Science and Technology

NIST IN THE 1990s

U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Institute of
Standards and Technology

Front cover. Physicist Kris Helmerson observes a tiny glowing cloud of sodium atoms caught by six intersecting laser beams. Such techniques produce the coldest temperatures in the universe—and may be the foundation for future standards of time, frequency, and length.

Top inset. Director John W. Lyons discusses advanced production techniques with electronics engineer Fred Proctor and mechanical engineer Keith Stouffer at the NIST Automated Manufacturing Research Facility.

Above and bottom inset. NIST Gaithersburg laboratories. (Aerial photo by Air Photographic, Inc.)

NIST in the 1990s

The decade of the 1990s may be the most exciting and demanding for the National Institute of Standards and Technology (NIST) since its creation as the National Bureau of Standards in 1901. After 90 years of steady progress supporting U.S. industry's needs for standards and ever more exacting measurement methods, NIST is expanding its domain.

We are building on our already extensive ties with industry to refocus and strengthen research programs and services that help U.S.-based companies compete in the global marketplace. And we're looking for ways to help companies master the three main elements of commercial success: quality, low cost, and speed to market.

We've made it every NIST researcher's job to seek out industrial partners to ensure that our work is relevant to industry needs. At the same time, we've greatly expanded our formal outreach efforts, including direct grants to industry for development of precompetitive generic technologies and regional centers to provide small and medium-sized businesses with advice on commercially available technologies and quality management.

We expect such extramural programs to represent a growing share of NIST's overall budget in the coming years. In addition, according to projections in the President's 1992 budget request, NIST's total appropriations will double by 1996.

Our goal—indeed our obligation—is to make NIST not only the nation's premier measurement laboratory, but also a "user friendly" resource of expertise on the latest technologies—superconductors, lightwave electronics, high-speed digital communications, biosensors, and artificial intelligence, for example. This expanded charge is consistent with the broader mission of NIST's parent agencies, the Technology Administration and the U.S. Department of Commerce to advance U.S. trade and competitiveness. It also reflects the Institute's congressional mandate:

- to help U.S. industry improve its competitiveness through new technologies, modernized production processes, improved quality control, and rapid commercialization.

At the same time, the Institute has two other very important goals serving the needs of its other major "customers"—government at all levels, academia, and the general public. These are:

- to improve public health, safety, and the environment through selected research programs, and
- to conduct fundamental research that advances science and engineering.

Some business pundits would have us believe that America's industrial fortunes are in a period of inexorable decline. Not so here at NIST; our vision of industry's future is bright. We see in our laboratories today many exciting technical advances that will fuel new product development and economic growth.

We present to you here a brief summary of NIST's strategic outlook for the 1990s. We hope you will find it helpful as you consider how your organization might work with ours to invest in America's future.

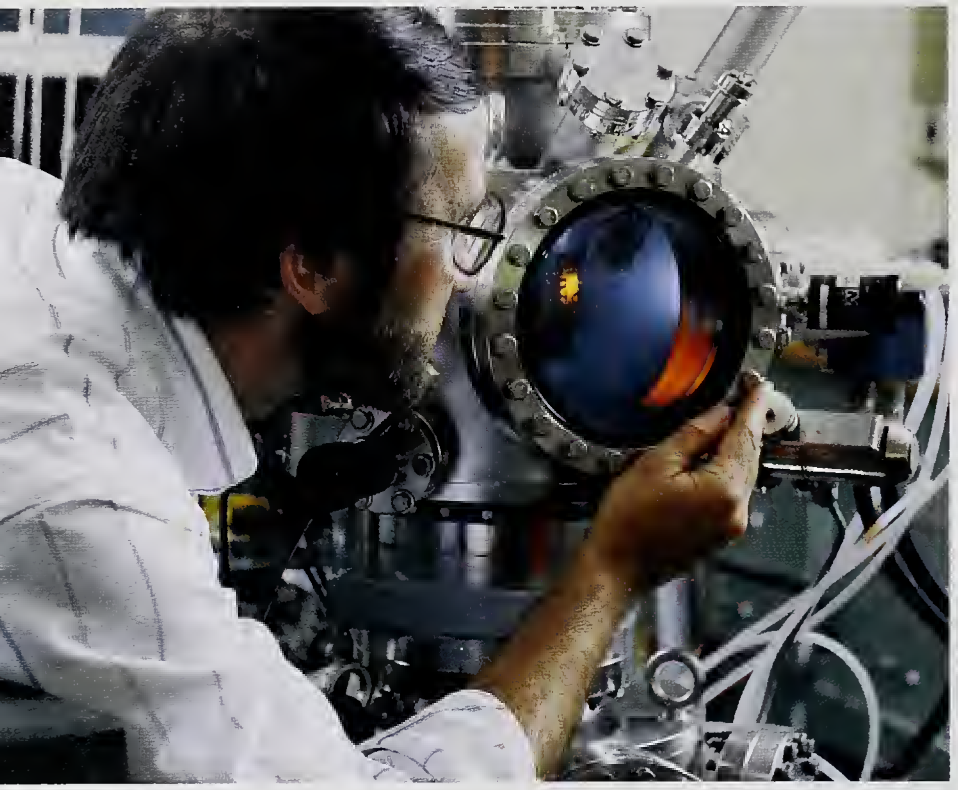
John W. Lyons

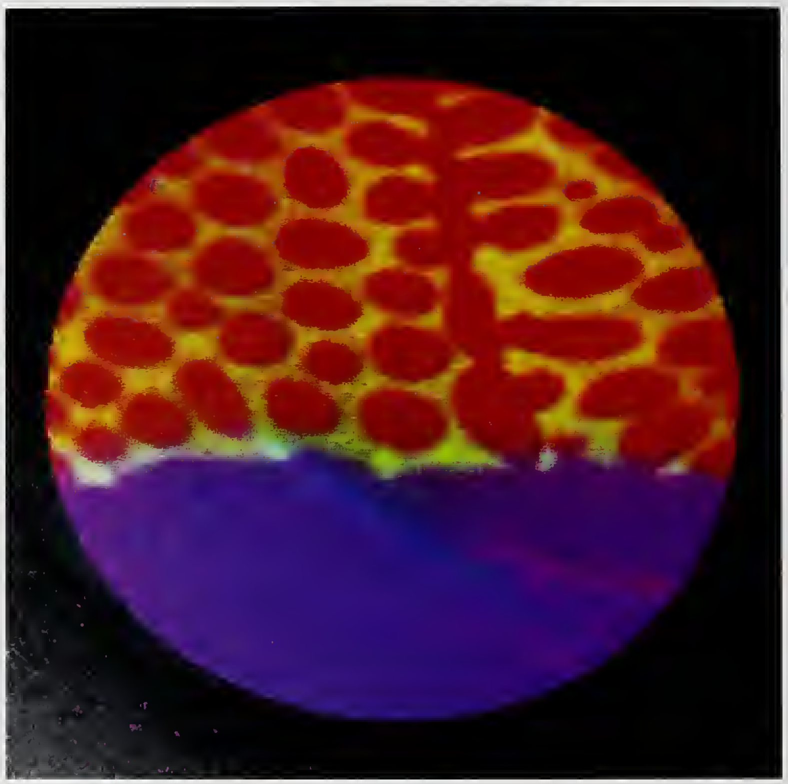
John W. Lyons
Director

Top. *Using ultrahigh vacuum instrumentation, physicist Steve Semancik prepares crystal-like tin oxide films on sapphire as part of a broader effort to develop faster, more reliable chemical sensors.*

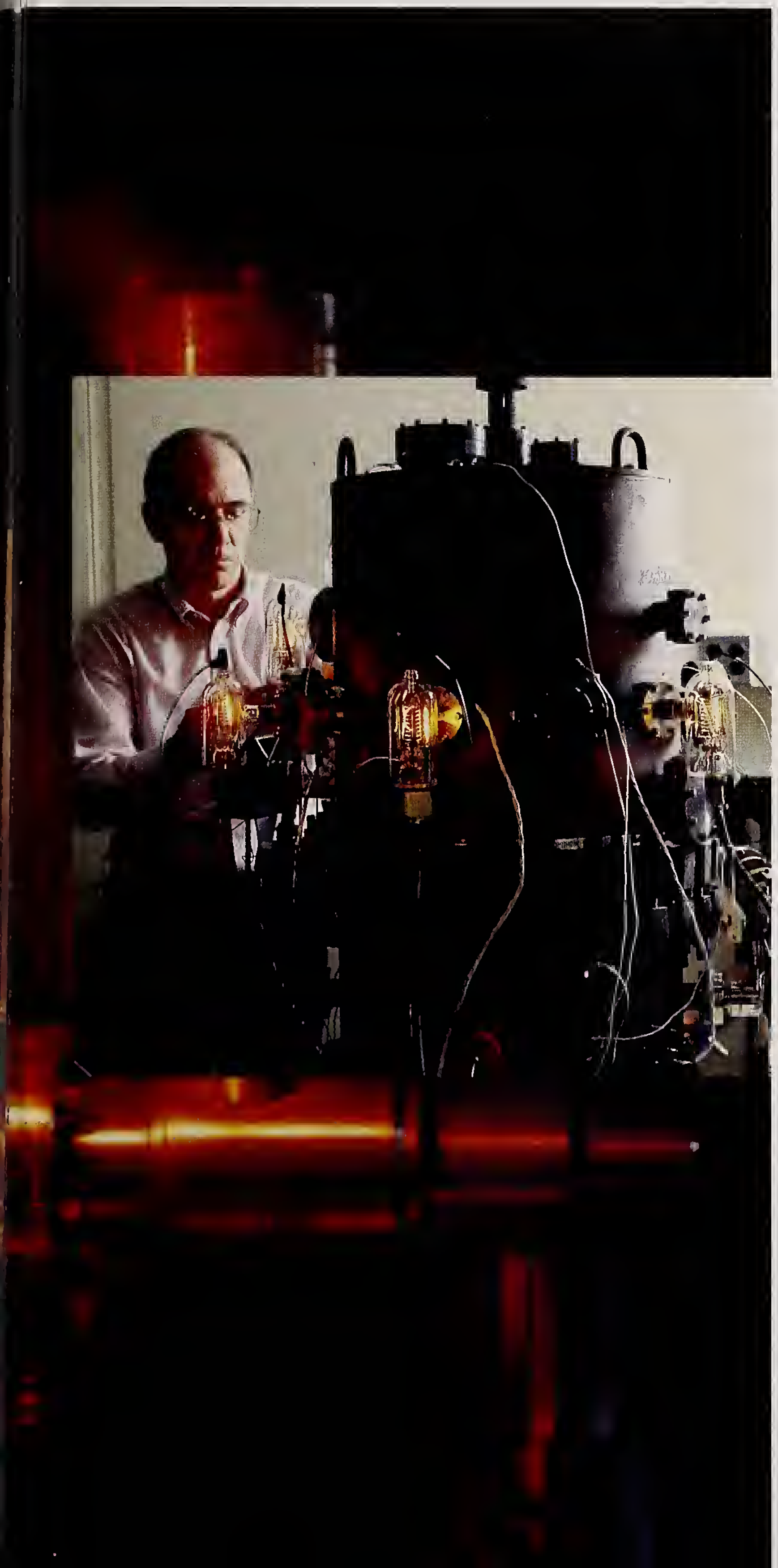
Bottom. *A NIST ion microscope allows Institute researchers to make detailed, quantitative chemical composition maps of materials. Poor blending between metals (designated with different colors) shown in this micrograph indicates a need for better processing methods for this aerospace alloy.*

Below and inset. *Physicist Albert Filippelli checks voltages on low-pressure gauges being calibrated with another NIST ultrahigh vacuum chamber. Such gauges are used to measure extremely low pressures in semiconductor manufacturing processes and in space simulation laboratories.*





Competitiveness



Racing Faster and Smarter

From one-product, Mom and Pop start-ups to multinational conglomerates, U.S. companies must continually adapt to a changing technological and economic landscape. By the year 2000, many more nations will have the skills and know-how to produce and distribute world-class products at cost-effective prices.

Since World War II, the largest unified market for those products has been the United States, giving domestic producers an inherent competitive advantage. Rapid political changes in the Soviet Union and Eastern Europe, the imminent creation of a unified European market, and the rise in the buying power of consumers in Pacific Rim nations—these developments will all work to erase any current U.S. marketing advantage.

In the face of stiff competition, the key to continued U.S. economic growth will be faster commercialization of a remaining U.S. advantage—the best science in the world. NIST is working to help U.S. firms turn scientific advances into commercial products faster.

It does so through cooperative research aimed at overcoming technical barriers to commercialization of emerging technologies; direct funding of corporations or industry-led joint ventures for development of generic technologies through the Advanced Technology Program; and development of improved measurement methods for monitoring production processes and ensuring the quality of new product lines.

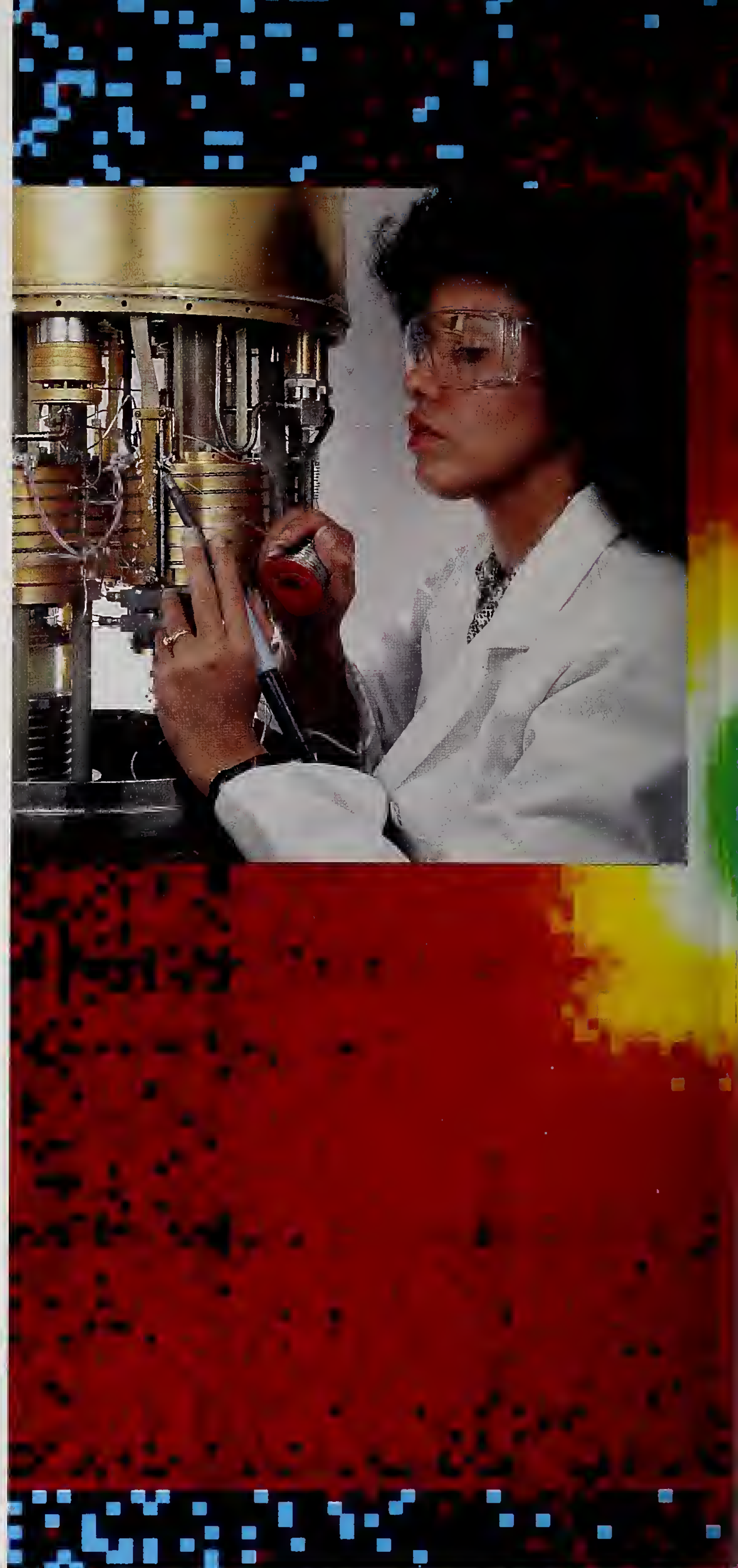
In the 1990s, the Institute also will take a series of steps to develop more and better partnerships with industry, to work with universities to strengthen NIST's technical staff, and to refurbish and improve its physical plant.

The Right Ingredients

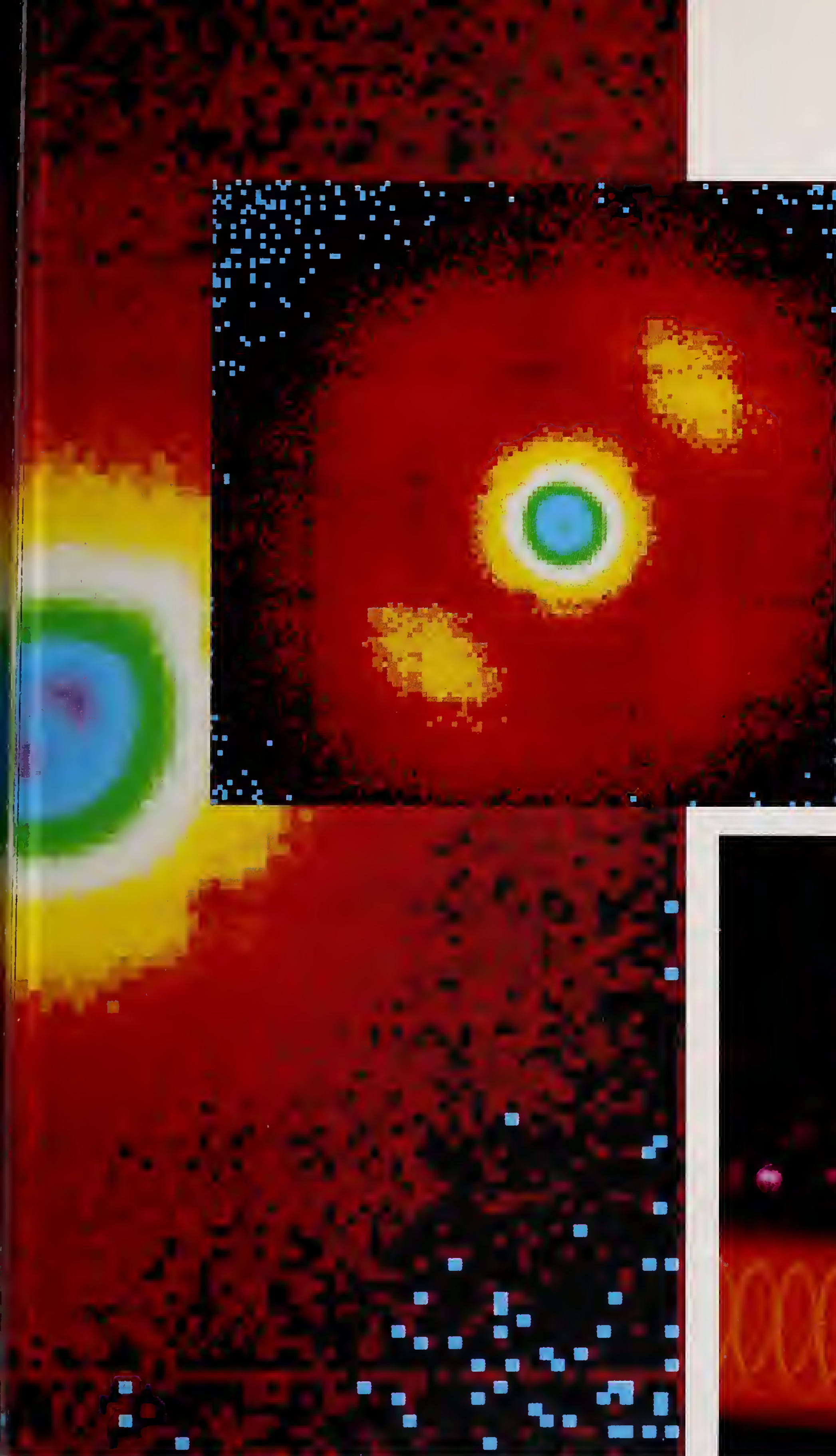
You can't make good products without the right materials. And you can't make good materials without the right processing methods. NIST has long been a leader in the characterization and measurement of materials of all types—from sheet metal to "nanocomposites" built in ultrahigh vacuum chambers a few atoms at a time.

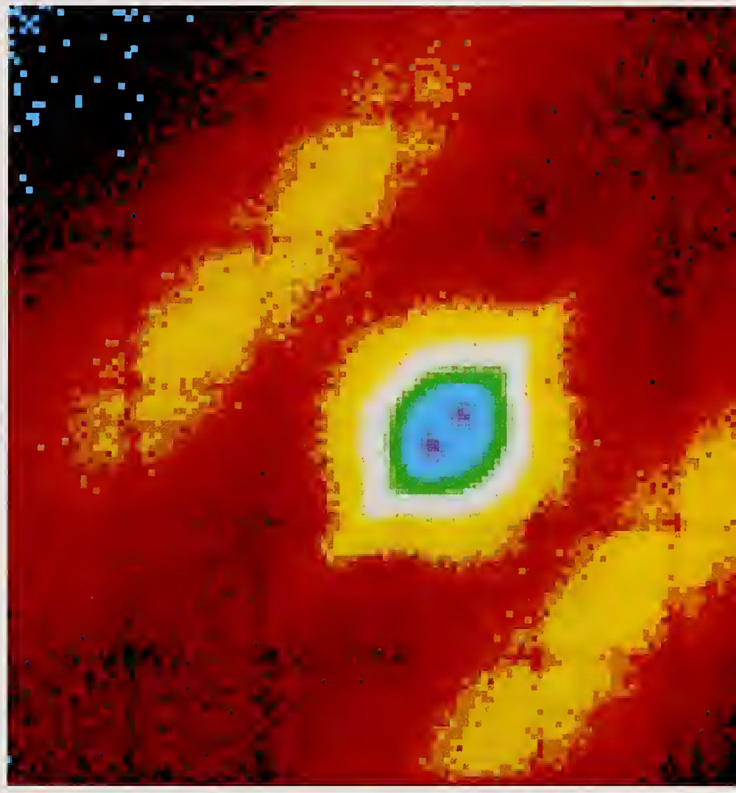
As allowable tolerances for material properties continue to narrow, the relationships between the suppliers and users of materials in the commercial marketplace become critical. NIST is responding to this trend by increasing its contacts and cooperative research efforts with the materials "user" community in the transportation, electronics, communications, and aerospace industries.

The Institute also is responding through a major research effort in "intelligent" processing. Sophisticated chemical, ultrasonic, optical, and other types of sensors now under development in NIST laboratories are designed to take the pulse of materials production processes in real-time. Ultimately, such systems should allow on-line control of materials manufacturing processes, reducing waste and improving quality. This research will receive high priority at NIST during the next decade.



***Left inset.** Chemical engineer Isaura Vazquez solders electrical connections in an apparatus used to study cryogenic refrigeration techniques. (Photo by Geoffrey Wheeler.)*





Above, right inset, and top right. *Diffraction patterns made with the NIST small-angle X-ray scattering facility show differences in microstructure as seen from end, top, and side views of a flat strip of specially prepared nylon. These differences help explain why this material is strong in the lengthwise direction, but its surface peels easily.*

Above. *NIST studies of the electrical and magnetic properties of high-temperature superconductors are designed to improve performance of these new materials. Here, materials research engineer John Blendell prepares a single crystal of barium-yttrium-copper-oxide in a specially designed furnace.*

Top. Electronics engineer Andrew Aust adjusts a laser used in a non-destructive NIST technique for measuring light loss in integrated optical waveguides. These devices are being tested for use in fiber optic telephone systems and optical sensors. (Photo by Geoffrey Wheeler.)

Bottom. Soft X-ray "mirrors," made from a sample material held here by physicist Richard Watts, could dramatically improve the performance of certain telescopes, lasers, microscopes, and semiconductor integrated circuits.

Below. The NIST molecular beam epitaxy facility provides an ultraclean, ultrahigh vacuum chamber for growing semiconductor devices one atomic layer at a time. For example, the facility is being used to fabricate tiny surface-emitting lasers that will allow manufacturers to increase the speed and decrease the size of integrated circuits.

Inset. A computer-controlled "coordinate measuring machine" (CMM) determines the exact dimensions of a precision-machined stainless steel part. NIST researchers use this and similar instruments to devise ways to improve machine tool and CMM performance.

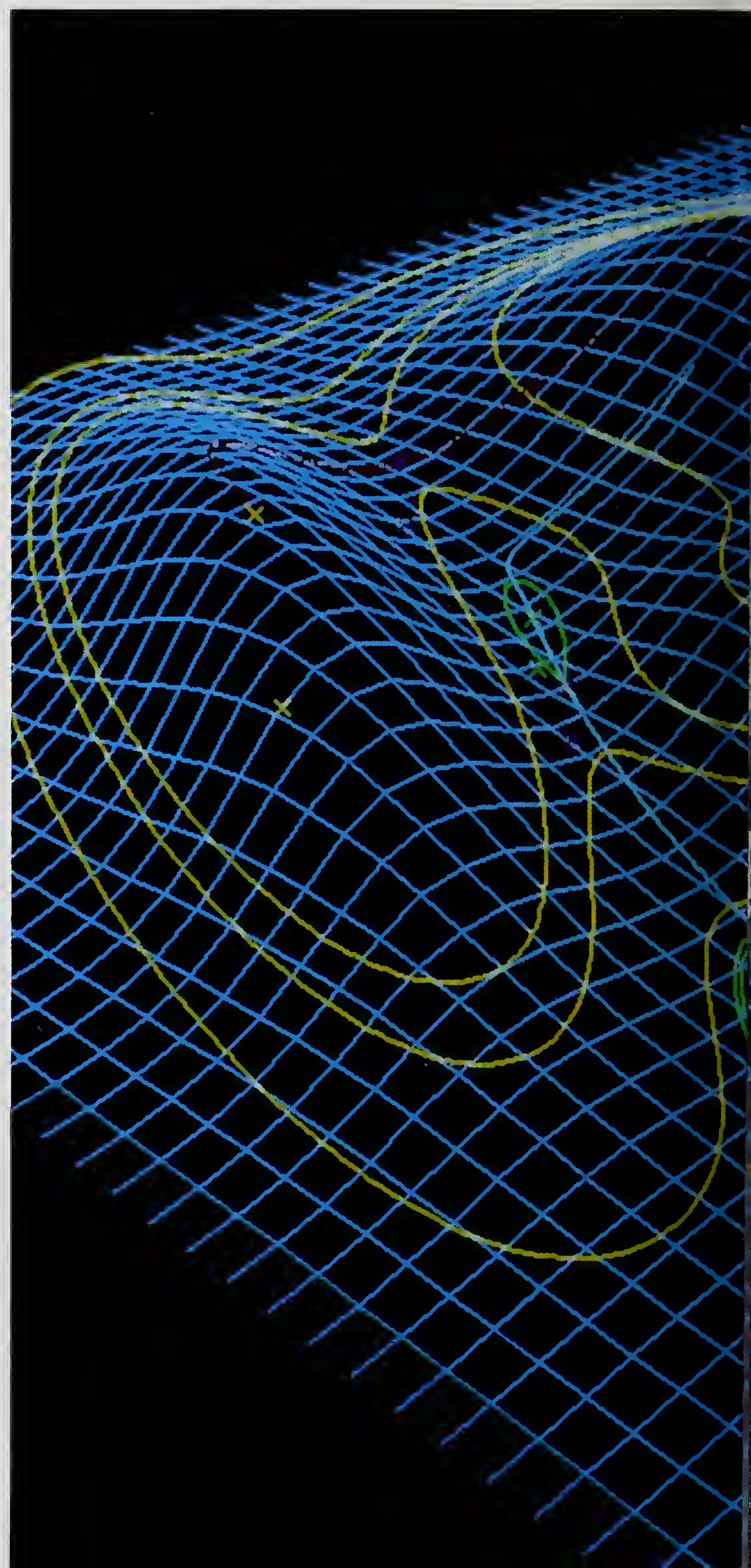
The Industrial "Art"

The efficiency of the tools used in manufacturing affect competitiveness as much as the quality of the basic materials. The finest wool in the world won't help a sweater maker compete if he can't produce a finished product at a cost his customers can afford.

Improvements in U.S. production technologies have lagged behind those of other countries in many industries. NIST research programs in automation, precision engineering, robotics, and standards for a "paperless" manufacturing and supply system are designed to help counter this trend in the coming years. Staff members in these areas, as well as NIST's regionally based Manufacturing Technology Centers, have already helped thousands of companies improve the efficiency of their operations through computer-aided design/manufacturing, numerically controlled machine tools, and other advanced technologies.

Other programs apply the unique capabilities of NIST scientific and engineering facilities to the specific needs of individual companies or industries. A NIST "soft" X-ray characterization laboratory measures the properties of multilayer X-ray "mirrors," expected to dramatically improve processing of semiconductor integrated circuits. A new Cold Neutron Research Facility—with capabilities previously unavailable in the United States—allows manufacturers making everything from magnetic computer disks to house paint to study the chemical composition and internal structures of their latest products in order to optimize production processes.

Below. This representation of a three-dimensional surface was generated with an industry-wide graphics programming standard. NIST computer scientists develop such standards to allow transfer of graphics application programs among different graphics devices and computer systems.



Getting the Message

Running the competitiveness race faster and smarter also requires the ability to process the massive amounts of information made possible by the continuing revolution in electronic and computer technologies.

Ironically, the explosion in information technologies has the potential for both speeding up and slowing down communications. In the absence of agreed-upon standards, incompatible formats and protocols in telecommunications and other fields proliferate, creating islands of unconnected users.

Several NIST efforts are under way to encourage consensus agreements between computer vendors and major users, such as the U.S. government, to ensure compatibility of advanced information systems made by different manufacturers. For example, the North American Integrated Services Digital Network (ISDN) Users' Forum, created jointly by NIST and industry, addresses protocol standards and other needs for this technology, which involves sending voice, data, and images simultaneously over fiber optic telephone lines.

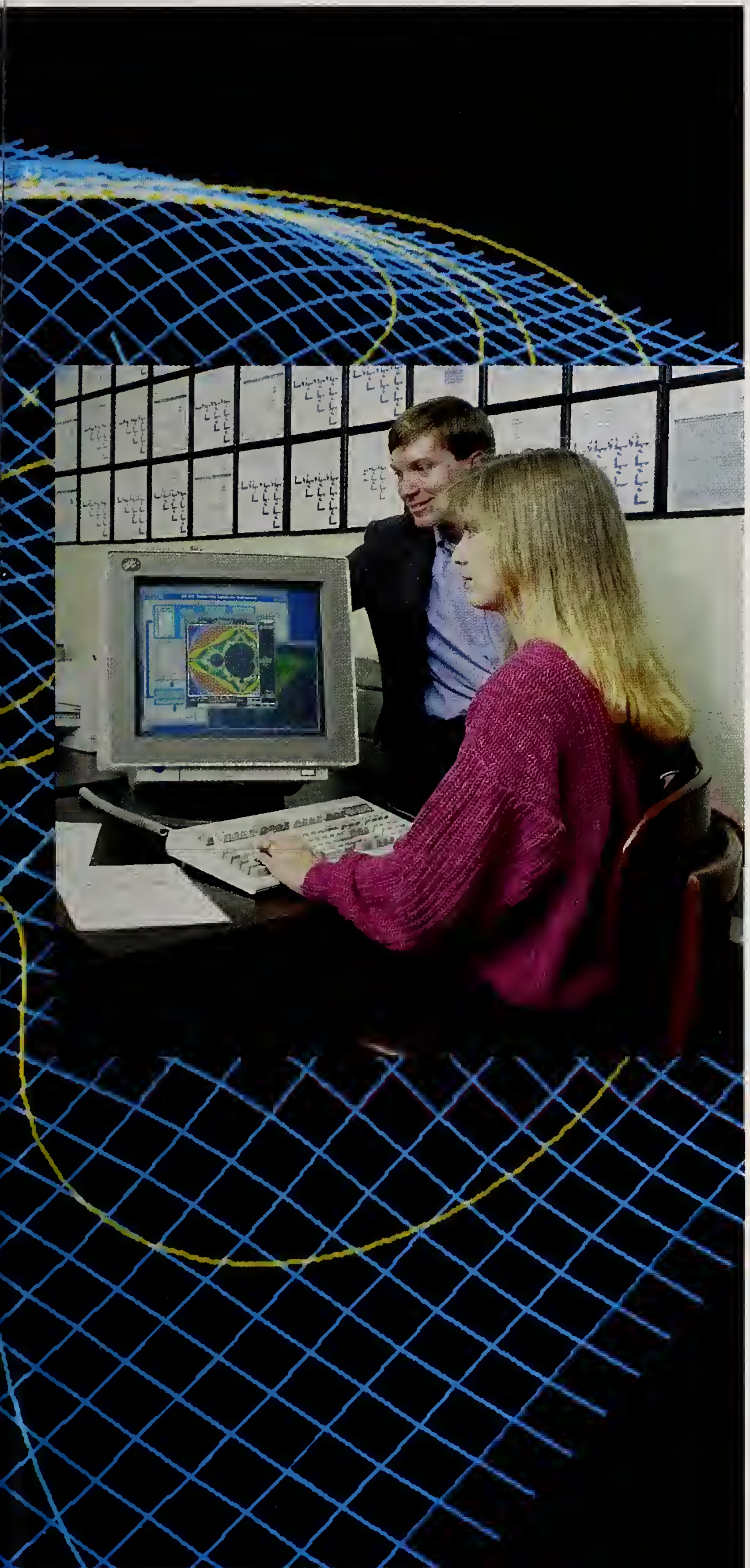
An analogous coordinated effort between users and vendors of computer-aided design and manufacturing equipment is working to produce consensus standards that would allow all aspects of a product's dimensions, materials, and performance characteristics to be shared easily among manufacturers, suppliers, and customers.

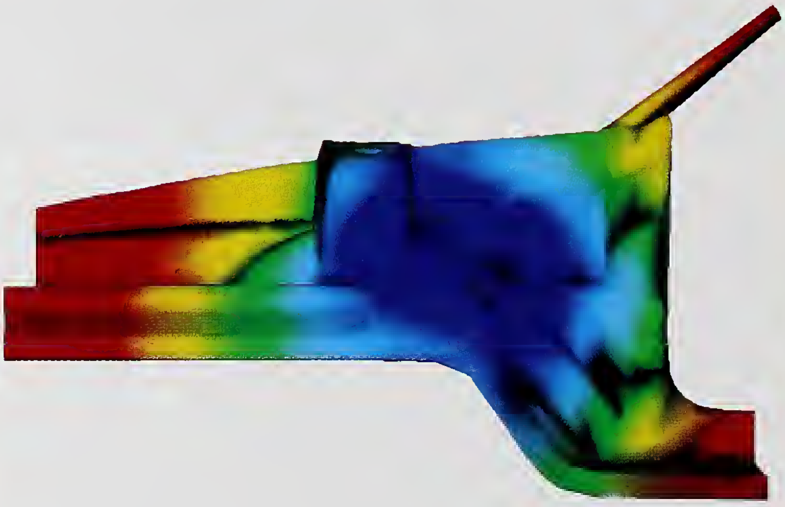
In the years ahead, computer users will depend increasingly on NIST to reduce the vulnerability of information technologies to security breaches. Techniques to protect the confidentiality and integrity of computer communications and data bases are of growing economic importance in international banking and many other fields.

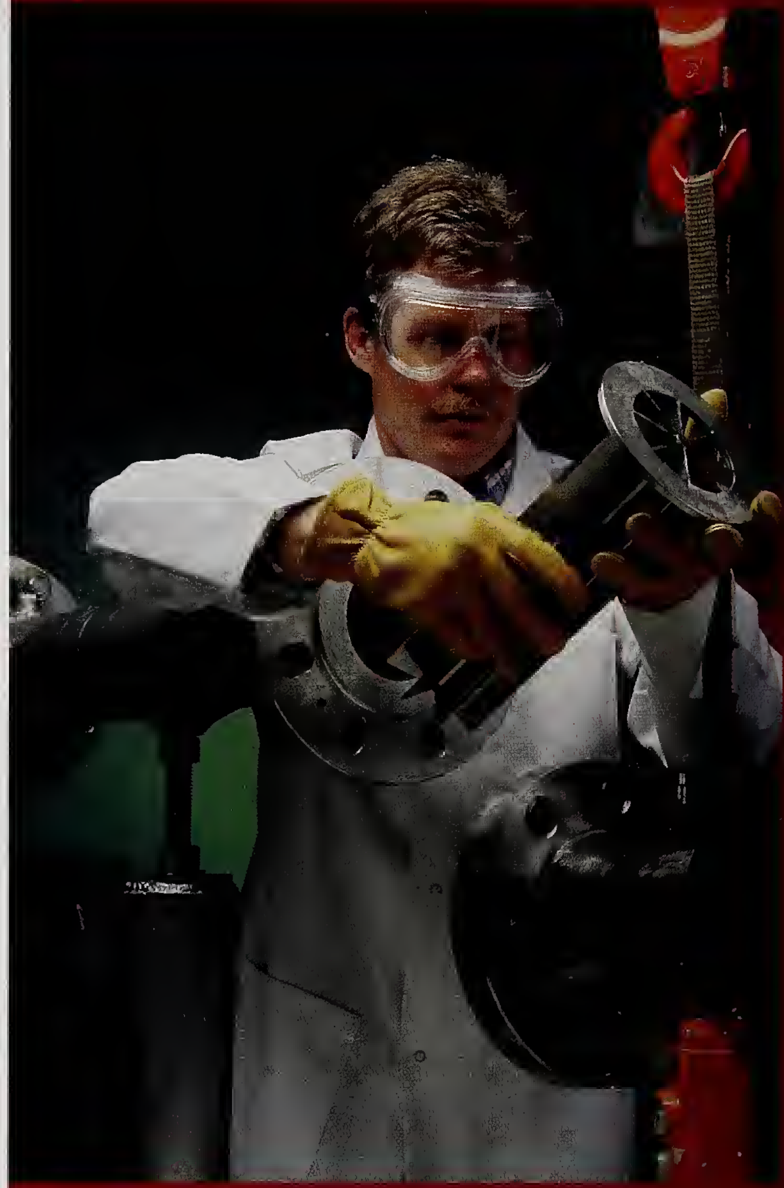
Inset. *Computer scientist Karen Olsen and computer specialist Robert Bagwill are among a number of NIST researchers working to improve standards for open systems environments that allow greater compatibility and interoperability among software systems.*

Top. *NIST's new Princeton Engine video supercomputer, demonstrated here by electronics engineer Bruce Field, is used to design circuits for processing high-definition television signals, to develop software strategies for programming massively parallel computers, and to improve scientific visualization techniques.*

Bottom. *A NIST computer program being developed identifies the essential and non-essential elements of each letter and numeral in the English alphabet in order to translate any printed handwriting sample into typed text.*



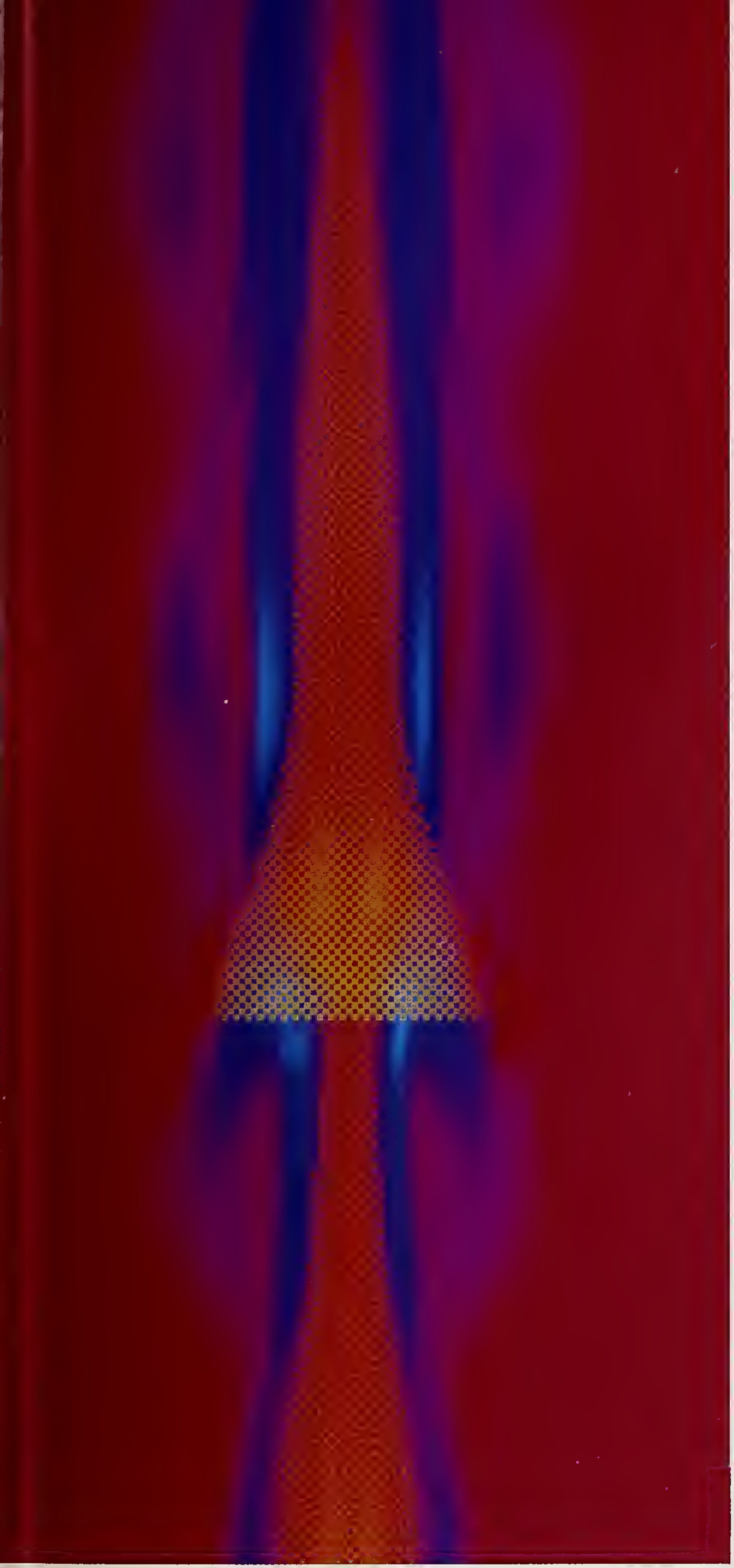




Top. Researcher John Berger uses an optical diffraction technique to measure strains in structural materials. This is part of NIST efforts to develop instruments, measurement procedures, and standards for evaluating the quality and reliability of materials. (Photo by Geoffrey Wheeler.)

Bottom. U.S. automobile manufacturers are working with NIST materials researchers to optimize production processes for new lightweight automobile frames made from fiber-reinforced polymer. This computer-generated graphic uses variation in color to show the expected flow patterns as the liquid prepolymer enters the frame mold.

Inset. Engineering technician Michael Lewis and colleagues at the NIST gas flow measurement facility provide the natural gas and chemical processing industries with precise calibrations of flowmeters. (Photo by Geoffrey Wheeler.)



Above. A complex NIST computer model produced this graphic prediction of flow patterns within a propane flame. U.S. Air Force researchers are using the model's results to improve the combustion efficiency of jet engines.

Quality. Quality. Quality.

The bottom line in competitiveness is that quality sells. Customers want value for their money. They have come to expect greater quality at lower cost, and companies that fail to make continuous improvements in their products soon find themselves without customers.

Over the years, NIST has produced a constant stream of new measurement technologies, Standard Reference Materials, and instrument/equipment calibration services to help U.S. industry improve the quality of its products. These services will grow to meet increasing industrial needs. Another area of increasing importance in the future will be the Design for Quality program, in which NIST statisticians collaborate with industry researchers to apply generic statistical methods to specific design and quality control problems.

The Malcolm Baldrige National Quality Award has had tremendous impact in just 4 years. Managed by NIST in partnership with the private sector, the award recognizes U.S. companies that excel in quality achievement and quality management. In 1991, more than 210,000 quality improvement guidelines—which double as award applications—were distributed. The guidelines include a detailed framework for implementing company-wide quality improvement efforts.

In the future, NIST will work to improve its networking with state and local economic development programs as a means to broaden dissemination of quality management concepts.

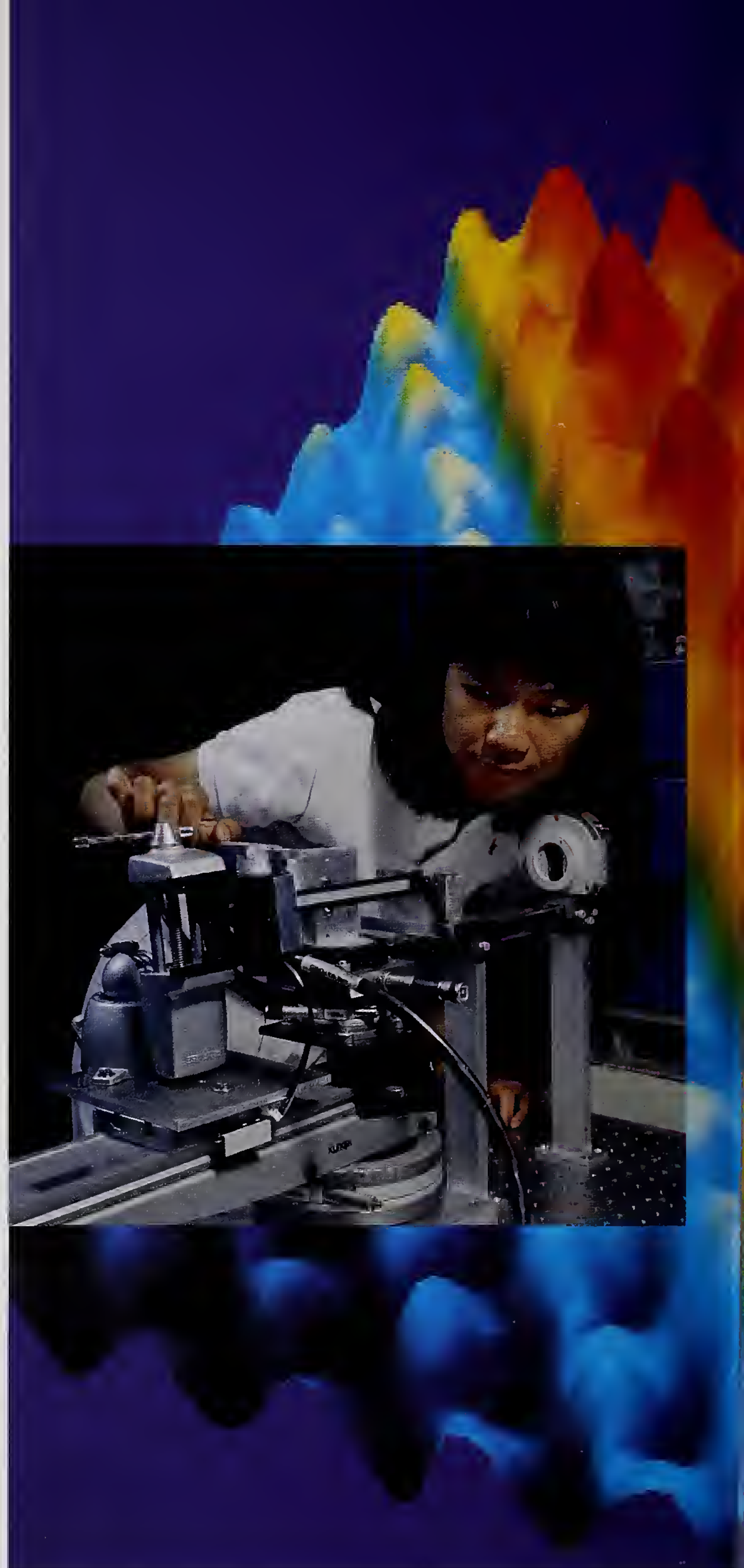
Atomic Worlds

Researchers studying fundamental atomic and molecular processes are continually pushing the limits of technology to better understand nature's basic laws. In fields like semiconductor electronics where the positions of single atoms may soon affect the performance of devices, such basic research will be increasingly relevant for solving practical industrial problems.

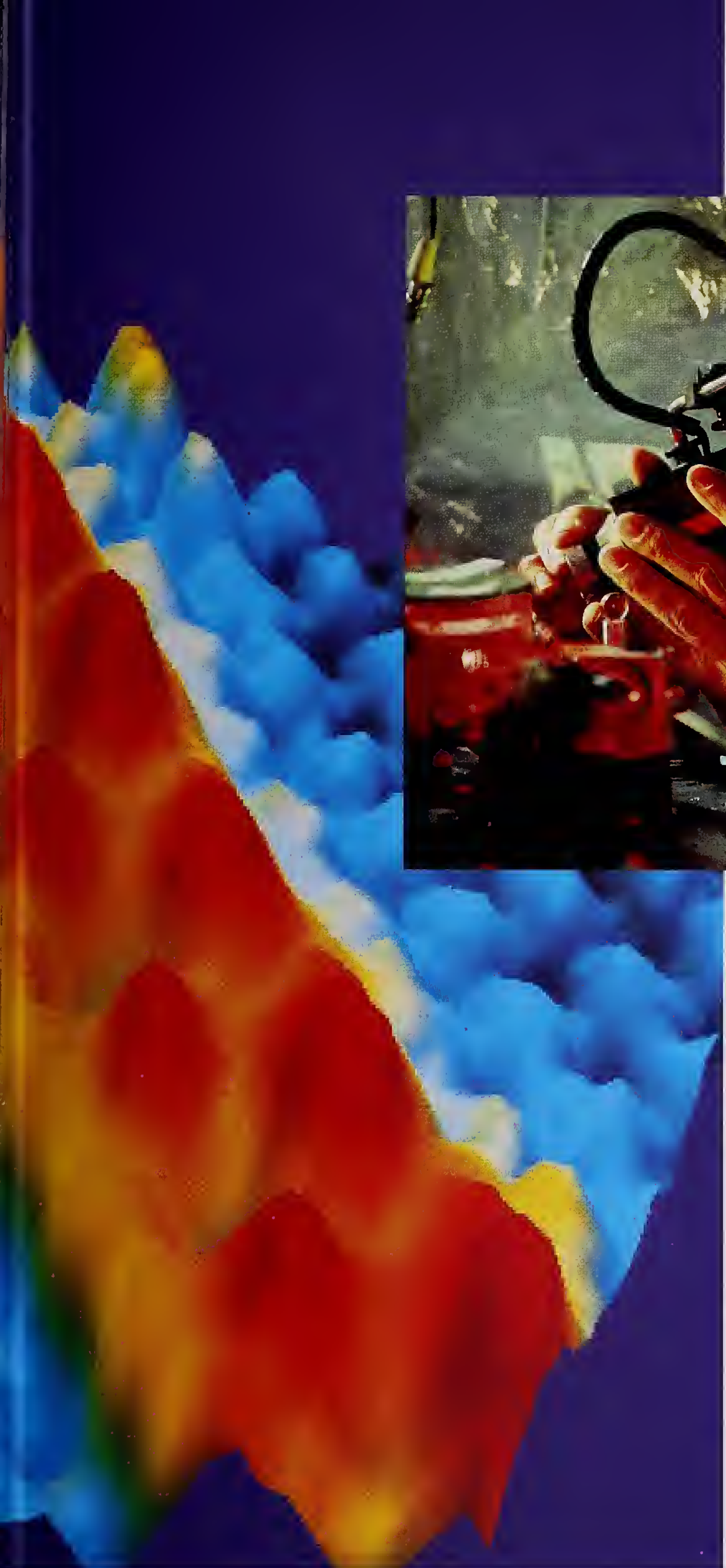
Nanotechnologies—the ability to manipulate and study individual atoms over distances measuring only a billionth of a meter or over time scales less than a billionth of a second long—are blossoming at NIST and many other laboratories. A wide assortment of new scientific instruments allow chemists and physicists to probe, position, and image individual atoms and to study their behavior directly for the first time.

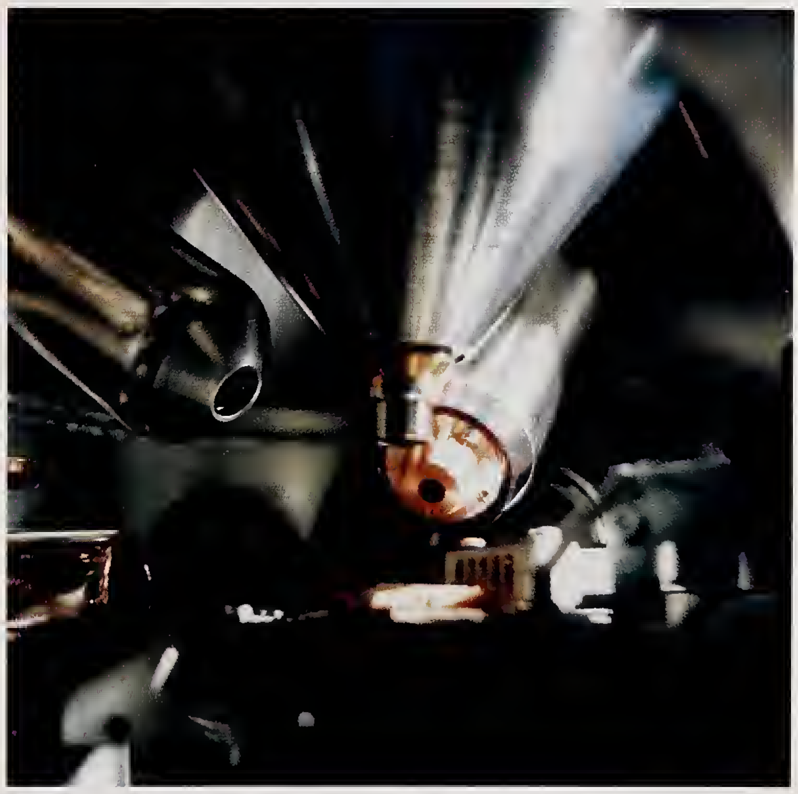
During the 1990s, about 15 percent of the agency's total budget will fund basic research. This will help ensure that the entire Institute makes the best use of cutting-edge science and technology.

NIST researchers are, and must remain, world leaders in numerous fields of science. Examples include ultraprecise measurement of fundamental physical constants such as the force of gravity or the half-life of the neutron, laser systems for detecting extremely short-lived chemical "radicals," and very accurate clocks that use individual atoms as timekeepers. These are areas the Institute will continue to emphasize.



Fundamental Science





Inset. At the NIST 20-megawatt research reactor, guest worker Heather Chen and colleagues design ways to focus neutrons for studies of the chemical composition of materials. Here, she aligns a neutron guide made from glass fibers, each one containing thousands of tiny channels.

Above. Two rows of cesium atoms (red peaks) placed on the surface of gallium-arsenide are shown in a scanning tunneling micrograph. NIST physicists found that cesium, a metal, does not conduct electricity unless at least two rows of atoms are stacked on top of one another.

Top. Physicist Robert Drullinger adjusts a laser system for NIST-7, the latest in a series of extremely accurate atomic clocks developed at NIST. (Photo by Alexander Tsiaras.)

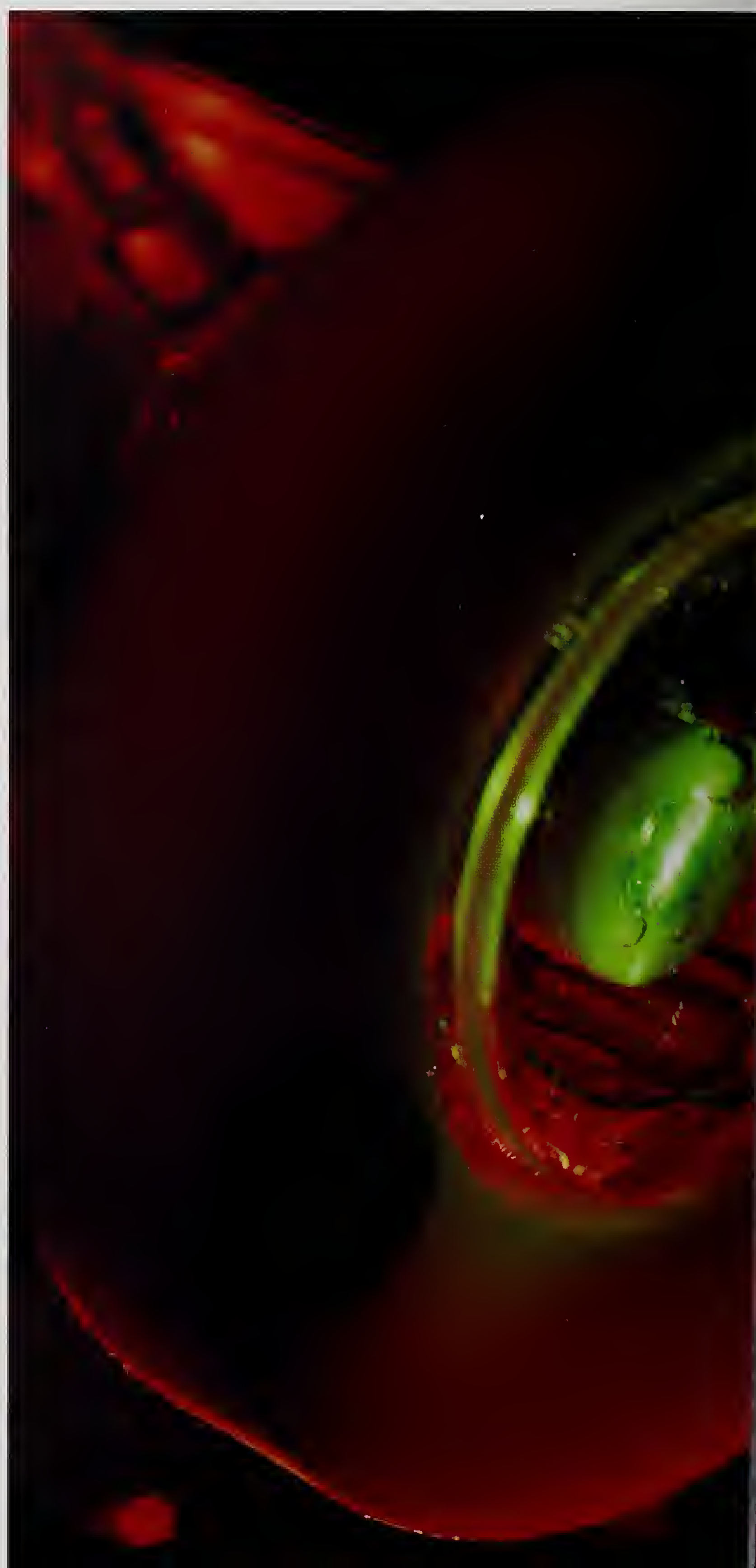
Bottom. A NIST electron spin detector paired with a scanning electron microscope allows researchers to make unusually detailed images of magnetic structures at the surfaces of various materials. (Photo by John Unguris.)

Top. *Research chemist Kristy Richie examines a fluorescent gel used in analysis of a new Standard Reference Material to help improve quality control for DNA "fingerprinting" techniques.*

Bottom. *NIST radiation standards are used to calibrate diagnostic and therapy procedures for hundreds of thousands of patients every year. (Photo by Uniphoto.)*

Below. *New NIST methods for detecting minute quantities of organic compounds are helping the biotechnology industry improve its efficiency. Green light from an argon laser directed at the center of this sample holder is used to sense extremely small amounts of insulin adsorbed on a silver electrode.*

Inset. *Precise measurements of the amounts of radiation absorbed in medical and industrial applications can be made at the NIST electron paramagnetic resonance facility. Here, physical science trainee Francoise Le inserts a bone fragment into the sample chamber.*



Health, Safety, and Environment

In the Public Interest

In many areas of health, safety, and environmental research, NIST programs directly benefit both industry and the general public.

Just as in the manufacturing sector, the health care industry requires increasingly precise and efficient measurement methods to improve quality and restrain cost increases.

New NIST measurement techniques for detecting small quantities of therapeutic drugs in blood serum allow doctors to improve treatment of disorders like asthma. NIST Standard Reference Materials with certified concentrations of blood components such as cholesterol help assure the quality of diagnostic tests. Radiation standards developed at NIST provide quality control in both diagnostic and therapeutic applications through a network of regionally based calibration centers at hospitals and other facilities.

As diagnostic and therapeutic practices advance in the 1990s, NIST quality control tools will increase in significance. For example, results from a recently launched NIST/industry program to apply automation and robotics technologies to analytical laboratory testing could reduce errors and decrease costs substantially in the years to come.

Biotechnology also will be an expanding research area for NIST. New technologies for relating specific proteins to their functions in human diseases like cancer and for improving the cloning of gene fragments used in DNA "fingerprinting" techniques are among several already under development.

Safer, Cleaner Equals Cheaper

A major trend in public safety and environmental protection is the convergence of industrial self interest with public welfare.

Environmentally responsible manufacturing processes that minimize or recycle waste products are often cheaper. New technologies that improve productivity in the construction industry also can make housing more affordable for consumers.

Methods for accurately predicting the fire safety of new products can identify problem areas before a hazardous material causes injuries, deaths, and costly litigation suits.

New refrigeration concepts using magnetic materials rather than ozone-depleting chlorofluorocarbons (CFCs) may produce lighter weight, more efficient air conditioners for automobiles.

And incorporation of "shock absorbers" into buildings and "lifelines," such as bridges and gas and water supply systems, can save lives when earthquakes strike, while avoiding billions of dollars in property damage.

NIST plans call for sustained research efforts in each of these and many other areas affecting public safety and the environment.

Inset. The burning of furnishings found in typical building settings, like the office workstation shown here, provides NIST fire researchers with heat release rates and other data important for minimizing fire hazards. (Photo by Jay McElroy.)

Above. *NIST researchers study the boiling properties of new environmentally compatible refrigerants in order to help industry improve the effectiveness of building air-conditioning systems.*

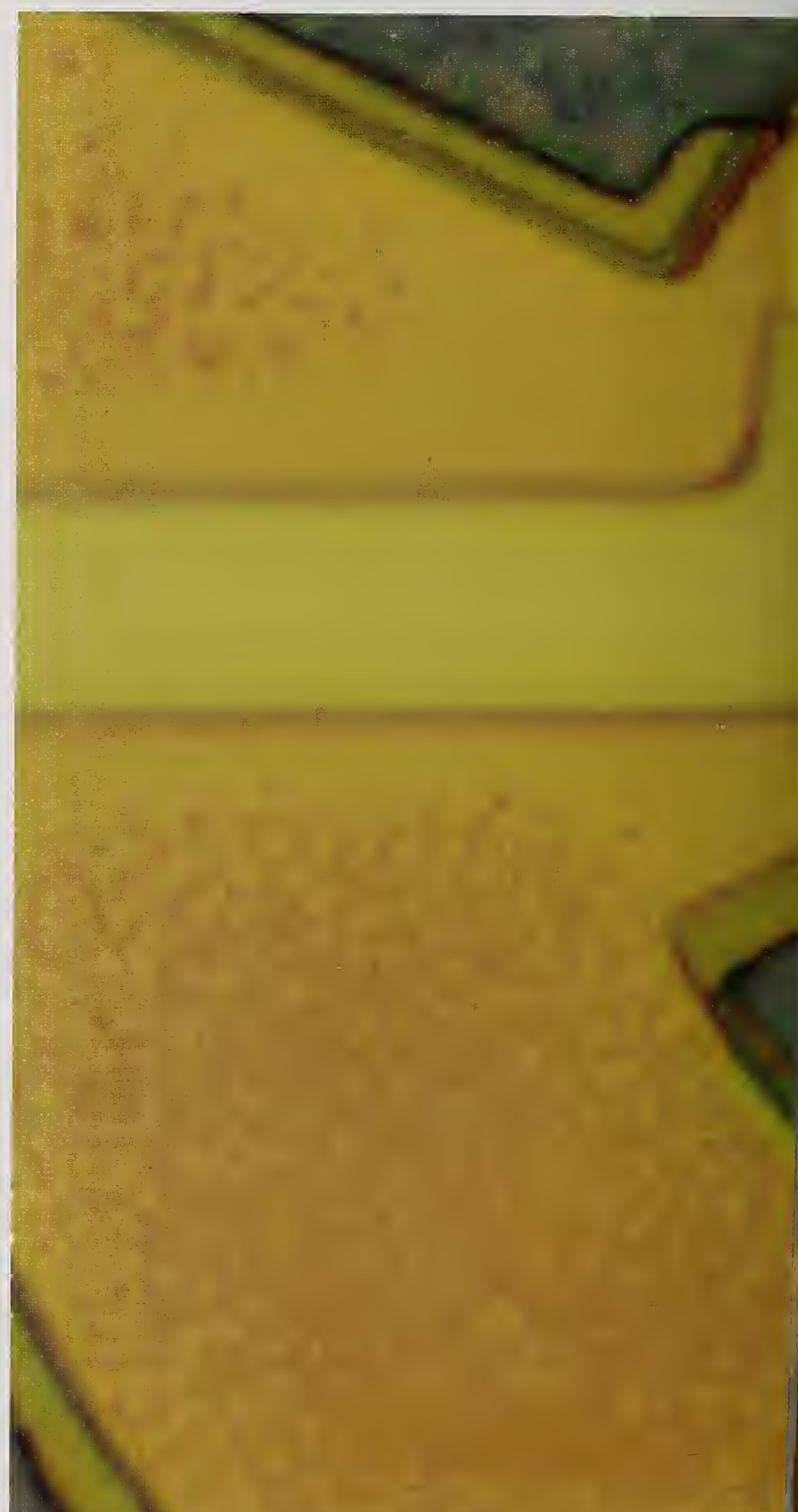
Top. *Technician Max Peltz examines cracks on a precast concrete beam being tested for strength and ductility at the NIST tri-directional test facility.*

Bottom. *An ultrasonic detector developed by physicist Ray Schramm can be embedded in train tracks to detect cracks in railroad wheels as a train rolls by. (Photo by Geoffrey Wheeler.)*

Technology Commercialization

Getting There First

Transforming laboratory curiosities into technically feasible commercial technologies is an essential part of the race to develop new products. The NIST Advanced Technology Program gives individual U.S. companies and industry-led joint ventures a financial boost to help them over the often formidable initial hurdles. Expected to grow substantially in the next decade, the program provides direct grants for the development of precompetitive, generic technologies with significant commercial potential.



The technical accomplishments of NIST research projects are also of little value if they are not put to use. NIST believes that efficient use of new technologies requires a two-way flow of information in which the Institute and its "customer,"—whether it be industry, government, or the scientific community—confer early and often to define goals, agree on exchange mechanisms, carry out the work, and use the results.

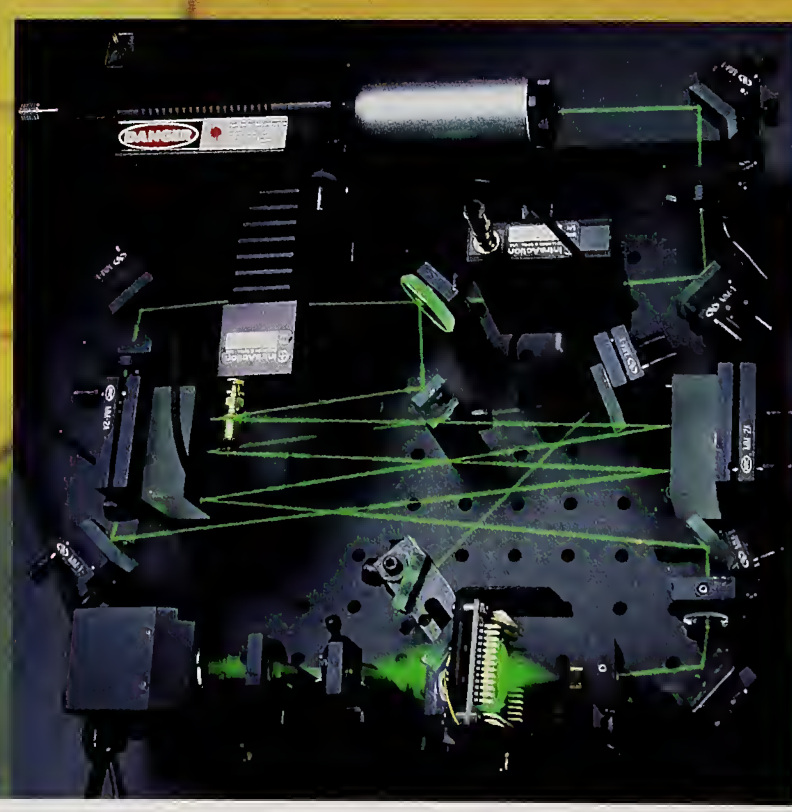
Collaborative research projects in which industry or academic researchers work side by side with NIST researchers on projects of mutual interest are often the best way to move Institute-developed technologies toward the marketplace. In this case, research results do not require "transfer." They are passed along continuously during the project. In recent years, NIST has completely revamped its policies on cooperative research efforts to take advantage of new laws that better protect joint intellectual property and improve incentives for industry to collaborate with federal laboratories.

The Institute's explicit congressional mission to serve the competitiveness needs of U.S. industry, its reputation for neutrality on regulatory matters, and the high technical competence of its research staff, make it an ideal research partner for any organization, large or small, interested in securing its technological future.

Below. *This greatly magnified image of a superconducting infrared detector developed at NIST uses less power and is 10 times more sensitive than conventional detectors currently used in satellites and ground-based, remote-sensing systems.*

Top. *Machinist apprentice Michael Hall monitors a machine tool retrofitted with a personal computer controller. The machine is located in NIST's Shop of the 90s where manufacturers can learn low-cost automation techniques to improve productivity and product quality.*

Bottom. *NIST's Advanced Technology Program provides grants to industry for development of generic technologies. A consortium of several U.S. companies received funding to develop support technologies for laser systems that use holograms to store computer data. (Photo courtesy of MCC.)*



NIST at a Glance

Mission and Goals

The National Institute of Standards and Technology (NIST) was established by Congress "to assist industry in the development of technology ... needed to improve product quality, to modernize manufacturing processes, to ensure product reliability, ... and to facilitate rapid commercialization ... of products based on new scientific discoveries."

A principal agency of the Commerce Department's Technology Administration, NIST has as its goals: to aid industry through research and services, to support the U.S. scientific and engineering research communities, and to contribute to public health, safety, and the environment.

NIST conducts basic and applied research in the physical sciences and engineering, developing measurement techniques, test methods, standards, and related services. The Institute does generic and precompetitive research and development work on new advanced technologies.

Sites	Gaithersburg, Md. (headquarters) Boulder, Colo.
Budget	$435 million (est. all sources, 1992)
Staff	3,000 scientists, engineers, technicians, and support personnel, plus some 1,000 visiting scientists each year
Main Research Areas	Building and fire research Chemical science and technology Computer systems Computing and applied mathematics Electronics and electrical engineering Manufacturing engineering Materials science and engineering Physics

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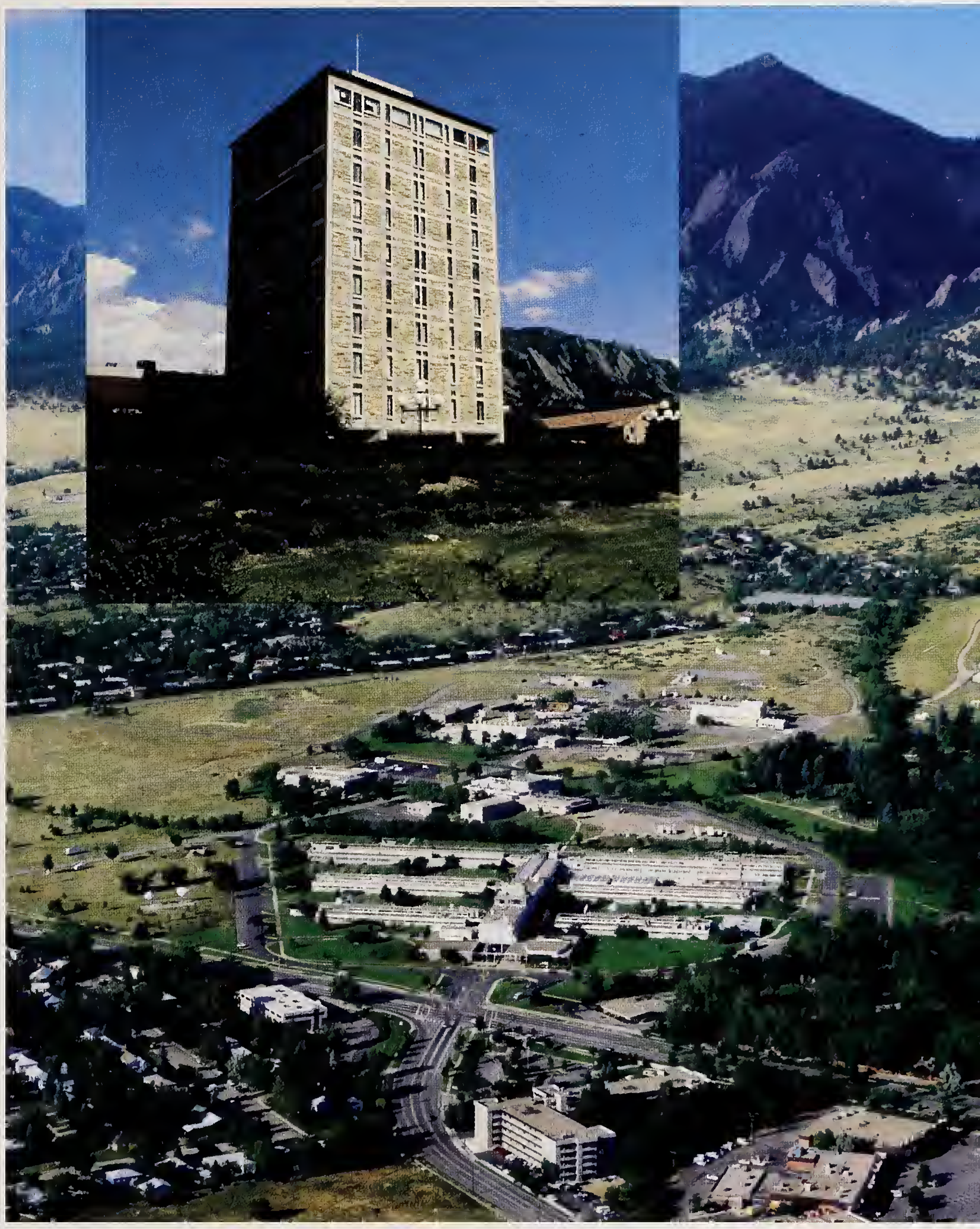

Above. *NIST Boulder laboratories. (Photo by The Photo Works.)*

Inset. *Joint Institute for Laboratory Astrophysics, a cooperative venture for advanced research operated by NIST and the University of Colorado. (Photo by Dar Miner.)*

NIST