Appendix D

How Poor Laboratory Facilities Hamper NIST's Service to the Economy, Science, and Government

The central mission of the NIST laboratory program is to continually improve the U.S. system of measurement needed by industry and science. As the official keeper of the nation's measurement standards, NIST conducts frontier metrology research to improve the accuracy with which measurements are made of fundamental quantities like length, time, electric current, temperature, radiation intensity, and mass. NIST researchers also strive to improve measurement methods for a host of additional quantities derived from these fundamental units—pressure, volume, hardness, flow rate, chemical composition, voltage, resistance, electromagnetic interference, and many others. Our economy and science base depend on this work.

The current poor quality of environmental controls and power supplies as well as other problems that are now pervasive in NIST buildings in both Gaithersburg and Boulder hit these core mission projects the hardest. These are the projects designing instruments to explore not just atoms but the spaces between atoms. These are the projects making sure that high-tech products like aircraft altitude sensors or medical scanners are supported with the necessary high-accuracy calibrations because lives depend on that accuracy. And these are the same projects that industry cannot possibly do for itself. Much of the forefront measurement research at NIST is carried out in only a handful of other national laboratories in the world.

Below are examples of how NIST's deteriorating physical facilities are hampering its mission to provide U.S. industry, other government agencies, and university researchers with the best possible measurement system.

These examples are symptomatic of problems that affect a broad range of NIST programs in nearly all of its laboratory buildings. An exhaustive list of current facilities problems can be found in the 1997 Retrace Study by SHG Inc.[1] This study established a matrix linking 27 categories of facilities failures to each of NIST's 48 technical divisions.

Chemical Composition

Chemistry Bldg., Gaithersburg

NIST's chemical microanalysis experts recently installed a $1.7 million field emission analytical electron microscope intended to help the Department of Defense and the U.S. semiconductor industry improve nanometer-level (billionth of a meter) mapping of chemical composition and contamination of silicon wafers. They spent nine months and about $50,000 trying to isolate the instrument from vibration, magnetic fields, dust particles, and temperature changes. Still, environmental conditions are the major limiting factors on the resolution of the microscope. The instrument can stay focused on a particular nanometer area for only about 1.5 seconds before temperature and vibration changes cause it to drift away to a different area before measurements can be completed. It's like trying to shoot a rifle at a distant target while the floor is constantly shifting under you. **"Semiconductor manufacturers need NIST to develop Standard Reference Materials for measuring wafer contamination, but we can't even bring one of their samples into our lab space without**

[1] SHG *NIST Capital Improvements Facilities Plan: 1997 Retrace Project*, June 1997.

ruining it due to poor air quality," says NIST researcher Eric Steel. The researchers have designed a special laboratory in the Advanced Measurement Laboratory that will allow them to carry out this work. Japan's counterpart to NIST already has modern facilities and is working on such standards now.

Pressure Calibrations

Metrology Bldg., Gaithersburg

Well-calibrated pressure gauges are critical to the altimeters that keep airplanes safely separated in vertical airspace over busy airports. They also are essential for making semiconductors, jet engines, pharmaceuticals, and many other high-technology products. U.S. industry depends on NIST to make these calibrations. **Poor temperature and vibration control, however, prevent the NIST pressure laboratory from using its best calibration instrument about one-third of the time**. Even when environmental conditions are within acceptable ranges, they limit the accuracy of NIST calibrations. As the sophistication of industry's products continues to increase, these limitations are becoming more critical for industry in meeting its measurement and quality control needs. In addition, the air quality in the laboratory is so poor high-tech companies have complained that their gauges, normally used in clean room environments, may be contaminated during calibration at NIST. The pressure lab—like all NIST general purpose laboratories in Gaithersburg—suffers from black grit emitted by a deteriorated, 30-year-old ventilation system. Moreover, the group's floor-to-ceiling high-pressure calibration equipment cannot receive normal maintenance within its current space. It must be hauled to a hole cut in the ceiling and hoisted to the laboratory above. The improved environment in the Advanced Measurement Laboratory would improve markedly both the quality and the efficiency of NIST pressure calibrations.

Coordinate Measuring Machines

Metrology Bldg., Gaithersburg

Challenged to produce parts with ever more complex features within ever finer tolerances, manufacturers are relying increasingly on coordinate measuring machines—robots that inspect the dimensions of parts. About 30,000 CMMs are employed in U.S. factories and laboratories. Several NIST programs are devoted to providing industry with measurement tools and services that help to ensure the accuracy of CMM measurements. NIST recently installed two advanced CMMs to help achieve higher measurement accuracies demanded by researchers and the $15 billion gear industry. One was sidelined almost immediately because particulate contaminants fouled the machine's air bearings. In all, eight staff months of effort were devoted to replacing the bearing, reassembling the CMM, and recharacterizing its geometry. CMMs also are very sensitive to temperature-caused expansion and contraction so each of NIST's room-sized machines is housed within an environmentally controlled enclosure with a dedicated air handling system. **The two systems, which can control temperature to within one-tenth of a degree Celsius, added a total of about $600,000 to the cost of the CMMs, while consuming one full module of precious basement lab space for the necessary air-handling equipment. (Competition is stiff for the limited amount of basement laboratory space at NIST since these laboratories have lower vibration levels.)** An Advanced Measurement Laboratory would provide temperature control 10 times better without add-on equipment as well as the improved air cleanliness, humidity, and vibrational control that will allow NIST researchers to keep up with industry's accelerating needs.

Semiconductor Processing

Technology Bldg., Gaithersburg

Semiconductor processing involves growing or depositing thin films of different materials on silicon wafers many times to make each circuit. Accurately measuring the properties of these films, often just nanometers thick, is a do-or-die procedure for industry. One mistake early in the process could ruin a $10,000 wafer. NIST's work in developing Standard Reference Materials and data for thin films, therefore, is critical in helping manufacturers precisely measure these layers. **To make reference materials, NIST lab conditions must**

mirror those of industry. NIST's current 12-year-old clean room, however, is far behind accepted semiconductor industry standards. An Advanced Measurement Laboratory's clean room would allow no more than 5 percent variation in relative humidity compared to today's routine 10 percent fluctuations. Temperature control would be accurate to one-fourth of a degree Celsius; in today's clean room, temperatures can change by several degrees without warning. Researchers will have much better vibration control to do lithography, the etching of features onto a circuit; **today, an airplane flying overhead can rattle equipment enough to smear features and ruin the device.** An AML will offer air that is 10 times cleaner in critical areas than is available in the current clean room; even dust specks less than one micrometer destroy a circuit. The Semiconductor Industry Association's Roadmap identifies thin-film standards and data as required to produce the next generations of microchips.

Lightwave Communication

Materials Bldg., Gaithersburg

Consumers count on speed when they send information over computer networks. Companies in the telecommunications, data storage, and other information technology industries respond by announcing products at dizzying rates—each one faster than the previous generation. Keeping a step ahead, researchers at NIST are developing measurement methods for ferroelectric oxide thin films, important to photonics applications for tomorrow's computers. But laboratory conditions often confound their work. The truly thin films—0.5 micrometer thick, or less than one-hundredth the width of a human hair—frequently are wrecked by black grit from the building's ventilation system. **The particles range from 10 to 50 micrometers in thickness—a veritable mountain on a thin-film sample—and can flush a month's research down the drain.** In one lab, temperature changes of four degrees Celsius occur over the span of several minutes. Temperature and vibration problems keep researchers from even attempting to study the holographic properties of thin films, potentially important to super-fast optical computing and high-density storage. One U.S. defense industry firm's 30-year research in holographic imaging has not come to market because of materials problems that NIST could be solving.

Atomic Nanostructures

Metrology Bldg., Gaithersburg

The NIST nanostructure physics researchers work at the smallest scales imaginable, manipulating individual atoms to develop new measurement technologies and even build nanoscale structures to serve as measurement standards. Among other achievements, the researchers have built a new type of highly accurate intrinsic length standard for the nanoscale—patterns of chromium lines on a silicon crystal spaced 0.21 micrometer apart. Some of the instruments are capable of measuring dimensions approaching 0.001 nanometer (about one-hundredth the size of an atom). The work supports industry's R&D and manufacturing in areas such as nano- and microprobe instrumentation, high-performance magnetic materials, and magnetic and optical data storage. Data storage alone is a $60 billion industry subject to intense international competition. Problems caused by the current poor facilities seriously compromise this work; it is very difficult, and sometimes impossible, to perform the needed experiments because of environmental noise, vibrations, and fluctuations in temperature and humidity. Frequently, the work of an entire day is lost because of some sort of environmental interference, e.g., electrical noise or power interruption. In addition, the accuracy of these measurements is limited by the lack of tight temperature control. An Advanced Measurement Laboratory would eliminate these problems and allow this program to offer NIST's customers nanomeasurement services that their foreign competitors cannot get.

Surface Science

Physics Bldg., Gaithersburg

NIST researchers are using very high-speed lasers to manipulate and probe chemical reactions at surfaces. Their studies eventually could lead to new, more efficient ways to catalyze chemical reactions or build billionth-of-a-meter-scale structures. However, environmental problems in NIST's general purpose laboratory space have made the experiments much more costly and time consuming than they otherwise would be. This high-precision work is critically impacted by vibrations, temperature, humidity, air cleanliness, and stability of the electric current. The experiments are conducted with very fast laser pulses measured in femtoseconds (quadrillionths of a second). Since light travels 0.3 millionths of a meter in one femtosecond, the 1.5 meter by 3 meter table holding the laser and optical equipment must vibrate no more than 0.3 millionths of a meter. Even with special temperature stabilization equipment, the table is stable for only about one hour. Problems with air particles and humidity have forced researchers to fabricate custom housing for the sensitive optics. Inconsistencies in the chilled water and electric current also stop work for hours or more at a time. Researchers estimate that they spend $10,000 annually in attempts to remedy these problems and lose about three weeks annually to chilled water failure and power interruptions.

Dopant Density

Technology Bldg., Gaithersburg

One of the newest and most promising tools for the semiconductor industry, the scanning capacitance microscope, non-destructively images the density of dopants, chemical additives that produce desired electrical characteristics in semiconductor microcircuits. Co-developed by NIST and a U.S. instrument maker, the microscope can image dopant density with the unprecedented resolution of about 10 nanometers. This measurement capability will be critical to semiconductor devices at the beginning of the next century—when they will have feature sizes of 0.18 micrometer—and was identified as a key requirement in the industry's National Technology Roadmap for Semiconductors. NIST researchers are working on precise calibration of the SCM by developing technology to tie the images produced to absolute measurement scales. The work has been hampered seriously by uncontrollable shifts in temperature and humidity in the Gaithersburg general purpose laboratories that distort SCM images and introduce errors in the measurements and by particulate filth from the ventilation system, which fouls samples that then must be laboriously cleaned. **"Solving problems caused by the building was one of the most time-consuming parts of the instrument's development and continues to slow throughput and further research,"** according to the lead researcher.

Cooling and Trapping Atoms

Physics Bldg., Gaithersburg

Using delicately balanced networks of finely tuned laser beams to capture and manipulate atoms, researchers in the NIST Physics Laboratory have achieved some of the lowest temperatures known to man, producing clouds of atoms at less than a millionth of a degree above absolute zero. In addition to being a Nobel prize winning contribution to pure research on the quantum nature of matter, this work is expected to have important long-term applications for next-generation time and frequency standards (essential to communications and navigation), and possibly even ultra-precise atomic-based gyroscopes for deep-space navigation. Present lab conditions, however, greatly magnify the difficulty of the work. **Uncontrollable humidity fluctuations degrade the stability and performance of the precision lasers and occasionally even damage components**. Drifting temperatures in labs that can be controlled to no better than a few degrees Celsius cause beams to drift out of alignment, requiring constant adjustment, and poor cleanliness of air necessitates constant cleaning of optics, leading to misalignment and wear. Problems with vibration and "dirty" electrical power require researchers to expend precious time and money over-designing equipment to cope with problems caused by the building. "Probably 20 to 30 percent of our time is spent dealing with environment problems that we wouldn't have in an Advanced Measurement Laboratory," according to the lead researcher.

Molecular Measuring Machine

Metrology Bldg., Gaithersburg

By the late 1990s, dimensions of the smallest features on leading-edge commercial semiconductor chips will shrink to 0.25 micrometer (millionths of a meter) or about one three-hundredth the width of a human hair. Soon the semiconductor industry will require measurement methods accurate to within 2.5 nanometers. NIST is working to make this possible with the Molecular Measuring Machine (M Cubed), a one-of-a-kind microscope that can “see” individual atoms and measure vast distances between them—an unprecedented capability. The onion-like, spherical shell that houses M Cubed’s sophisticated measurement equipment contains two vibration isolation systems, two shells for acoustic isolation, another for temperature control, and still other protections. **Ten years in the making, the prototype instrument has yet to meet fully its ambitious design goals. Environmental control problems loom as major obstacles to the group’s ultimate success**. The availability of Advanced Measurement Laboratory space would simplify greatly refinements of the prototype instruments and accelerate results from the project. “We are getting to a situation where we have the capability to manufacture smaller dimensions than we can accurately measure and certify,” explains James Greed, president of VLSI Standards, Inc. Without reliable, high-accuracy measurement capabilities like those provided by M Cubed, U.S. industry will confront serious production problems that jeopardize yields and quality.

Subatomic Rulers

Physics Bldg., Gaithersburg

The M Cubed instrument described above is a surveyor of atomic real estate. It maps large surface areas in order to return to an exact location on that surface, even relocate a specific atom previously visited. The reference grids underlying this mapping are supplied by optical interferometers, systems that use wavelengths of laser light to measure tiny changes in position. These instruments suffer from distortions that need to be understood and eliminated to allow production of future semiconductors. The “troika interferometer project” is a planned five-year effort to build and operate a testbed using three distinctly different types of interferometers to help limit current distortions. The goal is to produce a system that can accurately measure changes in position at the sub-atomic level over distances as large as 10 centimeters, a step on the way toward the projected size of future semiconductor wafers. A presently operating prototype of this project, involving subatomic measurements over much more restricted ranges, operates in a unique basement lab with the lowest vibration level available on the Gaithersburg campus. The room, however, is half the size of an office module. The air supply has considerable particulate contamination that leads to operational problems and premature failure of optical components. Available temperature control of only about ± one degree Celsius, together with the other problems, severely handicaps research progress, says project leader Richard Deslattes. **The improvements in an Advanced Measurement Laboratory’s planned environment should allow the project to achieve accurate subatomic positioning over distances 10 to 100 times greater than currently possible**.

Electronic Kilogram

Non-magnetic Bldg., Gaithersburg

High-accuracy measurements of mass are necessary for a diverse array of defense, commercial, and academic activities, from pharmaceutical manufacturing to weapons production to basic studies of the structure of matter. Mass is the only one of the seven basic measurement standards that is still defined in terms of a physical artifact, a century-old platinum-iridium cylinder weighing one kilogram that is housed in a special vault in France. The other six are defined in terms of naturally occurring phenomena like the speed of light or oscillations of the cesium atom. NIST’s electronic kilogram project aims to improve dramatically mass determinations by defining mass through electric current. The two-story-high NIST apparatus works on magnetic force principles analogous to those for proposed ultrafast trains that would float above superconducting tracks. The instrument measures exactly how much current and voltage pass through a system of electrical coils to balance the pull of gravity on a one kilogram mass standard. **To achieve an electronic definition of the kilogram substantially better than the current artifact system, NIST experiments will require every environmental control feasible**. In the current laboratory, even moderate winds and heavy trucks on local roads degrade the quality of data.

Mass Measurements

Technology Bldg., Gaithersburg

Measurements of mass standards—ranging from one milligram all the way up to 30,000 kilograms—are NIST's most heavily used calibration service. Customers, who include state weights and measures labs; the drug, chemical-processing, petroleum, and aerospace industries; and facilities that handle and store nuclear materials, are continually pressing NIST to achieve higher levels of mass-calibration accuracy. Increased accuracy at NIST—the first link in the nation's measurement chain—would enable customers to take full advantage of today's advanced measurement tools and of the even more capable equipment of tomorrow. At the same time, more accurate measurements of mass artifacts would further NIST's efforts to realize an electronic definition of the kilogram—a long-sought-after achievement that would substantially strengthen the nation's and the world's measurement systems. If performed in the proposed Advanced Measurement Laboratory, NIST's precision mass measurements could be improved up to tenfold over an important part of the measurement range. Responding to the needs of customers, the demands of science and technology, and the uncertainty surrounding the status of an AML, NIST has taken the intermediate step of building a $500,000 clean room to house its mass-calibration facility. Measurement accuracy will increase significantly but will fall far short of the levels of accuracy achievable in an AML. In the new clean room, temperature will be controlled to within 0.1 degree Celsius (the best that can be attained through costly re-engineering of NIST's existing facilities), which is 10 times poorer than in an AML. Vibrations will continue to confound measurements and, over time, degrade the point-like fulcrums of the mass comparators used to calibrate customers' artifacts.

Overlay Metrology

Metrology Bldg., Gaithersburg

When the Sunday newspaper is printed poorly, the color comics come out fuzzy. When semiconductor circuits are printed poorly, they don't work. NIST works with semiconductor manufacturers to develop tools to help ensure that each of the 10 or more photoprocessing layers in a semiconductor line up properly. According to an industry rule of thumb, misalignment errors should not exceed 10 percent of the size of a chip's smallest feature—now about 0.35 micrometer. Institute researchers have built a one-of-a-kind instrument for researching and measuring misalignment errors. The instrument's laser interferometer should be able to measure length differences of only 0.6 nanometer (less than the width of two atoms). **Because of temperature swings of up to two degrees Celsius, variations in humidity, and vibrations, however, the critical equipment cannot perform up to specifications**. The team could reduce vibration problems by moving to a basement lab from their current second floor lab, but basement "real estate" at NIST is at such a premium they have no hope of obtaining such space until other, even more sensitive, experiments move to new facilities.

Time and Frequency

Building 1, Boulder

Most of NIST's time and frequency work takes place in Boulder in converted office space in the main building (Bldg. 1). Over the past 40 years, this research group has made continual improvements in atomic clock technology that have made accurate launching and control of satellites and spacecraft and precision navigation with Global Positioning Satellites possible. This work also provides the standard of time for the United States through NIST-7, one of the two most accurate clocks in the world, which has an accuracy of 0.2 millionths of a second per year. Still, **the researchers responsible for this work say that reliable environmental controls for their laboratories would allow them to implement evolving frequency standards 100 times more accurate than today's**. Construction of the Boulder central utility plant will be a first step toward reaching this goal. All of the group's work depends on properly functioning laser systems that are extremely sensitive to vibration, electromagnetic interference, temperature changes, and humidity. More than 50 percent of the group's data collection takes place after hours when fewer people in the building make conditions more predictable. Past history demonstrates that demands for ever better frequency standards will not go away. Over the last 50 years, NIST's frequency standards have improved by a factor of 10 every seven years—and each time U.S. industries have quickly used those improvements to increase their products' competitiveness.

Temperature Calibrations

Physics Bldg., Gaithersburg

Nearly every industrial process depends on accurate measurement and control of temperature. Pharmaceutical, aerospace, utility, and electronics companies are among the many industries that rely on NIST for accurate temperature standards. However, problems with electrical power, heating, ventilation and air conditioning, chilled water, and plumbing in the general purpose laboratories have slowed significantly the transfer of temperature standards to U.S. industry. NIST has had to purchase conditioning filters for all instrumentation in temperature measurement labs due to dips and spikes in electrical current. However, the voltage is still often uneven. "You can't make measurements when the line voltage fluctuates because you lose temperature control," says researcher Gregory Strouse. "It disrupts our flow of doing calibration work for the customers." Scientists also have to stop work when they lose temperature control due to the deteriorating HVAC system and unscheduled outages in the chilled water supply. **All these interruptions effectively lower the laboratory's productivity by 10 percent**.

Electrical Resistance

Metrology Bldg., Gaithersburg

NIST researchers conduct calibrations of specialized electrical resistors for some 200 different aerospace, power and energy, semiconductor, academic, and other high-tech laboratories across the country. The program is located in the basement of the building with the best environmental controls on the Gaithersburg campus. Nevertheless, calibrations must be shut down regularly because of power outages, temperatures that are too hot, or humidity that is too high or too low. In order to maintain the lab's temperature at 23 degrees Celsius, as required for resistance calibrations, NIST researchers now routinely must turn off all lights and any unnecessary equipment and physically leave the room to remove all extraneous sources of heat. Lately, there have even been plumbing leaks from upper floors into the lab space. **With the reliable environmental conditions available in a renovated general purpose laboratory, NIST could cut in half the uncertainties associated with temperature and humidity for such calibrations, while hopefully shortening the current six-to-eight-week turnaround time**. Improvements in calibration accuracy will be increasingly important as manufacturers of semiconductors, medical instruments, and other electronic products design sensors for tiny current leakages that require calibration of resistors having extremely high resistance values (above 10^{14} ohms).

Antenna Measurements

Building 24, Boulder

For the last seven to eight years, NIST's antenna calibration group in Boulder has been **struggling with temperature control problems in laboratory space that force the program to shut down for one to two weeks at a time**. The researchers' mission is to provide high-accuracy calibrations for the antennas used in satellite communications and radar operations, including the satellites used for relaying telephone and television signals, for weather prediction, and for a host of scientific experiments in space. It also includes essential radar stations used by airports and the U.S. military for ensuring safe air travel and for monitoring U.S. airspace. The calibration facility is in such demand that it is sometimes run in multiple shifts to keep up with the workload. Yet, the researchers must contend with an antiquated air-handling system in Bldg. 24 that can produce heat or cooling but nothing in between. This causes major problems especially during the spring and fall. **"Either the people in the offices are comfortable or the labs are operating, but you can't have both,"** says project leader Andy Repjar. The measurements they make are sensitive to temperature shifts of one degree Celsius. If the temperature shifts during a measurement, a frequent problem, the measurements must be done over. Utility upgrades and renovation of Bldg. 24 will greatly improve productivity and customer service of this important NIST function.

Advanced Optical Measurements

Sound Bldg., Gaithersburg

To "catch" a gravity wave—the objective of the $365 million Laser Interferometer Gravitational Wave Observatory funded by the National Science Foundation—researchers need some of the most advanced optical equipment ever made. For the California Institute of Technology, NIST measured the exact shape of the eight mirrors to be used in the gravity wave experiments, a critical quality-assurance step before the mirrors were coated. The NIST work required 100 hours worth of measurements to get the one nanometer-level accuracy required. **The researchers built a special enclosure to isolate their instrument from vibration and dust, but even then doors closing down the hall spoiled their data**. So they did the experiments in the middle of the night, and they did massively more measuring and averaging than normal to try to improve the data's accuracy. Demands for high-accuracy mirror measurements will only increase. Extreme ultraviolet lithography systems for making next-generation semiconductors will require characterization of surfaces that are inherently more difficult to measure and yet need measurements that are five times more accurate than the gravity project. Only in an extremely stable environment will such measurements be feasible.

Scanning Electron Microscopes

Metrology Bldg., Gaithersburg

More than 50,000 scanning electron microscopes are in use worldwide for a variety of purposes. Semiconductor makers are among the major users, employing the high magnification and resolution instruments to measure surface features and dimensions during key stages of production. NIST develops and certifies SEM measurement reference standards to ensure the accuracy of these instruments. The general purpose laboratory used for this program has been retrofitted extensively to try to protect against vibrational disturbances, stray electric and magnetic fields, and unstable power and temperatures. Statistical methods have been devised to minimize other environmental factors. **"More effort is being expended on compensating for the environment than on developing standards,"** explains project leader Michael Postek. Still, measurements are ruined by unanticipated noises like the high-frequency vibrations from the wobbly wheel on a mail cart rolling down the adjacent corridor. The researchers currently are working to develop a new magnification standard needed by all SEM users, but especially semiconductor makers. The standard would help to ensure the accuracy of production-line SEMs that measure circuit quality. Before the standard can be distributed to industry, the NIST team must certify the pitch dimensions of artifact features as small as 0.2 micrometer with nanometer-level uncertainty, necessitating the highest levels of environmental control. "If environmental noise is a limiting factor to the NIST metrology, then the standard we develop will be useless to industry," says Postek.

The Candela Standard

Metrology Bldg., Gaithersburg

NIST establishes and maintains the national measurement scale for the candela, the international base unit for measuring light. NIST performs critical calibrations for the multi-billion-dollar-per-year lighting industry that requires accurate measurement of the amount of light from standard sources. However, poor air quality and temperature and humidity control take a toll on productivity and technical accuracy. **The NIST scientists responsible for this work estimate that they lose one month of productivity yearly to recoating optical surfaces that are fouled with particles in the air.** Poor air quality also produces higher uncertainties in measurements. NIST has spent $200,000 to install filters and portable clean rooms to maintain the candela standard and for other optical measurements. Although the filters help, they are not as effective as the planned renovations of the Gaithersburg general purpose labs would be. Insufficient temperature control (a change of a couple degrees Celsius per day) also introduces drift into instruments. "It's inefficient," says Optical Technology Division Chief Al Parr. "We could provide better quality when the planned renovations of the general purpose labs remedy these severe problems."

Optoelectronic Materials

Building 1, Boulder

Manufacturers of components for fiber optic telecommunications systems (including the rapidly expanding Internet) and for optical fiber gyro navigation systems used in aircraft, missiles, and satellites need reliable methods to inspect and select high-quality lithium niobate wafers used for the manufacture of key components. Current yields for these wafers, which are the base material for waveguides that channel laser light, are unacceptably low. NIST researchers in Boulder are developing a technique for characterizing the wafers that may help manufacturers better identify production control problems. The lack of centralized air-handling and power supplies, however, substantially limits the quality of data from their experiments. Mapping a single wafer may take as long as 16 hours and during that time temperatures can fluctuate as much as five to six degrees Celsius during certain seasons. **A recent single power spike cost the group $1,000 in repairs to laser equipment, a month of downtime, and delay of the delivery of key data to a sponsor**. Dust is a constant problem for their sensitive optical equipment, which can cost as much as $1,000 per one-inch-diameter mirror to replace. Without the Boulder central utility plant, the NIST researchers soon may be hamstrung to provide the higher quality data U.S. industry needs for emerging applications for lithium niobate materials in optical data storage, medical devices, and environmental sensors.

Reducing Fire Losses

Fire Research Bldg., Gaithersburg

Each year in the United States unwanted fires cause more than 4,500 deaths and $8.9 billion in property losses. NIST's fire research program works to reduce these losses by developing measurement methods and data that improve understanding of fire processes and causes, while paving the way for improved fire safety systems, environmentally friendly fire suppression systems, fire fighter safety and tactics, fire safe materials, and validation of computer fire models. In the past, NIST has been one of the few places in the country capable of conducting room-size fires in the controlled environment of a research facility for collecting detailed information on fire characteristics such as heat release rates, toxic gas and smoke emissions, and temperatures. For the last three years, however, NIST's researchers have been severely limited in the types of fire tests they can conduct due to an antiquated, inoperable emission control system. The system, purchased in the 1960s, is intended to remove smoke from the building's exhaust. It was used in Washington, D.C., before NIST moved to its current Gaithersburg location. To continue their work, NIST fire researchers have conducted fire experiments at other facilities around the country. This, however, is much more expensive, time consuming, and does not provide the quality measurements that can be obtained working at NIST. Therefore, it is not a cost-effective long-term solution. Funding of NIST's safety, capacity, maintenance, and major repairs (SCMMR) projects is necessary to allow the Institute to replace the outdated emission control system with one that complies with current safety and environmental requirements. This would return the fire research facility to full operation and greatly enhance the productivity of the fire research program.