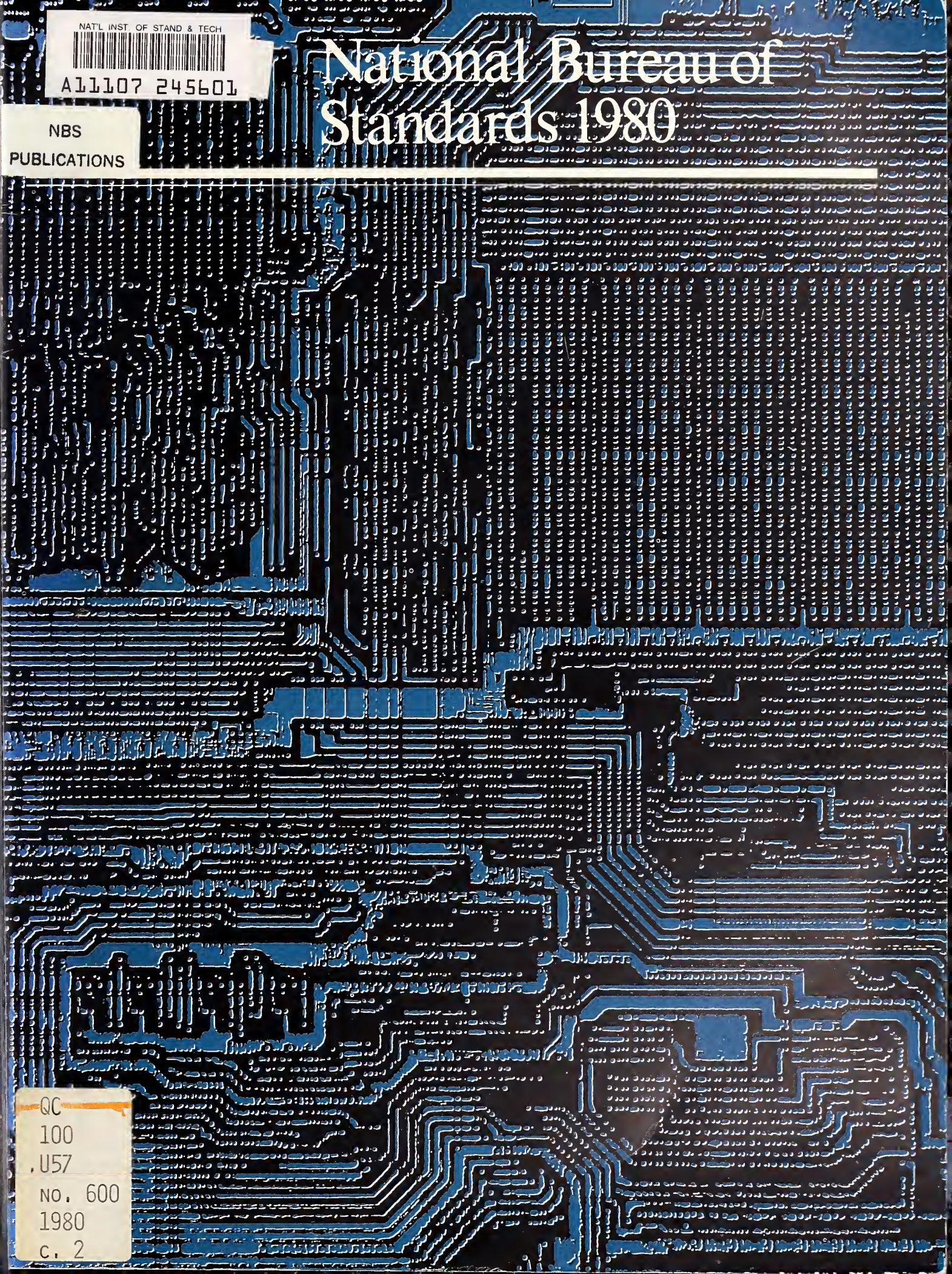
National Bureau of Standards 1980



What is NBS?

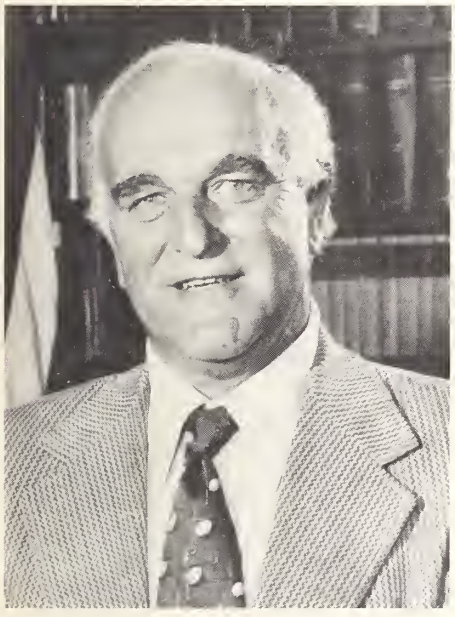
THE National Bureau of Standards (NBS) is many things as this report shows. Its most fundamental responsibility is to be the Nation's measurement laboratory in the physical and engineering sciences. An agency of the U.S. Department of Commerce, NBS was established by Congress in 1901 to help insure the compatibility of measurement standards needed by industry, consumers, the scientific community, and other government organizations. These standards provide the basis for the exchange of goods, the accurate specification of products, quality control methods for production, the equitable enforcement of environmental regulations, and the establishment of adequate guidelines for the protection of public health and safety.

NBS has built a reputation for accuracy and reliability. It is a laboratory used by industry, academia, and government alike as an independent, authoritative source of technical information and advice. Whatever the challenge, if it involves measurement in any way, NBS is probably working on the answers—or helping others to find the solutions.

Contents

Cover: Throughout its history, the National Bureau of Standards has aided industry, academia, and government in solving measurement problems. Today NBS is helping industry improve productivity and innovation by providing measurement techniques and standards for new and highly complex areas of science and technology such as electronics, symbolized here by a magnification of a Very Large Scale Integrated circuit.

Foreword



BEFORE you begin reading about what we at the National Bureau of Standards have accomplished during the past 2 years, I would like to focus for a moment on the future, and on how NBS research can help find solutions to this country's most important and complex problems.

Energy. Environment. Health. Public Safety. By now these concerns are quite familiar. Relatively new challenges with equally important consequences for our standard of living and general economic strength are the needs for improved industrial innovation and productivity. Innovation and productivity are frequently used terms and of obvious value, yet they are incredibly difficult concepts to mold and nurture to fruition. One way that the National Bureau of Standards can help is by supplying manufacturers with the basic measurements and standards for quality control that they need to produce their products efficiently and well. This, after all, has always been a basic mission for NBS, and it will become even more vital in the development of new products and processes.

The rapid shifting of international events and the trends of some markets where the United States has been losing ground to other countries have made the virtues of innovation and productivity increasingly apparent to the Nation at large. Add to this the prevailing, and I believe quite correct, wisdom that science and technology underlie all progress in these areas, and it is easy to see why Congress during 1980 paid special attention to NBS and its future directions.

For the first time in the Bureau's 80-year history, committees in both the House and Senate held authorization hearings to examine the Bureau's research activities and funding priorities in detail. The hearings served to bring important Bureau programs affecting innovation, productivity, and other national concerns into the congressional spotlight. It is my expectation, and I am assured by the House and Senate Committee Chairmen, that this process will contribute to the health and strength of both the Bureau and the country in the future.

International cooperation represents another way that I believe NBS and its research programs will become increasingly valuable. In a recent tour of science and technology laboratories in China, Japan, and Korea, I was very much impressed by their staffs' high level of enthusiasm and dedication for their work. Clearly we can learn something from these countries, just as they have learned by watching us.

The United States has, in the past, shown that proper use of science and technology can yield impressive results in worldwide respect and prosperity at home. I believe that we can maintain those hard-won commodities by moving with renewed dedication to address challenging scientific issues with sound scientific methods. I hope that as you read this report you will find we have taken these challenges to heart and are proceeding forward under full steam to meet them.

E. Ambler.

Ernest Ambler
Director, National Bureau of Standards

Introduction

IN the words of the chairman for a multinational chemical company, "Technology doesn't come from the tooth fairy."

Technology comes from hard work, enlightened research, and the foresight to plan ahead. Scientists and engineers from industry, academia, and government alike realize that research is too expensive and too important to the Nation's well-being to be entered into without focus and direction. Moreover, the best science and technology research doesn't follow today's trends, it anticipates tomorrow's.

During 1980 every effort has been made to tailor the research programs of the National Bureau of Standards to the technology needs of the coming decade. As part of that planning process, NBS projects concerned with building competence received renewed emphasis. These are programs aimed at maintaining and enhancing the quality of NBS research facilities and the expertise of the NBS staff in the fundamental areas of science and engineering that are expected to have the greatest impact on future national scientific and technological needs.

A significant number of these research projects promise to help bolster industrial productivity and innovation while encouraging energy conservation. Four particular areas stand out—electronics, automation, chemical processing, and advanced materials. When science and engineering leaders discuss research needs for the future, these fields are inevitably mentioned. NBS has planned major research programs to meet anticipated needs in each of them.

Electronics

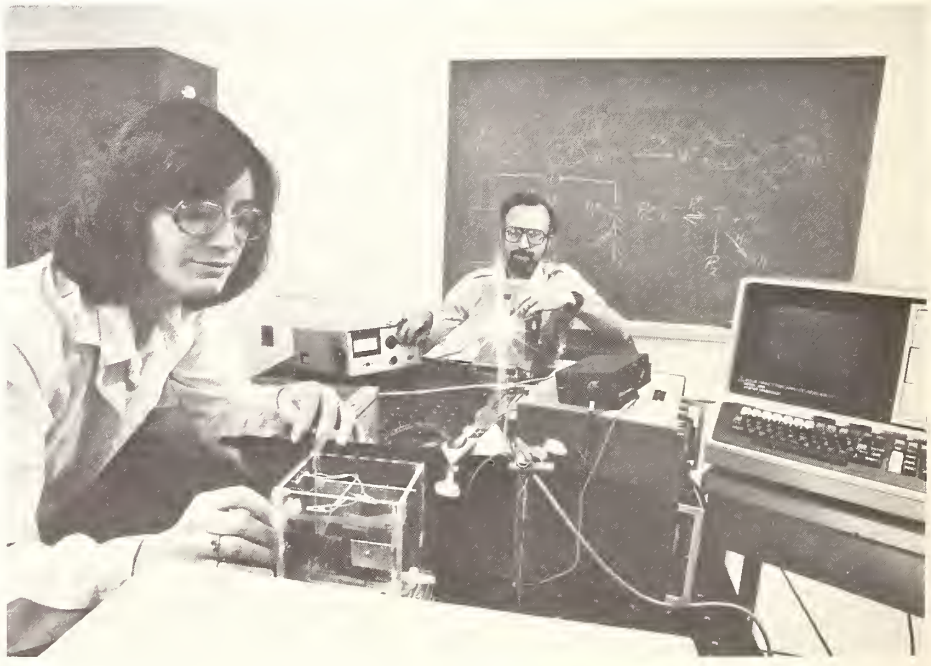
The perceptive judgment of history will doubtless look upon the 1980's as the silicon age. Electronics designers continue to shrink the integrated circuitry of microprocessers to infinitesimal dimensions. As a result, complex computational tasks are accomplished faster, with less energy, at lower cost.

Such trends are expected to increase worldwide sales of integrated circuits by 150 percent within the next 5 years. If U.S. manufacturers hope to profit from the increased demand, they must develop higher quality products at less cost than their foreign competitors.

One of the most promising ways to do this will be to perfect the production and quality control of Very Large Scale Integrated (VLSI) circuits. VLSI represents the next generation of semiconductor technology. VLSI circuits will channel electrical currents through "wires" 100 times thinner than a human hair. A single VLSI circuit chip will hold over 100,000 individual transistors or "switches" (present chips hold about 30,000).

Accurate quality control testing will be a major problem. With present methods a simple integrated circuit can be run through a complete functional test in a fraction of a second, a chip with medium-scale integration in about a week. Complete functional testing of VLSI devices is impossible with today's techniques. Whole new approaches to semiconductor quality inspection are needed before VLSI can be practical.

In the 1980's, NBS researchers will be studying how even the smallest misarrangement of atoms in integrated circuit materials can affect performance. They will be scaling down current NBS test patterns used by industry in quality control to the submicrometer dimensions necessary for VLSI. Methods for validating



One competence building project begun in 1979 is a study of mechanisms occurring during electrochemical reactions. In this photo, researchers Richard Durst and Mary Lou Fultz test a new computer-controlled, spectroelectrochemical system used to identify the intermediate and final products of certain reactions important in analytical biochemistry.

VLSI circuit design, for using computer-operated process monitors during manufacture, and for characterizing improved "packages" to protect completed circuits from damage will also be investigated.

Automation

Just as mass production dramatically improved industrial output in the early 1900's, increased use of automated methods of manufacturing and quality control is one of the most direct ways to boost today's industrial productivity. Machines directed by computers can churn out precise uniform parts at great speeds. Automated machine tools can produce higher quality products at lower costs.

The most versatile computer controlled machines are industrial robots. Industrial robots can be programmed to perform several different jobs, can complete a sequence of manufacturing tasks, and can do extremely monotonous or dangerous jobs that should not or cannot be done by people. While current models have none of the charm of an R2D2 or a C3PO, they are rapidly acquiring basic human-like senses. Rudimentary abilities to "see" and "touch" will soon allow robots to take corrective action when they encounter misplaced parts, manufacturing defects, or similar problems.

However, experts agree that computer-assisted manufacturing and robotics, despite their many attractions, still have a long way to go. As with any developing industry, computer-assisted manufacturing lacks necessary standards and calibration methods. Tools and robots made by different manufacturers may respond to similar program commands differently, and individual hardware designs make interfacing between machines nearly impossible. Bureau researchers are now building a prototype automated metalworking machine shop. The facility will include a machining center, a "sighted" robot, a computer, a controller, and other hardware. It will be used to test new calibration and measurement techniques, computer language standards, and interfacing methods. Advanced computer programs will be used to automate and optimize operations such as the sensing of equipment failures, the control of metal cutting tools, and the automated quality inspection of parts at every stage of manufacture.

Chemical Processing

U.S. chemical manufacturers are tuning up their processes. Most existing U.S. plants were designed when energy was cheap and abundant. Processes need to be refined to cut down on fuel costs. Alternatives to oil and gas must be used to compensate for uncertain supplies and steep prices. Stringent new Federal regulations demand more effective pollution control measures.

The development of energy sources such as synthetic fuels made from coal, oil shale, and tar sands may provide part of the answer. Processing chemicals in larger "batches" may also help. But these changes will require fundamental chemical data on rates of reactions, thermophysical properties, liquid and gas flow rates, and heat transfer, which are not now available.

NBS plans to concentrate efforts in the next few years to help provide the chemical industry with the fundamental data and measurement techniques it needs. New projects will also provide engineering design data, measurement principles, and standards to help increase energy efficiency and control advanced chemical separation methods.

New Materials

Metal parts made from powders. Polymers that conduct electricity. Super ceramics. Research and development of new, improved materials is a billion dollar business. Materials shortages, energy costs, and environmental concerns have made innovation in this field a high priority for industry.

Once again, however, accurate inspection methods and better systems for quality control stand in the way of broader application of new materials technology. To better appreciate the magnitude of the problem, consider the fact that materials imperfections at the micrometer level can degrade the performance of advanced technology products. Turbine blades for jet engines, for example, are used at such high temperatures that even minute inclusions and porosity within the microstructure can make them susceptible to failure.

Materials research, specifically the measurement of materials properties, has always been a major area of Bureau research. Future plans call for stepped-up activity in this area, especially in improving theories and measurement methods that relate the microstructure of materials to their performance and durability. Sophisticated NBS experimental facilities—such as laser-driven ultrasonic microscopy, high field nuclear magnetic resonance, and small angle neutron scattering—will permit detailed studies of the smallest elements of a wide range of materials structures.

These plans for research in electronics, automation, chemical processing, and materials are certainly important, yet even as examples they don't reflect the full scope of the Bureau's work that lies ahead. Throughout the next three sections, which highlight major accomplishments during the past 2 years, additional Bureau research strategies are included to round out the picture.

National Measurement Laboratory

FOR most people measurement is a rather ordinary, albeit necessary, part of life. For scientists and engineers measurement is another matter entirely.

It is at the very heart of just about every kind of research endeavor. It consists not only of what can be seen, heard, or felt, but also of things too incredibly small, too amazingly distant, or too ephemerally brief to be observed with human senses alone.

The vibrations of a cesium atom serve as an infallible clock, more precise than the rotation of the earth itself. Stabilized lasers act as rulers for measurements smaller than a fly's eye. Analytical instruments detect substances with masses less than a billionth the weight of a dollar bill.

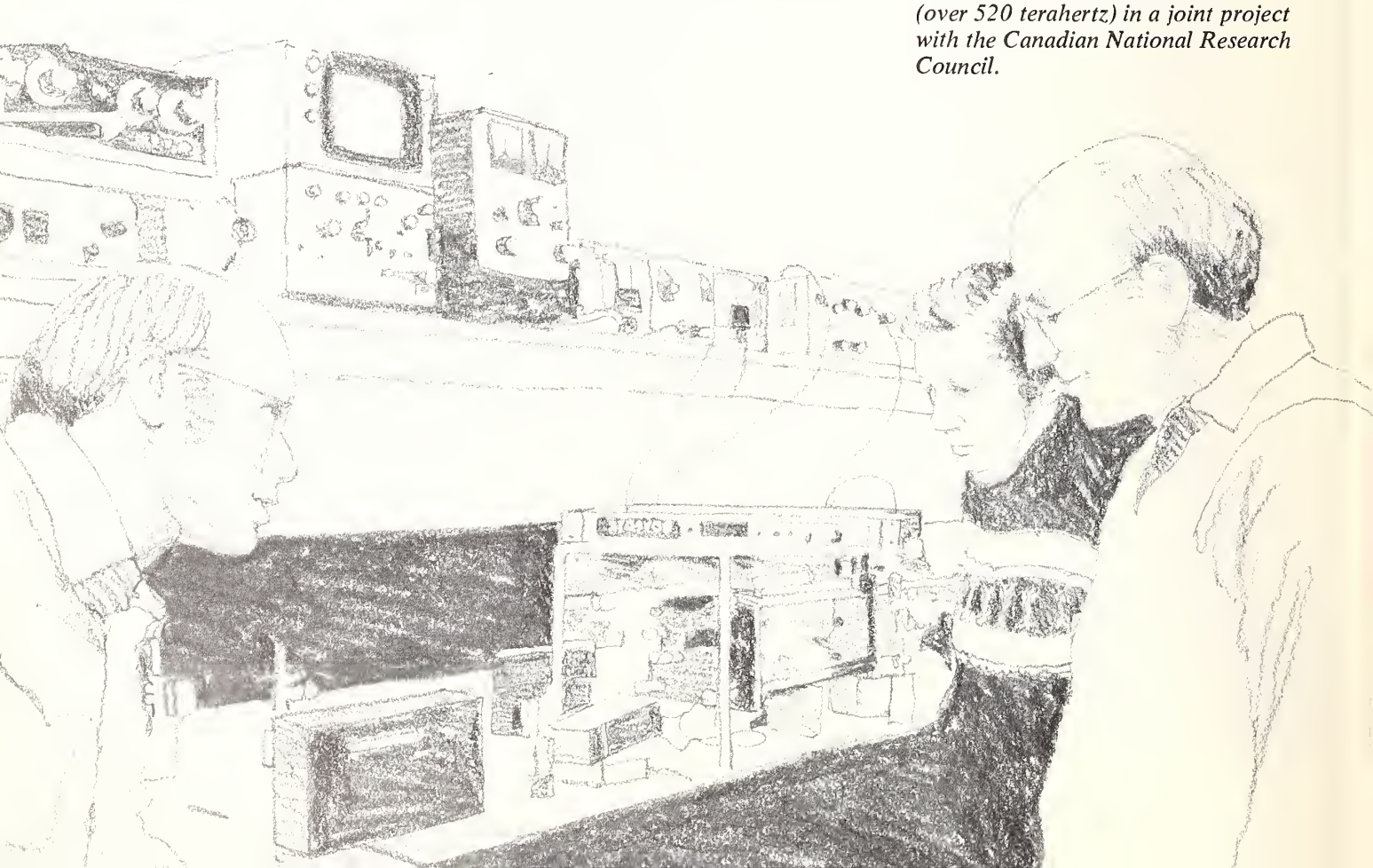
The ability to measure with such precision and to do it accurately has made possible many technological advances—jets, computers, satellites. New, even more exacting measurement methods will undoubtedly help bring about the technical achievements of the future.

The Bureau's National Measurement Laboratory (NML) bears responsibility for nurturing improvements in both the sophisticated measurement system required by science and technology and in the day-to-day measurements needed by everyone. It is the job of the NML technical staff to see to it that physical and chemical measurements within the United States can be traced to a consistent set of standards, reference methods, and reference materials that are also compatible with those used to regulate international trade.

As part of this process, the over 1,000 scientists and engineers of the Laboratory perform research within a multitude of scientific disciplines, across a broad range of topics. The ultimate aim of their research is to assure that technological development is not hindered by a lack of accurate physical or chemical measurement standards and, especially, to provide the basic measurement technology needed to support advanced scientific fields of critical importance to the Nation.

A few representative examples of NML research achievements for fiscal years 1979 and 1980 are described below.

Boulder laboratory researchers Kenneth Evenson, Donald Jennings, and Russell Petersen successfully accomplished the highest direct frequency measurement ever made (over 520 terahertz) in a joint project with the Canadian National Research Council.



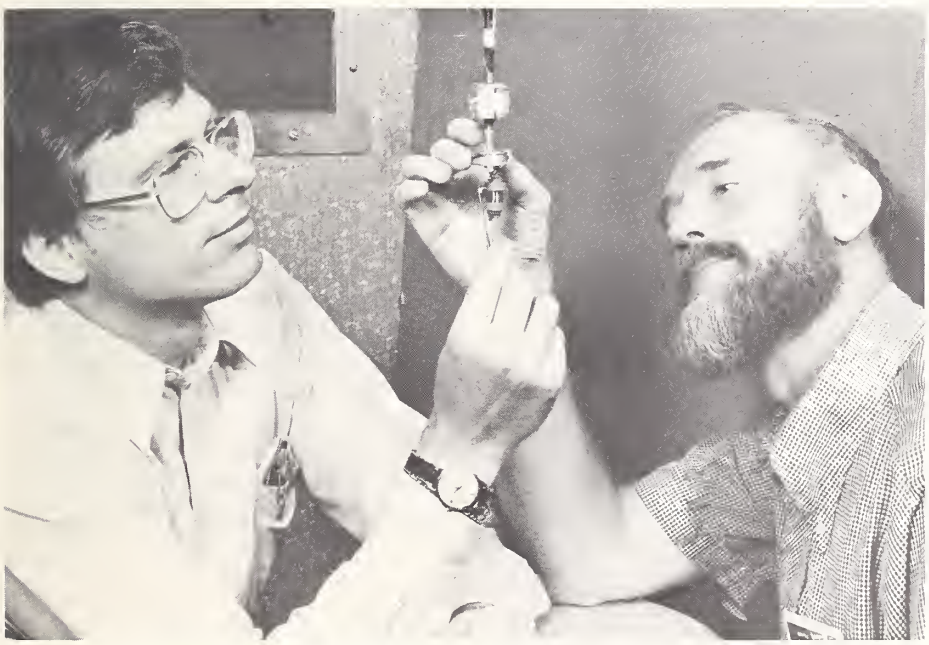
Basic Measurements and Standards

A measurement system can only be as precise as the units upon which it is based. To provide the precision and accuracy needed for the increasing demands of science and technology, NBS researchers are continually seeking to improve the way basic quantities such as length, mass, time and frequency, temperature, and electrical quantities are determined. The guiding thrust of this effort is to use the laws of physics to define basic units with ever better accuracy.

The area of time and frequency is a good illustration of how NBS satisfies the diverse spectrum of industrial, national, and international needs for basic measurements and standards. The principal elements of the program focus on realizing the international unit of time, the second; maintaining and disseminating the U.S. atomic time scale; coordinating time with other national laboratories; and conducting research to advance the state-of-the-art in frequency measurements and frequency standards. To satisfy a wide variety of civilian applications such as electrical power generation and commercial aviation, precise time and frequency signals are broadcast from NBS radio stations in Colorado and Hawaii. Synchronizing NBS atomic time with the time scales of other nations requires a higher level of precision which is accomplished using a U.S. Navy broadcast, LORAN-C, and portable atomic clocks. The highest precision transfers of the time standard are accomplished through measurements performed at NBS. Devices such as atomic clocks and quartz crystal oscillators are occasionally calibrated to meet the very high precision needs related to national defense and the space program.

An ongoing program of research is directed at extending the range and quality of NBS measurements and services. Last year NBS scientists, working in collaboration with researchers of the National Research Council of Canada (the NBS counterpart in Canada), achieved a major advance in this regard. In accomplishing the highest direct frequency measurement ever made of an electromagnetic wave, they paved the way for an improved definition of the meter. The second is defined in terms of the vibration of the cesium atom with an uncertainty of less than one part in 10^{13} (10 trillion). This leads to the potential for measurements much more accurate than the present length standard.

Using a sophisticated array of lasers and microwave generators, these researchers measured the frequency of visible light in a way which directly tied that measurement to the cesium standard. The success of this experiment makes possible the



Physicists Robert Soulen (left) and James Schooley check a calibration apparatus used to certify a new Standard Reference Material (SRM 767) called a superconductive fixed point device. SRM 767 consists of five wires of different metals (lead, indium, aluminum, zinc, and cadmium) that become superconducting at five different cryogenic (extremely low) temperatures. These reference temperatures are used as defining points for the new international 0.5 K to 30 K Provisional Temperature Scale.

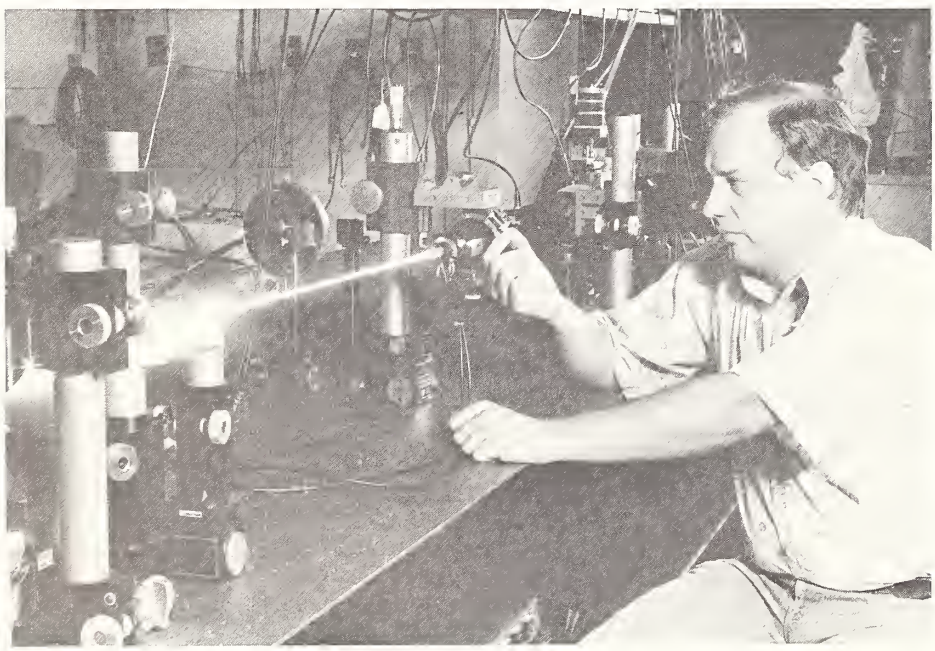
realization of a long-standing ambition among metrologists—the tying of all measurements of time and space to a single, very precise standard. A formal proposal to define the meter in terms of the cesium frequency standard and the speed of light has been made by the International Consultative Committee for the Definition of the Meter to the International Committee for Weights and Measures on the strength of the NBS/NRC experiment plus those performed at other standards laboratories. The new meter would be the distance travelled in a time interval of 1/299 792 458 of a second by plane electromagnetic waves in vacuum.

Researchers in the NBS Center for Radiation Research recently contributed to the accuracy with which another important quantity can be measured. Through detailed study of the photovoltaic effect, this research group developed an "absolute" method of calibrating silicon photodiodes. Their work should help improve measurements of the candela—the basic unit of light intensity.

Currently silicon photodiode calibrations revolve around the thermal physics of a known radiation source or thermal detector. The new method depends instead on a direct measure of a particular device's efficiency in converting incoming photons of light into an electrical current. The new technique requires a relatively simple electrical apparatus and produces accuracies as good or better than the previously used method.

In a related development, researchers in this same Center improved, by a factor of ten, light intensity measurements made at the NBS Synchrotron Ultraviolet Radiation Facility (SURF II). Accelerating electrons within the synchrotron "storage ring" produce intense radiation which can be "tuned" across frequencies from the infrared to the far ultraviolet. With extremely accurate silicon photodiodes, these researchers measured the flux or radiant power of the NBS synchrotron as a function of the number of electrons being accelerated within the ring. As the number of electrons within the ring decreased with time due to leakage, the researchers noted incremental decreases in light intensity. This counting of electrons permitted a mathematical determination of the synchrotron's light intensity which agreed to within 1 percent with silicon photodiode measurements made directly. The improved characterization of the NBS synchrotron radiation makes it an excellent instrument calibration source over a broad range of frequencies.

Improved methods of measuring light intensity have ready applications for climate research. In order to understand the world's past climate and to predict future climate trends, researchers monitor the optical radiation from the sun. To do this successfully, their measurements must be accurate to within 0.1 percent over a 22-year period as a sustained change of only a few tenths of a percent in



Physicist Jon Geist adjusts the alignment of a modulator used to stabilize the power of a krypton ion laser. The normally invisible ultraviolet laser is part of a new NBS system for direct calibration of silicon photodiode optical detectors.

this quantity, called the solar constant, could signal substantial changes in the world's climate.

Radiation measurements of a different kind were the subject of additional NBS efforts to improve basic measurements and standards. At the request of the U.S. Senate Committee on Commerce, Science and Transportation, NBS collaborated with the State Conference of Radiation Control Program Directors in a thorough study of needs for improving measurements of ionizing radiation important to public health and safety. Ionizing radiation is used not only in hospitals for diagnosis and therapy but also in industry for sterilizing products, curing plastics, inspecting products, and a variety of other applications, including the production of energy.

The recently released report stated that certain types of radiation, such as high-energy x-rays, high-energy electrons, and fast neutrons used in radiation therapy cannot be measured at desired levels of accuracy. Measurements of radiation such as neutrons or beta rays were reported to be hampered by a lack of proper field instruments. Options considered for improving this situation included: establishing a string of government-financed regional calibration laboratories; helping establish similar facilities run by the States or by private parties; and developing additional national radiation measurement standards and instrumentation.

Measurements For Energy Security

Major new energy technologies are not built overnight. According to recent projections by the National Research Council, it may take 20 years or more to develop fully successful energy alternatives to oil and natural gas. New forms of energy require specific chemical and physical data for use in maximizing the efficiency of processes. A number of NML research accomplishments during the past 2 years includes the development of instruments or measurement methods that may help in providing this sort of information.

Researchers in the Center for Thermodynamics and Molecular Science (CTMS) are developing new test methods for determining the energy content of municipal waste and processed waste called refuse-derived fuel (RDF), which can be burned to produce electricity or

Research chemist James Walker (right) discusses the results of differential scanning calorimetry experiments of recycled oil with Wing Tsang, chief of the NBS Chemical Kinetics Division. The object of this study is to develop test methods that can be used to compare accurately the oxidation stability of rerefined oil with that of a new oil.

steam for industrial applications. The Resource Conservation and Recovery Act, passed in 1976, directs NBS to develop guidelines for specifying the nature of products recovered from wastes and to work with voluntary standards-setting organizations to provide standards for these materials in order to speed their introduction as items of trade. The determination of heating values for refuse and RDF is hampered by the heterogeneous nature of city waste and by the relatively small burning capacity of traditional calorimeters, in which fuel samples are burned and the heat given off is measured precisely.

In FY 79 these researchers built a calorimeter that can accommodate 25 grams of material, ten times the capacity of instruments in current use. During the next 3 years, with funding from the Department of Energy, they will be developing progressively larger models with the goal of producing calorimeters capable of burning multikilogram samples. With a valid characterization technique for establishing a fair market value for a particular batch of fuel, the marketability of refuse and RDF should improve.

Another combustion measurement project involved the real-time identification of transient chemical species by researchers at the Joint Institute for Laboratory Astrophysics (JILA). (JILA is operated jointly by NBS and the University of Colorado.) A special laser system is used in this technique to excite specific molecules in a flowing gas mixture and initiate a chain combustion reaction. Meanwhile, a detector monitors the infrared radiation emitted by molecules formed throughout the process on a real-time basis. This high-speed tracking of combustion products and intermediate chemical species could provide engineers with the detailed information they need to design more fuel-efficient engines.

Almost simultaneously, Bureau researchers reported the success of an analogous technique—infrared-laser photolysis/mass spectrometry—for gathering similar dynamic chemical kinetics information. This method employs an infrared laser to initiate reactions and a mass spectrometer for time-resolved identification of reactant intermediates. Because the mass spectrometer is a very definitive instrument, able to identify unambiguously almost any molecule of interest, this work may have even wider applications for improving combustion technology.

Surface chemistry continued to be a major topic of interest. One NBS group of surface scientists discovered a particular class of molecules that seems well-suited to serve as an "anchor" on certain types of metal surfaces. Though this work is still in the initial stages, it may be possible to tailor-make special materials by attaching specific molecular groups to the surface using these "anchor" molecules. This could be a very useful development for solar energy research. The "anchors" could be used to create a surface full of molecules which best absorb the light frequencies emitted by the sun, thus increasing the efficiency of solar photovoltaic devices.

Stephen R. Leone (left) of the Joint Institute for Laboratory Astrophysics and David J. Nesbitt of the University of Colorado discuss the technique they developed to further the understanding of combustion processes.

Environmental Measurements

Many proposed energy alternatives to oil and natural gas, such as synfuels made from coal or biomass processes, will bring with them additional environmental concerns. Special care must be taken and new tools developed if the benefits to the environment realized during the 1970's are to be maintained and improved through the 1980's.

In the Center for Analytical Chemistry (CAC), researchers began a 5-year pilot project with the Environmental Protection Agency (EPA) in November 1979 to help provide the kind of baseline data and sensitive analytical methods that will be necessary to judge adequately the effectiveness of future environmental regulations. The NBS/EPA Pilot Environmental Specimen Bank is a feasibility study designed to provide a measurement system for monitoring pollutant trends by comparing pollutant concentrations in new biological and environmental samples with historic samples that are "on file." The pilot facility, located at NBS headquarters in Gaithersburg, Md., is the first environmental specimen bank of its kind in the world. Over 5 years of intensive research and planning by EPA, NBS, and West German scientists collaborating on the study were invested to develop valid sampling, analysis, and storage techniques.

The objective of this project is to test the validity of these methods. Through such long-term storage techniques as freezing in liquid nitrogen at temperatures of −196 °C, the researchers hope to show that specimens can be preserved for periods of up to 100 years with no chemical degradation. The success of methodology developed in the pilot specimen bank program would make possible the first truly valid, long-term pollutant concentration profiles and permit comparison of pollutant concentrations found in different regions of the country. This would greatly improve estimates of a given chemical's environmental significance.

Also within CAC, NBS scientists perfected a way to differentiate between air particulates produced by natural and wood-burning sources and those produced by the combustion of fossil fuels such as gasoline or coal. Adapted from radiocarbon-dating techniques, the method capitalizes on the fact that the carbon produced in the "breathing" process of trees and plants and in the burning of wood contains a certain percentage of the naturally radioactive isotope, carbon-14. In fossil fuels, however, this isotope has decayed to the point that it is no longer measurable.

By separating the total amount of carbon from an air particulate sample and measuring the ratio of ^{12}C to stable ^{14}C, the researchers were able to estimate the contribution

Research chemist Sally Harrison stores biological samples in a liquid nitrogen freezer as part of the joint NBS/EPA Pilot Environmental Specimen Bank Program.

of wood-burning and natural particulates to air pollution in the Portland, Oregon, area. Their technique is more than 100 times as sensitive as previous methods and could be used to analyze the sources of air pollution.

No description of NBS environmental measurements research would be complete without mention of environmental Standard Reference Materials (SRM's). SRM's are well characterized materials with chemical or physical properties certified by NBS, which can be used by other scientists to calibrate measurement methods or instruments. In environmental measurements, the use of SRM's is critical due to the extremely low levels (often a few parts per billion) at which some pollutants can cause environmental damage or toxic effects.

Two particularly important environmental SRM's were issued during FY 80—Oyster Tissue (SRM 1566) and Shale Oil (SRM 1580). The Oyster SRM should help improve measurements of toxic metal pollutants that become concentrated in oysters, mussels, and other marine animals used as foods. SRM 1580 is intended to provide a common baseline for measurements of five important organic pollutants present in shale oil, tar sands, liquefied coal, and crude petroleum. NBS researchers found that measurements made by different organic analysis laboratories, without the benefit of a suitable SRM for calibrations, on the same samples of shale oil varied by about 600 percent.

Measuring Materials Properties

The goal of the Bureau's work in materials science and engineering is to understand the properties and structure, improve the performance and durability, and reduce the cost of materials. Meeting these objectives requires a broad program of research in the development of new methods of materials properties measurement and data collection.

One program created in response to many materials needs broadens the applications of impedance spectroscopy. Impedance spectroscopy is basically a way to examine the electrical and structural properties of a material by measuring its resistance to an alternating current, as a function of the frequency of that current. Variations of the technique have been applied by researchers in the Center for Materials Science to examine electrodes and solid electrolytes proposed for use in high-temperature, electricity-generating fuel cells and for investigating the microstructure of new, temperature-resistant ceramics. Their work suggests processing strategies that could help better the performance of these materials.

Similar motivations spurred research into the dynamic thermophysical properties of electrically conducting materials under extreme conditions of rapid heating. During the period covered by this report, CTMS scientists designed a pulsed Michelson-type laser interferometer for rapid measurements of thermal expansion at high temperatures. This is the first such instrument capable of measuring thermal expansion at temperatures above 800 °C. Moreover, measurements made with a high-speed pyrometer (used in determining temperature) have pointed to large discrepancies between dynamic measurements of the heat capacity of temperature-resistant metals, such as molybdenum and tungsten, and the

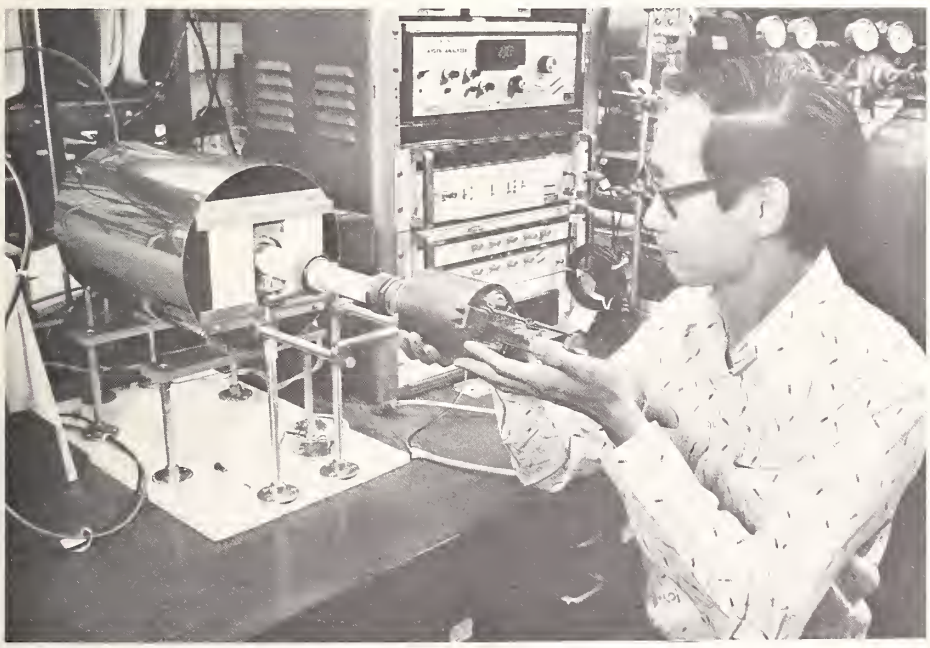
heat capacity predicted by currently accepted theories. These scientists are now in the process of trying to explain the differences through computer modeling studies of the materials' crystal structure. In an effort to extend heat capacity and other measurements of thermophysical properties to temperatures of up to 10,000 °C, they are also designing a new system which will provide measurements at microsecond intervals, 1,000 times faster than present instrumentation. The new system is expected to yield the first accurate data on the high-temperature, thermophysical properties of metals in their molten state.

The relation of theory and experiment has been the theme of many NBS studies in the polymers area. For example, an experimental study involving small-angle neutron scattering has refuted a theory that assumes individual molecules of synthetic rubber would imitate the deformation behavior of the bulk specimen. By "bouncing" neutrons off a specially prepared sample of stretched rubber, the researchers determined that individual molecules were not "stretched" in an analogous fashion, as might be expected. Further research in this area should help confirm theories which more accurately tie a polymer's molecular structure to its bulk properties.

Neutrons can also be used as nondestructive "probes" of materials important for energy research. With uranium becoming increasingly expensive and in short supply it could soon be necessary to reprocess the spent fuel of reactors to recover any unfissioned uranium^{238} remaining in fuel rods. If this practice becomes widespread, it will be important for reactor owners to have an accurate means of determining the distribution of uranium^{235} and uranium^{238} in fuel rods before processing for adequate accounting and safeguarding of the material.

In FY79 NBS researchers developed a nondestructive isotope measurement method that greatly improves present uranium assaying techniques. By passing a beam of neutrons through a sample of nuclear fuel, the location and quantity of U^{235} and U^{238} can be "mapped" to within 1.5 percent of actual concentrations. The method may also be useful in other processing industries such as in the separation of non-uniform heavy metals from ores.

And, in the economically important area of corrosion research, Bureau scientists demonstrated a new technique for measuring the corrosion of metal under organic coatings, which may prove useful as a research tool for paint and other coatings manufacturers. This new method combines two corrosion measurement strategies—ellipsometry (an optical technique) and pH changes—into a single, very sensitive apparatus for nondestructive monitoring of coated metal in corrosive environments. Preliminary studies indicate the method has application both as a basic research tool for unraveling the complicated chemistry needed to explain why paints and other organic coatings fail and for the systematic laboratory testing of various anti-corrosion paint systems containing chemical inhibitors.



At left. Research chemist Jeanice Brown-Thomas prepares a batch of shale oil samples for certification as Standard Reference Materials. Organic compounds are first separated using a high-performance liquid chromatograph, then the concentration of compounds of interest are determined with a fluorimeter.

Above. An instrument used in impedance spectroscopy studies is displayed by physicist C. K. Chiang. With this instrument, Chiang and Alan Franklin, project leader for these experiments, are investigating the effect of grain boundaries on the electrical properties of certain potential fuel cell materials.

National Engineering Laboratory

BASIC science was responsible for defining electricity and its properties, but engineering brought us the light bulb. Every scientific discipline—from physics, to biochemistry, to astronomy—helped make the Apollo space program possible, but it was advanced engineering that ultimately put men on the moon.

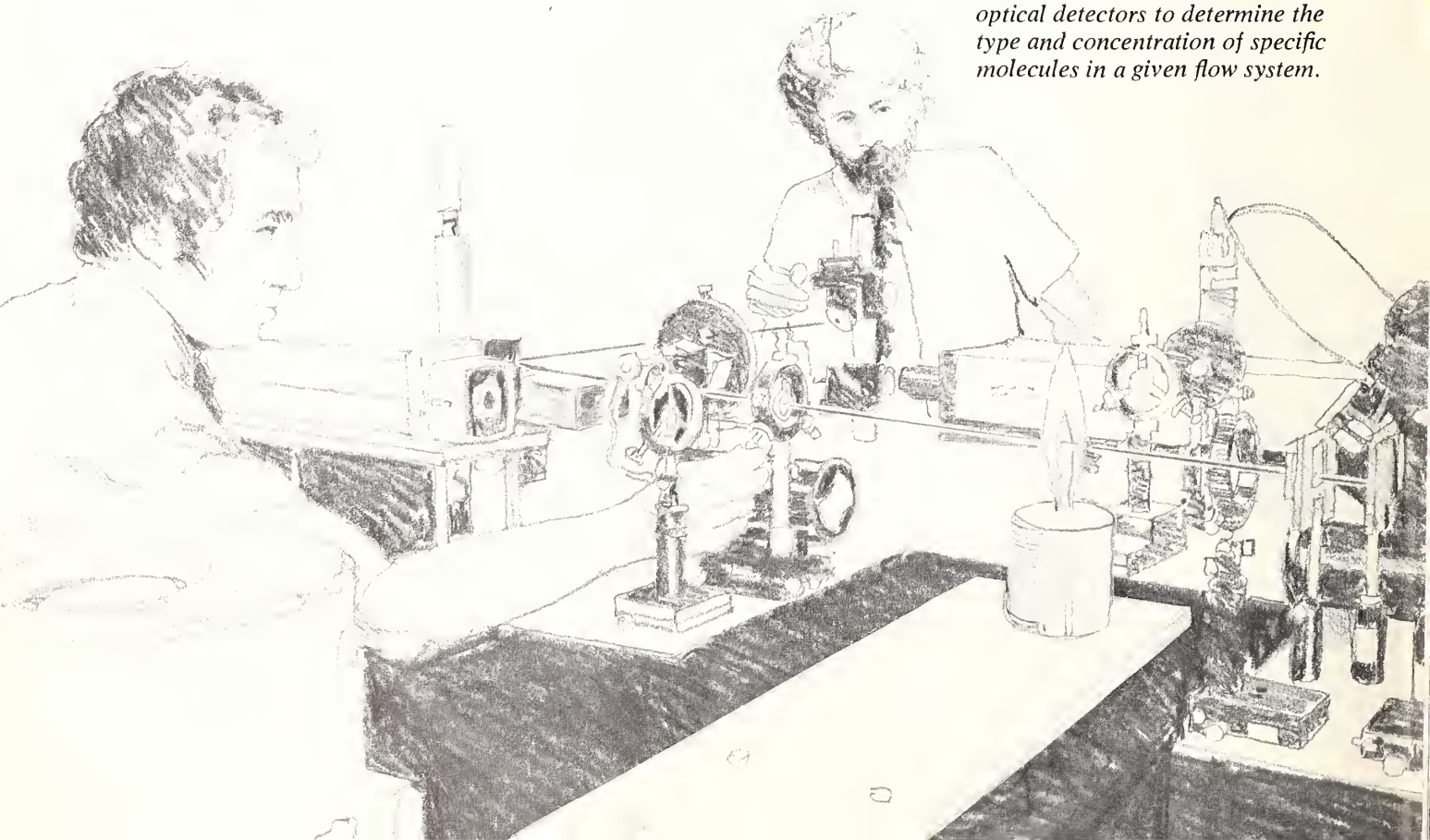
This symbiotic relationship between basic science and engineering research has been reflected in NBS activities throughout its history. While fulfilling its classical role as a central reference laboratory for all kinds of measurements in engineering, physics, and chemistry, the Bureau has applied this basic competence to the solution of a broad range of national problems. The Bureau's emphasis on basic research in the National Measurement Laboratory is complemented by its work in engineering measurements and standards centered in the National Engineering Laboratory (NEL).

The technical staff of NEL conduct research in engineering and the applied sciences, develop engineering data, and provide improved measurement techniques to the engineering community. Their research spans a gamut of disciplines including electrical, chemical, civil, and mechanical engineering and applied mathematics.

Because of the quality of its work and its objectivity, NEL is often called upon to provide technical assistance to Congress, other government agencies, technical and professional societies, standards-generating organizations, trade associations, and consumer, industry, and labor groups. Many of the Laboratory's programs, in fact, are mandated by Congress. The Consumer Product Safety Act, the Solar Heating and Cooling Demonstration Act, the Federal Fire Prevention and Control Act, the Energy Policy and Conservation Act, the Earthquake Hazards Reduction Act, and the Trade Agreements Act all address national problems that require technical information for their solution. And, the NEL staff are responding with technical data, standards, and measurement-related engineering research.

Examples of technical accomplishments during the past 2 years in these and other areas follow.

Illustrated here is a technique called optical tomography for taking cross-sectional data "pictures" of mixed gas or liquid flow systems that was developed by Hratch Semerjian and Robert Santoro. The technique uses an infrared laser and an array of optical detectors to determine the type and concentration of specific molecules in a given flow system.



Helping Improve Industrial Productivity

In view of the importance of productivity growth for the economic health of the Nation, research projects aimed at establishing a technical and measurement base for technological innovation by industry receive a large portion of NEL funding. This research emphasizes the development of engineering measurement technology, standards, and recommended practices for materials transfer, improved quality control of products, better manufacturing process control, energy conservation, and efficient regulatory compliance.

One such project completed in 1980, called IGES (Initial Graphics Exchange Specification), resulted in a system that permits data to be transferred from one CAD (Computer-Aided Design) system to another CAD system of different manufacture. IGES also provides a first step toward allowing data transfer from CAD systems to CAM (Computer-Aided Manufacturing) systems, robots, and other manufacturing components. CAD systems include intricate graphics programs which engineers use to design and visualize new products on computer display terminals. CAD-CAM data transfer systems use program commands specified in the engineers final design to provide instructions for the machine tools and/or robots building the product.

Until IGES was developed it was necessary to render the design data from one CAD system into some transportable form, such as a blueprint, and then reenter the data in the second CAD system. This has been a slow and costly process. With the support of the Air Force, Navy, Army, and NASA, an NBS expert in automation technology has led a group of specialists from U.S. industry and government in the development of IGES.

The American National Standards Institute (ANSI) is currently considering the adoption of IGES as part of a voluntary industry standard.

With the aid of the recently developed Initial Graphics Exchange Specification, product designs created using one Computer-Aided Design (CAD) system such as this can be transferred to a CAD system of different manufacture.

If IGES becomes an ANSI standard, CAD/CAM manufacturers would provide codes to translate data between their programs and IGES. Data could then be moved through an IGES link between any two systems. This should increase the flexibility of computerized manufacturing and make CAD/CAM sales more competitive.

Several projects within the Center for Electronics and Electrical Engineering (CEEE) focused on improving productivity through innovation in the quality control of semiconductor manufacturing. Materials imperfections are perhaps more critical in the production of integrated circuits than in the fabrication of any other type of device. Minute imperfections cause changes in the flow and leakage of current in the semiconductor in which the integrated circuits are built, thus degrading performance of the circuits. Generally though, these imperfections and the current flow or leakage changes are too tiny to be measured without tedious, time-consuming, and difficult testing.

A device called an integrated gated-diode electrometer, developed by NBS researchers, can be used to make these same measurements in a few seconds with a computer. The time savings lies in the fact that the device, which is manufactured along with the product integrated circuits, includes an electrical amplifier that makes extremely small leakage currents and other quality problems

easy to measure. By incorporating the NBS electrometer on every wafer of a given production lot, manufacturers can test wafers at high speed and remove from the production line any that fail specified performance criteria, thus avoiding the cost of separating and packaging faulty circuits. The result: better quality devices with less materials waste.

Another NBS-developed testing system allows nondestructive evaluation of the on/off switching capability of certain semiconductor devices called bipolar power transistors. Bipolar power transistors rapidly switch high currents and voltages on and off, including, for example, automobile ignition systems. Existing tests of safe operating limits for these transistors expose the devices to destructive currents. Thus, only a random sample of transistors can be tested and, due to the high variability among devices, this provides an unreliable estimate of the quality of those transistors ultimately sold.

The NBS testing circuit subjects these transistors to a variety of electrical conditions. Whenever potentially destructive voltage drops occur, the circuit drains all current from the device within 40 nanoseconds, saving it from destruction in the nick of time. Such a system may make it possible to test the devices which will actually be sold, improving quality control. And because repeated measurements can be made on the same device, the tests are more accurate. These researchers have written a step-by-step construction manual so that semiconductor manufacturers can reproduce the test circuit.

In a third project within CEEE, a new algorithm and circuit designed at NBS could make possible the first practical production-line tests of noise in analog-to-digital (A/D) converters. A/D converters measure the continuously changing outputs of sensors and convert the data into a succession of numbers corresponding to the instantaneous values measured. Without A/D converters, a whole array of important computer-operated scientific instruments would not exist. Noise or random currents within an A/D converter limit both its accuracy and speed, but are very difficult to determine quantitatively.

The NBS system consists of a well characterized voltage source that pinpoints the exact amount of additional current needed for a given A/D converter to assign the next highest digit. The fluctuations in the converter's measured "decision points" are then calculated with a new mathematical model for a measure of the converter's "inherent noise." The simplicity and speed of this automated measurement method make it a good quality control inspection technique for manufacturers. It could also help instrument makers insure that the A/D converters they buy meet performance requirements.

Physicist Gary Carver inserts a semiconductor wafer containing solid state imagers into a test station. By testing integrated gated diode electrometers incorporated in each imager chip, Carver is able to quickly and easily determine materials-related properties that affect the electrical quality of the devices.

Using Energy Efficiently

While alternative energy sources are being developed, energy efficiency and conservation are essential measures. From an industrial point of view, the more expensive oil and gas become, the more advantageous it is to have full control over the energy use of combustion and other chemical processes.

A new system developed by researchers in the NBS Continuous Process Technology Program could do for the energy efficiency of the chemical industry what the CAT scanner did for diagnosis in medicine. The NBS technique, called optical tomography, takes cross-sectional data "pictures" of mixed gas or liquid flow systems. The "pictures" result from absorption of light from a tunable laser by molecules in the flow. The pattern of absorption picked up by detectors indicates both the types of molecules and their concentrations. Because gas and liquid flow systems found in industrial combustion and other high temperature reactions are highly variable, the kind of comprehensive data provided by optical tomography should prove very useful to process control engineers in tailoring reaction products for maximum efficiency.

Research work designed to help improve the energy efficiency of major home appliances such as furnaces, air conditoners, and heat pumps continued in the Center for Building Technology (CBT). This work stems from the National Energy Policy and Conservation Act of 1975 and later legislation which require that NBS assist the Department of Energy (DOE) in developing test methods for energy-using residential appliances. In order to have test procedures reflect conditions encountered during normal use as much as possible, NBS researchers in CBT recommended test methods to DOE that account for the effect of on/off cycling and variations in outdoor temperatures on the seasonal efficiency and the annual energy consumption of central heating and cooling systems. Some furnaces, air conditioners, and heat pumps use less energy than others when responding to these part-load and seasonal conditions. DOE prepared a final set of test procedures for residential air conditioning and heat pumps in December 1979 based on this NBS work. Standard test methods completed in May 1978 for residential furnaces have now been extended to include residential condensing furnaces and boilers. In 1981 NBS researchers plan to recommend to DOE certain modifications to central air conditioning and heat pump test procedures that will include more efficient systems which have been marketed since the first test procedures were written. Also, equipment simulation modeling work is continuing so as to lessen the testing burden that is now required of the manufacturer.

Researchers in the NBS Center for Consumer Product Technology finished a project during 1979 to

Engineering technicians John McAuley (left) and Richard Petersen make final adjustments to the Bureau's new guarded hot plate, which will provide extremely accurate thermal measurements of insulation specimens up to 350 mm (14 inches). NBS calibrated transfer specimens can then be used by insulation manufacturers to determine R-values for thick layers of insulation.

determine the energy-saving potential of water conservation devices. This project, funded by the NBS Office of Energy-Related Inventions, showed that while these devices produced substantial savings of water, they were even more effective in reducing home water-heating energy requirements.

A survey of currently available water-saving devices, such as flow restrictors for shower heads, faucets, and toilets, revealed that complete replacement of plumbing fixtures and appliances with these devices could be expected to cut water-related energy needs by about 35 percent. Over 90 percent of that savings would come from reductions in water heating. The study also examined the potential energy savings possible with home water recycling systems where water used in one part of the house is reused in another after minimal filtration or chemical treatment. Full use of water recycling could reduce water-related energy consumption by half, but it may be some time before such savings can be realized due to technical problems, acceptance by homeowners, and the need for such systems to be built into a home when it is constructed.

Improving Performance and Fire Safety of Buildings

Safety and performance research is another high priority—much of NEL's work concerns the performance and fire safety of buildings, as well as basic science studies of fire properties.

For example, CBT researchers recently completed a major effort to make building design easier and more reliable. They devised a system of probability-based load factors and load combinations which can be used to specify structural requirements for particular building applications regardless of the construction materials ultimately used (i.e., wood, masonry, steel, reinforced concrete). Currently, building codes specify minimum structural requirements according to materials usage; different load and resistance factors or allowable stresses are required for different materials. This complicates

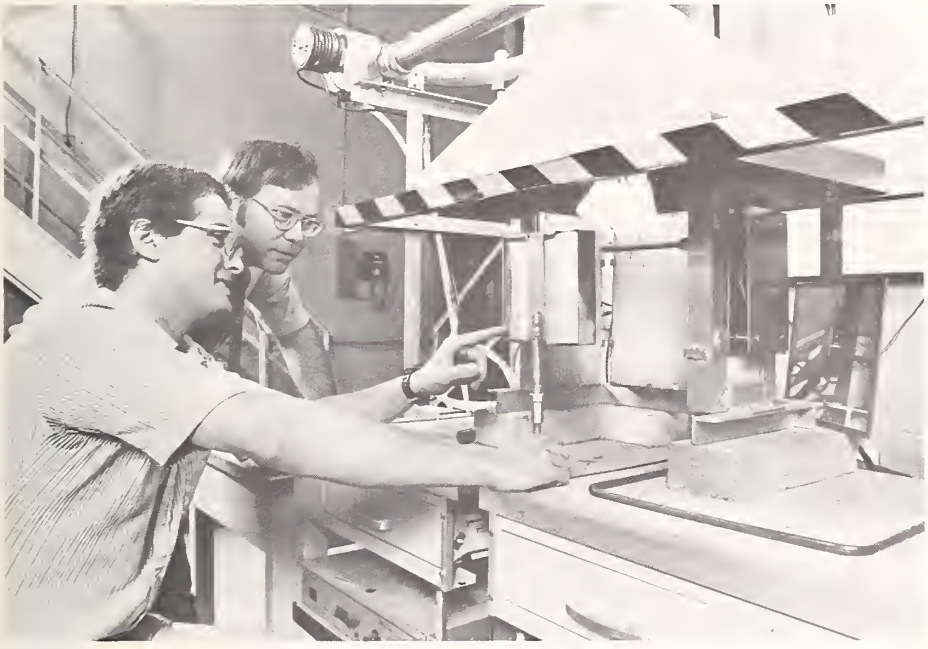
Above. NBS researchers have developed a system of probability-based load factors and load combinations that will insure consistent levels of reliability against structural failure or poor service performance.

Top right. French guest worker Olivier Carret (left) and NBS researcher Randy Lawson demonstrate an oxygen consumption calorimeter that provides measurements of a material's rate of heat release.

Lower right. With a new NBS device, research chemist Merritt Birky calibrates a combustible vapor detector used in arson investigations.

building design, especially when more than one construction material is used in a single building. Use of this new load criterion would insure consistent levels of reliability against structural failure or poor service performance for all buildings, while simplifving design. Because it applies to all types of materials, the model would be easier for building designers to implement. The load criterion is now under review by professional groups and will be considered for adoption as part of the ANSI A58 standard on structural loads.

Under the sponsorship of the Department of Health and Human Services (formerly the Department of Health, Education and Welfare), Bureau researchers in the Center for Fire Research (CFR), CBT, and the Center for Applied Mathematics designed a system for evaluating the fire safety of hospitals and other health care buildings that could save those facilities millions of dollars in retrofitting costs. The Fire Safety Evaluation System provides a model that allows health care administrators and fire safety engineers to determine which alternatives among thousands of options offer the least costly means of building or retrofitting facilities so that they satisfy the fire safety requirements of the widely used Life Safety Code of the National Fire Protection Association. By using this computerized technique to select corrective fire safety measures for existing buildings, health care facilities can cut the cost of complying with the Life Safety Code by up to one half without reducing protection to their patients or staff.



On the more basic side of fire research, a new technique developed to measure more accurately the rate of heat release (RHR) for different materials promises to make important contributions to the understanding of fire spread and the development of upholstered furniture flammability tests. Bureau researchers, in collaboration with guest workers from the United States and abroad, have come up with an innovative instrument for determining RHR values that uses a substantially different approach than previous techniques. The instrument measures the oxygen consumed while a sample material burns. The technique relies on the fact that most materials release about the same amount of heat for each unit of oxygen used. The more quickly oxygen is consumed, the higher the rate of heat

release, the more likely a fire will spread quickly. Dubbed the oxygen consumption calorimeter, this device improves the accuracy of heat release rate measurements, is potentially less costly to produce, and is considerably simpler in design and operation than previous RHR instruments.

The Bureau's work in fire science also includes improvements for measuring tools used in the field of arson detection. For many years, arson investigators have used portable detectors at the scene of extinguished fires to "sniff out" vapors of hydrocarbons, the trademark of arsonists who set fires with accelerants such as gasoline, kerosene, or paint thinner. Samples of debris in the vicinity of vapors located with the detector can then be analyzed chemically to establish whether arson was the probable cause of the fire. Even though such detectors are widely used, fire investigators have had no way to check the sensitivity of these devices to insure acceptable levels of detection. To alleviate this problem, Bureau researchers adapted technology used in air pollution monitoring to produce a portable instrument which generates a standard hydrocarbon vapor. Using the standard vapor as a check, investigators will now be able to calibrate their detectors regularly.

Developing Other Measurement and Calibration Methods

There are many areas of engineering measurement in which NBS researchers serve as the U.S. experts. The measurement of electromagnetic interference or EMI fits into this category. EMI is a kind of pollution of the airwaves which can create spurious signals in electronic or electrical equipment. It is caused by the proliferation of commercial radio and television signals, CB radio transmission, microwave ovens, high voltage power lines, and other electromagnetic radiation sources. The Bureau has a growing commitment to understand better and to limit the effects of EMI through improvements in measurement technology.

The development of the broadband isotropic electric field meter by NBS researchers has permitted particularly important gains in field measurements during the past 2 years. This portable instrument can measure the strength of electromagnetic radiation between 500 kilohertz and 1 gigahertz, representing radio frequencies to microwave signals used in radar, with twice the sensitivity of present meters. The new meter also has a much broader range of detection than other meters in both very strong fields and very weak ones and eliminates the need to account for the direction or distance of the radiating source.

Designed with commercial production in mind, the device is already being manufactured by a private company. Its immediate applications are many: monitoring radio frequency emitters used in industrial processing to maintain safe exposure levels for plant workers; determining the electric fields generated by high power TV and radio antennas; characterizing EMI levels around sophisticated electronics as in hospital intensive care units; and evaluating the emission of electromagnetic radiation from microwave ovens and other products.

Meanwhile, other researchers showed the Army Communications Command a way to help improve the reception of their small ground-based satellite receiving stations which are scattered throughout the world. Bureau electromagnetic interference researchers devised methods of using the moon and the sun as standardized sources of microwave signals which can establish the quality of small dish antennas between 4.0 and 5.5 meters in diameter. Basically, the method involves pointing the antenna at the sun or moon and comparing the signal received with that received when the antenna is pointed away from all sources of radiation. Use of this system will help the Army maximize the performance of its current communications stations and select new antenna systems with

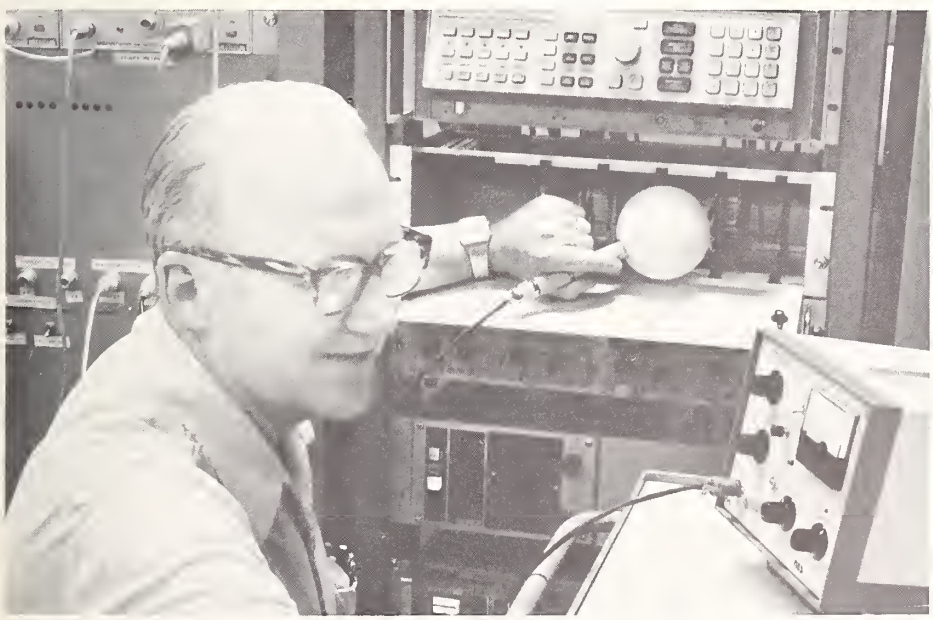
the best reception quality.

The military is also the recipient of NBS expertise in superconducting circuits, electronic components maintained at extremely cold (cryogenic) temperatures to vastly improve their speed of operation. An NBS research group in CEEE has succeeded in fabricating the fastest superconducting analog-to-digital converter ever made. The device is ten times as fast as the best A/D converters now available. In addition to a number of military applications, the device promises to improve significantly NBS capabilities in high-speed research measurements. One future advanced measurement application may be in characterizing laser pulses used in experimental fusion facilities. These powerful bursts of laser radiation last only several billionths of a second and cannot be studied adequately with current technology.

In the nuclear energy area, NBS researchers made improvements in calibration procedures for fuel processing tanks that will help in safeguarding fissionable uranium supplies. Spent fuel from nuclear reactors is sometimes processed to recover any remaining fissionable materials. This requires strict accounting procedures in many stages of the process to account for and control materials, thereby safeguarding these special nuclear materials. For this reason, volume and density measurements are required each time solutions containing fissionable materials, such as uranium, are transferred from one process to another.

The calibration of these tanks involves a laborious process where 50- to 100-gallon (189- to 379-liter) test measures are repeatedly filled with water and drained into the tanks to check the accuracy of volume-measurement systems. A prototype automated tank calibration system, built by Bureau researchers, improves the accuracy of this method while decreasing the effort required for the task. In the new system, two turbine flow meters allow unattended filling of the tank with water while a mini-computer continuously monitors the flowrate and the tank's response system. During fiscal year 1981, the NBS researchers plan to test this instrument at a nuclear processing plant.

In addition to providing technical assistance in the solution of immediate national problems, NEL is devoting its competence building funds to future problems in areas important to productivity growth, such as electronics, industrial automation, and continuous process technology. For example, in electronics NBS researchers are focusing on cryoelectronic metrology. They are developing the underlying measurement technology for a new generation of high-speed, high-sensitivity electromagnetic instrumentation for test equipment, communication, radar, and other systems with data handling and sampling rates on the order of 1 gigahertz. NEL is also concerned with improved measurement concepts for other programs such as the development of a refrigeration system suitable for use with superconducting electronics.



Here electronic engineer Francis Ries operates the broadband isotropic electric field meter developed at NBS to help government and industry measure electromagnetic radiation that might interfere with some electronic products.

Institute for Computer Sciences and Technology

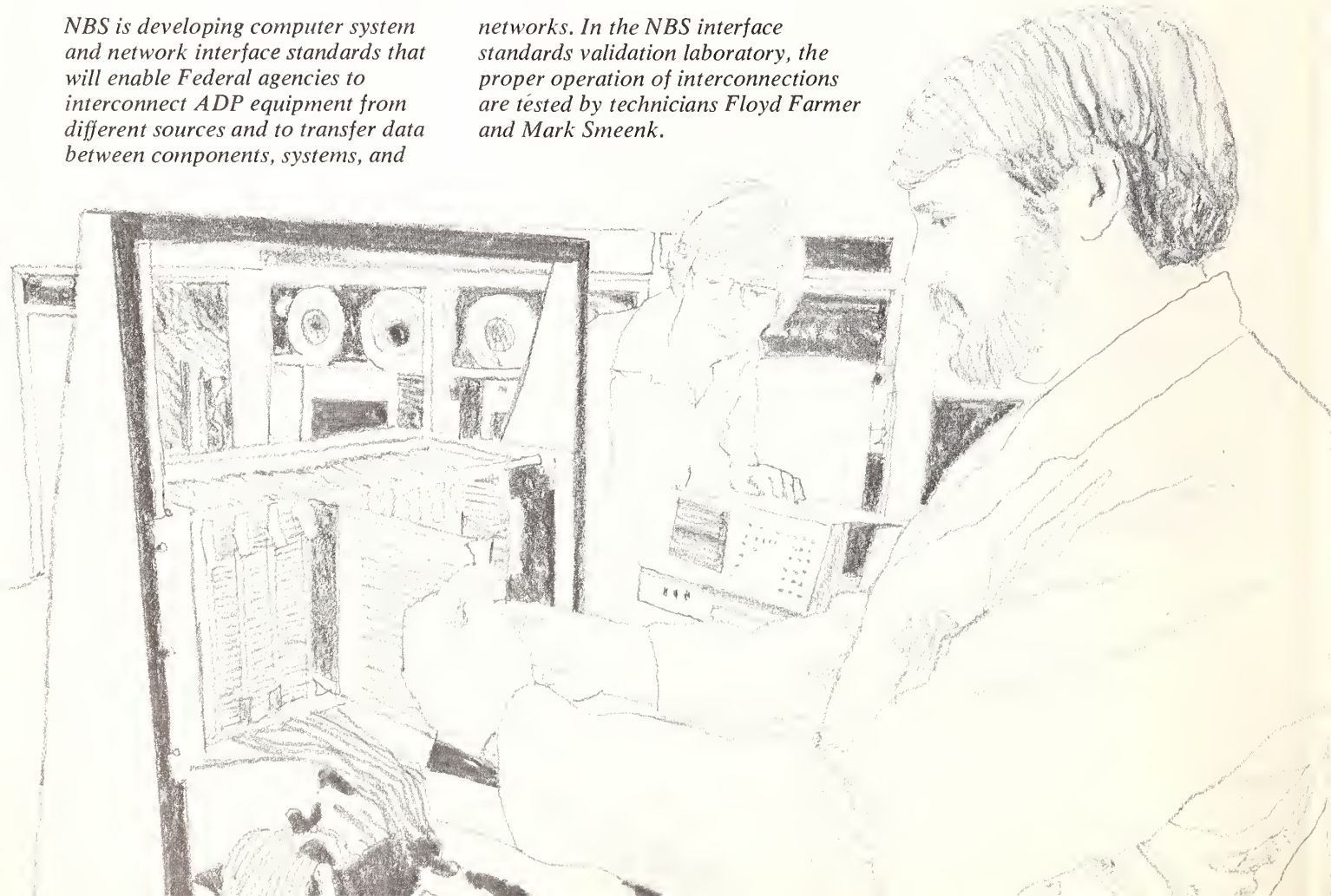
THEY monitor air traffic, process Social Security benefits, control defense and space systems, print the paychecks of millions of employees, and dutifully perform countless other tasks from the simple to the sublime. Computers are so widely used today that it is difficult to visualize what life was like without them just 30 years ago.

And, as applications for computer technology multiply with amazing speed and the complexity of computer systems grows, efficient use and management of computers become a challenge to Federal managers.

The NBS Institute for Computer Sciences and Technology (ICST) plays an important role in helping Federal agencies use computers to improve the delivery of public services and the management of government programs. Under responsibilities given it by the Brooks Act of 1965 (P.L. 89-306), ICST develops Federal automatic data processing (ADP) standards, provides technical assistance, and conducts supporting research to help reduce the costs and improve the effectiveness of the Federal government's computer operations. The Brooks Act was passed to promote the economic and efficient selection, acquisition, maintenance, operation, and use of ADP equipment by the Federal government. Because the Federal government, one of the world's largest computer users, spends over $10 billion each year on ADP equipment, services, and salaries for technical personnel, ICST efforts have a major effect on the expenditure of tax dollars.

Fiscal years 1979 and 1980 were important ones for the Institute. With the backing of the Office of Management and Budget (OMB) and Congress, the ICST budget was increased to support the development of priority standards set forth in a long range plan drawn up by ICST. At the same time, the Institute strengthened the overall management of the Federal ADP standards effort and its ties with other Federal agencies, the private sector, and voluntary standards development groups.

In 1979 at the request of OMB, Federal agencies appointed senior management officials to provide ICST with agency views on ADP concerns and standards needs. To further



NBS is developing computer system and network interface standards that will enable Federal agencies to interconnect ADP equipment from different sources and to transfer data between components, systems, and networks. In the NBS interface standards validation laboratory, the proper operation of interconnections are tested by technicians Floyd Farmer and Mark Smeenk.

improve communications with these groups, ICST issued in May 1980 the first of a series of periodic newsletters covering the development of standards and guidelines, Federal ADP policy issues, and reports on technical publications and activities. And, through a program of contracts with private, non-profit, and academic organizations for technical and economic impact studies, ICST has improved its technology forecasting and program development and evaluation capabilities.

Computer Standards and Guidelines

ICST's long range plan calls for the development of standards and guidelines needed by Federal agencies to address the major problems of ADP use: to reduce the high costs of software development and maintenance and to improve software quality; to encourage the more efficient use and interchange of data; to better ADP operations, especially the security and integrity of operations; and to improve capabilities for interconnecting components, systems, and networks.

Among the significant accomplishments during this 2-year period was the completion of several new Federal Information Processing Standards (FIPS), the NBS publication series for ADP standards and guidelines developed by ICST. The Federal repertoire of programming languages was expanded to include standards for the Minimal BASIC and FORTRAN programming languages (FIPS 68 and 69).

Minimal BASIC is a general purpose computer programming language suited to the fast creation of computer programs needed to solve small, nonrecurring problems. FORTRAN is a general purpose language designed primarily for scientific and engineering applications. The use of these new standards is expected to reduce substantially the costs of transferring programs from one computer to another. Programs written in standard languages will also be easier to develop and maintain, since programmers will have to learn only one set of rules for a language. FIPS 68 and 69 adopt voluntary industry standards developed by the American National Standards Institute (ANSI) with the participation of ICST staff members.

Government savings of $61 million are expected over the next 5 years from the use of four input/output channel level interface standards (FIPS 60-63). These specifications insure the compatibility of magnetic disk or tape peripheral equipment with large- and medium-scale computer systems made by different manufacturers. Use of these standards will mean that Federal agencies will be able to save money by buying peripheral equipment competitively. FIPS 60 and 61 define the mechanical, electrical, and basic functional specifications for channel-level interface and the power sequencing for the connection of peripheral equipment. FIPS 62 and 63 provide the operational specifications for connecting tape and disk units to central computers.

To help Federal agencies protect the integrity of their data, computer scientist Stuart Katzke has prepared a guideline based on risk management and software development techniques that will improve security of funds dispersing, inventory control, and other computer application systems.

To improve software quality through better documentation practices, ICST issued FIPS 64, *Guidelines for Documentation of Computer Programs and Automated Data Systems for the Initiation Phase.* This guideline provides a structured format for recording the initial planning, feasibility studies, and cost-benefit analysis work which precede the development of computer programs and automated data systems. Such information is useful in the development of new software systems and the modification of established software. Used in conjunction with a previously issued guideline on documentation (FIPS 38, *Guidelines for Documentation of Computer Programs and Automated Data Systems*), FIPS 64 helps agency project managers determine the extent and type of documentation needed for cost-effective software development and management.

Another guideline issued during this period helps agencies assess the potential risks to their ADP systems and select cost-effective safeguards to counter those risks. FIPS 65, *Guideline for Automatic Data Processing Risk Analysis,* details the reasons, forms, and procedures for carrying out a risk analysis and provides a methodology for managers to use in striking a balance between risks and the cost of protective measures.

Several standards for improving the processing and interchange of Federal data were adopted also. FIPS 58, 59, 66, and 6-3 provide standard ways for representing and formating computer data related to time, economic activities, and counties of the United States.

ICST's long range plan calls for continuing emphasis on the development of needed standards and guidelines and on strengthened management of the Federal ADP standards program. This includes work with agencies in collecting data on the use of standards and in assessing their impact as well as continued cooperation with voluntary standards efforts.

Efficient Use and Management of Computers

During this 2-year period, ICST's technical assistance and research activities were limited to the direct support of standards development. However, under funding to encourage NBS research competency, ICST started research projects in two areas of increasing importance in Federal computer applications. In the area of data base technology, ICST researchers are developing ways to express and manipulate the complex data structures that are found in database management and other information processing systems. These software systems are used by Federal agencies to manage and control their data resources and to provide the capability for data sharing among many users. In the second area of research, investigators are developing techniques to measure and improve the flow of data traffic in local area communication networks. Through the cost-effective sharing of communications facilities, such networks enable agencies to link their computers and terminals in a limited geographic area such as an office complex.

Electronic engineer Daniel Stokesberry, seated at a display unit in the Networks Measurement Laboratory, is developing performance measurements for interface standards to improve reliability and reduce costs of local area networks.

Science and Technology Transfer: Services and Special Programs

THE National Bureau of Standards offers a broad range of services and opportunities for cooperative activity with Federal, State, and local governments, industry, universities, technical societies, voluntary standards groups, trade associations, international organizations, and the general public. Supplementing an informal, long-standing tradition of consultation with the public and private sectors, these efforts are designed to foster the widest possible transfer of science and technology from the Bureau to all scientific and technical communities. Listed below are some of these services and programs, along with information about how to obtain additional details.

Calibration Services

The calibration of instruments and devices is an essential feature of the NBS mission to provide the basis for a complete and consistent national system of physical measurements. The Bureau's calibration services cover: mass and dimensional metrology; mechanics and acoustics; electrical measurements (dc and low frequency); electromagnetic measurements at radio, microwave, millimeter wave, and laser frequencies; time and frequency; thermodynamic quantities; optical radiation measurements; and ionizing radiation. A complete description of these and related measurement services is provided in *Calibration and Related Measurement Services of the National Bureau of Standards,* NBS Special Publication 250.

Standard Reference Materials (SRM's)

SRM's are well characterized, homogeneous, stable materials or simple artifacts with specific properties measured and certified by NBS. They are widely used in a variety of measurement applications, including the evaluation of the accuracy of test methods, improvement of measurement compatibility among different laboratories, and establishment of measurement traceability to NBS. The Bureau currently has over 1,000 different SRM's available. During FY 1980, NBS sold approximately 40,000 SRM units to more than 10,000 users around the world. The program is operated by the NBS Office of Standard Reference Materials, B311 Chemistry Building, (301) 921-2045.

National Standard Reference Data System (NSRDS)

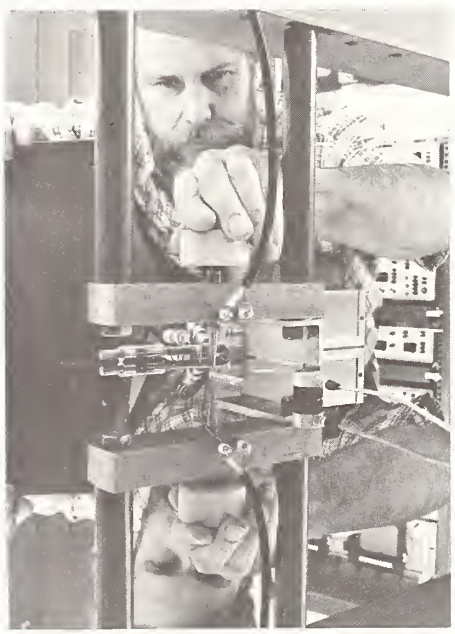
NSRDS, a nationwide program, gives scientists and engineers easy access to critically evaluated, reliable data. The program is coordinated by NBS, but involves many groups in universities, government laboratories, and private industry. More than 20 NSRDS data centers, located at NBS and throughout the country, pull together the results from many diverse research activities around the world and organize these data in a more dependable and useful form. Further information, including lists of data centers, is available from the NBS Office of Standard Reference Data, A323 Physics Building, (301) 921-2467.

Measurement Assurance Programs

A series of Measurement Assurance Programs developed by NBS assists laboratories in improving or verifying their capabilities for making accurate measurements. These measurement assurance services allow public or private laboratories to test their entire measurement system, from people to equipment to basic methodologies, for accuracy and traceability to NBS. At present, NBS offers measurement assurance services in voltage, mass, resistance, laser power and energy, and several other areas. For further information, contact the NBS Office of Measurement Services, B362 Physics Building, (301) 921-2805.

Standards Information Service

The NBS Standards Information Service (NBS-SIS) maintains a comprehensive reference collection of engineering and related standards. The NBS-SIS collection includes over 240,000 standards, specifications, test methods, codes, and recommended practices issued by U.S. technical societies, professional organizations, trade associations, State purchasing offices, Federal agencies, and foreign national and international standards organizations. The collection also contains reference books, articles, reports, newsletters, and microfilm files. Searches of the standards literature by NBS-SIS, with names of organizations where copies of the standards can be obtained, are available. Address requests (as specifically as possible) to the Standards Information Service, Room B162 Technology Building or telephone (301) 921-2587 or use Telex 89-8493.



Physicist Franklin Breckenridge calibrates an acoustic emission detector (transducer) made by a manufacturer. The calibration is made by breaking a glass capillary on a massive steel block and comparing the response of the manufacturer's detector with the response of the reference transducer developed by NBS.

Energy-Related Inventions Evaluation

To ensure that promising energy-related inventions receive a thorough, objective review—particularly inventions from individual inventors and small firms—the NBS Office of Energy-Related Inventions offers free evaluations. Established by the Federal Nonnuclear Energy Research and Development Act of 1974, the NBS program provides a way for anyone with a nonnuclear, energy-related invention to have a technical review of the device, material, process, and/or procedure. If the evaluation by NBS indicates that an invention shows significant promise for saving or producing energy, NBS recommends it to the Department of Energy (DOE), which will consider assisting the inventor in its development.

Last year, NBS received 3,484 requests for evaluations and recommended 31 inventions to DOE as especially promising. From mid-1975, when NBS opened its inventions evaluation office, through May 30, 1980, the Bureau received 14,693 requests for evaluations and recommended 139 inventions to DOE. For more information and an evaluation request form, contact the NBS Office of Energy-Related Inventions, A46 Technology Building, (301) 921-3694.

Research Associate Program

This program enables scientists and engineers from industrial, professional, trade, and other organizations to work for specified periods at NBS, under the sponsorship of their employers, on projects of clear mutual interest to the sponsor and NBS. The program offers industry an opportunity to do cooperative research with NBS professionals and to take advantage of the Bureau's extensive laboratories and related facilities. The program provides a means for communicating directly to NBS industry's views on its needs and problems.

During FY 1979, more than 110 Research Associates worked with NBS on 32 different projects of which approximately half were sponsored by private industrial companies and half by trade or professional organizations. More than 400 organizations and 1,000 individuals have participated in the program since it began in 1921. For more information, contact Industrial Liaison Officer, A402 Administration Building, (301) 921-3591.

State and Local Liaison

An important portion of NBS activities addresses matters of substantial interest to State and local governments, such as the Bureau's measurement work in the areas of weights and measures, air and water quality, and radiation. Also important are NBS research and its applications in the fields of fire prevention, building codes and standards, computers, energy conservation, building rehabilitation, and resource recovery. To promote a productive liaison that furthers the effective transfer of these technologies to their appropriate users, NBS works closely with Federal, State, and local organizations. The NBS Office of State and Local Governmental Affairs serves as a point of contact for representatives of State and local governments, providing information on NBS resources, publications, meetings, and professional organizations that serve the needs of States and localities. For information, write to the Liaison Officer, State and Local Governmental Affairs, A402 Administration Building, (301) 921-3814.

Guest Worker Program

NBS also has a Guest Worker Program that brings researchers to the Bureau to work on specific projects as a way of providing better dissemination of NBS research directly into user communities. The program permits specialists to work with NBS staff on projects of mutual interest for periods of several months up to 2 years. Foreign institutions and governments, international organizations, or U.S. groups provide the support for these workers. Interested researchers from abroad should contact the NBS Office of International Relations, A511 Administration Building, (301) 921-2463. U.S. researchers should contact individual NBS divisions or centers directly.

As part of a Science and Technology Enrichment Program, sponsored by NBS and the Montgomery County Public Schools, NBS researcher Jonice Harris explains the stress tests done on synthetic implants to students. A major goal of the program is to interest more children, especially girls and minorities, in careers in science.

Postdoctoral Research Associate Program

The NBS Postdoctoral Research Associate Program enables postdoctoral scientists and engineers of unusual promise and ability to conduct research at NBS on problems that are compatible with Bureau interests and contribute to the overall NBS research effort. Operated in cooperation with the National Research Council, the program is intended to be analogous to fellowships, associateships, and other temporary programs at the doctoral level in universities. Further details may be obtained from the Chairman, Postdoctoral Research Associate Program, A113 Materials Building, (301) 921-2103.

Conferences, Tours, Exhibits, Films

As one of the world's crossroads for science and technology, NBS is a meeting place for the exchange of information and ideas. From October 1978 to July 1980, the Bureau sponsored or cosponsored 176 major conferences with more than 22,808 participants. These meetings provide a forum for NBS professionals and other attendees to keep pace with the latest advances and needs in a wide range of science and technology areas.

Each year, the Bureau receives several thousand national and international visitors who are conducted on special tours of NBS facilities. NBS also offers a general guided tour of its Gaithersburg, Maryland, facilities on a regular basis and of its Boulder, Colorado, facilities by special arrangement. For tour information write or call the Public Information Division, A635 Administration Building, (301) 921-2721 in Gaithersburg, or the Program Information Office, 4001 Radio Building, (303) 497-3244 in Boulder.

Information on Bureau activities and services is also provided through exhibits. From October 1978 to July 1980, special exhibits explaining a variety of NBS activities were shown at 192 conferences, trade shows, science centers, and other events, where they were viewed by more than 1.8 million people.

A variety of audiovisual programs describing results from NBS research activities are available to the public. Subject areas include building technology, the environment, energy conservation, safety, fire research, electronic technology, computers, chemistry, material science, measurement techniques, dental research, and general interest. For information, write the NBS Inquiry Unit, A617 Administration Building, or call (301) 921-2318.

General and Media Information

The Bureau's Inquiry Unit receives and responds annually to over 65,000 requests for information from the general public. These include requests for NBS publications and general and technical information about Bureau programs. Anyone wishing more detailed information on NBS activities may contact the NBS Inquiry Unit, A617 Administration Building, (301) 921-2318.

The news media rely on NBS to provide accurate information on an array of subjects spanning every Bureau activity from time and frequency measurements to consumer product safety. Besides providing support to all NBS programs and publishing the Bureau's general magazine, DIMENSIONS/NBS, the Media Liaison and General Publications units answer inquiries about NBS research from newspapers, magazines, radio, and television. More than 1,300 press queries were responded to last year. Members of the news media can contact the Media Liaison Office, A627 Administration Building, (301) 921-3181, for general or detailed information about NBS and its research. For information on the Bureau's Boulder facilities, write to the Program Information Office, 4001 Radio Building, or call (303) 497-3244.

Publications

NBS publications are among the most important conduits through which the Bureau shares the results of its research and studies with its many user audiences. Fifteen categories of publications, including the *NBS Journal of Research,* handbooks, and monographs, are issued. Last year, NBS published in excess of 47,000 pages of research in the open literature.

During FY 1979, more than 1,700 papers appeared in NBS publications and external journals. A selected list of Bureau publications issued during this period is provided below, along with several bibliographies. Unless otherwise stated, all publications are available at the price indicated from either the Superintendent of Documents, U.S. Government Printing Office (Supt. Docs.), Washington, DC 20402, or the National Technical Information Service (NTIS), Springfield, VA 22161, as noted. For foreign orders, there is a 25 percent mailing charge through Supt. Docs. and through NTIS the charge is twice the U.S. cost for paper copy and $5.25 for microfiche. For a complete annual list of NBS publications, write Supt. Docs. for *Publications of the National Bureau of Standards,* NBS SP 305, Supplement 11, S/N003-003-02194-6, $11. The *NBS Publications Newsletter* provides a free, bimonthly listing of all Bureau publications with abstracts. To be placed on the mailing list for this document, write the Technical Information and Publications Division, National Bureau of Standards, Washington, DC 20234.

Timely reports of both technical and general interest on the work performed by NBS are available in the pages of *DIMENSIONS/NBS,* the Bureau's magazine. A year's subscription (10 issues) is available from Supt. Docs. for $11 (use Code DNBS).

Basic Measurements

"Model State Laws and Regulations" (HB 130), Supt. Docs. S/N 003-003-02152-1, $4.50.

"Specifications, Tolerances and Other Technical Requirements for Weighing and Measuring Devices" (HB 44), Supt. Docs. S/N 003-003-02143-1, $6.

"Catalog of Federal Metrology and Calibration Capabilities" (SP 546), Kathryn O. Leedy. Supt. Docs. S/N 003-003-02082-6, $2.50.

"Calibration and Related Measurement Services of the National Bureau of Standards" (SP 250), B. C. Belanger, Editor. Supt. Docs. S/N 003-003-01888-1, $2.75.

"Standard Reference Material Catalog" (SP 260). Supt. Docs. 003-003-02048-6, $3.

Public Health and Safety

"Proceedings of a Conference on Neutrons from Electron Medical Accelerators" (SP 554), H. T. Heaton II and R. Jacobs. Supt. Docs. S/N 003-003-02115-6, $4.75.

"Organizations Engaged in Preparing Standards for Dental Materials and Therapeutic Agents With Lists of Standards" (SP 571), George Paffenbarger, R. W. Rupp, and Margaret Malmstedt. Supt. Docs. S/N 003-003-02163-6, $3.50.

"A System for Fire Safety Evaluation of Health Care Facilities (NBSIR 78-1555), Harold E. Nelson and Abe J. Schibe. NTIS, PB#292273, $7.50.

"Development of a Probability Based Load Criterion for American National Standard A58" (SP 577), Bruce Ellingwood. Supt. Docs. S/N 003-003-02200-4, $6.

Energy

"Simplified Energy Design Economics" (SP 544), Harold E. Marshall and Rosalie T. Ruegg; Forest Wilson, Editor. Supt. Docs. S/N 003-003-02156-3, $3.50.

"Potential for Energy Savings With Water Conservation Devices" (NBSIR 79-1770), Robert J. Palla, Jr., NTIS PB#80-127202, $6.

"LNG Materials and Fluids User's Manual" (second supplement), Thermophysical Properties Division, NBS, Boulder, CO 80303, $15.

"Standards for Photovoltaic Energy Conversion Systems" (NBSIR 79-1743), Harry Schafft. NTIS, PB#296274, $4.

"Table of Recommended Rate Constants for Chemical Reactions Occurring in Combustion" (NSRD-NBS-67), Francis Westley. Supt. Docs. S/N 003-003-02145-8, $4.25.

Materials

"Accuracy in Powder Diffraction" (SP 567), S. Block and C. R. Hubbard, Editors. Supt. Docs. S/N 003-003-02153-9, $9.

"10th Materials Research Symposium on Characterization of High Temperature Vapors and Gases" (SP 561, vol. 1 and 2), John W. Hastie, Editor. Supt. Docs. 003-003-02124-5, $20.

"Analytical Methods for Safeguards and Accountability Measurements of Special Nuclear Material" (SP 528), H. Thomas Yolken and John E. Bullard, Editors. Supt. Docs. 003-003-01996-8, $4.75.

Industrial Productivity

"Large Scale Integration Digital Testing —Annotated Bibliography, 1969-1978" (TN 1102), Thomas F. Leedy. Supt. Docs. S/N 003-003-02097-4, $2.25.

"The NBS Semiconductor Technology Program and VLSI" (NBSIR 80-2057), W. Murray Bullis and R. I. Scace. NTIS, PB#80-185531, $5.

"A Reverse-Bias Safe Operating Area Transistor Tester" (SP 400-54), David W. Berning. Supt. Docs. S/N 003-003-02046-0, $1.70.

"A Production-Compatible Microelectronic Test Pattern for Evaluating Photomask Misalignment" (SP 400-51), T. J. Russell and D. A. Maxwell. Supt. Docs. S/N 003-003-02035-4, $1.50.

Computer Science

"Computers, Personnel Administration and Citizen Rights" (SP 500-50), Alan F. Westin. Supt. Docs. S/N 003-003-01681-1, $8.

"Guideline for Major Job Accounting Systems: The System Management Facilities for IBM Systems Under OS/MTV" (SP 500-40), Gary Durbin, Todd Kinney, Peter Lamasney, Edward Newman, and Edward Syrett. Supt. Docs. S/N 003-003-01989-5, $4.

"Technology Assessment: ADP Installation Performance Measurement and Reporting" (SP 500-53), Carol B. Wilson. Supt. Docs. S/N 003-003-02123-7, $2.

"Design and Implementation of the National Bureau of Standards' Network Access Machine (NAM)" (SP 500-35), Robert Rosenthal and Bruce D. Lucas. Supt. Docs. S/N 003-003-01949-6, $2.20.

"OMNIDATA: An Interactive System for Data Retrieval, Statistical and Graphical Analysis, and Data-base Management—A User's Manual" (HB 125), Joseph Hilsenrath and Bettijoyce Breen. Supt. Docs. S/N 003-003-01972-1, $6.25.

Miscellaneous

"Selected Tables of Atomic Spectra" Section 8, (NSRDS-NBS-3), Charlotte E. Moore. Supt. Docs. S/N 003-003-01964-0, $1.60.

"Trace Organic Analysis: A New Frontier in Analytical Chemistry" (SP 519), Harry S. Hertz and Stephen N. Chesler, Editors. Supt. Docs. S/N 003-003-02054-1, $14.

"An Assessment of the Backscatter Technique as a Means for Estimating Loss In Optical Waveguides" (TN 1018), B. L. Danielson. Supt. Docs. S/N 003-003-02160-1, $3.75.

"Contributions to Color Science by Deane B. Judd" (SP 545), David L. MacAdam, Editor. Supt. Docs. S/N 003-003-02126-1, $14.

"National Measurement Laboratory: 1979 Technical Highlights" (SP 572). Supt. Docs. S/N 003-003-02203-7, $4.25.

"Building Technology Publications— Supplement 3: 78" (SP 457-3). Supt. Docs. S/N 003-003-02096-6, $4.

Funds and Facilities

TO carry out its research and services, NBS operates modern physical facilities in two locations. In Gaithersburg, Maryland, located north of Washington, D.C., NBS has 26 buildings in a campus-like setting on 230 hectares (575 acres). The Bureau also has 14 buildings on 83 hectares (208 acres) in Boulder, Colorado. The Joint Institute for Laboratory Astrophysics, cosponsored by NBS and the University of Colorado, is also located in Boulder. Here scientists carry out studies in atomic and molecular physics and astrophysics.

At Ft. Collins, Colorado, NBS radio stations WWV and WWVB broadcast standard time and frequency information. Another station, WWVH, broadcasts from Kauai, Hawaii.

As one of the Nation's largest physical science laboratories, the Bureau houses a number of special facilities and equipment. A high flux

NBS Boulder

NBS Gaithersburg

nuclear research reactor is used daily by scientists from NBS, other agencies, and universities in projects ranging from nuclear theory to analysis of food contaminants. An electron accelerator capable of producing well-focused electron beams of 140 million volts is used to produce high energy electrons, positrons, photons, and neutrons for nuclear research by NBS scientists and in cooperative studies with a number of university groups.

Another facility, the Synchrotron Ultraviolet Radiation Facility (SURF), is one of the few of its kind in North America. Having been converted into a storage ring, SURF is now capable of producing intense short wavelength ultraviolet radiation, which is especially useful for radiometry in studies of controlled nuclear fusion energy sources and atmospheric space science programs.

Among other NBS facilities are a fire research laboratory, an experimental computer facility, and several environmental chambers. In addition, an extensive instrument shops division answers specialized research needs. Shop capabilities include glass blowing, optics, and metalworking.

Many of the Bureau's facilities are available for use by the scientific and engineering communities. These facilities are described more fully in *Special Technical Facilities at the National Bureau of Standards*. This 50-page booklet is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, and may be ordered by Stock No. 003-003-01601-2/1976 Ed., for $1.35.

The Bureau's budget for FY 1979 was $150.7 million. Direct Congressional appropriations accounted for about 56 percent of NBS funds, with an additional 38 percent resulting from work performed by NBS for other government agencies. The sale of NBS goods and services, such as Standard Reference Materials and calibrations, provided the final 6 percent. Support for Bureau programs from other agencies reflects NBS role as a major physical sciences research laboratory for the entire Federal Government.

Total NBS Operating Funds--All Sources

(in millions of dollars)	Fiscal 1979 actual	Fiscal 1980 est.*	Fiscal 1981 est.
Measurement Research and Standards	**66.8**	**73.5**	**76.0**
Physical and chemical measurements and standards	23.2	23.9	24.7
Materials and thermodynamic measurements and standards	23.3	27.3	28.0
Measurement assurance programs	2.5	2.9	2.9
Applied measurement programs	17.8	19.4	20.4
Engineering Measurements and Standards	**61.7**	**67.6**	**72.7**
Engineering standards	3.0	3.0	2.9
Safety and performance engineering research	19.1	21.3	22.6
Technical support to industrial productivity	28.3	30.5	33.5
Mathematical sciences	3.6	3.9	4.0
Fire science and engineering	7.7	8.9	9.7
Computer Sciences & Technology	**12.3**	**13.3**	**12.9**
Government-wide ADP standards	10.6	12.1	11.6
Scientific and technological advisory services	1.7	1.2	1.3
Cooperative Technology	**1.2**	**.7**	
Central Technical Support	**5.5**	**9.0**	**11.5**
Maintenance of technical competence	4.0	8.7	11.0
Capital Transfers and Facilities	1.5	.3	.5
Non-technical Supporting Services for Other Agencies	**3.2**	**3.4**	**3.7**
Total NBS	**150.7**	**167.5**	**176.8**

* Includes pending pay raise supplemental of $2.7 million.

People

GUIDED by the NBS Executive Board and the Visiting Committee, the Bureau staff works to increase measurement competence and share its expertise with the scientific and technical community, industry, and the public.

The NBS Executive Board oversees the efforts of the entire Bureau staff. A series of evaluation panels appointed by the National Academy of Sciences (National Research Council) provides the Executive Board with valuable aid in these oversight functions. At the top of these evaluation and advisory functions is the NBS Visiting Committee, created by the NBS Organic Act and responsible for reporting annually to the Secretary of Commerce "upon the efficiency of its (NBS) scientific work and the condition of its equipment."

The staff has grown from its original team of 11 in 1901 to about 3,170 full-time employees. Approximately 2,790 are located in Gaithersburg, Maryland, with the remainder in Boulder, Colorado. The 1,282 Bureau physical scientists and engineers are complemented by 258 economists, architects, and other professionals. More than 46 percent of the research and scientific staff have earned doctorates. The research and scientific staff, the largest percentage of NBS employees, is supported by 266 technicians and by administrative, clerical, housekeeping, and groundskeeping personnel.

The contributions of NBS employees to the advancement of science and technology are often recognized by outside organizations. During the past 2 years, those staff members honored by independent and professional organizations included:

L. Kenneth Armstrong of the Program Information Office and **Juli Chappell,** former *DIMENSIONS/NBS* editor, received awards from the Washington, D.C., chapter of the Society for Technical Communication for the article, "Colder than Cold."

Michael Baum of the Public Information Division won awards from the Washington, D.C., chapter of the Society for Technical Communication for outstanding writing of periodical articles and news releases on NBS research.

Brian Belanger, director of the Office of Measurement Services, was given the National Conference of Standards Laboratories' Woodington Award for the best workshop at the 1979 annual conference, "Metrology Quality Requirements."

Theodore H. Benzinger of the Temperature Measurements and Standards Division received the Senior U.S. Scientist Award of the Alexander von Humboldt-Siftung Foundation.

Robert E. Berger of the Product Safety Technology Division was elected a Fellow of the Washington Academy of Sciences.

Douglas Blackburn and **Wolfgang Haller** of the Ceramics, Glass and Solid State Science Division received one of *Industrial Research & Development* magazine's I-R 100 awards jointly with Lawrence Livermore Laboratory, Hoya Optics, Owens-Illinois, and Schott Optical Glass, Inc. They were honored for developing a neodymium-doped fluorophosphate glass for high-energy lasers which can be used in experimental fusion systems to heat and compress fuel to high-temperature reaction conditions.

Roscoe L. Bloss of the Center for Consumer Product Technology was elected a Fellow of the American Society for Testing and Materials.

William J. Boettinger, Harold E. Burdette, and **Masao Kuriyama** of the Metallurgy Division received one of *Industrial Research Development* magazine's 1979 I-R 100 awards for inventing an x-ray magnifier which greatly improves the resolution of real-time x-ray images and can be used in rapid x-ray inspections of equipment in industrial operations.

David W. Bonnell and **John W. Hastie** of the Chemical Stability and Corrosion Division received one of *Industrial Research & Development* magazine's I-R 100 awards for 1980 for the development of a mass spectrometric apparatus coupled to a high temperature and pressure transpiration device. The apparatus allows the accurate mass spectrometry technology to be applied to the study of reactions taking place at temperatures and pressures normally beyond the limits of the spectrometer.

Gerhard M. Brauer of the Polymer Science and Standards Division was awarded the Charles Gordon Service Award of the American Chemical Society's Washington Section for continuing leadership.

Frederick E. Brinckman of the Chemical Stability and Corrosion Division received the 1978 Richard Merton Visiting Professorship in Geosciences of the Johannes Gutenberg University, Mainz, Germany, and was the first American appointed to this chair.

Eleazar Bromberg of the Scientific Computing Division was elected a Fellow of the American Association for the Advancement of Science.

Walter E. Brown, a research associate with the American Dental Association Health Foundation program in the Polymer Science and Standards Division, was given an Honorary Fellowship in the American College of Dentists in 1979 for significant contributions to dental research. He also received the 1980 Biological Mineralization Award of the International Association of Dental Research for work in the physiochemical basis of dental caries and prevention techniques.

W. Murray Bullis, chief of the Electron Devices Division, was elected a Fellow of the American Society for Testing and Materials.

Robert J. Celotta of the Radiation Physics Division was designated one of three distinguished young scientists by the Maryland Academy of Sciences for his work in spin-polarized electron beams and high-resolution electron spectroscopy.

Robert J. Celotta and **Daniel T. Pierce** of the Radiation Physics Division received one of *Industrial Research & Development* magazine's I-R 100 awards for 1980 for the development of polarized low-energy electron diffraction (PLEED) in a system which functions as a sensitive surface magnetometer capable of distinguishing the degree of magnetization of the top few layers of atoms in a crystal.

Edith L. R. Corliss of the Center for Mechanical Engineering and Process Technology won the 1979 American Speech and Hearing Association Distinguished Service Award for work in speech-language pathology and audiology.

Myron L. Crawford of the Electromagnetic Fields Division earned a Certificate of Achievement from the Institute of Electrical and Electronics Engineers, Electromagnetic Compatibility Society for developing a transverse electromagnetic (TEM) cell for testing electronic equipment's susceptibility to electromagnetic interference.

Dicky D. Davis and **Joseph V. Cateora** of the Time and Frequency Division and D. Wayne Hanson, formerly with the Center for Absolute Physical Quantities, earned awards from the National Technical Information Service for inventing a satellite-controlled digital clock system.

The National Bureau of Standards, together with the Public Broadcasting Service and the American Broadcasting Company, was awarded an Emmy by the Academy of Television Arts & Sciences. The Emmy was presented for outstanding achievement in engineering development for the invention and development of closed TV captioning for the deaf. Closed captioning had its roots in a system called "TvTime" developed by NBS engineers **Dicky D. Davis, James L. Jespersen,** and **George Kamas** of the Time and Frequency Division.

Harry Davis and **Meyer Waxman** of the Thermophysics Division received one of *Industrial Research & Development* magazines 1979 I-R 100 awards for developing a deep-ocean sampler that microbiologists can use to retrieve water samples from the deepest parts of the ocean while maintaining them at their original temperature and pressure.

John R. Dise of the Office of Testing Laboratory Evaluation Technology was awarded the American Concrete Institute's Delmar L. Bloem Distinguished Service Award for distinguished leadership of a committee.

Lanny D. Driver and **Francis X. Ries** of the Electromagnetic Fields Division received one of *Industrial Research & Development* magazine's I-R 100 awards for 1980 for the development of a new type of radiofrequency voltage comparator which couples a greatly expanded frequency and dynamic range with extreme simplicity of operation.

Bruce Ellingwood of the Structures and Materials Division received the National Capital Award from the Engineering and Architectural Societies' District of Columbia Council for research in assessing structural design criteria.

Joseph Flynn of the Polymer Science and Standards Division received the 1980 North American Thermal Analysis Society's Mettler Award in Thermal Analysis.

J. Wiliam Gadzuk of the Surface Science Division won the 1978 Arthur S. Flemming Award, one of ten made to Federal employees under 40, for outstanding research in surface properties and interactions of radiation with surfaces.

Lucy B. Hagan, scientific assistant to the director of the Center for Analytical Chemistry, was named recipient of the Alumni Achievement Award, highest award of Georgia College, for distinguished service in the advancement of science.

William C. Haight and **Robert J. Hocken** of the Automated Production Technology Division received one of *Industrial Research Development* magazine's I-R 100 awards for 1980 for the development of a large-scale coordinate measuring machine which is portable, automated, and at least 10 times more accurate than traditional survey techniques.

William P. Harris of the Polymer Science and Standards Division earned the Arnold H. Scott Award from the American Society for Testing and Materials' Electrical Insulating Materials Committee for outstanding work in electrical insulation technology.

Mechanical engineer William Haight (left) and physicist Robert Hocken stand amid the components of the large-scale, three-dimensional machine that won an I-R 100 award from Industrial Research & Development *magazine.*

Mat Heyman, chief of Media Liaison, and **Madeleine Jacobs,** former chief of Media Liaison and General Publications, of the Public Information Division and **William Welsh,** chief of Graphics in the Visual Arts, received awards from the Washington, D.C., chapter of the Society for Technical Communication for outstanding writing, editing, and design of the NBS 1978 annual report.

Kent Higgins of the Program Information Office earned an award from the Rocky Mountain chapter of the Society for Technical Communication for a *DIMENSIONS/NBS* staff report, "Girth Weld Standards for Alaskan Natural Gas Pipeline."

David Hillhouse, Oskars Petersons, and **Wilbur Sze** of the Electrosystems Division received the 1979 Outstanding Paper Award from the Institute of Electrical and Electronics Engineers' Measurements Committee.

David G. Hummer of the Joint Institute for Laboratory Astrophysics was elected a Fellow of the American Association for the Advancement of Science.

Nelson N. Hsu of the Mechanical Production Technology Division received one of *Industrial Research & Development* magazine's I-R 100 awards for 1980 for the development of a simple, convenient source of reproducible stress waves for acoustic emission testing.

Stephen Hsu of the Chemical Stability and Corrosion Division won an award for coauthoring the best paper published by a member of the American Society of Lubrication Engineers.

James L. Jespersen of the Time and Frequency Division won an Award of Excellence in the Society for Technical Communications' International Competition for coauthoring the book, "From Sundials to Atomic Clocks."

Philip S. Klebanoff of the Continuous Process Technology Program was elected a Fellow of the American Institute of Aeronautics and Astronautics.

Tamami Kusada of the Building Thermal and Service Systems Division was cited by the Department of Energy for exemplary work in developing the Building Energy Performance Standards.

Tom Lee of the Fire Science Division received a U.S. Patent Office award for his invention of an *in situ* smoke-detector tester.

H. S. Lew of the Structures and Materals Division was awarded the Leonard C. Wason Medal from the American Concrete Institute for the coauthored paper, "Prediction of Strength of Concrete from Maturity."

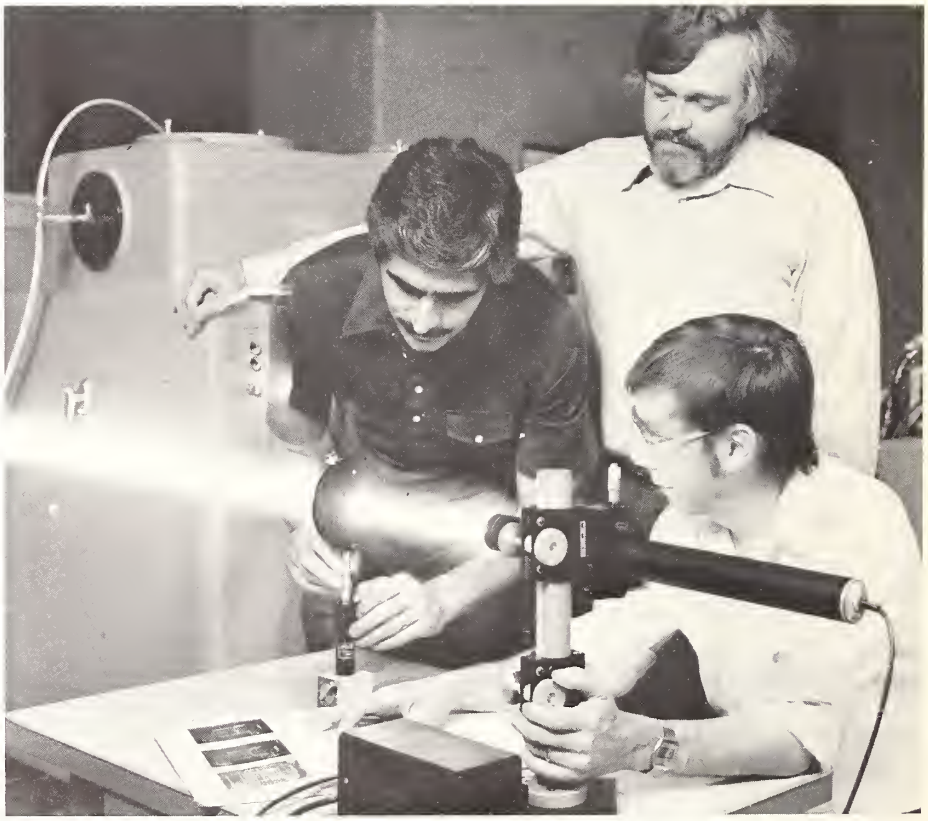
Thomas B. Lucatorto and **Thomas J. McIlrath** of the Radiation Physics Division and **James R. Roberts** of the Atomic and Plasma Radiation Division received one of *Industrial Research & Development* magazine's I-R 100 Awards for 1980 for the development of a "multicapilalry array" window for optical studies which can transmit vacuum ultraviolet light from a relatively high pressure region to an extremely low pressure region.

John Mandel, senior statistical consultant in the National Measurement Laboratory, received an Award of Merit from the American Society for Testing and Materials' Statistical Methods Committee.

Ron E. Meininger, chief of Audiovisual Information, Public Information Division, and **Harold E. Nelson** of the Fire Science Division earned awards from the 1979 International Industrial Film/Videotape Festival for the slide-audio presentation, "Flashover: Point of No Return."

David Orr of the Electromagnetic Fields Division was given an award from the National Association of Government Communicators for outstanding writing of a news release.

H. Steffen Peiser, special consultant to NBS and former chief of the Office of



Physicists Thomas Lucatorto, James Roberts, and Thomas McIlrath demonstrate their "multicapillary array" vacuum ultraviolet window which won an I-R 100 award from Industrial Research & Development *magazine.*

International Relations, was awarded the Dongbaeg Civilian National Honor Medal from the Korean government for outstanding service and also an honorary doctorate from Chungnam National University in Daejeon, Korea, for scientific-technical contributions to Korean economic development.

Anton Peterlin of the Polymer Science and Standards Division was given an Honorary Doctor of Science Degree from the Johannes Gutenberg University in Mainz, Germany, for work in physics and physical chemistry.

Gail Porter of the Public Information Division won awards from the Washington, D.C., chapter of the Society for Technical Communication for outstanding writing of a periodical article and from the National Association of Government Communicators for superior editing of *DIMENSIONS/NBS*.

Edward J. Prosen of the Chemical Thermodynamics Division earned the 1979 Hugh Huffman Award at the Annual Calorimetry Conference for outstanding work in calorimetry and chemical thermodynamics.

Thomas N. Pyke, Jr., director of the Center for Computer Systems Engineering was appointed a member of the Executive Office of the President's Advisory Committee on Information Network Structure and Functions.

Jacob Rabinow, consultant to the Office of Energy-Related Inventions, was elected a Fellow of the American Association for the Advancement of Science. Rabinow was also named 1980 Scientist of the Year by *Industrial Research & Development* magazine for his innovative contributions to modern American technology.

Robert I. Scace of the Center for Electronics and Electrical Engineering was elected a Fellow of the American Society for Testing and Materials.

Robert Schaffer of the Organic Analytical Research Division received the American Association for Clinical Chemistry's 1979 Award for Outstanding Contributions to Clinical Chemistry.

Thomas P. Sheahen of the Continuous Process Technology Program was named Centennial Scholar by Case Western Reserve University at the second 1980 National Conference on Energy Auditing and Conservation.

Douglas R. Shier of the Center for Applied Mathematics received the 1979 Operations Research Division's Achievement Award in Mathematics and Computer Science from the Washington Academy of Science.

Daniel P. Stokesberry and **Kenneth W. Yee** of the Center for Consumer Product Technology won an award from the Institute for Electrical and Electronic Engineers, the Association of Home Appliance Manufacturers, and Herrick Laboratories for their paper on a method to predict a product's life expectancy.

Bradford M. Smith of the Center for Mechanical Engineering and Process Technology was given the California Society of Professional Engineers' Archimedes Engineering Achievement Award, 1979, for innovative contributions to the engineering profession.

James J. Snyder of the Center for Absolute Physical Quantities earned an inventor-incentive award from the National Technical Information Service for an apparatus that determines wave length calibrations for tunable lasers.

John Tesk of the Polymer Science and Standards Division was awarded a Silver Certificate from the American Society for Metals for work in developing base metal alternatives for gold-alloy dental restorations.

M. Zane Thornton, deputy director of the Institute for Computer Sciences and Technology, received a 1979 Presidential Recognition Program Award for extraordinary leadership in restructuring the ICST's ongoing program and developing a long range plan for Federal computer standards.

John B. Wachtman, Jr., director of the Center for Materials Science, was given the 1978 Hobart M. Kraner Award of the American Ceramic Society's Lehigh Valley Section for distinguished achievements in the field of ceramics.

Jacquelyn A. Wise of the Temperature Measurements and Standards Division received the Robert D. Thompson Memorial Award from the American Society for Testing and Materials for outstanding service.

Richard Wright, director of the Center for Building Technology, accepted the American Concrete Institute's 1979 Charles S. Whitney Award given to the Center for excellence of research.

NBS Executive Board

Dr. Ernest Ambler
Director

Mr. Raymond G. Kammer
Deputy Director

Dr. John D. Hoffman
Director
National Measurement Laboratory

Dr. John W. Lyons
Director
National Engineering Laboratory

Mr. James H. Burrows
Director
Institute for Computer Sciences and Technology

Mr. Bascom W. Birmingham
Director
NBS/Boulder Laboratories

Mr. Guy W. Chamberlin, Jr.
Director of Administrative and Information Systems

Mr. Raymond G. Kammer
Associate Director for Programs, Budget, and Finance

Visiting Committee

Dr. W. Dale Compton, Chairman
Vice President, Research
Ford Motor Company

Mr. William D. Carey
Executive Officer
American Association for the Advancement of Science

William K. Linvill*
Professor of Engineering-Economic Systems
Stanford University

Dr. Dorothy M. Simon
Vice President for Research
AVCO Corporation

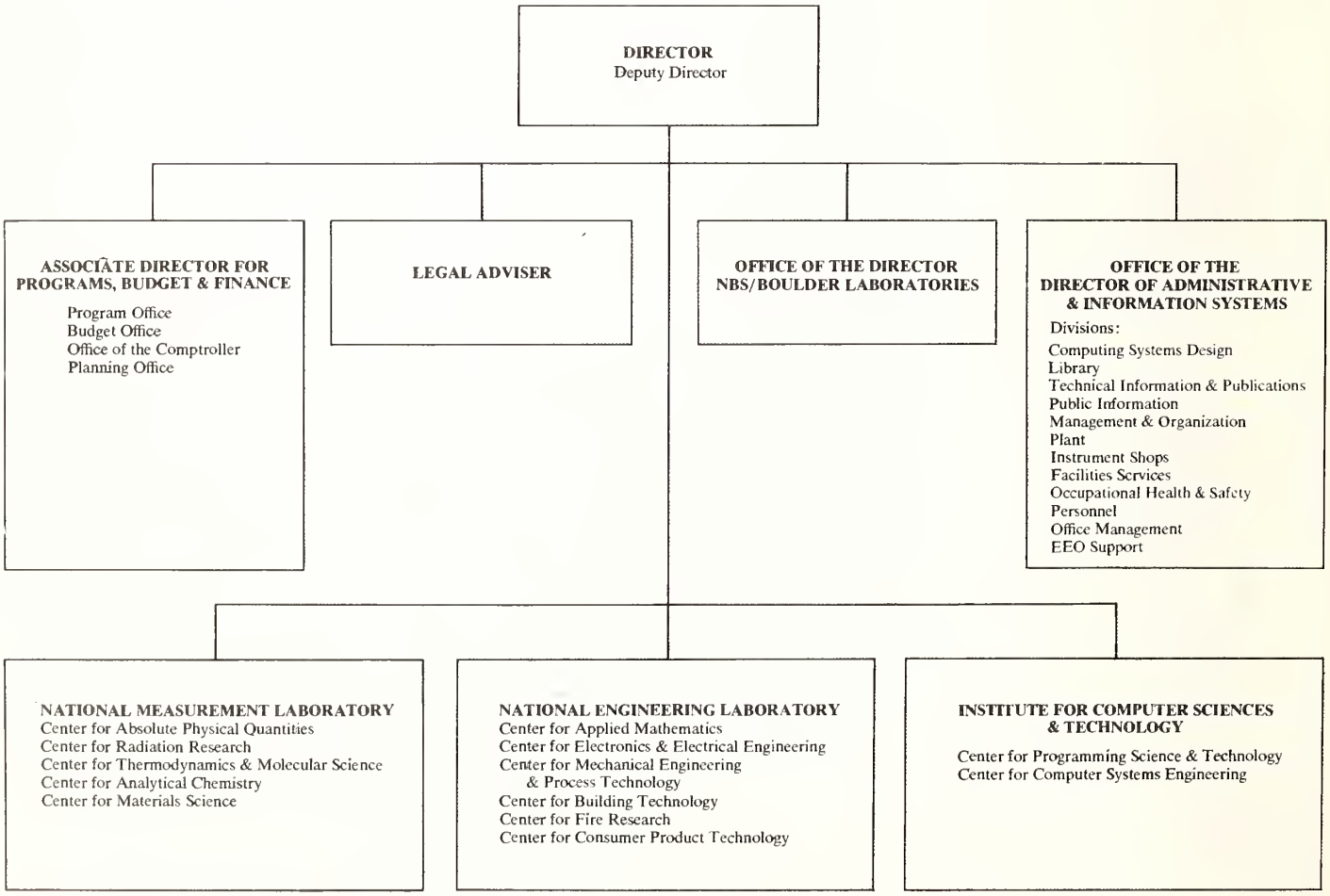
Dr. Walter H. Stockmayer
Department of Chemistry
Dartmouth College

* deceased

Directory

TECHNICAL work at NBS is carried out in the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology. These groups are supported by the Office of the Director of Administrative and Information Systems; 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. The 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 report has only highlighted 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, Washington, DC 20234. Bureau staff located in Boulder, CO, can be contacted on (303) 497 + extension noted in the directory, or write to the National Bureau of Standards, Boulder CO 80303. Boulder staff members are designated in the directory with asterisks.



Office of the Director

Dr. Ernest Ambler, Director (2411)

Mr. Raymond G. Kammer, Deputy Director (2451)

Mr. Allen J. Farrar, Legal Adviser (2425)

Mrs. Esther C. Cassidy, Congressional Affairs Officer (2441)

Dr. Howard E. Sorrows, Technology Adviser to the Director (2226)

Mr. Peter R. De Bruyn, Industrial Liaison Officer (3591)

Mr. James M. Wyckoff, State and Local Governments Liaison Officer (3814)

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

Mr. Frederick L. Haynes, Director, Office of Cooperative Generic Technology (202/377-5905)

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.

Mr. Raymond G. Kammer, Associate Director (3361)

Dr. Samuel R. Stein, Chief, Program Office (3137)

Mr. Thomas A. Gary, Chief, Budget Office (2544)

Mr. David B. Shreve, Comptroller, Office of the Comptroller (2507)

Dr. Kenneth Gordon, Director, Planning Office (3872)

Mr. Robert E. Parsons, Director, Center for Field Methods (3185)

Office of the Director of Administrative and Information Systems

The Office of the Director of Administrative and Information Systems directs the management of Bureau-wide facilities and information and administrative systems including information and office services, procurement, technical and public information functions, personnel, and management consulting services, health, safety, and security functions, as well as physical plant, facilities, space management, and instruments shop responsibilities. The Office also decides on policies and plans and directs implementation actions to assure the responsiveness of these services to the needs of the technical programs.

Mr. Guy W. Chamberlin, Jr., Director (2477)

Mr. Karl E. Bell, Deputy Director for Administrative Systems (3444)

Mr. Roger A. Dixon, Deputy Director for Information Systems (3567)

Mr. Eugene I. Grunby, Chief, Computing Systems Design Division (3384)

Ms. Patricia W. Berger, Chief, Library Division (3405)

Mr. John J. Rochford, Chief, Technical Information and Publications Division (2264)

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

Mrs. Theodora K. Watts, Chief, Management and Organization Division (3581)

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

Mr. David S. Bettwy, Chief, Instrument Shops Division (2436)

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

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

Ms. Elizabeth W. Stroud, Chief, Personnel Division (3555)

Mr. Richard de la Menardiere, Chief, Office Management Division (3521)

Boulder Executive Office

Mr. Arthur R. Hauler, Executive Officer (3955)*

Mr. Donald W. Cook, Chief, Instrument Shops Division (3856)*

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

Office of the Director, NBS/Boulder Laboratories

The Office of the Director, NBS/Boulder Laboratories, which is located in Boulder, CO, provides support to the technical programs of the NBS/Boulder Laboratories. These laboratories conduct research comprising work on measurement science for the National Measurement Laboratory in time and frequency, quantum physics, thermodynamics, and materials science. The laboratories also carry out programs for the National Engineering Laboratory in electromagnetics, thermophysical properties, and fluid dynamics.
Mr. Bascom W. Birmingham, Director (3237)*

* Boulder staff member. To call dial (303) 497 + extension given.

National Measurement Laboratory

The National Measurement Laboratory provides the national system of physical, chemical, and materials measurement; coordinates the system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce. It conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and government. 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. John D. Hoffman, Director (2828)

Dr. Donald R. Johnson, Deputy Director for Resources and Operations (2878)

Dr. C. Cary Gravatt, Deputy Director for Programs (2822)

Dr. David T. Goldman, Associate Director for Long-Range Planning (3304)

Dr. Arthur O. McCoubrey, Associate Director for Measurement Services (3301)

Office of Nondestructive Evaluation

The Office of Nondestructive Evaluation (NDE) manages an interdisciplinary program to advance the effectiveness of NDE for controlling the quality of materials and products and assuring the integrity of structures. The program involves the development and the dissemination of standards, calibrations, and techniques which enhance the reliability of NDE measurements.

Mr. Harold Berger, Chief (3331)

Office of Environmental Measurements

The Office of Environmental Measurements constitutes a primary Federal effort to improve measurement methods, to develop calibration techniques, to gather and evaluate data needed to assess air and water pollution measurement problems, and to develop, continually validate, and supply Standard Reference Materials and procedures for use in the calibration of field methods employed in a wide variety of environmental measurement activities.

Dr. William H. Kirchhoff, Chief (3775)

Office of Standard Reference Materials

The Office of Standard Reference Materials assures accurate measurements throughout the world through the development and distribution of Standard Reference Materials (SRM's). SRM's are well characterized, stable, homogeneous materials having one or more physical or chemical properties measured and certified by NBS. Approximately 40,000 SRM's are used each year in industrial quality control, environmental analysis, clinical analysis, and basic metrology applications.

Mr. George A. Uriano, Chief (3479)

Office of Standard Reference Data

The Office of Standard Reference Data (OSRD) manages the activities of the National Standard Reference Data System (NSRDS), monitoring and coordinating work of its various data centers and projects. OSRD provides inquiry services, maintains a major collection of data compilations in the physical sciences, develops computer database management and support activities for the NSRDS, and determines dissemination mechanisms for NSRDS databases and compilations.

Dr. David R. Lide, Chief (2467)

Office of Measurements for Nuclear Technology

The Office of Measurements for Nuclear Technology provides the Nation with the central measurement standards and services needed for accountability in safeguarding nuclear materials. It plans, directs, and coordinates the program's laboratory work at NBS and disseminates these standards and services domestically and to other nations through international organizations.

Dr. H. Thomas Yolken, Chief (3868)

Office of Recycled Materials

The Office of Recycled Materials manages two programs: The Resource Conservation and Recovery Program, as directed by the Resource Conservation and Recovery Act of 1976, establishes and publishes guidelines for the development of specifications for classification of materials recovered from waste. The Recycled Oil Program, in response to the Energy Policy and Conservation Act, develops test procedures to determine the substantial equivalence of rerefined oil and new oil for all end uses.

Dr. Harvey Yakowitz, Chief (2621)

Office of Weights and Measures

The Office of Weights and Measures provides services necessary for tracing State and local weights and measures activities to national standards. It makes NBS technical expertise available to weights and measures agencies, promoting uniformity in weights and measures law and enforcement through publications, training, model codes and regulations, NBS research, and sponsorship of the National Conference on Weights and Measures.

Mr. Albert T. Tholen, Chief (2401)

Office of Measurement Services

The Office of Measurement Services coordinates and provides administrative services for calibration and measurement assurance programs; manages a program to develop measurement assurance services for the public; provides consulting help to NBS staff on measurement quality control; and develops policies and establishes priorities for reimbursable measurement services.

Dr. Brian C. Belanger, Chief (2805)

Office of Domestic and International Measurement Standards

The Office of Domestic and International Measurement Standards plans, administers, and actively participates in an extensive program directed towards: managing assigned NBS responsibilities to represent the United States in the International Organization of Legal Metrology; coordinating the NML involvement in domestic and international voluntary standards activities; and coordinating and facilitating NML staff participation in international cooperative scientific programs.

Mr. David E. Edgerly, Chief (3307)

Center for Absolute Physical Quantities

The Center for Absolute Physical Quantities is responsible for the integrity of the U.S. physical measurement standards and their further development. A supporting research program in physics is directed toward accurate measurement of fundamental physical constants and processes and verification of the underlying laws of nature.

Dr. Karl G. Kessler, Director (2001)

Vacant, Deputy Director (2034)

Dr. Richard D. Deslattes, Senior Research Fellow, Leader, Quantum Metrology Group (2061)

Dr. Barry N. Taylor, Chief, Electrical Measurements and Standards Division (2701)

Dr. James F. Schooley, Chief, Temperature and Pressure Measurements and Standards Division (3315)

Vacant, Chief, Length and Mass Measurements and Standards Division (2034)

Dr. James A. Barnes, Chief, Time and Frequency Division (3294)*

Dr. Gordon H. Dunn, Chief, Quantum Physics Division (3527)*

Center for Radiation Research

The Center for Radiation Research develops and maintains the scientific competences and experimental facilities necessary to provide the Nation with a central basis for uniform physical measurements, measurement methodology, and measurement services in the areas of optical radiation, ultraviolet radiation, and ionizing radiation such as x-rays, gamma rays, electrons, neutrons, and radioactivity.

Dr. Chris E. Kuyatt, Director (2551)

Dr. Wayne A. Cassatt, Deputy Director (2551)

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

Dr. Randall S. Caswell, Chief, Nuclear Radiation Division (2625)

Dr. Lewis V. Spencer, Acting Chief, Radiation Physics Division (3201)

Dr. Jack L. Tech, Chief, Radiometric Physics Division (3864)

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

Center for Thermodynamics and Molecular Science

The Center for Thermodynamics and Molecular Science provides information on basic molecular processes, theoretical methods and concepts, predictive equations and models, and reliable physico-chemical data. It supplies measurement methods, services, and standards applicable to bulk, surface, and molecular properties of static and reactive systems of chemical elements, compounds, and their mixtures.

Dr. Peter L. M. Heydemann, Director (2711)

Dr. David Garvin, Acting Deputy Director (2711)

Dr. Cedric Powell, Chief, Surface Science Division (2188)

Dr. Wing Tsang, Chief, Chemical Kinetics Division (2792)

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

Dr. Harold J. Raveché, Chief, Thermophysics Division (2433)

Dr. Merrill M. Hessel, Chief, Molecular Spectroscopy Division (2021)

Center for Analytical Chemistry

The Center for Analytical Chemistry maintains the scientific competences and experimental facilities necessary to conduct basic and applied research that will provide the Nation with uniform and compatible measurements, measurement technology, and measurement services in analytical chemistry. It develops and improves methods for accurate characterization of materials and develops and certifies Standard Reference Materials.

Dr. Curt W. Reimann, Director (2851)

Dr. Rance A. Velapoldi, Deputy Director (2852)

Dr. Ernest L. Garner, Chief, Inorganic Analytical Research Division (3674)

Dr. Harry S. Hertz, Chief, Inorganic Analytical Research Division (3778)

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

Center for Materials Science

The Center for Materials Science performs research in the effective application and utilization of materials (metals, polymers, and inorganic) to support commerce and industry. Activities focus on the processing, structure/property, and durability sciences to advance innovative processing, improved design, and efficient use. It supplies technical information in the form of reference data, materials measurement methods, and standards.

Dr. John B. Wachtman, Jr., Director (2891)

Dr. Darrell H. Reneker, Deputy Director (2893)

Dr. Thomas D. Coyle, Chief, Chemical Stability and Corrosion Division (2847)

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

Dr. Ronald K. Eby, Chief, Polymer Science and Standards Division (3734)

Dr. Robert Mehrabian, Chief, Metallurgy Division (2811)

Dr. Hans P. R. Frederikse, Chief, Ceramics, Glass, and Solid State Science Division (2845)

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

Institute for Computer Sciences and Technology

The Institute for Computer Sciences and Technology 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. James H. Burrows, Director (3151)

Mr. M. Zane Thornton, Deputy Director (3151)

Program Development Office

The Program Development Office assists the Institute Director in planning, establishing priorities, and monitoring programs for ICST's standards development, research, and advisory services activities; assists the Director in allocating resources to ICST's programs; maintains working relationships with Federal agencies; and reports on progress and plans.

Mr. Ross C. Bainbridge, Chief (2834)

Standards Administration Office

The Standards Administration Office provides administrative processing support for issuing Federal Information Processing Standards (FIPS) and is the focal point for information about FIPS, their availability, and their prices.

Mr. Harry S. White, Jr., Chief (3157)

Center for Programming Science and Technology

The Center for Programming Science and Technology develops standards, provides technical assistance, and conducts research in: computer programming languages, operating systems, text editors, database management systems, programming tools and other utility software, data elements and codes, computer security, system certification and validation, performance assurance, and evaluation techniques such as auditing, programming productivity measurement, workload characterization, and system performance measurement.

Mr. S. Jeffery, Director (3531)

Mr. John F. Wood, Associate Director for Program Planning (3553)

Dr. Selden L. Stewart, Chief, Programming Science Division (3485)

Dr. Dennis W. Fife, Chief, Application Systems Division (3491)

Dr. Thomas C. Lowe, Chief, Operations Engineering Division (2750)

Center for Computer Systems Engineering

The Center for Computer Systems Engineering develops standards, provides technical assistance, and conducts research in: computer system and network architecture, network protocols, local networks and office systems, network measurement, computer system interfaces, data communications, data acquisition and storage, terminals and peripherals, data interchange media, network access control, and system specification, languages, and verification techniques.

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

Mr. Robert P. Blanc, Chief, Systems and Network Architecture Division (3817)

Dr. John P. Riganati, Chief, System Components Division (2705)

National Engineering Laboratory

The National Engineering Laboratory furnishes technology and technical services to users in the public and private sectors to address national needs and to solve national problems in the public interest. NEL conducts research in engineering and applied science in support of objectives in these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; 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; develops and improves mechanisms to transfer results of its research to the ultimate user; and develops and demonstrates new institutional practices to stimulate the use of technology.

Dr. John W. Lyons, Director (3434)

Dr. James R. Wright, Deputy Director (3574)

Mr. Samuel Kramer, Associate Director for Program Coordination (3231)

Mr. Kenneth R. Goodwin, Associate Director for Program Planning (3235)

Dr. George A. Sinnott, Associate Director for Technical Evaluation (3231)

Center for Applied Mathematics

The Center for Applied Mathematics provides support in the mathematical and computer sciences and central computer services for NBS programs and NBS staff. Activities include consultation and collaboration, conduct of research, and development of mathematical methods and scientific computing techniques for the solution of problems arising in NBS program efforts.

Dr. Burton H. Colvin, Director (2541)

Dr. Joan R. Rosenblatt, Deputy Director (2541)

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

Dr. Christoph J. Witzgall, Acting Chief, Operations Research Division (3855)

Dr. Glenn R. Ingram, Chief, Scientific Computing Division (3395)

Dr. Harry H. Ku, Chief, Statistical Engineering Division (3651)

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

Center for Electronics and Electrical Engineering

The Center for Electronics and Electrical Engineering conducts research and development in the fields of electronic and electrical materials and engineering. It develops practical data, measurement methods, theory, standards, instrumentation, and technology. The Center also provides technical services, national reference standards, and engineering measurement traceability for the benefit of government, industry, the scientific community, and the consumer.

Mr. Judson C. French, Director (3357)

Dr. Alvin H. Sher, Deputy Director (3357)

Dr. W. Murray Bullis, Chief, Electron Devices Division (3786)

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

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

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

Center for Mechanical Engineering and Process Technology

The Center for Mechanical Engineering and Process Technology provides competence in production engineering, mechanical metrology, automation and control technology, and industrial and mechanical engineering to support the discrete parts manufacturing industries.

Dr. John A. Simpson, Director (3421)

Mr. Gene A. Rowland, Deputy Director (3421)

Mr. Daniel R. Flynn, Acting Chief, Mechanical Production Metrology Division (3565)

Dr. Russell D. Young, Acting Chief, Industrial Systems Division (2181)

Dr. Robert Hocken, Acting Chief, Automated Production Technology Division (2216)

Continuous Process Technology Program

The Continuous Process Technology Program helps meet the measurement and data needs of the chemical, petrochemical, petroleum, rubber, and metals industries and others.

Mr. Jesse Hord, Director (5108)*

Dr. Kenneth Kreider, Acting Deputy Director (3281)

Center for Building Technology

The Center for Building Technology performs analytical, laboratory, and field research involving architecture, engineering, and the physical and social sciences. The Center produces performance criteria and measurement technology for use by building owners, occupants, designers, manufacturers, builders, regulatory authorities of State and local governments, and Federal agencies with building programs.

Dr. Richard N. Wright, Director (3377)

Dr. Charles G. Culver, Deputy Director (3375)

Dr. Edward O. Pfrang, Chief, Structures and Materials Division (2196)

Dr. Preston E. McNall, Chief, Building Thermal Performance Division (3637)

Dr. Francis T. Ventre, Chief, Environmental Design Research Division (3704)

Mr. James G. Gross, Chief, Building Economics and Regulatory Technology Division (3447)

Dr. James E. Hill, Chief, Building Equipment Division (3637)

Center for Fire Research

The Center for Fire Research, established by Congress in 1974, performs and supports research in all aspects of fire. Work includes: fundamental studies on the basic chemistry and physics of the fire process; test methods for evaluating the performance of materials and products when exposed to fire; and tools for scientists, engineers, public officials, and building designers to use in predicting fire risks.

Dr. Frederic B. Clarke, Director (3143)

Dr. Clayton M. Huggett, Deputy Director (3143)

Mr. Richard L. P. Custer, Associate Director (3143)

Dr. Richard Gann, Head, Exploratory Fire Research Group (3771)

Dr. Robert S. Levine, Chief, Fire Research Resources Division (3845)

Mr. Irwin A. Benjamin, Chief, Fire Safety Engineering Division (3255)

Mr. Richard L. P. Custer, Acting Chief, Fire Performance Evaluation Division (3255)

Center for Consumer Product Technology

The Center for Consumer Product Technology performs research and develops the technology needed to measure and evaluate the safety, energy efficiency, and other performance characteristics of consumer products and law enforcement equipment. In its activities, the Center applies the physical and behavioral sciences, engineering, systems analysis, ergonomics, economics, and statistics.

Dr. Stanley I. Warshaw, Director (3751)

Mr. John L. Donaldson, Deputy Director (3751)

Dr. Harold P. Van Cott, Chief, Consumer Sciences Division (2907)

Dr. Andrew J. Fowell, Chief, Product Performance Engineering Division (3748)

Mr. Walter G. Leight, Chief, Product Safety Technology Division (3750)

Office of Engineering Standards

The Office of Engineering Standards provides technical support to the Department of Commerce by developing and applying criteria and procedures for accrediting testing laboratories. It provides domestic and international engineering services, assisting in the development of needed voluntary product standards and providing technical information and assistance to NBS units, other government agencies, and private sector organizations concerned with the development, promulgation, and use of foreign and domestic engineering standards.

Dr. Stanley I. Warshaw, Director (3751)

Mr. William C. Cullen, Deputy Director (3731)

Mr. James E. French, Chief, Office of Standards Information, Analysis, and Development (3272)

Mr. James O. Bryson, Chief, Office of Testing Laboratory Evaluation Technology (2368)

Vacant, Chief, Office of International Engineering Standards (2152)

Office of Energy Programs

The Office of Energy Programs provides overall planning, management, and coordination of NEL's energy-related programs. These programs address performance criteria and measurement technology needed to meet national goals for energy conservation and conversion in buildings, consumer products, and industry, as well as technologies for alternate energy supplies. The Office also reviews, evaluates, and recommends to the Department of Energy technically valid inventions with energy-conserving potential.

Dr. Jack E. Snell, Director (3275)

Dr. Albert E. Paladino, Deputy Director (3275)

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

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

U.S. DEPARTMENT OF COMMERCE
Philip M. Klutznick, Secretary
Jordan J. Baruch, Assistant Secretary for
Productivity, Technology and Innovation

National Bureau of Standards
Ernest Ambler, Director

National Bureau of Standards
Washington, DC 20234
(301) 921-3181

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

January 1981

NBS Special Publication 600

Credits
Writer: Gail Porter
Editor: Sharon Shaffer
Designer: William Welsh
Production Coordination: Nancy Starnes
Editorial Assistant: Virginia Covahey
Photography: Mark Helfer and
Bessmarie Young,
all photos except as noted below.
Darwin Miner, pg. 8; Computer Vision,
pg. 13; U.S. Department of Housing
and Urban Development, pg. 16; Rex
Powell, pg. 19; National Oceanic &
Atmospheric Administration, p. 28.

U.S. Department of Commerce
National Bureau of Standards