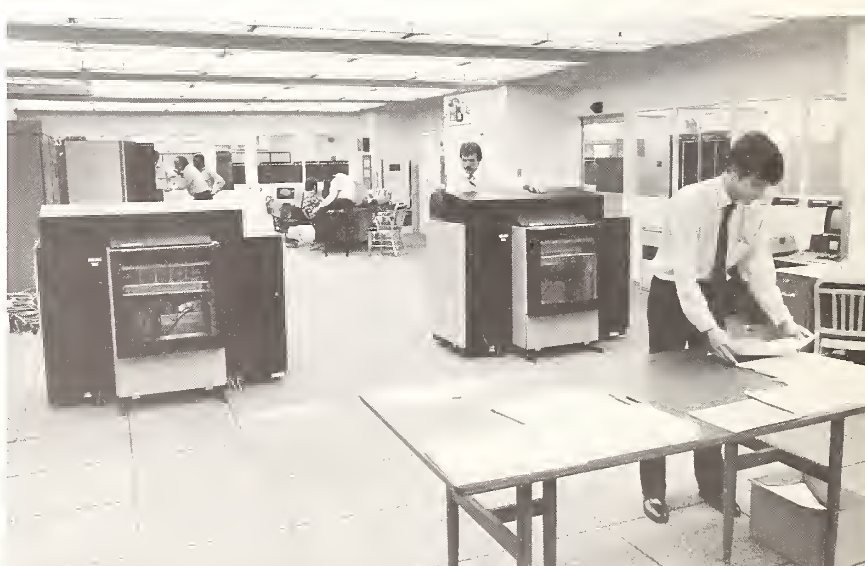
In providing its support service, the Center's professional staff interacts and collaborates with the NBS scientific staff to solve a wide variety of scientific and engineering problems. This work calls for research into computing methods and for computer-intensive studies in the applied mathematical sciences. Current applications involve all aspects of modern scientific computing, including advanced programming languages, knowledge-based systems, interactive software tools, color graphics, and supercomputer algorithms.

The Center also operates the central computing facility—a CDC Cyber 205 supercomputer with a Cyber 855 "front end"—which serves both the NBS Gaithersburg and Boulder sites as well as the National Oceanic and Atmospheric Administration's Environmental Research Laboratories and the National Telecommunications and Information Administration. In addition to managing the central facility, Center staff run local area networks in Gaithersburg and Boulder and provide engineering and software support for distributed computing.

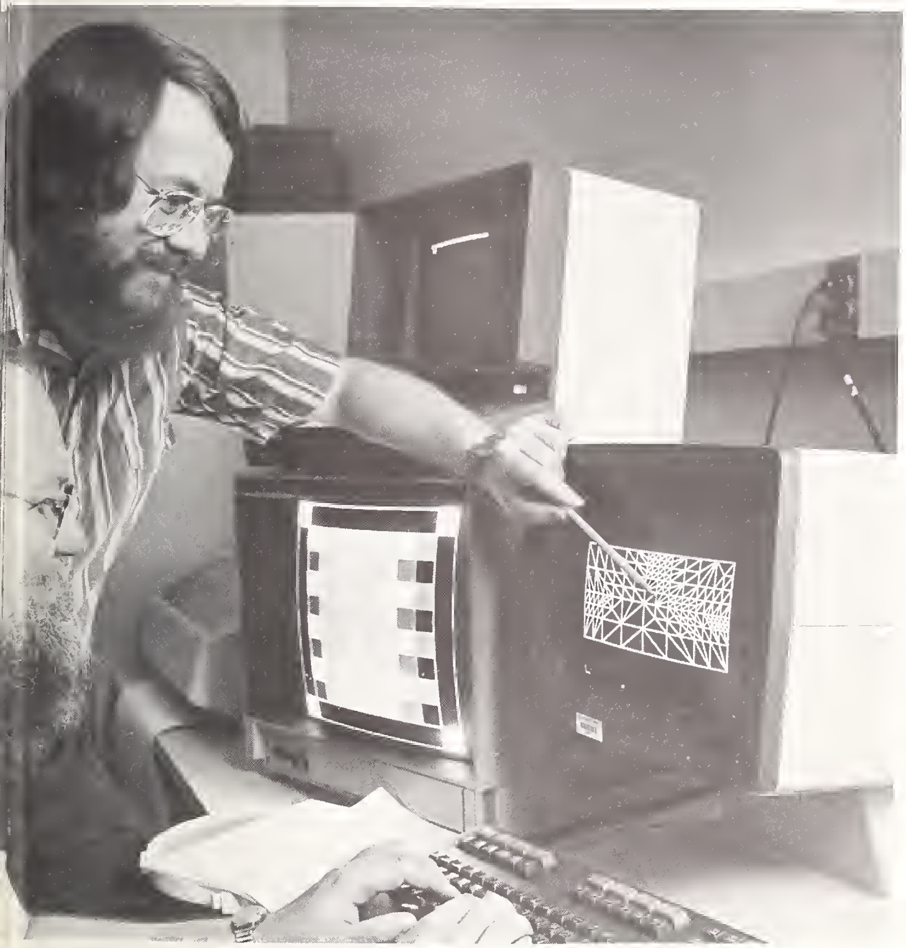
One recently completed project helps fire researchers understand how indoor fires behave. CAM, in collaboration with the Center for Fire Research, developed, tested, and validated a mathematical model of fluid motion and smoke evolution patterns for an indoor fire. Researchers tested calculations based on both two- and three-dimensional models.

The high-resolution dynamic graphics display system used in this project allows researchers to observe the swirling motion of heated air on a computer screen. The system, also permits 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 introduction, the Center's graphics display system became popular throughout NBS, providing new ways to study a variety of phenomena. The Institute for Materials Science and Engineering used it to develop dynamic displays of polymer chains and molecular structures. The Center for Chemical Engineering used it to simulate molecular behavior in a dense liquid, taking into account local interactions between very large numbers of atoms in order to achieve realistic answers.



A supercomputer facility has been installed at NBS to meet its large-scale scientific computing needs as well as those of the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration and the Institute of Telecommunication Sciences of the National Telecommunications and Information Administration.



Mathematician James Blue (standing), CAM, and senior research scientist 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.

The need for a 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. CAM is working with the Bureau's Center for Manufacturing Engineering to develop algorithms and software which will plan trajectories for moving objects in space. They are constructing efficient methods for determining paths through regions, avoiding obstructions.

The Center 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 depends on efficient computer-aided design tools. Cooperating with the Center for Electronics and Electrical Engineering, CAM mathematicians are designing a family of specialized computer packages which can be run on minicomputers. The CS 1 package offers features that were previously available only in codes which required large mainframe computers. It has been provided to more than 80 users since 1982.

Applied mathematics also makes an important contribution to the quality and validity of the Bureau's measurement services. Specifically, CAM statisticians blend their theoretical statistical research with extensive experience to aid in the design of measurement assurance programs and in the development and certification of Standard Reference Materials.

Measurement assurance programs provide a framework for industrial and other government laboratories to compare their measurement system to national standards and, thus, improve quality control. Working with the Office of Measurement Services, Center statisticians develop specific measurement sequences and control procedures. They have, for example, helped implement four pilot measurement assurance programs at the Ford Motor Company Central Research Laboratory.

In the case of Standard Reference Materials, which are homogeneous, stable materials that have one or more physical and/or chemical properties accurately measured and certified by NBS, Center researchers plan investigations of homogeneity of the materials and evaluate variability from different sources. In current work, they are investigating improved methods for using Standard Reference Materials to enhance the precision of measurements in the laboratory.

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 that generates camera-ready diagrams.

☐ Designed a model that 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.

☐ Helped develop a model that improves control of a manufacturing method known as unidirectional solidification, used in the production of high-quality metal alloys and semiconductors.

Center for Electronics and Electrical Engineering

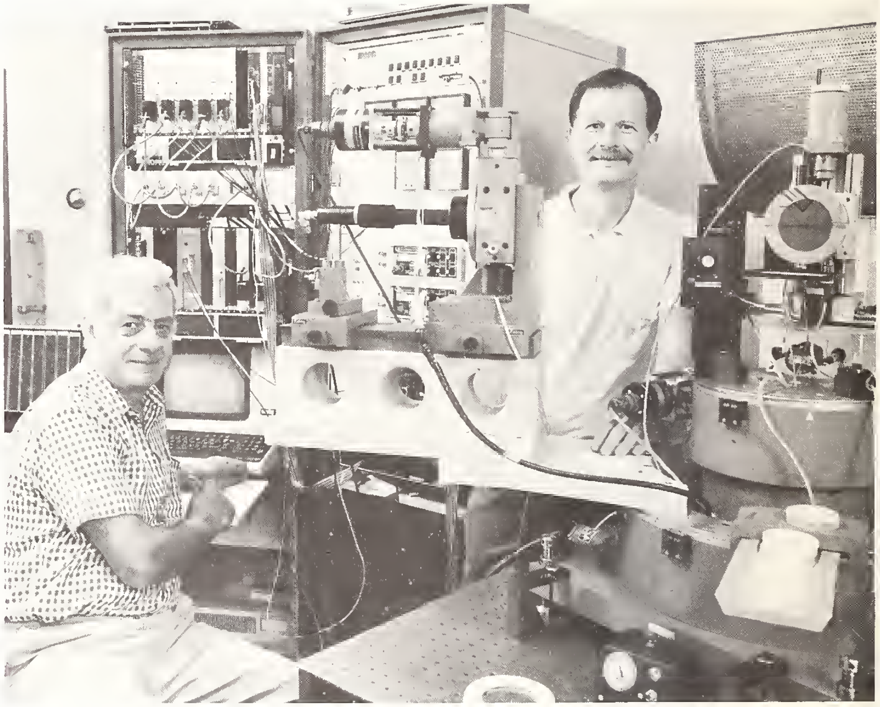
The scope of research in the NBS Center for Electronics and Electrical Engineering (CEEE) extends quite literally from the sand to the stars. Grains of sand are the genesis of silicon-based integrated circuits, the "miracle chips" of the computer industry and one major focus of CEEE's work. Distant stars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

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

Very large-scale integration (VLSI), which yields integrated circuits with hundreds of thousands of transistors on a single "chip" of silicon, is revolutionizing signal processing, communications, and computing. Before the full potential of VSLI 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, analytical techniques, and Standard Reference Materials (SRM's) for evaluating the quality of semiconductor materials and the performance of integrated circuit fabrication equipment, fabrication processes, and circuit elements.



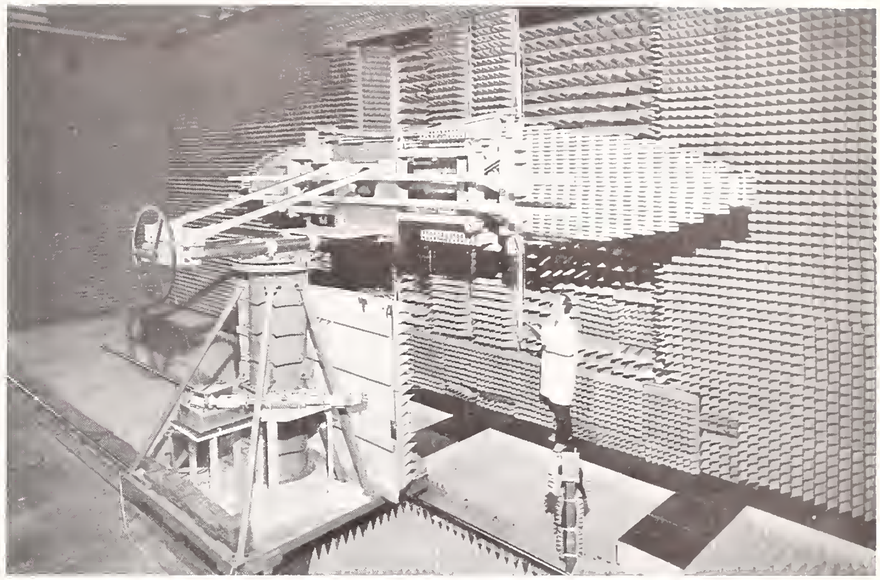
CEEE, for example, has prepared SRM's for calibrating equipment used to measure semiconductor resistivity by the four-probe and spreading resistance techniques. These SRM's help engineers in the semiconductor industry to obtain more accurate measurements of resistivity, one of the most important material parameters in the fabrication of integrated circuits.

As international trade increases and computer technology spreads throughout the world, 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 can have a common basis in the United States, Europe, and Japan.

Techniques developed by CEEE for measuring linewidths on photomasks have been transferred to virtually every U.S. manufacturer of integrated circuits as well as to manufacturers of photomask equipment. Photomasks, which define the integrated circuit patterns on semiconductor wafers, are key elements in the fabrication of integrated circuits. This work was disseminated to the semiconductor community through a series of training seminars, NBS reports and archival papers, and professional meetings. Future work in this area, which will cover measurements for a broadened range of structures and instruments important to microlithography, will be carried out by the NBS Center for Manufacturing Engineering.

Physical chemist George Candela (left) and physicist Deane Chandler-Horowitz are shown with the computer-controlled principal-angle ellipsometer they designed for measuring the optical properties of thin films on various materials.

Physicist Robert Hebner adjusts a unique NBS device that optically measures electrical fields and space charges in high-voltage insulating systems.



Engineering aide David Dean takes readings of phase shifter settings of the large (4 feet by 25 feet) AWACS antenna being measured in the newly enlarged NBS near-field facility.

Integrated circuit test structures developed by CEEE are widely used by the semiconductor industry and other government agencies. These specially-designed semiconductor devices can be used to characterize integrated circuit fabrication processes, to evaluate the effectiveness of semiconductor processing equipment, to obtain crucial parameters for device and process models, and for product acceptance. Continuing collaborations with several integrated circuit manufacturers are yielding improved test structures and procedures.

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

The Center has taken the lead in providing the technical basis for measurement methods and standards for the rapidly expanding optical fiber communications industry. Measurement methods are tested in round-robin intercomparisons organized in collaboration with a committee of the Electronics Industry Association (EIA), refined in the laboratory, and disseminated as EIA or military standards. This work has aided the transition from multimode to single-mode fibers and will continue to help advance the application of optical communications technology.

In the area of microwave and millimeter-wave parameters, CEEE is developing high-accuracy six-port measurement systems to support calibration services focusing on critical quantities to 50 GHz. The Center is also working on an automated radiometer that will aid in the calibration of solid-state and gas-discharge noise sources by extending noise measurements first into the range 1 to 12 GHz and then to 50 GHz. A 94-GHz noise standard of novel design is already in place which will permit extension of noise standards to millimeter-wave frequencies.

Center researchers have developed a new test system for accurately determining the important properties of precision 12-18 bit digital-to-analog (D/A) and analog-to-digital (A/D) converters. Both static linearity and dynamic step response characteristics can be measured and reported in an NBS calibration service now available for these devices.

Using precision waveform synthesis techniques that incorporate microprocessor-based electronics, CEEE

Here electrical engineer Robert Gallawa measures the bandwidth of multimode optical fibers as part of an NBS program to develop measurement methods that can be used in fiber development, fiber evaluation in the marketplace, and fiber compatibility in communications systems.

researchers are working on a new generation of waveform standards. An audio frequency phase-angle standard with 5-20 millidegree accuracy over 2 Hz to 50 kHz now provides special calibration tests for phase-angle meters. New voltage, power, and energy calibrations are being developed based on a dual-channel synthesized waveform source, with 18 bit D/A converters, that generates precision amplitude and phase ac waveforms.

Many Center projects involve direct collaboration with industrial firms and laboratories. For instance, CEEE completed a special study for a major domestic aerospace manufacturer. The company wanted to know if near-field antenna testing could provide accuracies as good as 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 a new satellite. The indoor near-field technique, pioneered by NBS, offers higher resolution as well as savings in personnel, travel, and equipment costs over the conventional outdoor far-field technique. It is frequently used by industry for performance testing and is now finding use in manufacturing process control for complex antennas.

Some projects involve international collaboration. NBS researchers, working with scientists from a West German standards laboratory, have demonstrated constant voltage steps at 1.2 volts from a series array of 1,464 Josephson junctions operating with a 90-GHz signal. This major achievement showed that there are no scientific barriers to the development of Josephson-junction voltage standards at convenient voltage levels. NBS researchers are proceeding with the development of such a practical, convenient standard.

A recent achievement is a microcomputer-based standard for measuring the average power contained in highly distorted electrical waveforms. This standard provides an improved basis for comparing the performance of commercially available wideband wattmeters and permits on-site power tests using an NBS standard.

Much of the Center's work in advanced power metrology has been performed in the newly completed high-voltage and high-current laboratories. These laboratories can generate voltage pulses with peak amplitudes up to 600,000 volts and current pulses with peak amplitudes up to 100,000 amperes. They are also equipped with a wide range of conventional, computer-based, and optical systems to measure these pulses and the responses of various systems to pulsed stimuli. These facilities are being used by university and industrial guest scientists in collaboration with Center staff.

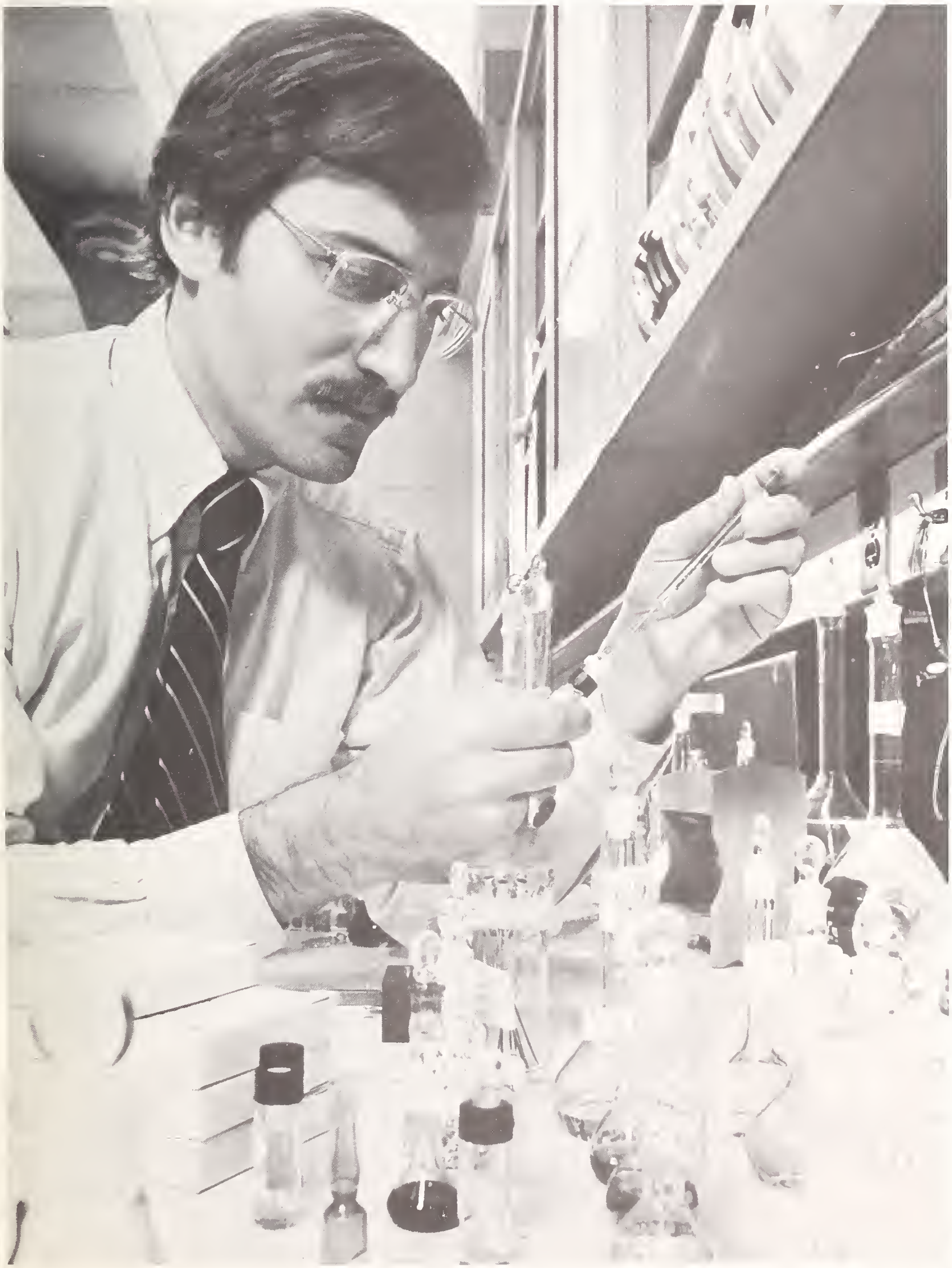
The nation's electrical power systems, communications networks, computers, and defense systems are all vulnerable to disturbance by electromagnetic pulses. To resolve system performance problems caused by electromagnetic interference, scientists must be able to measure electromagnetic environmental conditions produced by signal patterns from multiple sources. The Center is focusing on measurements of complex, interfering electromagnetic fields and electromagnetic emissions and on generating standard fields for immunity testing.

As part of this work, the Center, in collaboration with Sandia National Laboratories, has performed electro-optical measurements of 2.5 million-volt pulses of 100-nanosecond duration. The Center also has developed the capability to characterize voltage sensors in the 1-nanosecond range, a first step toward standardized techniques for evaluating pulse power systems. In addition, the Center has the capability to make the quantitative measurements necessary to evaluate the effects of aging on gaseous insulation.

Research to characterize the electromagnetic environment requires new tools. Broadband sensors (covering from 10 MHz to beyond 10 GHz) and electro-optic transducers in conjunction with fiber optic transmission lines are under development. Center researchers are also working on smaller isotropic sensors needed for measuring fields within small enclosures, such as electronic instrument cases.

All of these projects provide some of the world's most advanced measurement techniques for the rapid development of the electrical and electronics technology which pervades almost every facet of modern 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 NBS 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.

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 provide a variety of measurement services to the public.

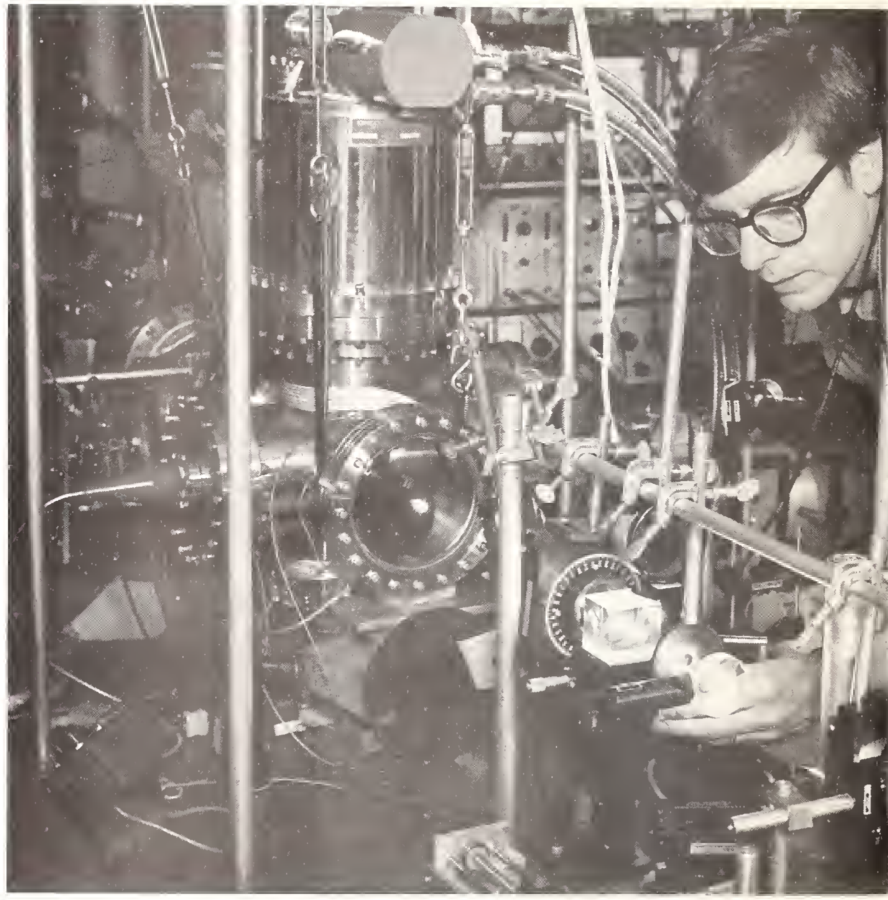
In addition, the Center conducts basic experimental and theoretical research to build a stronger and more accurate foundation for physical measurements and to improve our understanding of the phenomena upon which physical measurements are based. For example, researchers in the Center and their collaborators from the State University of New York at Stony Brook (SUNY) recently announced the first electromagnetic trapping of neutral atoms in experiments at NBS Gaithersburg. To trap the atoms, the NBS/SUNY team developed techniques for producing ultra-cold atoms using laser cooling. With these techniques, an atomic sodium beam is decelerated, stopped, and finally trapped using the radiation pressure from a laser beam. The stopped atoms are then confined in a magnetic trap. Demonstration of a practical method of confining neutral atoms in a trap opens the possibility of a new generation of experiments in atomic physics.

The Center is also working vigorously to develop an "atomic" standard of resistance based on a phenomenon of solid-state physics known as the quantum Hall effect or QHE. This phenomenon occurs in certain semiconductor devices when they are cooled to temperatures near absolute zero and placed in a large magnetic field. Under these conditions, the resistance of the device is quantitized, that is, it has specific, discrete values, and these values depend upon certain invariant fundamental constants of nature. Center researchers have now devised and put into operation a new automated resistance bridge for measuring quantitized Hall resistances with an accuracy of a few parts in 100 million. The QHE has been used to monitor the U.S. legal ohm since the summer of 1983, and it is expected that by 1987 the QHE will be used to define and maintain the U.S. legal ohm.

To assure accuracy of the kilogram, the last remaining artifact standard, the NBS kilograms were compared with those at the International Bureau of Weights and Measures, and they were found to agree to a few parts per billion. A new generation of high-precision kilogram comparators is now being designed and constructed at NBS.

As part of its responsibilities for maintaining and disseminating the nation's physical measurement standards for the benefit of industry, commerce, and science, the Center presents seminars on standards and measurement technology for technicians engaged in industrial metrology. The Center also has published the first volume of a new industrial Measurement Series, called *A Primer for Mass Metrology*.

Through the Joint Institute for Laboratory Astrophysics in Boulder, Colo., which NBS cosponsors with the University of Colorado, Center scientists collaborate with university faculty and visiting scientists to conduct the kind of long-term basic research on which the Bureau's standards, measurements, and data ultimately depend. One recent achievement complementing the atom-trapping experiments in Gaithersburg has been the use of



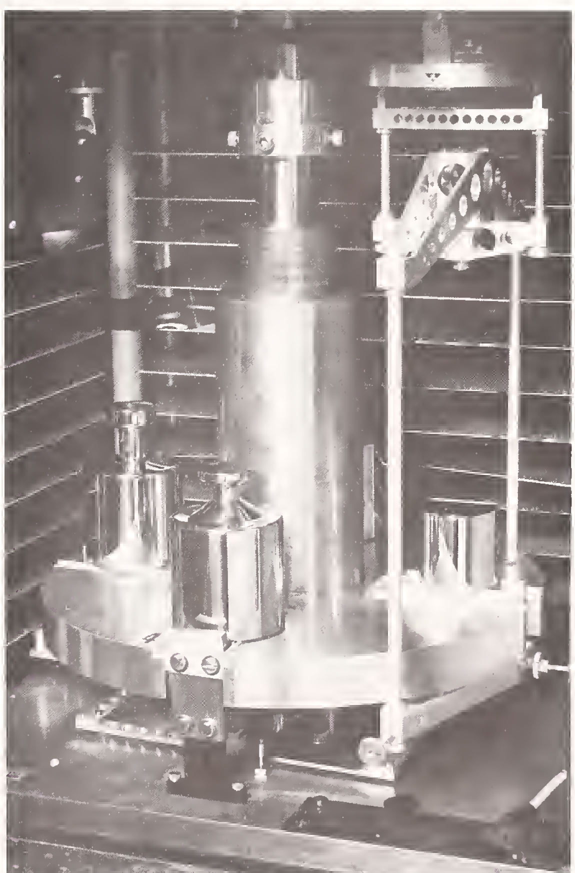
With researchers from the State University of New York, physicists Alan Migdall, John Prodan, and William Phillips, pictured, completed what is believed to be the first successful experiment to trap neutral atoms, an important advance in the technology of atomic physics.

Kilogram Prototype K-20, one of two prototypes that define a kilogram of mass in the United States, 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.

radiation from a tunable dye laser to slow, stop, and reverse a free-flying atomic beam of sodium. The major innovation here is the development of efficient electro-optic phase modulators that produce a frequency-swept laser sideband to match the changing absorption frequency as the atoms slow down. In addition to potential advances in frequency standards, these experiments should make it possible to test theories in quantum electrodynamics and general relativity.

Center scientists also are exploring the practicality of a space experiment to detect gravitational waves from sources such as binary stars. The experiment involves the use of laser heterodyne techniques to measure variations in the million-kilometer separation of three masses in Earth-like orbits around the Sun.

A new generation of portable absolute gravity meters designed by Center scientists will aid in geodetic, geophysical, geological, tidal, and tectonic studies. The instruments use the free fall method and consist of four parts: a drag-free dropping chamber, a long-period isolation device, a stabilized laser, and the necessary timing electronics. The meters are sensitive enough to detect vertical tectonic motions as small as 2 centimeters.



In other experiments, Center researchers have demonstrated an ingenious new approach for measuring highly accurate photodissociation quantum yields of electronically excited states. The method uses a fast time response laser probe to measure the gain immediately after photolysis and the subsequent total absorption, the ratio giving a relative quantum yield that is independent of most experimental parameters. Another researcher has succeeded in measuring the relative abundance of the radicals composed of silicon and hydrogen present in electrical discharges in silane. Such discharges are used in producing solar cells of amorphous silicon, which could be valuable sources of solar-derived energy if the processes involved in the deposition of the silicon compounds were better understood.

In parallel experiments, Center scientists will use an optical fiber thermometer (OFT) and a new NBS photoelectric pyrometer to determine the difference between the thermodynamic temperatures of gold and silver freezing points. The goal of the experiments is to provide state-of-the-art measurements of the various parameters of the OFT so the overall uncertainty of a temperature determination will be less than 20 parts per million.

Because of its high index of refraction and its proximity to the source, the sapphire probe of the OFT captures significantly more signal than the optics of conventional pyrometers. As a consequence, the OFT has greater sensitivity and can operate at lower temperatures than those instruments. In principle, once the OFT is calibrated at a single temperature within its range, it is capable of measuring thermodynamic temperatures over its entire range (600 to 2000 °C).

Using high-energy accelerators and reactors around the world, Center scientists have developed the capability of making very accurate x-ray and gamma-ray wavelength measurements. They have also designed new techniques for investigating the structure of matter and studying high-energy interactions that test fundamental theories. Experiments have been carried out at a number of locations including the reactors at the Institute Laue-Langevin in Grenoble, France, and at the Gesellschaft fu Schwerionenforschung in Darmstadt, Germany. Work is planned for a new beam line on the National Synchrotron Light Source at Brookhaven National Laboratory.

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.

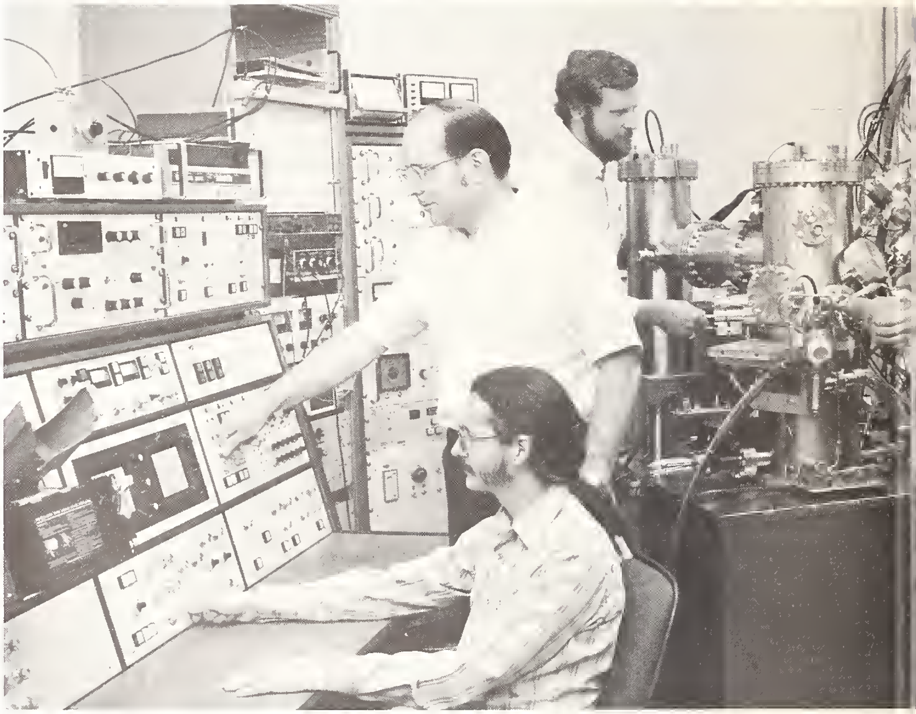
In the NBS Center for Radiation Research (CRR), scientists examine both electromagnetic radiation, including visible light and x rays, and particle radiation, such as beams of electrons, ions, and neutrons. They study and measure ways in which such radiation interacts with matter, ranging from extended materials 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. To do so, they need new measurement tools and data describing how radiation interacts with the human body.

One research group in CRR is studying the chemical mechanisms through which ionizing radiation affects biological systems. Such information is vital to the proper use of radiation, food irradiation processing, and post-irradiation dosimetry, a technique used to determine if a substance has been irradiated and how much radiation it has received.

CRR scientists have discovered novel physiological antioxidants that may inhibit the effects of radiation or, possibly, even promote recovery from radiation damage. Some of their findings, which show how the structure of antioxidants affects their performance, could be used in the design of novel, tailor-made antioxidants. These researchers are also exploring the role structure plays in the behavior of DNA-base materials in irradiated cells.

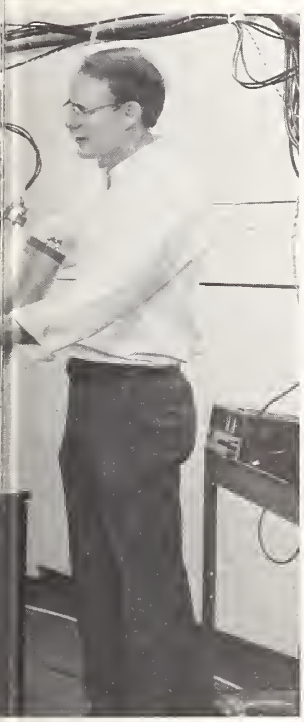
In addition, Center scientists are collaborating with researchers from local universities, the National Cancer Institute, and the Armed Forces Radiation Research Institute to study the DNA-damage/radiation-sensitivity correlations in normal and Alzheimer cells.



Other research is aiding in the real-time monitoring of radiation used to treat cancer patients where the accuracy with which the dose is administered helps determine treatment success. Special optical waveguide dosimeters with the same response characteristics as human tissue are being developed at CRR to improve clinical dosimetry and thereby help reduce the dangerous side effects of radiotherapy. These dosimeters are small enough to be placed directly into the body through conventional catheters.

The radiation-processing industry is growing by about 30 percent annually, in part because 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.

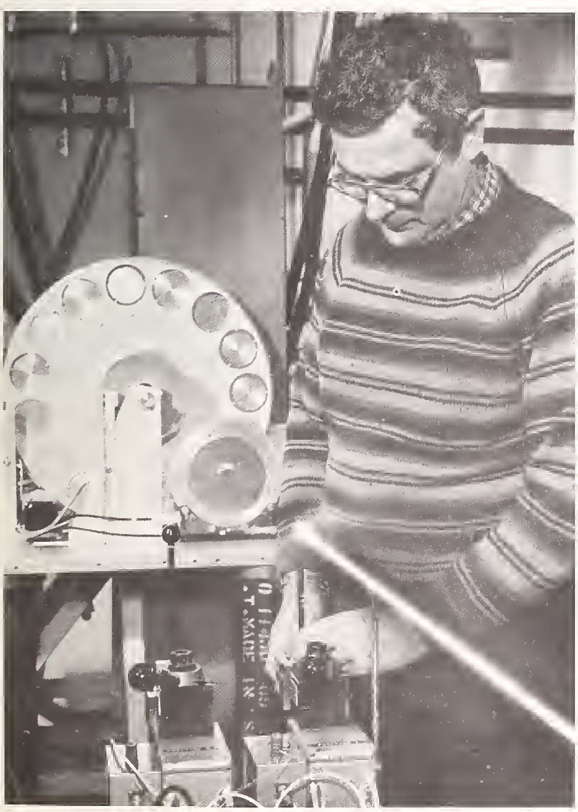
By combining an ultrahigh vacuum, high-resolution scanning electron microscope with a new, compact electron spin-polarization detector, physicists (l. to r.) Gary Hembree, CME, Robert Celotta, John Unguris, and Daniel Pierce can observe simultaneously the magnetic character of a surface and its physical structure over dimensions as small as 100 angstroms.



The steady growth of the use of radiation in medical, industrial, and energy applications has created a need for increased assurance of measurement accuracy. A system of secondary laboratories that will provide the supporting services required for measurement quality assurance is being developed in conjunction with interested organizations in the private, state, and federal sectors. These laboratories will meet documented performance criteria and use procedures that achieve a high degree of consistency with the standards maintained by CRR.

To produce radiation for experimental purposes, the Center builds and operates sophisticated accelerators and other radiation sources that it shares with the general scientific community. The largest is the Synchrotron Ultraviolet Radiation Facility (SURF II), which attracts users from a wide range of universities, government laboratories, and private companies.

SURF II is one of a few sources in the world that 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 far ultraviolet range of the light spectrum (below 100 nanometers). 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.



Physicist Paul Lamperti adjusts an ion-chamber type detector in an x-ray calibration facility (laser beam is used to align the detector). The ion chamber will be used as a "transfer standard" to calibrate x-ray sources and other detectors.

In collaboration with the Naval Research Laboratory and the University of Maryland, with support from the National Science Foundation, a high-resolution spectrometer was installed on SURF II to permit research on the dynamics of energy transfer in atoms and molecules with an energy resolution 10 times better than was previously obtainable.

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

- ☐ Combining scanning electron microscopy with electron polarization analysis to produce high-resolution images of microscopic magnetic domains. Developed in cooperation with the NBS Center for Manufacturing Engineering, this new measurement technique is being used to study submicron magnetic microstructure of advanced magnetic materials. It is expected to have important applications in a number of fields, including the development of high-density magnetic recording media for computers and small, high-efficiency electric motors.
- ☐ Constructing a race-track microtron (RTM) electron accelerator that will be used in a variety of radiation research programs of interest to NBS, other government agencies, industrial laboratories, and university researchers.
- ☐ Establishing a new calibration service for beta particle sources and transfer instruments to assist users involved in radiation monitoring in medicine and nuclear power.
- ☐ Calibrating rocket-, satellite-, and shuttle-borne instruments used to measure far ultraviolet radiations from the Sun and stars.
- ☐ Developing atomic physics codes needed to identify atomic ions produced by hot plasmas in fusion reactions and other computer codes that describe collisional interactions between ions and plasmas. These codes provide data necessary for modeling fusion plasma behavior.

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.

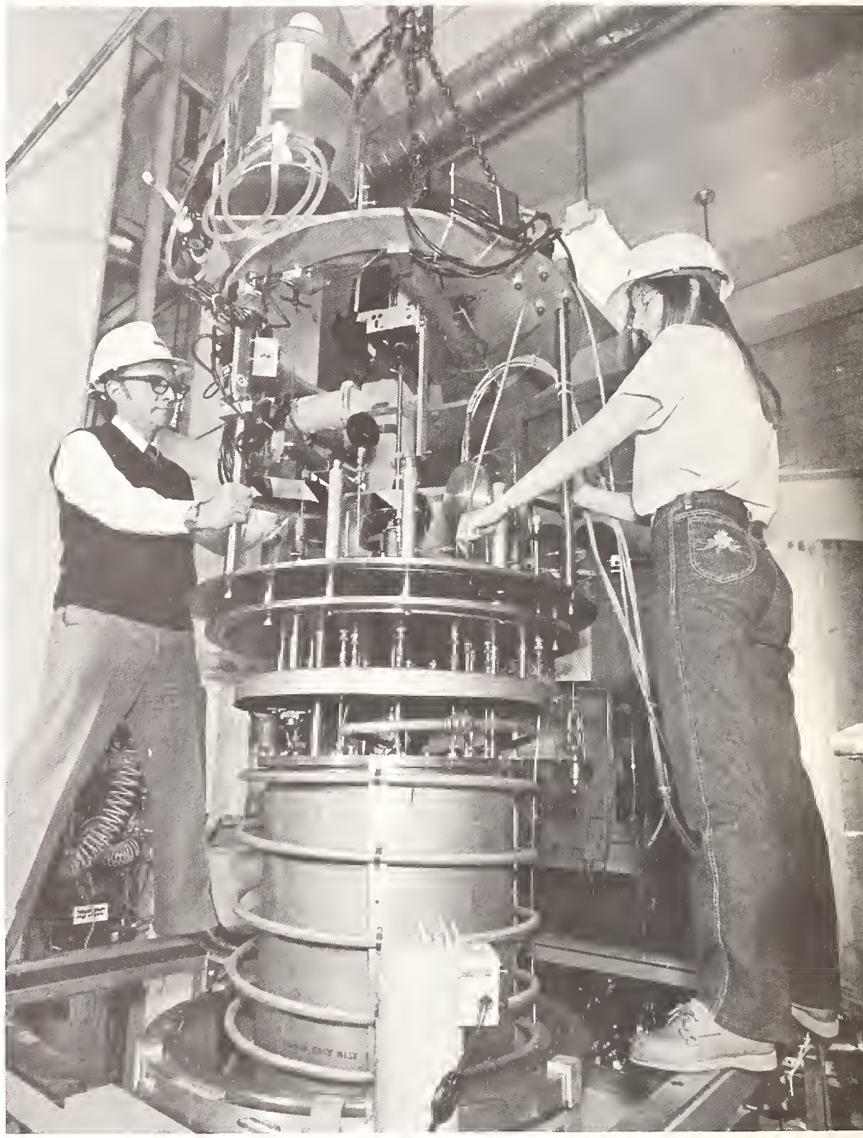
Many rapidly growing areas of technology, including the development of high-performance materials, computers, and semiconductors, involve surface characterization. One thrust of NBS surface science research is to develop measurement techniques for surface characterization. A second major goal of NBS 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, for example, constructed an atom probe field ion microscope that 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 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 and industry are now using this microscope to analyze high-technology 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, of interest to industry, energy, defense, and standards experts. For example, Center researchers have proposed a new way to monitor the effectiveness of the burning of hazardous waste using tracer compounds known to be more difficult to destroy than the hazardous components of the waste mixture.

They have also conducted the first definitive study of the chlorine content of municipal solid waste in the United States. This work provides an important foundation for understanding how chlorinated pollutants, such as dioxins, are formed and destroyed during waste incineration. Sponsored by the Department of Energy, this research is part of a cooperative effort with the Warren Spring Laboratory, United Kingdom, to study waste combustion. In addition, CCP scientists are cooperating



Physical chemist Eugene Domalski and engineering technician Sally Bruce assemble the NBS 2.5-kilogram combustion flow calorimeter for an experiment to measure the heating value of a refuse-derived fuel.

with the Solar Energy Research Institute to provide evaluated thermodynamic data for major components of solid waste.

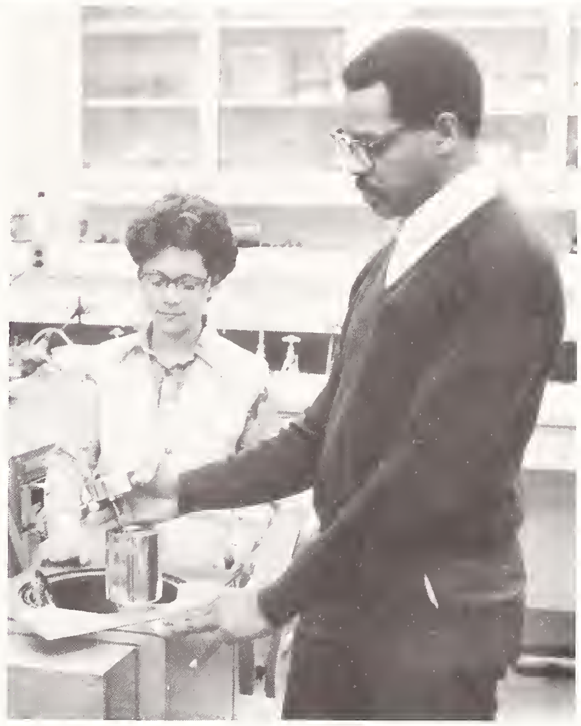
Industry is interested in the Center's recently patented idea that could help solve the nation's acid rain problem. Center scientists proposed a new chemical process for removing the noxious pollutant sulfur dioxide from industrial gas streams, which could prove more efficient and reliable than the slurry systems presently in use. Other Center scientists are compiling and evaluating thermodynamic data for flue gas cleanup using current fossil fuel technology.

The nationwide effort to develop more efficient and less polluting combustion systems has created 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.

As part of its data evaluation services, the Center, in conjunction with the Standard Reference Data Program, produced 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 is beginning studies in the area of biothermodynamics. CCP researchers are evaluating existing thermodynamic data to estimate the properties of important biological building blocks. They are examining enzyme-catalyzed reactions to obtain data on product formation under varying process conditions and 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 are being used to investigate the thermodynamics of isomerization reactions.

In a related area, CCP and the National Foundation for Cancer Research have established 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 how complex systems of organic molecules interact with metal ions. These calculations will enable them to predict important chemical properties.



Research chemists Jennifer Colbert and Duane Kirklin prepare Standard Reference Materials using this precision calorimeter which measures the thermodynamic properties of foods, biological materials, and fuels.

Another major effort in the Center is a study of the properties of weakly bonded molecules. Center scientists are presently interested in hydrogen bonding at the molecular level in condensed phase systems. They are coupling theoretical spectroscopy with their infrared and microwave experimental results to explain the highly resolved rotation-vibration spectrum of hydrogen-bonded molecules. From this spectroscopic data, scientists can obtain bond strengths and potential energies of the hydrogen-bonded systems.

In support of the National Aeronautics and Space Administration's project HALOE, Center scientists are making very precise spectroscopic measurements of hydrogen fluoride and hydrogen chloride. This work is aimed at broadening the database used to make and evaluate spectroscopic measurements of atmospheric constituents by ground-based and balloon- and satellite-borne instruments. They are also collaborating with the Chemical Manufacturers Association to develop the spectroscopy needed for the direct detection of trace components of the stratosphere. Most recently, they studied the compound hypochlorus acid, thought to be important in ozone destruction.

Center for Analytical Chemistry

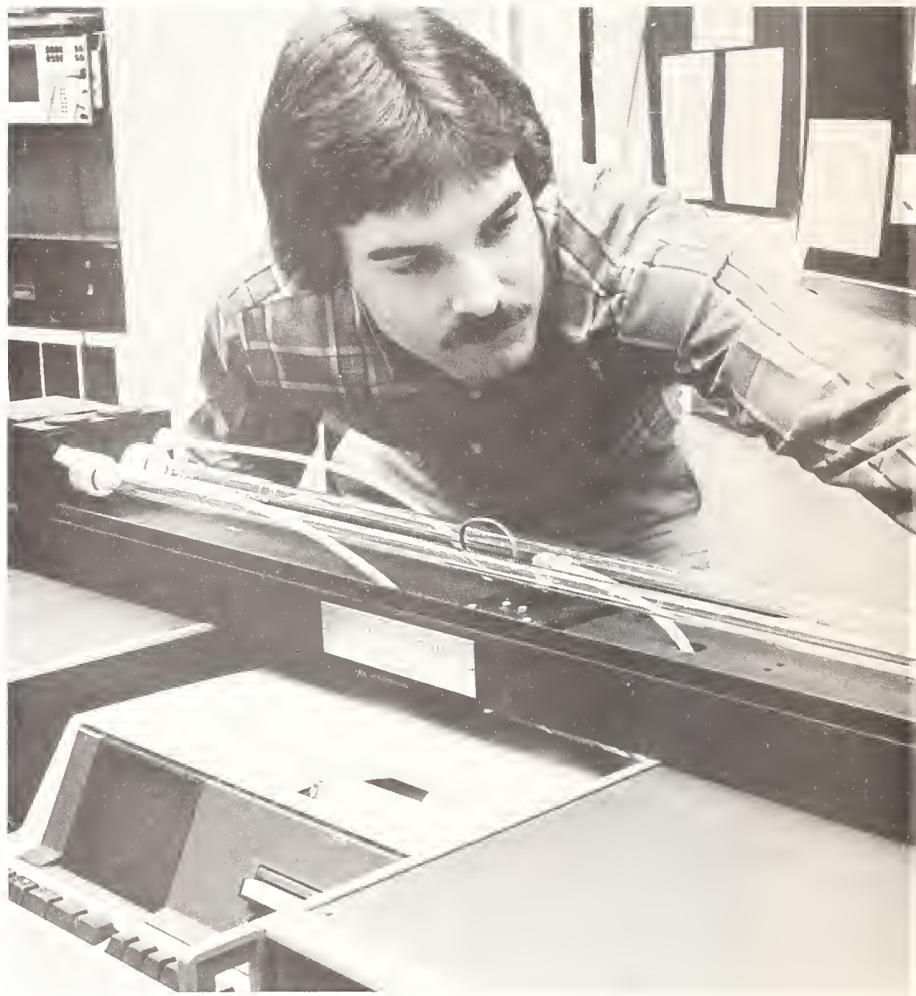
More than 50 billion chemical analyses are performed each year in the United States by scientists and technicians in government, industry, academia, and private and public testing laboratories. The NBS Center for Analytical Chemistry (CAC) helps to ensure the accuracy of these analyses. The Center serves 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 measurement methods and Standard Reference Materials (SRM's) by: (1) investigating fundamental chemical and physical principles to develop new analytical procedures; (2) developing analytical methods, which have been investigated exhaustively to remove bias and obtain high measurement accuracy and precision; (3) extending and modifying existing analytical methods to include new sample types and to permit accurate measurement of samples with lower concentrations of important chemical constituents; and (4) performing standardization research, including certification of chemical compositions in SRM's.

Much of the Center's research has important applications in technology development. For example, 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 more than 15 guest workers and research associates from the aerospace, metals, and electronics industries, academia, and other national laboratories, Center scientists are using beams of neutrons and ions to measure elemental compositions in materials important in high-technology industries. The data from these techniques—neutron depth profiling and microprobe analysis—are combined using digital image processing to form compositional maps. These maps, with resolution at the tens to hundreds of nanometer levels, can play a major role in establishing relationships between the chemical composition of materials and their performance.

In the biotechnology area, the Center's work has two focuses: to develop measurement methods and standards for use in separating, identifying, and measuring biomolecules and to use the very specialized reaction properties of biomolecules themselves as measurement tools. This research will give scientists in the public and private sectors the means to determine the purity of molecules, such as insulin, produced by bioengineering and to monitor processes in bioreactors. The research can also be used in such unique applications as identifying subspecies of commercially important fish and other marine organisms by protein profiles and determining the effects of various pollutants on the genetic make up of species in the food chain.

While developing new chemical measurement methods and techniques at the cutting edge of technology, Center researchers also produce highly accurate methods that are the cornerstone of quantitative analytical chemistry. Using these methods, Center scientists determine chemical concentrations for a wide variety of complex sample types and have certified the chemical composition of more than 700 SRM's. These SRM's cover a broad spectrum of inorganic and/or organic constituents in a variety of matrices, including human serum, metals, gases, nuclear materials, and



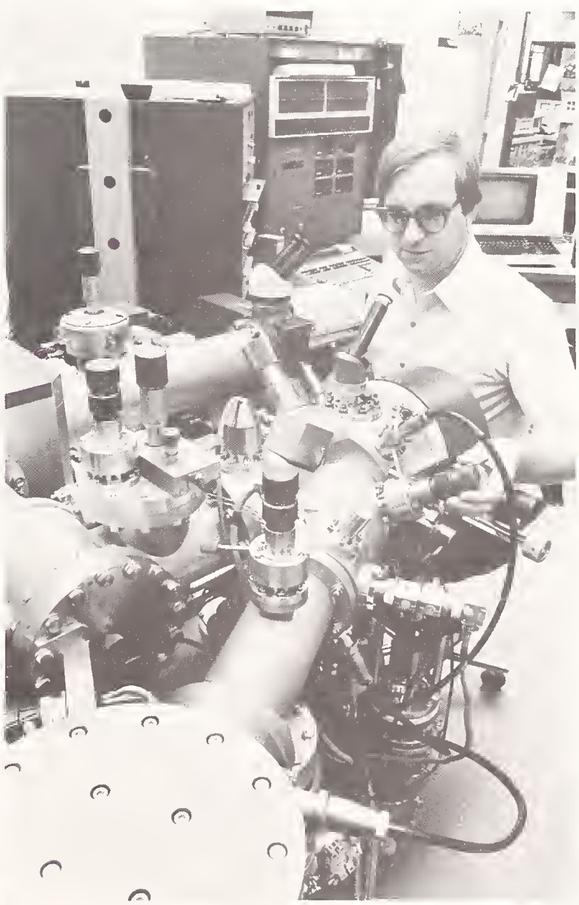
Technician James Norris adjusts the Bureau's ozone reference photometer which is used as a "definitive" standard for calibrating the reference photometers in Environmental Protection Agency regional laboratories.

Using a secondary ion mass spectrometry instrument, metallurgist Dale Newbury is able to map the distribution of elements both on and below a sample's surface.

glasses. Scientists in both the public and private sectors use SRM's to assess the accuracy of their own analytical methods.

In one specific area of research, Center scientists use very accurate mass spectrometry to determine isotopic ratios. They have, for example, recently redetermined the atomic weights of gallium and silver. An accurate value for the atomic weight of gallium is important in the semiconductor industry while an accurate value for silver is needed to determine fundamental physical constants such as the faraday.

The International Ozone Commission has recommended to the World Meteorological Organization that CAC ozone cross-section data be accepted as the international standard. These cross sections, important in determining accurate concentrations of ozone in the atmosphere and stratosphere, are used in the modeling of ozone atmospheric processes and have already significantly reduced previously reported discrepancies between aerial- (plane and satellite) and ground-based ozone measurements.



Center scientists are also developing measurement methods and reference materials for selected vitamins and trace elements in foods and body fluids as part of a major National Cancer Institute epidemiological study to assess the effect of nutrition in cancer prevention.

To provide the more accurate and highly complex measurements that are needed today, Center researchers have investigated the interaction between chromatographic column materials and the chemicals being analyzed. Using the results of this investigation, they will be able to develop chromatographic systems tailored for the separation and analysis of specific organic compounds in complex samples containing thousands of chemicals.

In other work done to respond to new requirements arising from health and environmental concerns, Center scientists analyzed the reactive gases nitric oxide, nitrogen dioxide, and nitric acid using infrared diode lasers to resolve discrepancies in measurements. They analyzed cholestrol and other constituents in human serum for proficiency testing in collaboration with the College of American Pathologists, and developed a diesel particulate SRM and a nitro-polynuclear aromatic hydrocarbon reference material with the Coordinating Research Council. In addition, they produced trace organic reference materials for analysis of toxic polychlorinated biphenyls (PCB's) and dioxins and, in cooperation with industry and the Food and Drug Administration, developed microspectrofluorimetric standards for use in medical research.

The Center, in cooperation with the Environmental Protection Agency, established a pilot environmental specimen bank that 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 that may occur over time and also to distinguish human-caused changes from natural ones. The project 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. Several international conferences have resulted from this project, and collaboration has expanded to include the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the Food and Drug Administration as well as the governments of Germany, Japan, Canada, and Sweden.

Reliable measurements can help avoid costly manufacturing mistakes and ensure more effective 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 that ensure the accuracy and compatibility of measurements on a national and international scale. Through these services NBS-developed measurement technology also is disseminated to users around the world. Two such programs are directed by the NBS Office of Measurement Services: the Standard Reference Materials (SRM) Program and the Calibration Services Program.

SRM's, produced by NBS since 1906, are stable, homogeneous materials that 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 *NBS Standard Reference Materials Catalog 1986-87,* NBS Special Publication 260. Each year, NBS sells nearly 40,000 SRM units to over 10,000 customers, including 2,500 foreign customers.

While NBS has been providing basic measurement services such as SRM's for about 80 years, the accelerated pace of technology development has called for new and more accurately certified SRM's. Some of the most recently developed SRM's are used in high-technology applications and advanced materials production. These include SRM's designed for controlling the quality of integrated circuits, for evaluating the performance of automated analytical instrument systems such as mass spectrometers, and for evaluating the performance properties of new materials, such as advanced lubricating oils.

Billions of tiny (10-micrometer) polystyrene spheres made aboard the Space Shuttle Challenger have been certified as SRM 1960, the first product made in space to be offered for sale. This SRM is one of a series of micro-dimensional SRM's designed for calibrating particle-sizing equipment used in such fields as metallurgy, clinical chemistry, environmental monitoring, and food technology, as well as in the production of printing inks, explosive powders, and cement. Developed by Lehigh University and the National Aeronautics and Space Administration, SRM 1960 was certified by NBS, in cooperation with a research associate sponsored by ASTM, using an array-sizing optical microscope technique.

Machinist Frank Mills uses a lathe to chip metal that will be ground, sieved, and blended into a titanium alloy Standard Reference Material, which manufacturers will be able to use to control the quality of their titanium products.

The steel and basic metals industries use more than 250 different reference materials to assure quality production and to calibrate automated measurement systems. The SRM 1200 series of low-alloy steels, prepared to NBS specifications, has been the standard for the low-alloy steel industry for more than a decade. NBS is in the process of replacing this entire series of SRM's by materials that meet state-of-the-art specifications. Other recently developed metal SRM's include: unalloyed titanium, low-carbon and sulfur-silicon steel, cast irons, and nickel steels.

SRM's are used not only in America's basic industries and manufacturing but also in areas important to public health and safety such as environmental monitoring and clinical chemistry. NBS now has over 30 SRM's to support clinical chemistry measurements and over 100 SRM's for use in environmental testing, including a new SRM series for use in the analysis of trace organic pollutants.

The calibration and other physical measurement services provided by NBS are as essential as the SRM services. By calibrating a variety of measurement standards and instruments of industry and other government agencies, these services provide the basis for a complete and consistent national system of physical measurements. NBS offers over 300 different calibration services, which are described in NBS Special Publication 250, *NBS Calibration Services Users Guide 1986-88*. Services include a variety of calibrations and special tests for important parameters including fundamental quantities (mass, length, time, electrical current, and temperature) and derived quantities (such as fluid flow rate, electrical resistance, spectral radiance, and microwave attenuation). NBS performs nearly 7,000 calibrations each year on a variety of instruments and transfer standards submitted by more than 1,500 customers.

In its continuing search to identify new measurement requirements and develop priorities for new services, NBS works very closely with such organizations as the National Conference of Standards Laboratories, the Council on Optical Radiation Measurements, and the Institute for Electronics and Electrical Engineers. These organizations have recently issued several reports aimed at assisting NBS in planning future physical measurement service activities.

When customers properly use instruments calibrated by NBS, they can be reasonably assured of accurate measurements 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 measurements. For customers whose measurements must be of the highest accuracy and traceable to national measurement standards, NBS has developed a limited number of Measurement Assurance Program (MAP) services.

MAP's are multilaboratory testing programs that enable participants to evaluate the performance of their total measurement systems relative to national standards maintained by NBS and to the performance of other participating laboratories. NBS offers MAP services for electrical resistance, dc voltage, platinum resistance thermometers, mass, gage blocks, watt-hour meters, laser power and energy, optical retro-reflectance, and optical transmittance. MAP's have been shown to improve the precision and accuracy of participants' measurement systems substantially. To provide information on how to set up and operate a MAP, NBS has published a two-volume manual designated as NBS Special Publications 676-I and 676-II, *Measurement Assurance Programs*.

To enhance the use of accurate measurements throughout the scientific community, NBS has also developed a series of special measurement assurance seminars and training courses, which are held periodically at different locations throughout the United States. These seminars provide in-depth training in both measurement techniques and statistical evaluation of measurement processes and are intended to assist participants in establishing rigorous quality control programs in their laboratories. Areas covered by these seminars include electrical measurements, precision thermometry, and calibration of piston gages. NBS also offers a very popular seminar in the field of chemical measurements, which covers the use of SRM's in chemical measurement applications.

Here engineering technician Linwood Jenkins calibrates a force-measuring instrument which is in turn used to calibrate equipment that tests the strength of materials.

Office of Standard Reference Data

Scientists and engineers frequently find it difficult to be sure about the reliability of data in technical papers. Yet research and development decisions based on inadequate or outdated technical information often result in the costly overdesign of industrial facilities or failure of products.

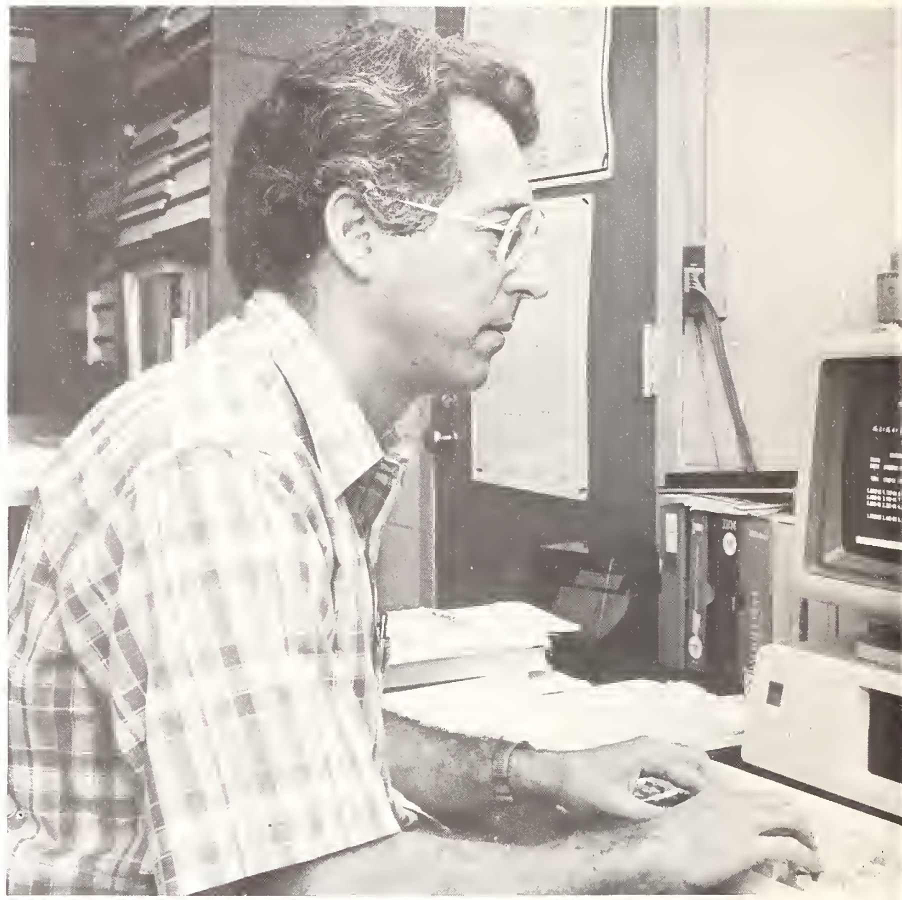
Researchers at all levels of industry, government, and academia depend on the evaluated physical and chemical databases developed and distributed by the NBS Office of Standard Reference Data. This program, mandated by the Standard Reference Data Act (Public Law 90-396), coordinates the activities of 23 continuing data centers and 40 other data evaluation projects. Each data center monitors an important scientific area and develops and maintains one or several databases, while the smaller data projects often answer the need for specialized databases in particularly important areas of science and technology. These databases are then made available to the technical community in several formats: published, computer-readable, or on-line.

The Office now distributes 10 major databases in computer-readable format on magnetic tape in its Standard Reference Database Series. 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. For example, the Photon and Charged Particle Data Center has just prepared two such databases 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. The first, called Photon Attenuation Coefficients in Materials, contains data pertaining to the interaction of x rays and gamma rays with substances in the energy region 1 keV and 100 GeV. The second, which is known as Electron and Positron Stopping Powers of Materials, consists of stopping powers for electrons in 285 materials and for positrons in 29 materials of dosimetric interest in the energy range 10 keV to 10 GeV.

The other 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, Interactive Fortran Program to Calculate Thermophysical Properties of Six Fluids, Activity and Osmotic Coefficients of Aqueous Electrolyte Solutions, and the NBS Steam Tables.

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



▲ Physicist Stephen Seltzer works on an evaluated, interactive x-ray attenuation database designed to be used in radiation safety and medical physics.

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.

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 $167 billion in 1985. 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 Institute for Materials Science and Engineering. 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. As a result of this cooperative effort, the Office will disseminate the magnetic tape version of the American Institute of Chemical Engineers DIPPR database.

In addition to new activities, the Office of Standard Reference Data enjoys a number of long-standing cooperative arrangements. One is its 14-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 that 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

One of the most significant technological developments of the past 40 years, computer technology is used to carry out basic manufacturing processes, to manage programs and financial activities, and to provide a broad range of consumer and information services. It has spawned increases in productivity throughout the American economy, contributed to the development of high-technology products and services, and advanced science and engineering research.

The NBS Institute for Computer Sciences and Technology (ICST) plays a vital and unique role in providing the standards, specifications, measurement and test methods, and technical guidance needed by government and industry to make better use of computer technology. ICST services and research contribute to the development of better products, the growth of markets, and productive applications of computer products and services.

Through participation in the development of national and international voluntary standards, ICST supports U.S. industry competitiveness and leadership in computer technology.

To improve the management of information resources, computer scientists (l. to r.) Patricia Konig, Helen Wood, and Alan Goldfine are working on specifications for a federal, ANSI, and international standard for data dictionary software.

Computer technology—a technology of rapid change—results in new products and new applications of computers almost every day. As with all new, changing technologies, however, this also leads to new problems relating to computer use.

The Institute for Computer Sciences and Technology's programs in standards development, technical assistance, and research focus on helping government and industry manage this changing technology to improve productivity and help U.S. industry keep its technical lead in international trade.

To carry out its programs, ICST researchers work cooperatively with a broad spectrum of organizations, such as federal, state, and local governments; industry computer users and manufacturers; research organizations; and voluntary standards groups. In many cases, scientists and engineers from industry come to ICST laboratories to collaborate on joint research projects. Technology and test methods developed in Institute laboratories are transferred to industry and academia as well as other government agencies. Industry depends upon ICST's neutrality and technical expertise to support the development of broad consensus standards and the impartial tests needed to assure that products conform to standards.

Voluntary computer standards continue to be one of the most effective means for managing change. Standards help to bring order to the computer marketplace and to broaden the market for computer products. The complexities of computer systems and their many interfaces between users, programs, data, operating systems, hardware, and communications systems make it difficult to link different components and systems, to exchange information between different automated activities, and to take full advantage of automation.

As a large computer user, the federal government's requirements for standards are similar to other large users. More than $15 billion is spent annually on computer-related activities by federal agencies, and the implications of faulty computer operations, waste, and inefficiency are far reaching. Many organizations have made large investments in small computers for individual applications, while microcomputers and large mainframe computers serve other organizational needs. Yet tying these systems together for true distributed processing is still a technical challenge.

As more users need to integrate existing automated systems, the standards process becomes more complex and distributed. Standards development is segmented by technical issues addressed, by special user community needs, and by organizations developing the standards. To meet the federal government's need for coherent and compatible standards, ICST supports the development of voluntary national and international standards that are cooperatively produced by users and industry and that result in off-the-shelf, compatible hardware and software products.

Investigating ways to make software maintenance less complex and time consuming are computer scientists Wilma Osborne and Roger Martin.

ICST staff members provide technical expertise and leadership to the voluntary standards development process by helping to write technical specifications and providing laboratory results. They work with more than 70 different committees in national and international organizations such as the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), the International Organization for Standardization (ISO), the European Computer Manufacturers Association (ECMA), and the Consultative Committee on International Telegraph and Telephone (CCITT). Increasingly, the focus of the Institute's standards-making activities has been in international organizations because of the global nature of communications and information exchange and the importance of having U.S. technology used in international standards. As a result of its close collaboration with U.S. industry, ICST represents U.S. interests in international standards development.

For several years, the Institute has been conducting workshops for vendors and users to discuss the implementation of the Open Systems Interconnection (OSI) Reference Model. The OSI Reference Model, which was developed by ISO with ICST assistance, provides the framework for the development of a complex system of standards that will enable different manufacturers' equipment to work together in computer networks. ICST

ICST researchers (l. to r.) Richard Linn, Jr., Jeffrey Gura, Daniel Rorrer, Wayne McCoy, and Stephen Nightingale (seated) worked with industry to develop a transport protocol test system, which allows vendors and users to test their computer systems to make sure they conform to networking standards.

is cooperating with ISO, ANSI, and other groups to develop the needed standards and with industry in implementing the standards in commercial products for the office and factory.

Participants in the workshops have represented more than 175 organizations, including computer manufacturers, semiconductor manufacturers, word processing vendors, process control vendors, communications carriers, and industry and government users from the United States, Canada, and Europe. Two successful demonstrations—one at the 1984 National Computer Conference, the other at AUTOFACT '85—of standards for the OSI reference model have resulted from the workshops. Two major U.S. corporations, General Motors and Boeing Computer Services, have adopted standards for their computer operations based on the workshop effort. The corporate standards are Manufacturing Automation Protocol (MAP) and Technical and Office Protocol (TOP), respectively.

ICST contributed to these demonstrations and to the development of commercial products implementing the standards by helping participating organizations test their products using test methods developed in Institute laboratories. New techniques were also devised to automate the design-to-implementation, testing, and performance measurement processes, thereby reducing the time needed to write the sophisticated testing procedures. In addition, ICST will coordinate a globally distributed digital data network for OSI research—called OSINET—to which 15 companies have agreed to commit resources.

Institute researchers are also working on the standards needed to integrate different computer programs and user applications and to establish standard formats and definitions for data processed by computer. They have contributed to voluntary standards for programming applications for database and graphics systems as well as for tying these applications languages to high-level programming languages. These standards will make programming easier and programs, training, and skills transportable from one system to another.

ICST's standards efforts cover other application areas, including system interfaces and information exchange. For example, Institute researchers are involved in developing standards for magnetic media and for structuring data files on media. ICST is supporting more than 35 different final, proposed, and planned standards that represent basic requirements for exchanging information stored on different types of magnetic media.

Developing standards is just the first step toward compatibility of products. The standards must be implemented properly in products to assure compatibility with other products, and test and measurement methods are essential for ensuring that products and systems meet the increasingly complex standards. Without tests, standards are simply paper specifications, and no one can be sure that products are compatible.

Industry is contributing to this effort by providing researchers to collaborate with Institute staff members and by donating research equipment. More than 20 major computer and communications companies have been working with ICST in developing test methods for network standards. To extend that effort to the critical software needed for processing data distributed in networks, ICST has started a new project with industry to develop test methods for software standards. These include database management systems, data dictionary systems, computer graphics, programming languages, user interfaces to operating systems, and office systems/document interchange.

In the case of magnetic media, reference measurement systems and reference materials are needed to support the standards that are developed for tapes, disks, and cartridges. ICST has developed and maintains such reference services for six different types of magnetic media. Standard Reference Materials are used to evaluate the performance of media and systems and to maintain quality control over their production.

NBS and the Physikalisch-Technische Bundersanstalt (PTB) in West Germany are the only organizations providing these services. To focus the efforts of both organizations more effectively, NBS has agreed to concentrate on developing new Standard Reference Materials for magnetic tape products while PTB will center its work around the production of reference materials for flexible disk cartridges. ICST is also working on standards and supporting services for optical digital data disks, a new storage technology.

Electronics engineer James Park works on Standard Reference Materials that can be used to evaluate the performance of magnetic storage media.

Institute researchers provide technical assistance to other government agencies and industry in a number of areas, including computer security, communications security, and reduction of software management costs. The need for security has increased as organizations become more dependent on computers. Systems and networks must be protected against all hazards including "hacker break-ins," computer center disasters, computer-related crimes, erroneous funds disbursements, disclosure of sensitive information, and theft of data and software. If left uncorrected, system and network vulnerabilities could result in costly losses and dangerous interruptions to data processing.

ICST researchers are currently investigating security for small computer systems, contingency planning, communications security, and personal identification methods. Other technical efforts involve development of risk assessment methods, use of cryptography, and development of computer-access controls. A number of management guides, tests, performance measures, standards, and guidelines have been developed to assist organizations in protecting their computer information from unauthorized modification, destruction, or disclosure and in assuring that computers are available for processing when needed.

Working with the President's Council on Integrity and Efficiency as well as computer experts and auditors from government and industry, the Institute is developing procedures to help auditors determine the most critical aspects of system security to review.

Protection of electronic funds transfers is important to the stability of the banking system as billions of dollars are transferred electronically each day. ICST researchers are working with the banking community and the Treasury Department to apply data encryption techniques to protect the transfer of financial messages. A Treasury policy requires that electronic funds transfer (EFT) messages be authenticated using federal and voluntary industry standards to assure that messages have been sent by an authorized party and have not been tampered with during transmission. These researchers are also helping the voluntary standards community to develop the standards needed for data authentication and encryption of data.

As part of the same project, ICST researchers have developed tests to validate devices that implement the standards. Vendors can now test their devices via electronic hook up with the Institute. The test results will be used by Treasury to certify devices for use in EFT transmissions. The National Security Agency is also assisting in this effort.

Institute researchers are planning a cooperative program to investigate the possible use of small, credit-card-sized devices for personal identification and record keeping. Meetings with government and industry representatives have pointed up the potential applications of such devices, as well as the security technology that is needed to make them practical and effective.

Several ICST projects support the Office of Management and Budget's government-wide initiatives to reduce the costs of software management and to manage end-user computing. Well-publicized problems with complex systems have focused attention on the critical need for high-quality, error-free software. The Institute is investigating ways to make the process of software maintenance less complex and time consuming.

While the use of off-the-shelf software packages avoids software development costs, these software packages must be compatible with existing software if they are to be integrated into existing systems. Institute researchers are examining approaches for evaluating software packages to assure that they meet user requirements. They then plan to issue guidelines to help federal agencies develop their requirements for off-the-shelf software and to aid in the selection of software packages that meet their needs.

ICST is also studying other ways to improve the productivity of workers who develop their own computer applications, for example, the use of fourth-generation programming languages to make programming methods more efficient and easier to maintain. To make the exchange of information between computer-based office systems more efficient, ICST is developing standards for document interchange between different manufacturers' systems.

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 and guidelines; evaluation of the data management capabilities of software; assistance in developing and implementing computer security procedures; 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 transfers technology about new applications to users. The Institute is also experimenting with automated information services that computer users can reach by phone using computer terminals and small computers. In other cases, teleconferences are used to exchange information with state and local governments and industry users. Working directly with industry and computer users to get standards implemented in products is ICST's preferred way of transferring technology. This helps to advance the development of standard products and the productive application of computers.

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.

Research associate Eric Reisenauer from Naval Ordnance Station examines a microcomputer-controlled buffer system for robot fingers, turning center collets, and quick-change tooling in the NBS Automated Manufacturing Research Facility.

International Affairs

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, India, Italy, Korea, China, Yugoslavia, Spain, Egypt, Hungary, Pakistan, and other countries.

☐ Provision of training and technical assistance to developing countries.

☐ Interchange of guest scientists with foreign countries. In 1985, NBS hosted several hundred short-term foreign visitors, plus 265 foreign guest scientists from 40 countries who worked at the Bureau for periods from 2 weeks to 1 year or more. The number of foreign scientists working at the Bureau has increased dramatically in recent years, as has the number of NBS personnel visiting or working at foreign institutions.

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.

Literally hundreds of guest workers from other countries visit or work at NBS each year. Shown here is Yang Zu Zhang of the Shanghai Bureau of Metrology, People's Republic of China, who is working with researchers in the Center for Analytical Chemistry.

Office of Research and Technology Applications

The competitiveness of U.S. industry and the well-being of U.S. society are increasingly dependent on technology. In 1985 the United States spent $107 billion on research and development. The federal government spent about $50 billion of that amount, with federal laboratories doing approximately $10 billion of the research and development. For the nation to gain the maximum benefit from the federally sponsored research, the results must be actively made available to users and interested members of the public. The Stevenson-Wydler Technology Innovation Act of 1980 promotes the active transfer of federal technology to private industry and state and local governments.

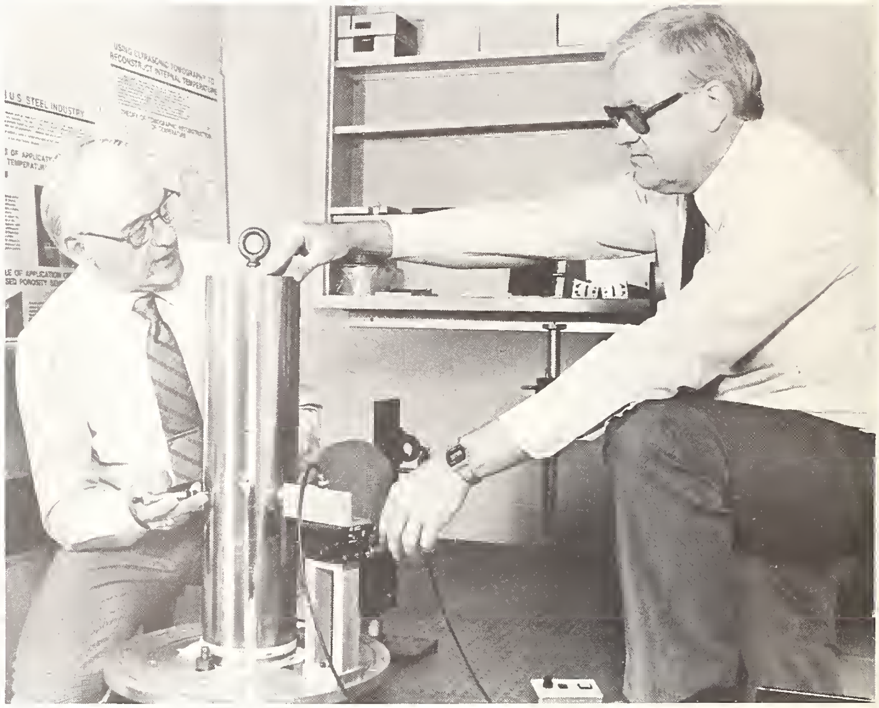
At NBS, the Office of Research and Technology Applications (ORTA), as required by this Act, provides private industry and state and local governments ready access to federal technology and to NBS research and facilities, in particular. ORTA staff respond to inquiries and establish cooperative research programs between NBS and other organizations.

One of the most popular and effective 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 NBS researchers in solving technical problems of mutual interest. Industrial interest in collaborative research is at an all-time high: Industry currently sponsors and pays the salaries of about 200 research associates in more than 80 different programs at the Bureau. Recent changes make the program even more attractive to industry. For example, revisions in patent policy give industrial research associates rights to inventions conceived while working at NBS. And, under prescribed circumstances, companies can now conduct proprietary research in NBS facilities.

In keeping with the growing national interest in industry-government interaction, ORTA participates in a wide range of joint activities. The Office arranges and participates in industry-government workshops that promote the exchange of information on exciting advances in technology. The Office also helps state officials organize and implement conferences on opportunities for using federal technology. ORTA staff and other NBS managers joined the Department of Commerce Office of Intergovernmental Affairs and representatives from other Commerce agencies in visits to Louisiana, Oregon, Pennsylvania, and Minnesota to advise the state officials about federal services that might promote their economic development.

The Office is part of a federal laboratory computer network set up to locate federal technology and facilitate its transfer to potential users. Also, ORTA staff provide leadership for the U.S. Technology Transfer Society.

ORTA participates in the national and regional meetings, panels, and workshops of city, county, and state government officials to help them solve their technical problems. Subjects of particular current interest to these officials are computer security and technology, fire research, building technology, and law enforcement product standards.



In a cooperative industry/government effort to develop process control sensors for the steel industry, NBS metallurgist Floyd A. Mauer (left) and David C. 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.

Office of Product Standards Policy

The NBS Office of Product Standards Policy (OPSP) formulates and carries out 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. The Office also provides guidance and services to state and local weights and measures jurisdictions and manages U.S. international legal metrology obligations.

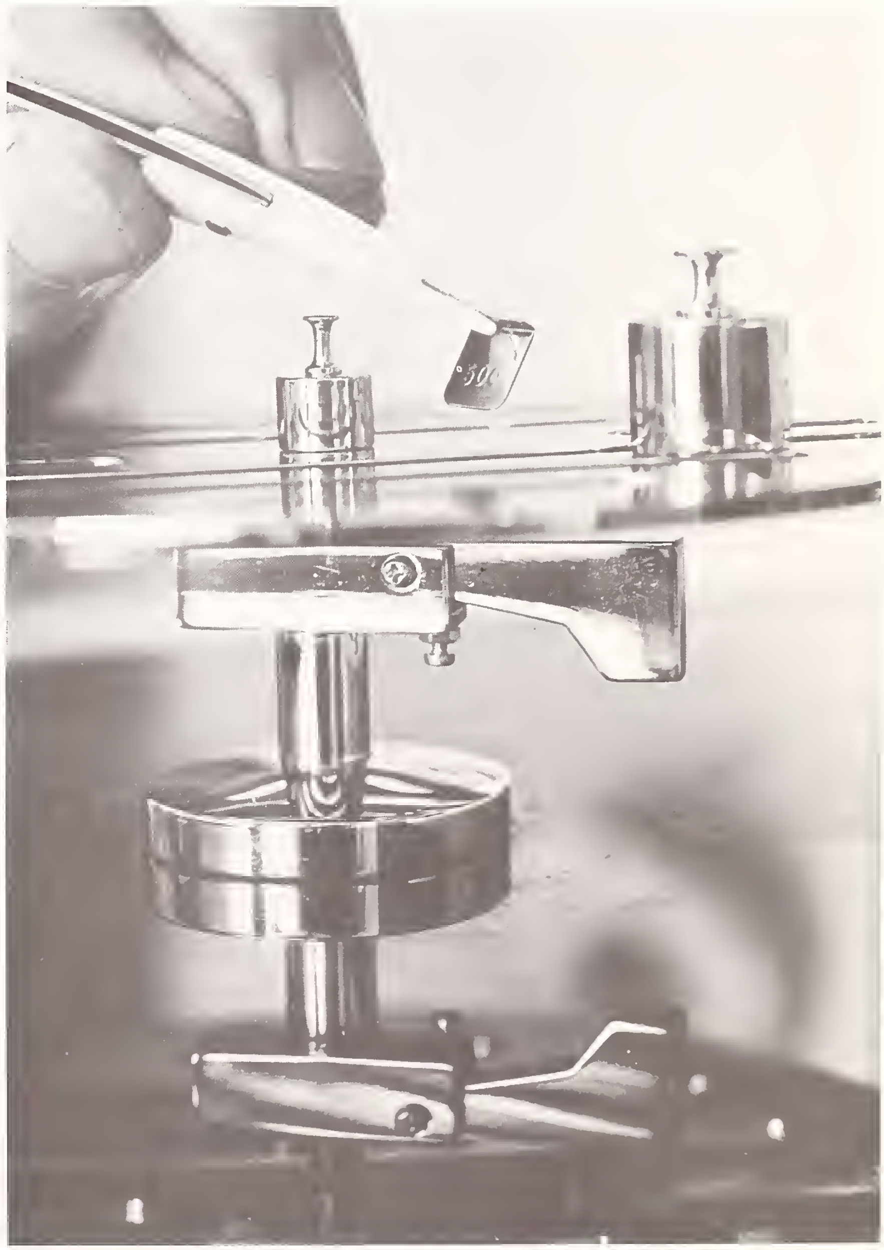
The Office maintains information on a quarter of a million standards-related documents and responds to thousands of inquiries each year. Its National Center for Standards and Certification Information develops directories and indexes and disseminates information to the public. In support of U.S. trade, the Office serves as the U.S. Inquiry Point for the Agreement on Technical Barriers to Trade ("Standards Code") of the General Agreement on Tariffs and Trade and furnishes technical assistance to industry and trade negotiators in addressing trade problems with other countries.

To promote equity in the marketplace, OPSP sponsors the National Conference on Weights and Measures. Office staff develop procedures to evaluate measuring instruments for the marketplace, coordinate training programs, support state metrology laboratories, and cooperate with the Conference to promote nationwide uniformity of state and local government requirements pertaining to measurements in the marketplace. At the international level the Office manages U.S. participation in over 100 committees of the International Organization of Legal Metrology (OIML), which aims for international uniformity of requirements for legal metrology.

In view of the importance of having valid U.S. test data accepted abroad, the Office works at the national and international levels to assure reliable laboratory testing. OPSP conducts workshops on test methods, develops techniques for proficiency testing, and operates the National Voluntary Laboratory Accreditation Program (NVLAP). NVLAP is a voluntary system for assessing and evaluating testing laboratories and accrediting those found competent to perform specific test methods or types of tests on products and materials. Through this program, laboratories are accredited for testing a variety of products, including telecommunications equipment, thermal insulation, and radiation dosimeters.

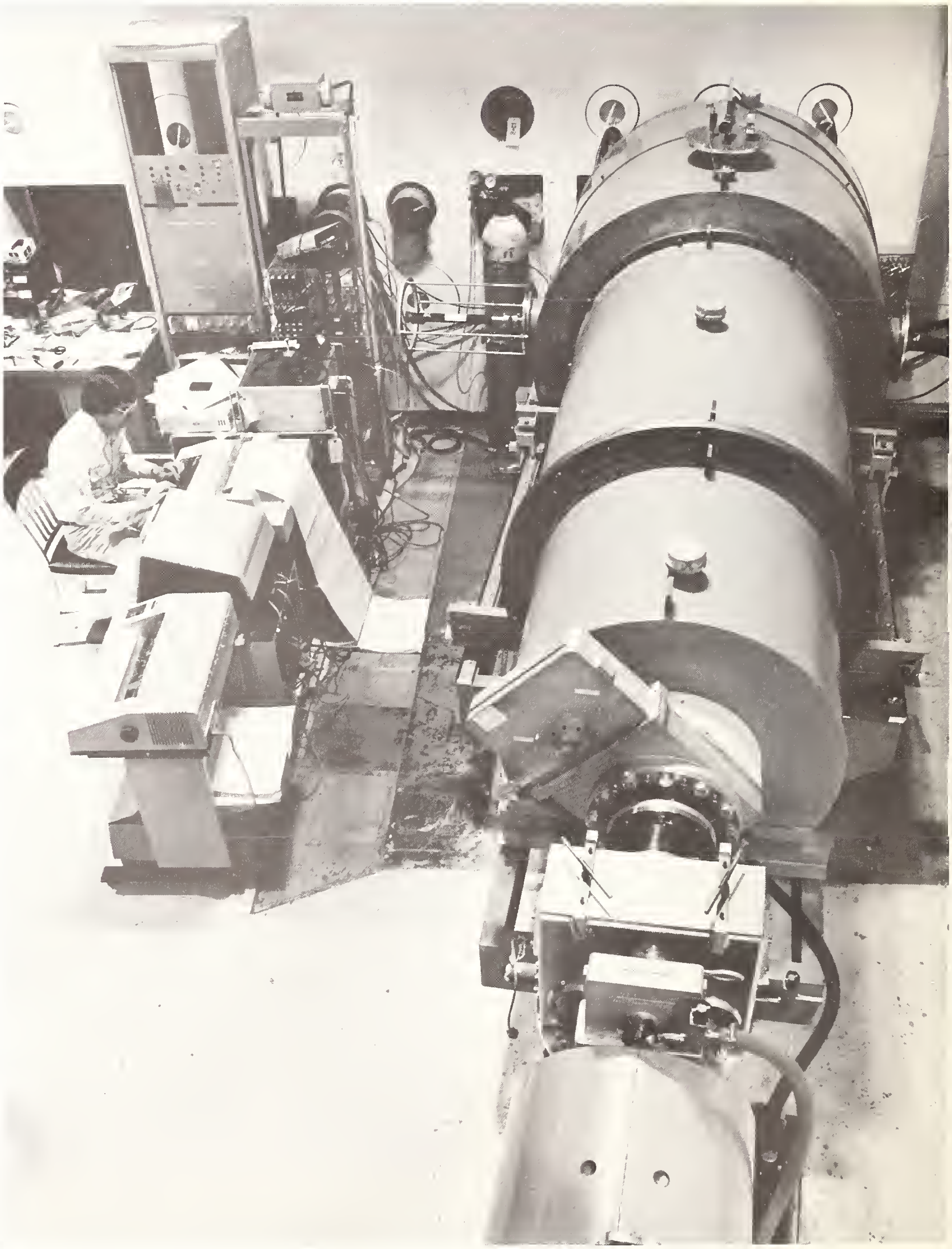
The Office works closely with international organizations to have U.S. technology and practices incorporated in international standards and guidelines. Its staff serve on key committees of the United Nations Economic Commission for Europe, the International Laboratory Accreditation Conference, the International Electrotechnical Commission, the International Organization for Standardization, OIML, and many others.

To provide traceability to national standards, the Office supports the system of state weights and measures laboratories.



The Bureau's work is carried out by highly skilled staff who are often recognized as national or international leaders in their specialties. In Gaithersburg, Maryland, located north of Washington, D.C., NBS has about 2,350 full-time employees working in 26 buildings on 576 acres.

The Bureau also has nearly 390 full-time staffers who work in 14 buildings on 208 acres in Boulder, Colorado. The Joint Institute for Laboratory Astrophysics, co-sponsored 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 20-megawatt research reactor is a major national facility for cooperative research in materials characterization. About 200 scientists from industrial firms, universities, and federal agencies use the NBS reactor each year 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 electron 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-electron-volt racetrack microtron, which will be a user facility for research in nuclear physics, is now being installed. The microtron, which is scheduled to be available for research in late 1987, is expected to have a number of unique performance characteristics, including a continuous-wave beam, high current, easily variable energy over a wide range, excellent emittance, and very small energy spread.

The Bureau's Synchrotron Ultraviolet Radiation Facility (SURF II) is a 280-million-electron-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 1985, direct Congressional appropriations accounted for about 60 percent of NBS' budget of $208.9 million. The balance resulted from work performed by NBS for other government agencies, and from the sale of NBS goods and services such as Standard Reference Materials and calibrations.

Total NBS Operating Funds—All Sources

(in millions of dollars)

	FY 1984 (actual)	FY 1985 (actual)	FY 1986 (estimate)
Measurement research and standards	$ 55.8	$ 60.7	$ 61.7
Materials science and engineering	27.5	31.2	33.4
Engineering measurements and standards	72.1	77.9	79.1
Computer sciences and technology	12.4	13.6	13.0
Research support activities	28.9	25.5	26.2
Total NBS	**$196.7**	**$208.9**	**$213.4**

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

Standards Code & Information

Laboratory Accreditation

Standards Management

Weights & Measures

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

Personnel

Acquisition & Assistance

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

Center for Applied Mathematics

Center for Electronics & Electrical Engineering

Center for Manufacturing Engineering

Center for Building Technology

Center for Fire Research

Center for Chemical Engineering

Institute for Computer Sciences & Technology

Center for Programming Science & Technology

Center for Computer Systems Engineering

Institute for Materials Science & Engineering

Ceramics

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 Institute for Materials Science and Engineering. 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 or write to the National Bureau of Standards, Boulder, CO 80303. Boulder staff members are designated in the directory with asterisks.

Office of the Director

Dr. E. Ambler, Director (2411)
Mr. R.G. Kammer, Deputy Director (2451)

Legal Adviser
Mr. A.J. Farrar (2425)

Office of Congressional and Legislative Affairs
Mrs. E.C. Cassidy, Director (2441)

Office of Research and Technology Applications
Dr. H.E. Sorrows, Director (2226)

Industrial Liaison/Research Associates
Dr. H.E. Sorrows (2226)

State and Local Governments Liaison
Mr. J.M. Wyckoff (3814)

Associate Director for International Affairs
Dr. E.L. Brady (3641)

Office of Product Standards Policy
Dr. S.I. Warshaw, Director (3751)
Mr. J.L. Donaldson, Deputy Director (3751)

Office of the Director, NBS/Boulder Laboratories

The Office of the Director, NBS/ Boulder Laboratories, which is located in Boulder, Colo., 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 Institute for Materials Science and Engineering. The Laboratories also carry out programs for the National Engineering Laboratory in electromagnetics, thermophysical properties, and fluid dynamics.

Dr. R.A. Kamper, Director (3237)*

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.

Dr. P.L.M. Heydemann, Associate Director (3361)

Program Office
Dr. A.H. Sher, Chief (3137)

Budget Office
Mr. T.A. Gary, Budget Officer (2544)

Office of the Comptroller
Vacant (2814)

Office of the Director of Administration

The Office of the Director of Administration directs the management of Bureau-wide facilities, information systems, and management and administrative services including information resources 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.

Mr. G.W. Chamberlin, Jr., Director (2477)
Mr. K.E. Bell, Deputy Director (3444)

Equal Employment Opportunity Support Division
Mr. A.C. Lewis, Chief (3494)

Public Information Division
Mr. R.S. Franzen, Chief (3112)

Management Systems Division
Mr. O.H. Tobey, Chief (3384)

Information Resources and Services Division
Ms. P.W. Berger, Chief (3405)

Plant Division
Mr. J.N. Brewer, Chief (2825)

Facilities Services Division
Mr. W.J. Rabbitt, Chief (2525)

Occupational Health and Safety Division
Mr. L.E. Pevey, Chief (3366)

Personnel Division
Mrs. E.W. Stroud, Chief (3555)

Acquisition and Assistance Division
Mr. R. de la Menardiere, Chief (3521)

Boulder Executive Office
Mr. F.P. McGehan, Acting Executive Officer (3955)*

Instrument Shops Division
Mr. D.W. Cook, Chief (3855)*

Plant Division
Mr. R.L. Rodger, Chief (3886)*

Institute for Materials Science and Engineering

The Institute for Materials Science and Engineering (IMSE) 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. IMSE also obtains accurate experimental data on the behavior and properties of materials under service conditions to assure effective use of materials.

Dr. L.H. Schwartz, Director (2891)

Office of Nondestructive Evaluation
Dr. H.T. Yolken, Chief (3331)

Ceramics Division
Dr. S.M. Hsu, Chief (2847)

Fracture and Deformation Division
Dr. R.P. Reed, Chief (3870)*

Polymers Division
Dr. L.E. Smith, Chief (3734)

Metallurgy Division
Dr. E.N. Pugh, Chief (2811)

Reactor Radiation Division
Dr. R.S. Carter, Chief (2421)

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.

Dr. D.R. Johnson, Director (2828)
Dr. C.W. Reimann, Deputy Director for Resources and Operations (2878)

Standard Reference Data

Dr. D.R. Lide, Jr., Director (2467)

Measurement Services

Mr. G.A. Uriano, Director (3231)

Office of Standard Reference Materials
Mr. S.D. Rasberry, Chief (3479)

Office of Physical Measurement Services
Mr. E. Garner, Chief (2805)

Center for Basic Standards

Dr. K.G. Kessler, Director (2001)
Dr. J.D. Simmons, Deputy Director (2001)

Electricity Division
Dr. B.N. Taylor, Chief (2701)

Temperature and Pressure Division
Dr. R.J. Soulen, Jr., Chief (3315)

Length and Mass Division
Dr. J.D. Simmons, Chief (2001)

Time and Frequency Division
Dr. D.B. Sullivan, Chief (3772)*

Quantum Physics Division
Dr. K.B. Gebbie, Chief (3527)*

Center for Radiation Research

Dr. C.E. Kuyatt, Director (2551)
Dr. W.A. Cassatt, Deputy Director (2551)

Atomic and Plasma Radiation Division
Dr. W.L. Wiese, Chief (2071)

Radiation Physics Division
Dr. W.R. Ott, Chief (3201)

Radiometric Physics Division
Dr. K.D. Mielenz, Chief (3864)

Radiation Source and Instrumentation Division
Dr. S. Penner, Chief (2503)

Ionizing Radiation Division
Dr. R.S. Caswell, Chief (2625)

Center for Chemical Physics

Dr. P.J. Ausloos, Director (2711)
Dr. R.A. Haines, Deputy Director (2711)

Surface Science Division
Dr. C.J. Powell, Chief (2188)

Chemical Kinetics Division
Dr. S. Stein, Chief (2792)

Chemical Thermodynamics Division
Dr. S. Abramowitz, Chief (2131)

Molecular Spectroscopy Division
Dr. A. Weber, Chief (2021)

Center for Analytical Chemistry

Dr. H.S. Hertz, Director (2851)
Dr. R.A. Durst, Acting Deputy Director (2852)

Inorganic Analytical Research Division
Dr. J.R. DeVoe, Chief (2748)

Organic Analytical Research Division
Dr. W.E. May, Chief (3778)

Gas and Particulate Science Division
Dr. H.L. Rook, Chief (2886)

Institute for Computer Sciences and Technology

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.

Mr. J.H. Burrows, Director (3151)

Center for Programming Science and Technology

Mr. T.N. Pyke, Jr., Director (3436)

Information Systems Engineering Division
Ms. H.M. Wood, Chief (3553)

Systems and Software Technology Division
Mr. A.L. Hankinson, Chief (2208)

Center for Computer Systems Engineering

Mr. R.P. Blanc, Director (3817)

Systems and Network Architecture Division
Dr. J.F. Heafner, Chief (3537)

Systems Components Division
Vacant (2705)

National Engineering Laboratory

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 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.

Dr. J.W. Lyons, Director (3434)
Mr. S. Kramer, Deputy Director (3233)
Dr. G.A. Sinnott, Associate Director for Technical Evaluation (3235)

Office of Energy-Related Inventions
Mr. G.P. Lewett, Chief (3694)

Law Enforcement Standards Laboratory
Mr. L. Eliason, Chief (3161)

Office of Product Safety Technology
Mr. S. Kramer, Acting Chief (3233)

Center for Applied Mathematics

Dr. B.H. Colvin, Director (2541)
Dr. J.R. Rosenblatt, Deputy Director (2541)

Mathematical Analysis Division
Dr. F.C. Johnson, Chief (2631)

Scientific Computing Division
Dr. F.E. Sullivan, Chief (3395)

Statistical Engineering Division
Mrs. M.G. Natrella, Acting Chief (3651)

Computer Services Division
Mr. M.R. Shaver, Chief (3424)

Computer Systems and Communications Division
Mr. S. White, Chief (2905)

Center for Electronics and Electrical Engineering

Mr. J.C. French, Director (3357)
Mr. R.I. Scace, Deputy Director (3357)

Electrosystems Division
Dr. O. Petersons, Chief (2328)

Electromagnetic Fields Division
Mr. C.K.S. Miller, Chief (3131)*

Electromagnetic Technology Division
Dr. R.A. Kamper, Chief (3535)*

Semiconductor Electronics Division
Dr. K.F. Galloway, Chief (3541)

Center for Manufacturing Engineering

Dr. J.A. Simpson, Director (3421)
Dr. D.A. Swyt, Deputy Director (3421)

Factory Automation Systems Division
Mr. H.M. Bloom, Chief (2461)

Fabrication Technology Division
Mr. R.T. Penn, Chief (2436)

Automated Production Technology Division
Mr. D.S. Blomquist, Chief (3565)

Precision Engineering Division
Dr. R.J. Hocken, Chief (2577)

Robot Systems Division
Dr. J.S. Albus, Chief (2181)

Center for Building Technology

Dr. R.N. Wright, Director (3377)
Mr. J.G. Gross, Deputy Director (3375)

Structures Division
Dr. C.G. Culver, Chief (2196)

Building Physics Division
Dr. T. Kusuda, Chief (3637)

Building Equipment Division
Dr. J.E. Hill, Chief (3465)

Building Materials Division
Dr. G.J. Frohnsdorff, Chief (3704)

Center for Fire Research

Dr. J.E. Snell, Director (3143)
Mr. J. Winger, Deputy Director (3143)

Office of Fire Research Resources
Dr. R.S. Levine, Chief (3845)

Fire Safety Technology Division
Dr. A.J. Fowell, Chief (3255)

Fire Measurement and Research Division
Dr. R.G. Gann, Chief (2963)

Center for Chemical Engineering

Mr. J. Hord, Director (5108)*
Dr. M.M. Hessel, Deputy Director (2034)

Chemical Engineering Sciences Division
Mr. M.J. Sikdar, Chief (5232)*

Thermophysics Division
Mr. N.A. Olien, Chief (3257)*

Chemical Process Metrology Division
Dr. J.J. Ulbrecht, Chief (3558)

U.S. GOVERNMENT PRINTING OFFICE 1986 - 491-097 - 814/52532