CLINTON PHILOSOPHY TRANSFORMS NIST INTO 'PARTNER FOR INDUSTRY'

In 1904 the great Baltimore fire drew fire-fighting companies from as far away as New York, Philadelphia and Wilmington. Presumably few realized before they arrived that they would only watch the fire, not fight it. More than 1500 buildings in the city's downtown area were destroyed because the fire-fighters could not connect their equipment to the "foreign" threads on the hydrants of the Baltimore water system.

Three years earlier, having anticipated that problems of this sort would appear with the great scientific and engineering progress begun in the 19th century, and concerned about analogous issues affecting international trade, Congress had established the National Bureau of Standards. Physicists eventually came to think of NBS as a font of world-class basic research in quantum, electron, optical, atomic, molecular and radiation physics. In addition to overseeing fundamental physical standards, NBS was also responsible for helping industry set commercial standards, as the Baltimore fire reminded the then-fledgling agency.

These days, while the budget for physics research is staying slightly ahead of inflation, business concerns dominate the agenda, and the agency, now part of the Department of Commerce, has become a technology-funding minipower.

In 1988 Congress passed the Omnibus Trade and Competitiveness Act, which among its provisions, renamed the NBS the National Institute of Standards and Technology. The legislation also enlarged the agency's mission: "to assist industry in the development of technology and procedures needed to improve quality, to modernize manufacturing processes . . . and to facilitate the more rapid commercialization" of products based on new science. NIST was given an extra $5 million in the FY1989 budget for the trial establishment of regional manufacturing technology centers, which would provide technical assistance for smaller companies. More recently, the large growth in NIST's budget under President Clinton illustrates the Administration's belief in direct government assistance on behalf of US business in the war of global economic competition. In last year's "Guide to NIST" booklet, director Arati Prabhakar wrote of the agency's plans "to transform itself from primarily a measurement laboratory program with three relatively small extramural programs to a full-service technology development, funding, extension and quality improvement partner for US industry."

As a symbol of the importance attributed to strengthening US business, NIST also manages the Malcolm Baldrige National Quality Award, established by Congress in 1987. (The Baldrige Foundation funds the award, and the American Society for Quality Control administers the award for NIST.) The criteria for winning are "leadership, information and analysis, strategic quality planning, human resource development and management, management of process quality, quality and operational results, and customer focus and satisfaction."

Technology to the fore

The expanded tasks of NIST are best shown by the phenomenal growth of the Advanced Technology Program, which was established in 1990 and has since become the primary vehicle for the agency's new mission. The ATP encourages high-risk technologies by funding R&D projects at US companies. Much as an academic physicist would submit a research proposal to the National Science Foundation, companies submit technology-development proposals to NIST. In contrast to the NIST Physics Laboratory, the ATP is an "extramural" program. In fiscal 1990 it was allocated $10 million, but by FY1993, in the last budget of the Bush Administration (see PHYSICS TODAY, June 1993, page 83), the ATP's budget had grown to about $68 million. Under Clinton, NIST's budget is skyrocketing, and the ATP is leading the way.

What started with a small supplement six years ago has become the largest part of NIST's budget. For FY1995 the Clinton Administration requested $451 million for the ATP, or just under half of the amount requested for all of NIST. Congress came through with $431 million out of NIST's total of $855 million (see PHYSICS TODAY, October, page 59). In FY1997, the last budget year of this four-year presidential term, the Administration's target for the ATP is $750 million.

By contrast, NIST's physics program will see only a modest increase. Its budget for FY1995 will rise to the $30 million level, about 7% more than last year (see the box on page 76). Katharine B. Gebbie, the director of NIST's Physics Laboratory, admits that the change in emphasis has challenged the agency's physicists, "but that's the excitement—to demonstrate that supporting the highest-quality physics is entirely consistent with addressing national needs."

Changing cultures?

To understand the new NIST, start with its director. Arati Prabhakar is doing her part to implement the Clinton Administration's industrial philosophy, which was sketched in February 1993 in "Technology for America's Economic Growth—A New Direction to Build Economic Strength," by President Clinton and Vice President Gore (see PHYSICS TODAY, April 1993, page 43). Born in New Delhi, India, Prabhakar received her BS in electrical engineering from Texas Tech University (1979) and her MS in electrical engineering (1980) and PhD in applied physics (1984) from the California Institute of Technology. She told PHYSICS TODAY that she learned something very important about herself in graduate school: "I didn't want to do research myself for the rest of my life, or ever again."

Immediately after receiving her PhD, Prabhakar came to Washington as a Congressional Fellow in the Office of Technology Assessment, where

Physics by Any Other Name . . .

The scientists at NIST's Physics Laboratory perform, in the words of its director, Katharine Gebbie, "directed" research. As has generally been the case at NIST, one finds within the Physics Laboratory both pure and applied physics to support industry on timescales from the immediate to the long range. The lab's new mission statement, developed by Gebbie and her division leaders, lays out the goal explicitly: "to support US industry by providing measurement services and research for electronic, optical and radiation technology."

Gebbie and her colleagues have thus chosen to concentrate on assisting three types of technologies. But the research areas are still wide among the lab's eight divisions, each of which has its own specific mission. The divisions are further divided into research groups. From an afternoon spent touring several NIST labs in Gaithersburg, Maryland—where snatches of overheard conversations gave the distinct impression of enthusiastic scientists at work—here are a few brief examples:

Within the electron and optical physics division, the electron physics group studies exchange coupling in magnetic films. They have found that when a nonmagnetic material is placed between two magnetic materials in a sandwich of order 10^{-9} meters thick, the magnetic coupling between the material reverses direction whenever the spacer thickness changes by only a single layer of atoms. This work supports technological applications involving recording heads and sensors. The group also studies very small magnetic structures using scanning electron microscopy with polarization analysis. This work, of fundamental scientific interest, has practical applications in magnetic storage. The group is also studying laser focusing of neutral atoms for possible nanostructure fabrication. Here the laser electromagnetic fields act for atoms as lenses and mirrors do for photons.

William Phillips of the atomic physics division, who in 1990, with Claude N. Cohen-Tannoudji, explained what were then new mechanisms for laser cooling to readers of PHYSICS TODAY (October 1990, page 33), has carried that work further, cooling atoms below 1 microkelvin. How does this research fit with NIST's mission? With an accuracy of one part in 10^{14}, NIST-7 is now the world's most accurate atomic clock, but application of laser cooling to clock making will substantially improve this accuracy, perhaps by as much as a factor of 100. Further research, such as that on laser-cooled trapped ions at NIST's Boulder, Colorado, laboratories, may lead to clocks with accuracies of a part in 10^{18}.

Through the radiation interactions and dosimetry group of the ionizing radiation division, NIST helps provide radiation standards for those directly involved in medical physics, for those in industry who help develop products using radiation, and for all those who work near sources of radioactivity, such as nuclear submarines and food irradiation facilities; NBS started this work in 1927. NIST works with government regulators, such as the Nuclear Regulatory Commission and the Food and Drug Administration, as well as those who produce radioactive sources, such as radiopharmaceutical companies. Scientists in this group do physics inside an energy range of 20 keV to 30 MeV.

The neutron interactions and dosimetry group has established a neutron interferometry station at the Cold Neutron Research Facility. (See PHYSICS TODAY, September 1991, page 17.) Taking advantage of the quantum mechanical "wave-like" characteristics of neutrons, the apparatus allows the study of phenomena using matter–wave interferometry. In neutron interferometry a neutron beam is spatially split and recombined using perfect crystals of silicon as optical elements. The group claimed to have the best such setup in the world and expects further improvements in the future. According to Gebbie, this program is motivated by a desire to carry out worthwhile fundamental physics while developing new measurement techniques. Ultimately, neutron interferometry may provide a new tool for materials science.

The desire to develop tools for materials research has also motivated a program for the polarization of neutrons using nuclear-spin-polarized ^{3}He spin filters. Recently groups outside NIST have made significant progress in ^{3}He polarization, motivated by target development for medium- and high-energy electron scattering experiments. NIST is engaged in extending this technology for neutron polarization for tests of fundamental symmetries as well as for its applications in polarized neutron scattering.

Agency with a mission

How does NIST differ from a typical university physics laboratory? Gebbie pointed out that NIST is a mission-oriented agency and all its research is directed toward fulfilling that mission. Phillips told PHYSICS TODAY that one of the advantages he sees in doing physics at NIST—a place he called "extremely stimulating and exciting"—is the opportunity to work in a strong research group with a team of focused senior colleagues and young National Research Council postdoctoral fellows. In Phillips's picture of NIST, top-notch senior scientists bring great experience and an institutional memory, and the postdocs bring new ideas and "new energy."

While overall funding for NIST has grown greatly and may be expected to continue to grow during the Clinton Administration, the Physics Laboratory enjoys more modest increases. Gebbie says she has had the freedom to make decisions about redirecting Physics Laboratory programs, a process that began in the Bush Administration when she reprogrammed a project to build a free electron laser and greatly reduced efforts in astrophysics. She explains, "NIST cannot do everything. We have to make decisions about those programs where we can have the greatest impact on our mission."

Gebbie thinks that one of the great strengths of NIST physics is to instill confidence: "I feel very strongly—and I think I am supported by NIST's upper management—that the quality of our services really depends on the strength, breadth and excellence of our scientific research. Our contributions are credible only to the extent that they're based on the best scientific judgment available."

she analyzed microelectronics research and development at the request of the House science, research and technology subcommittee. In 1986 she moved to the Defense Department's Advanced Research Projects Agency as a program manager in the electronic sciences division. She helped create ARPA's microelectronics technology office and served for two years as its director, managing a $300 million budget, before coming to NIST at the end of May 1993.

Illustrating why many are saying that the best vehicle for technology transfer is the moving van, Prabhakar brought the corporate culture of ARPA to NIST. She speaks the business language heard often these days in Washington. "Ultimately, our customer is the taxpayer," she says. NIST must "maximize the value we deliver," help change the "behavior" of companies, but let them "drive the agenda" of the ATP, which she describes as a "partnership" between NIST and the company it's working with.

Prabhakar says the ATP is "designed to do a job that lies between research and product development." In the "proposal preparation kit" for 1994's competition, one sees the new goal of NIST manifest in the ATP. "The ATP mission," it states, "is to stimulate economic growth in the United States through technology development." It defines ATP projects as having "a relatively high technical risk."

This notion of taking more risks, of stretching, pervades more than one Federal agency. At NASA headquarters, one high-ranking official was heard to say that "you'll know that NASA's turned the corner when someone is rewarded for a project that failed." Prabhakar told of a former DARPA director who would "accost program managers and ask if they'd had any funding requests bounced. If they said no, he'd chew them out for not taking enough risks." At NIST, Prabhakar continued, "We're trying to get some of that culture—I think we got it."

Funding through the ATP lies somewhere in a middle ground between grants and contracts. Unlike a contract, no specific product is demanded. Compared with a grant, the ATP provides more technical support and monitors a project's progress more closely. Also, the company or consortium of companies always shares its project costs with NIST.

Consider the case of X-Ray Optical Systems, a physics-related company with eight employees, located in Albany, New York. It first qualified for a Cooperative Research and Development Agreement with NIST to develop x-ray and neutron lenses from arrays of carefully bundled tiny glass capillaries. After failing on its initial attempt to get funding through the ATP, the company's second try netted $1.9 million to develop lenses to form parallel beams of x rays; the company contributes $350 000.

Specific technologies

Prior to this year the ATP had been open to proposals in any area of technology. In April Commerce added to the general competition five "focused program areas": tools for DNA diagnostics ($145 million spread over the five years); information infrastructure for health care ($185 million); manufacturing advanced composite structures ($160 million); component-based software ($150 million); and computer-integrated manufacturing for electronics ($105 million). More program areas are expected to be announced late this year, and NIST projects about 20 such programs by FY1997.

Although NIST asked for help in choosing the program areas through "white papers" from industry, some are not impressed with the government's track record in picking winners and do not agree with this idea of a "focused" ATP. Robert White, who now chairs the department of electrical and computer engineering at Carnegie-Mellon University, was undersecretary of commerce for technology in the Bush Administration, and, as such, one of the fathers of the ATP. He believes that "potentially, ATP is a good program," but he cautions against too much focusing "at the expense of a category that may contain the seeds of a whole new industry."

Prabhakar and others at NIST argue that the focusing has improved the proposals themselves, because the business and technical goals are worked out in advance with industry. But the application numbers may suggest that those actually submitting proposals prefer the general competition. This year 200 proposals were received in all of the five focused areas together, compared with 397 received in the general competition.

NIST's Physics Laboratory

Of the eight divisions in the Physics Laboratory, the first six listed below are located at the main NIST center in Gaithersburg, Maryland; the last two are in Boulder, Colorado.

- Electron and optical physics
- Atomic physics
- Molecular physics
- Radiometric physics
- Quantum metrology
- Ionizing radiation
- Time and frequency
- Quantum

Making the grade

In contrast to typical scientific grant proposals, ATP proposals have two ingredients, technical and economic. The evaluation criteria include scientific and technical strength, as well as "plans for eventual commercialization of the research" and "potential broad-based economic benefits."

NIST can usually find knowledgeable government people to do the scientific and technological "expert" review—the NIST term. But for judging the business plan, private-sector experts are needed. In either case, Prabhakar is adamant that "the criteria are the criteria are the criteria, period. We're constantly working to see if we can improve the process, but that review is non-negotiable. A program like this will crater if it becomes politically driven—by any kind of politics."

After the projects have been chosen and funded, what about understanding the effects? In January NIST published a booklet, "Setting Priorities and Measuring Results at the National Institute of Standards and Technology," which warns that "there is little precedent in the Federal government—and inconsistent results in industry—when it comes to measuring the results of technological investments." In regard to the ATP, the booklet says that "too high a technical success rate would suggest that the project selections are overly conservative."

Prabhakar admits that "there are things that are easy to measure, and there are things that tell you a lot about how well you're doing, and they're almost two distinct sets." She still feels that the "easy" things (typically, things that can be easily counted) are important to measure because they tell you "if the activities are at the right level." However, she says, the real measure of what's coming out of the ATP is whether companies are working in new areas (and new markets) or dramatically shortening their time horizons for research and development: "Basically, it's behavior changes that lead to opportunities that are different. These are the kind of indicators that say to me that we're on track."

Several studies commissioned by NIST confirm that the ATP benefits those it funds, but can one distinguish between effects specific to the ATP and the simple advantage of having more money available? In a February 1993 report by an outside firm, the first recipients described what they felt was the single most important effect of an ATP award. The report summarized three main types of perceived benefits: 1) affordability of research that is deemed high risk, with possible pay-offs a long time in coming; 2) a so-called halo effect, where winning an award increases stature and validates the pursuit of the new technology; and 3) increased industry–industry collaboration (facilitated by NIST). White mentioned that numerous consortia have been created to apply for ATP funds, including one that he is heavily involved with, the National Storage Industry Consortium.

In the complacent 1950s, says Prabhakar, the US was the unchallenged global leader in one industry after another, and inefficiency didn't matter very much back then. These days of global competition are different, and she enjoys the challenge: "It's really good for your soul to have to run hard and fast. We're having a blast." —DENIS F. CIOFFI ■