National Institute of Standards and Technology

NIST

Facilities Improvement Plan

February 1998

U.S. Department of Commerce • Technology Administration

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Executive Summary

The FY 1998 Appropriations Act for the Commerce Department and other agencies (P.L. 105-119) enacted by Congress and signed into law by President Clinton on November 26, 1997, included $95 million for construction, renovation, and maintenance of National Institute of Standards and Technology facilities. The Act specifies that of the $95 million appropriated, "$78,308,000 shall be available for obligation and expenditure only after submission of a plan for the expenditure of these funds." The Act's conference report requires "a spending plan which corresponds to NIST's long-term facilities master plan."

This report is submitted to fulfill that requirement. Presented here are NIST's long-term facilities construction, renovation, and maintenance needs and a plan to meet them. The "Executive Summary" presents the highlights of NIST's plan, with emphasis on the five items mandated by Congress in the NIST FY 1998 appropriation. These five items are: "(1) a detailed analysis of NIST office and laboratory space requirements including an assessment of any unused space in existing facilities (owned or leased), and a detailed description of all assumptions on which the analysis is based; (2) a prioritized list of maintenance projects; (3) a prioritized list of new construction projects; (4) a prioritized list of renovation projects; and (5) an annualized breakdown of costs associated with each proposed construction, renovation, and maintenance project."

The "Introduction" section of this report provides background material on NIST's mission and the inadequacy of its current facilities. The section "Current Plan and Priorities" provides the detailed rationale behind NIST's prioritization of maintenance, construction, and renovation projects. Appendices provide supporting documentation.

NIST maintains about 50 specialized laboratory, office, and support buildings on two campuses in Gaithersburg, Md., and Boulder, Colo. Almost all of these buildings are 30- to 45-years old and are deteriorating at an accelerating rate (as major infrastructure systems reach the end of their useful lives).

The aggregate effect of NIST's current facilities inefficiencies on the U.S. economy is large. More than a dozen economic impact studies of a broad range of NIST programs (e.g. semiconductors, optical fibers, etc.) have found benefit/cost ratios ranging from 3 to 1 to more than 100 to 1. In other words, for every dollar spent on NIST research in the studied areas, benefits of $3 to more than $100 were realized by the U.S. economy. Each year that the conditions and capabilities of NIST facilities continue to deteriorate, the U.S. public receives less return on their annual investment (about $400 million[1] in FY 1998) in NIST laboratory efforts.

The Facilities Improvement Plan presented in this report is designed to guide the replacement, renovation, or repair of the Institute's buildings so that NIST can continue to provide U.S. industry and science with the best possible measurement system. The plan presents an orderly, cost-effective approach that:

- protects the health and safety of NIST employees,
- provides those facilities most urgently needed to meet near- and long-term strategic research goals,
- ensures the greatest possible use of existing facilities at NIST and specialized facilities elsewhere in the United States,
- tailors levels of environmental control for both new construction and renovation to specific program needs, and
- minimizes disruption to ongoing NIST measurement programs critical to U.S. industry and science.

The plan is based on a long history of extensive independent assessments of NIST's technical laboratory needs and on an independent economic analysis of various alternatives for meeting them. (See Appendix A.)

FY 98 Spending Plan

Summarized below are NIST's plans for spending the $95 million of facilities improvement funding included in the FY 1998 Appropriations Act.

Safety, Capacity, Maintenance, and Major Repairs, or SCMMR, is the title NIST has given to a broad set of facility improvement needs related to failing or inadequate infrastructure. (See Appendix B.) Phase 1 of FY 1998 SCMMR spending began with the start of FY 1998 and is ongoing. It addresses 26 high priority SCMMR projects listed in Appendix C. Phase 2 of SCMMR spending begins with the submission of this Facility Improvement Plan to Congress. Phase 2 addresses 26 additional high priority SCMMR projects (also detailed in Appendix C).

[1] Includes direct appropriations, funding from other agencies, and reimbursable fees.

FY 1998 Spending Plan

Activity	Phase	Expenditure
Safety, Capacity, Maintenance, and Major Repairs	1	$16,692,000
Safety, Capacity, Maintenance, and Major Repairs	2	$15,308,000
Update design for Advanced Measurement Laboratory	2	2,000,000
For procurement/construction of AML[2]	3	61,000,000
Total		**$95,000,000**

Phase 2 also provides for a needed updating of the design for the Advanced Measurement Laboratory (AML). The current design was completed in 1996. In Phase 3 NIST proposes to hold the remaining $61,000,000 available in the FY 1998 appropriation for construction of the AML. The total cost in FY 1999 dollars for AML construction is $218 million. In the FY 1999 budget, the Administration is requesting legislative language providing advanced appropriations that would allow NIST to begin procurement/ construction of the AML upon enactment of the FY 1999 budget.

Space Analysis

In 1991 and again in 1997, detailed analyses of NIST's available office and laboratory space were conducted for NIST by SHG Inc. These studies[3,4] found that several NIST buildings and programs were "severely compacted and overcrowded, resulting in safety hazards and unsafe egress." SHG recommended that laboratory space per researcher be increased from about 290 net assignable square feet (nasf) per person to about 400 nasf. SHG based its recommendation on benchmarking with other government and industry R&D laboratories.

As of February 1998, the NIST Gaithersburg and Boulder sites have 591,000 net assignable square feet (nasf) of office space and 770,000 nasf of laboratory space. These totals include about 86,000 square feet of leased office and laboratory space off campus (NIST North). The Institute has a total of about 3,600 staff members requiring office space, of which about 2,630 require laboratory space. These totals include a conservative estimate of the office and laboratory space requirements of the more than 1,000 guest researchers, post-doctoral researchers, industry collaborators, contractors, and others whose full- and part-time work on the NIST campuses is critical to the success of its ongoing research programs. Dividing the total nasf by the number of staff members produces a current (FY 1998) average of about 160 nasf per person of office space and 290 nasf of per person of laboratory space.

NIST's Longer-Term Goals

NIST's goals for its Facilities Improvement Plan are to alleviate current overcrowding in laboratories, while providing the much higher quality laboratory environments needed for NIST research to meet the needs of U.S. industry and science. Implementation of NIST's plan will result in about 183,000 nasf of additional laboratory space and 84,000 nasf less office space, leading to an average of about 140 nasf of office space per person and an average of about 360 nasf of laboratory space per person. These are reasonable goals given that the General Services Administration guideline is 153 nasf of office space per person and that SHG recommended that NIST provide approximately 400 nasf of laboratory space per person.

Maintenance Priorities

Some of NIST's most serious facilities deterioration problems affect the health and safety of the Institute's more than 3,600 employees, guest researchers and other visitors present on the site at any given time. NIST has consistently placed the safety and health of its employees and visitors as its highest facilities improvement priority. In addition, NIST sites suffer from severe systems capacity problems such as inadequate delivery of chilled water to high technology laboratories and antiquated electrical systems. Finally, there are large numbers of maintenance and major repair projects such as replacement of 30- to 45 year-old roofs and replacement of failed emissions control systems.

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[2] To be held pending enactment of FY 1999 budget.
[3] SHG Associates, Johnson, Johnson and Roy Inc., *NIST Capital Improvements Facilities Plan: Programming Phase*, 1992, 220 pp.
[4] SHG, *NIST Capital Improvements Facilities Plan: 1997 Retrace Project*, June 1997.

Planned Safety, Capacity, Maintenance and Major Repairs (SCMMR) Projects
($ in Thousands)

Project Categories	FY 1998 Total	FY 1999+ Four Years
Architectural Repairs/Replacements	1,250	5,180
Central Utility Plant Expansion/Replacements/Upgrades	5,350	1,736
Civil and Site Environmental Repairs/Replacements/Upgrades	800	2,808
Conveying System Repairs/Replacements	0	1,336
Energy Conservation Projects	600	8,012
Exhaust Air Filtration System Repairs/Replacements	6,550	1,336
Handicap and Accessibility Projects	1,350	1,568
Hazardous Materials Projects	1,230	4,826
Mechanical-Electrical System Replacements/Upgrades	6,520	29,300
Site Alarm System and Fire Safety Upgrades	500	3,644
Site Utility System Replacements/Upgrades	7,350	22,656
Structural Repairs/Replacements	500	1,168
Totals	**32,000**	**83,570**

***Note**: Spending in FY's 1999 and beyond is in FY 1999 dollars and is projected using established project priorities for FY 1998. Project priorities are adjusted when necessary to meet changing demands and/or funding levels.*

Over a 25-year period beginning in 1965, appropriations for building maintenance and improvement remained essentially flat in constant dollars. At the same, time, the buildings' advanced age produced a substantial backlog of urgent safety, capacity, maintenance and major repair projects (SCMMR). Since NIST first began receiving congressional appropriations specifically for facilities improvement in 1993 (Construction of Research Facilities (CRF) appropriation) the Institute has received a total of $80 million dollars in funding for SCMMR on both sites. Projects paid for with these appropriations have included: installation of a fire safety sprinkler system in the 11-story Administration Bldg.; construction of a hazardous waste materials handling facility; increased capacity for Gaithersburg's central utility plant and systems (including additional chillers, cooling tower cells, and pumping systems); upgrades to sewer lines, water lines, and electrical distribution systems; replacement of steam manholes; and structural repairs to NIST's 750-seat auditorium.

While progress has been made, only a small fraction of a backlog of needed SCMMR projects totaling about $400 million (as of the end of FY 1997, in FY 1999 dollars) had been addressed by the start of FY 1998. Over the next 5 years, NIST hopes to achieve a significant reduction in the most urgent components of this backlog. Estimated five-year expected costs in FY 1999 dollars for currently known projects are shown in the box above. Prioritization of projects among and within these categories depends on multiple factors such as importance of the project to life safety, probability of imminent failure, compliance with applicable regulations, impact of the project on litigation exposure, and importance for meeting NIST's program needs.

Given NIST's current substantial backlog of projects, prioritization necessarily depends on an up-to-date assessment of current facility conditions and the amount of funding available. Appendix C presents specific project priorities for $16.7 million in SCMMR FY 1998 funding appropriated and released at the start of the fiscal year in October 1997 (Phase 1); for $15.3 million in FY 1998 funding specified by Congress to become available upon submission of a NIST Facilities Improvement Plan (Phase 2); and for $16.7 million in funding requested by the Administration for FY 1999. The President's FY 1999 budget projects continuation of the FY 1999 request for SCMMR projects of $16.7 million into the outyears FY 2000-FY 2003.

NIST's Longer-Term Goals

NIST facilities planners believe that the proportion of SCMMR projects in each category is likely to remain relatively stable over the next 10 years. An annual SCMMR budget of about $16.7 million, as included in the Administration's outyear estimates, approaches the GSA standard level of 1.5 percent of federal capital facilities replacement value. However, because of the advanced age of NIST facilities the Institute will be able to attack only its most urgent SCMMR problems. NIST's long-term goal is to reach a level of SCMMR funding in line with industry standards for high-technology laboratories and Booz·Allen's recommendations[5] of about 4 percent of facilities replacement costs, or about $50 million per year (FY 1999 dollars).

New Construction Priorities

NIST's Facilities Improvement Plan proposes new construction only when existing facilities cannot be cost-effectively renovated to meet the technical needs of critical NIST measurement research programs.

NIST's current plans for new construction include the following in priority order:

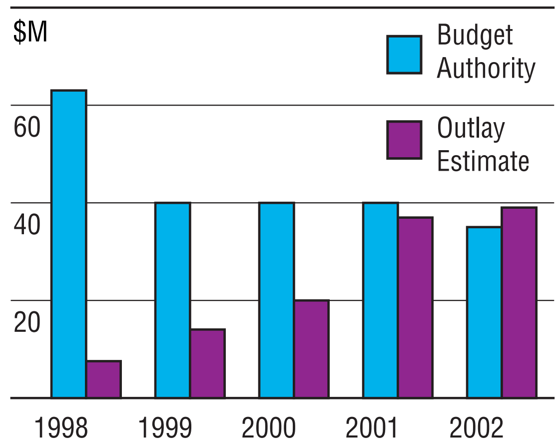
- completion of the Advanced Chemical Sciences Laboratory (ACSL) in Gaithersburg by early 1999 (fully funded with previous appropriations), and
- construction of an Advanced Measurement Laboratory (AML) in Gaithersburg.

Since 1991, all studies assessing NIST's long-term facilities needs have clearly shown that no existing building on the Gaithersburg or Boulder campuses or elsewhere can be retrofitted economically to the high levels of environmental control needed by NIST's most advanced physics, chemistry, electronics, engineering, and materials science research projects. (See examples, Appendix D.) This has been confirmed in a 1997 "retrace" of this original needs assessment.[4]

Other U.S. industrial or other government sites may have substantially better air quality, temperature control, vibration isolation, power stability, or humidity control than currently available controls in NIST facilities. However, few have strict control in all of these areas simultaneously, as NIST plans to achieve through construction of the Advanced Measurement Laboratory. The growth of the U.S. economy is increasingly dependent on advanced technology, and the AML is critical to developing the measurement science required to support these advanced technologies. Both the SHG 1997 "retrace" report[4] and a Booz·Allen economic analysis study[5] recommended that NIST build an Advanced Measurement Laboratory without delay.

[5] Booz·Allen & Hamilton Inc., *Capital Assets Economic Analysis: Business Case for the National Institute of Standards and Technology,* 1997, 62 pp. (Final)

Budget Authority v. Outlays for Advanced Measurement Laboratory



NIST plans to dedicate $63 million of the FY 1998 appropriation to the AML project. To complete the AML, the President's FY 1999 budget requests that $40 million remain in the NIST base for the next three years (FY 1999 to FY 2001) and $35 million in FY 2002. (Detailed information on the AML cost estimate, contract strategy, program management, and cash flow and major milestones during construction can be found in Appendix E.) The President's budget also requests legislative language providing advanced appropriation in the outyears to allow NIST to start construction upon approval of the FY 1999 budget. This is critical to avoid escalation in the project's costs and to expedite construction of this facility.

The chart above shows estimated budget authority and outlay amounts included in the Administration's current outyear planning for the AML. According to this spending plan, construction of the AML will require 44 months at a total cost of $218 million in FY 1999 dollars. Construction of the AML is a complex process requiring state-of-the-art building methods and design features. A comprehensive AML design was completed in 1996. Minor updating of the design is required. NIST estimates that the design update and reactivating the AML project will cost $2 million. This would be funded from the FY 1998 appropriation. Numerous analyses have concluded that the project is best managed and will be most economically constructed in a single phase. Phasing the project would entail substantial redesign of the AML, would raise the cost about $65 million, and would delay completion about 3 years.

Completion of this program of new construction will result in approximately 20 percent of NIST's laboratory space meeting the criteria of modern laboratories or better. If the failure rate of the remaining laboratories can be maintained at the 67 percent level or below, the overall failure rate of NIST's facilities might be expected to decrease from the 67 percent found in the most recent SHG study[4] to approximately 50 percent.

With completion of the ACSL, and a commitment to the AML, NIST will have dedicated more than $310 million to new construction in Gaithersburg since 1993.

NIST's Longer-Term Goals

NIST's longer-term goals for new construction include the following in priority order:

- improved utility services and distribution system in Boulder, and
- improved and expanded clean room facilities in Boulder.

When the NIST Boulder site was built in the 1950s, buildings were supplied with individual utility systems as was common for that time period, rather than the more economical and efficient central utility systems that are standard practice for laboratories today. Systems delivering laboratory services such as chilled water, steam and compressed air also were individual and not centrally provided. The lack of centrally distributed, high-quality air, temperature and humidity control, and power supplies has been a costly burden on research productivity at the Boulder site for more than a decade. Moreover, centralized utilities make it possible to economically serve state-of-the-art clean room facilities needed by four of NIST's Boulder divisions for research on superconductivity, microelectronics, optoelectronics, and advanced materials.

The current clean room facilities in Boulder are inadequate. Researchers working on voltage standards, nanoscale electronics, superconducting electronics, magnetic recording metrology, and other areas currently use extremely overcrowded and outdated clean room space in Building 1. Part of this space was renovated about five years ago, but the critical photolithography area is 10 years old and inadequate for the complexity of circuits NIST fabricates in the facility. Improved and expanded clean room facilities are needed to provide enough space to serve current program needs more safely and productively while providing the substantially better environment needed to produce standards with the ultra small semiconductor circuit feature sizes industry needs.

Major Renovation Priorities

No major renovation projects are included in the President's FY 1999 budget or outyear projections, and so all such projects fall into the category of NIST's longer-term goals.

Many more NIST projects need tight environmental controls than can be accommodated in the Advanced Measurement Laboratory or Boulder clean room facilities. These projects require renovated General Purpose Laboratories (GPLs). All of the NIST General Purpose Laboratories are at least 30 years old and suffer from severe deterioration and obsolescence of major building systems. No major laboratory renovation projects have ever been undertaken at either site.

Major renovations in Gaithersburg depend upon the successful construction of the AML and continued leasing of off-site space (NIST North). Major renovations in Boulder depend upon addressing the utility and clean room deficiencies. Due to current overcrowding of laboratory space as described above, NIST needs the additional laboratories provided by these new construction projects in order to have sufficient laboratory "swing space" so that whole buildings, or independent wings of buildings (as in the case of Boulder's Bldg. 1), can be renovated at one time. Renovating whole buildings or wings is substantially more cost-effective than partial renovations, causes the least disruption to important measurement research and services, and best protects the health and safety of NIST researchers from asbestos removal and other hazards.

The renovation process would be a lengthy and sequential process. As the ultimate U.S. authority for the traceability of measurements for length, time, electric current, temperature and a host of other basic units, NIST cannot simply close down precision calibrations and other standards research and services for two to three years at a time (the time required for major GPL renovations) without serious repercussions for the U.S. economy.

Annualized Breakdown of Costs

Developing accurate annualized breakdowns of costs for NIST's Facilities Improvement Plan is complex. With release of the first two phases of the FY 1998 appropriation, NIST will be able to continue a concentrated attack on the growing backlog of safety, capacity, maintenance and major repairs projects and update the design of the AML. With approval of the FY 1999 budget and advanced appropriations, it will be possible to begin AML construction in FY 1999 and to have an estimated completion date of late FY 2002. (See Appendix F for a schedule of spending on SCMMR projects and the AML consistent with the President's FY 1999 budget.)

NIST's Longer-Term Goals

NIST's longer-term facilities planning necessarily extends beyond the five-year time frame of the President's budget and outyear estimates. NIST's ultimate goal is to increase spending on SCMMR projects until a steady level of about $50 million (FY 1999 dollars) is reached. In its economic analysis study, Booz·Allen recommended that NIST allocate $18.7 million yearly (FY 1999 dollars) for the next 15 years to "buy down" the current backlog of SCMMR projects, in addition to spending $48 million yearly (FY 1999 dollars) on SCMMR projects to prevent the backlog from growing. Booz·Allen based its recommendation on "generally acceptable methods used to estimate appropriate levels for this expenditure" for research facilities.

In addition, NIST hopes to undertake a program of major renovations of its General Purpose Laboratories (GPLs) following completion of the AML. Completion of the AML and relocation of personnel into the new building will create vacant space in Gaithersburg. This space will form the mainstay of "swing space" that would allow the start of major renovations on the Gaithersburg campus, beginning with the Metrology Bldg. and followed by the Physics Bldg. Additional major renovations to the remaining Gaithersburg GPLs (Chemistry, Materials, Polymers, Technology, and Building Research) would follow.

Improvement of utility services and distribution systems in Boulder would be followed by improved and expanded clean room facilities. Next would come limited renovation of Bldg. 4, renovation of Bldg. 1's wings 3 & 4, wing 6, wing 5, spine, wings 1 & 2, as well as renovation of Bldg. 2 and Bldg. 24.

For a detailed breakdown of the estimated costs required to accomplish these projects in priority order see Appendix G.

Maps of both sites are provided in Appendix H that identify those buildings that would be affected in NIST's long-term Facilities Improvement Plan.

The goal of this extended program of new construction and renovation would be to bring at least two-thirds of NIST's laboratory space up to the level of modern laboratories. If the failure rate of the remaining laboratories can be maintained at the 67 percent level or below, the overall failure rate of NIST's facilities might be expected to decrease to somewhere in the vicinity of 20 percent.

The Administration recognizes the importance of the facilities improvement needs addressed in this report, and this need is clearly articulated in the Commerce Department's Strategic Plan. However, the long-range time table provided in this report should be regarded as a planning guide rather than a firm request for a specific funding level in any given year. As always, annual Administration funding requests will depend upon a continuing reassessment of priorities that balances NIST construction, renovation, and maintenance needs against other funding requirements for NIST, the Department of Commerce, and other executive branch agencies.

Introduction

The majority of the current 30- to 45-year-old laboratory facilities of the National Institute of Standards and Technology (NIST) are failing to adequately support the Institute's mission of providing U.S. industry and science with the best possible measurement system. Within the next five years—as technical program needs continue to escalate and building systems continue to deteriorate—more than 80 percent of NIST's laboratory facilities will fail to adequately support the needs of U.S. industry and science.

The fair exchange of more than $3 trillion annually in U.S. products depends on NIST's maintenance of accurate weights and measures. Trillions of dollars in additional sales are supported by the availability of reference materials, measurement techniques, equipment calibrations, and standards provided by NIST researchers. In addition, U.S. scientists rely daily on NIST's research and measurement data to conduct experiments at the frontiers of science.

For at least the last 10 years, NIST buildings have been failing to provide the required environment for precision measurement research. NIST researchers are attempting to conduct atomic-level measurements in laboratories where particles of black grit are emitted from air vents. In overcrowded laboratories subjected to wide swings in temperature and unacceptable levels of vibration, NIST scientists are working to provide accurate calibrations of critically important pressure gauges used in making aircraft altimeters. They are making measurements of trace chemical composition to help understand diseases like Alzheimer's in laboratories where frequent power failures and poor voltage stability degrade the quality of data from sensitive instruments.

HISTORY OF NIST's FACILITIES PROGRAM

Since 1991 NIST has continually reassessed its program and building needs. In 1992, NIST proposed a 10-year plan to upgrade its facilities to the high-performance condition necessary to efficiently provide U.S. industry and science with world-class measurements. The plan requested $540 million in funding for a combination of new construction and major renovation of selected buildings to provide the high-quality building environmental control systems required for modern research. NIST's proposal was endorsed by both the Bush and Clinton Administrations and received bipartisan congressional support.

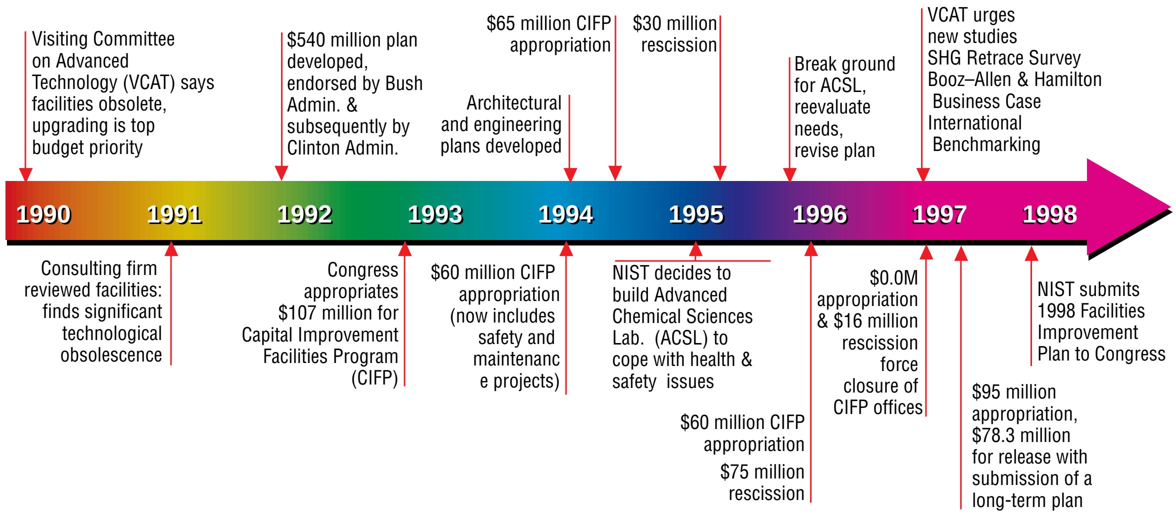
At the same time, NIST developed a separate plan to begin addressing specific critical safety, maintenance, and systems capacity needs, such as repairing cracking building structural support beams and columns or upgrading inadequate fire safety systems. A substantial backlog (now estimated at about $400 million) of these critical projects had developed due to a continuing lack of adequate funding and the advancing age of NIST's buildings.

The Institute has received $386 million in direct CRF facilities improvement appropriations from Congress since 1993, but has lost $121 million through rescissions. Of the remaining $265 million, $80 million has been assigned to urgent safety and maintenance projects, and $185 million has been dedicated to new construction. Original plans called for completion of new, high-quality measurement laboratory space at both the Gaithersburg, Md., and Boulder, Colo., campuses by the end of FY 1997. Lower-than-anticipated funding and the accelerated failure of ventilation and disposal systems in the NIST Chemistry Building in Gaithersburg have forced the Institute to change substantially its facilities improvement plans.

NIST has made important progress. In Gaithersburg, a new Advanced Chemical Sciences Laboratory (ACSL) building is nearing completion with expected occupancy starting in early 1999. The project is on time and within budget. An Advanced Measurement Laboratory (AML) has been designed at a cost of $17 million to provide flexible, world-class research space for NIST programs requiring the most stringent environmental controls. Detailed research projects have been completed to confirm that planned vibration, temperature, and humidity control systems included in the AML will perform in accordance with design criteria. In addition, a number of important safety and maintenance projects have been completed or are under way. (See timeline graphic.) Still, NIST's planned AML project is years behind the schedule set by the Bush and Clinton Administrations in 1992.

Encouraged and supported by its Visiting Committee on Advanced Technology, NIST has reorganized the management of its facilities planning activities and in FY 1997 launched a renewed effort to revise and update its Facilities Master Plan. It established a clear set of objectives for this activity and used information provided by several new studies to re-evaluate and reprioritize its facilities needs. These studies include: several by the department's Office of the Inspector

NIST Facilities Program



General;[6] a thorough technical needs assessment by SHG[4] to validate and update the extensive study conducted in 1991;[3] an economic analysis by Booz·Allen of several alternative ways to address the identified needs;[5] and a comparison of NIST functions, facilities, and resources with counterpart organizations in Germany, Japan, and Brazil. Appendix A provides a complete list of all significant planning documents and engineering design reports prepared by and for NIST from 1992 to the present.

This plan and supporting information has been prepared by a multi-disciplinary team. An essential element of this process was the development of several long-range capital facilities analysis scenarios for the purpose of assisting NIST in making choices among alternatives in the design of its plan, and the evaluation of these scenarios and alternatives in terms of both relative construction costs and 30-year life cycle costs. This information was synthesized by the NIST facilities planning group, reviewed by the NIST Laboratory Council and NIST upper management, and incorporated into this new Facilities Improvement Plan.

The new Capital Programming Guide developed by the Office of Management and Budget[7] also has provided extremely useful guidance to NIST in developing its new plan.

[6] These are IPE-7828 (March 1996), IPE-8377-1 (August 1996), IPE-8377-2 (July 1996), and IPE-8377-3 (January 1997).
[7] Version 1.0, July 1997.
[8] Department of Commerce Strategic Plan for 1997—2002 (September 1997).

The NIST facilities plan is also firmly linked to the Department of Commerce Strategic Plan.[8] "Strategic Theme 1—Economic Infrastructure" states that the department will "build for the future and promote U.S. competitiveness in the global marketplace, by strengthening and safeguarding the nation's economic infrastructure." One of the strategic objectives of this theme is for NIST to "provide technical leadership for the Nation's measurement and standards infrastructure, and assure the availability of needed measurement capabilities" by creating and maintaining "world-class measurement facilities to support U.S. industry." The external factors and current trends and issues section for this theme states *"NIST facilities lack the high-quality environmental system controls needed to make precision measurements under predictable, stable conditions. The deterioration and obsolescence of the NIST laboratories is a critical issue that must be addressed."*

DoC "Strategic Theme 2—Science/Technology/Information" states that the department will "strive to keep America competitive with cutting edge science and technology and an unrivaled information base." A strategic objective for NIST under this theme is to "partner with industry to accelerate the development and application of cutting-edge technologies." The external factors and current trends and issues section for this theme states, *"The combination of advancing age and increasingly sophisticated technological needs are rapidly making NIST's current facilities inadequate for supporting its mission of providing*

U.S. industry with essential infrastructural technology, measurements, and standards. NIST also cannot adequately support the major technologies that were undreamed of when NIST facilities were built—lasers, microprocessors, biotechnology, and nanomaterials—that have become commonplace in U.S. industry."

In accordance with OMB Circular A-11, the explicit discussion of the need has been described in an updated needs assessment and will be addressed in the Commerce Annual Performance Plan. NIST now has in place a capital asset plan that addresses this management challenge and prioritizes the projects in the plan to improve NIST's capital asset portfolio.

This plan is an outgrowth of active engagement by NIST management with continuous departmental oversight, and is the culmination of a long and thorough effort to ensure that NIST catches up and keeps pace with evolving trends in science and technology, and with the requirements of the nation's measurement and standards infrastructure.

The highly technical nature of the NIST facilities, combined with changing program priorities, the continuing aging of the facilities, and other factors mandate that this plan be regarded as a changeable document that will require updating on a periodic basis.

NIST'S MISSION

It is not surprising that the Constitution of the United States assigns to the federal government responsibility to "coin money" and in the very next phrase to "fix the standard of weights and measures." Even in an age of horse-drawn carriages, the founding fathers understood that standards of measurement are crucial to fair commerce. Trade of any kind, domestic or foreign, requires an agreed-upon value for currency and agreed-upon methods for measuring a host of things that determine the quantity and the quality of the product being sold.

More than 200 years later, these agreed-upon measurement methods and standards have become critically important. Without them, a host of everyday products could not be made at all. Pocket cellular phones, hand-held video games, compact disks, supermarket price scanners—all are now a common part of modern life. All of these require precise physical, chemical, or electromagnetic measurements for their design and manufacture.

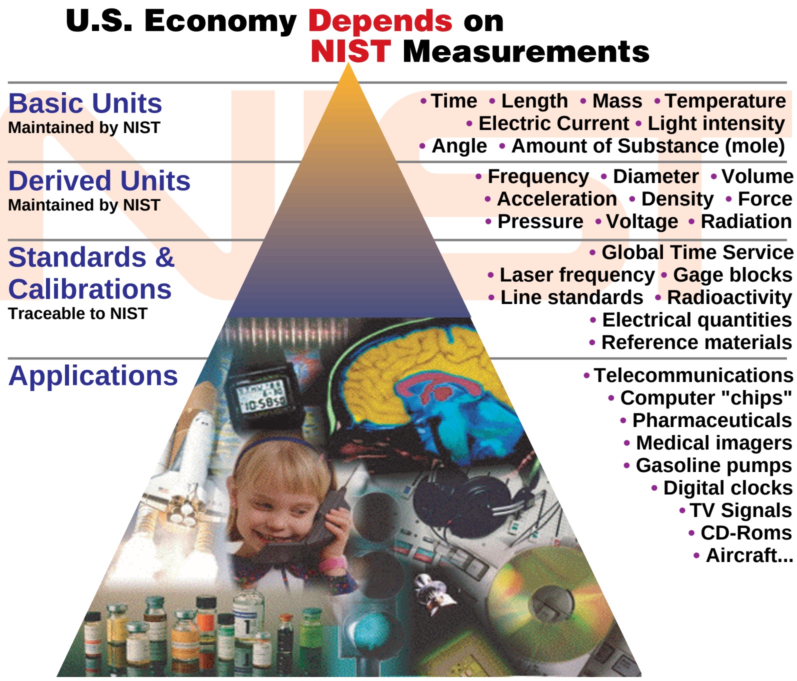
NIST's mission is to promote U.S. economic growth by working with industry to develop and apply technology, measurements, and standards. It is the only federal agency directed to "fix the standard of weights and measures" for the nation. To carry out this and its broader mission in support of U.S. competitiveness, NIST has four major programs: the multi-disciplinary Measurement and Standards Laboratories, the Advanced Technology Program, the Manufacturing Extension Partnership, and the Baldrige National Quality Program. This document describes the need for new and renovated laboratory facilities and, therefore, focuses on the measurement and standards program only.

MEASUREMENT AND STANDARDS

NIST's measurement and standards program was established in 1901 with the creation by Congress of the National Bureau of Standards. Congress expanded the Bureau's mission and changed its name to NIST in 1988. Throughout NIST's history, it has maintained close cooperative research efforts with U.S. industry, universities, and other government agencies and has planned its future work based on projected industry needs.

There has never been a time in which measuring accurately has been more important to the health of the U.S. economy. We are living in an age in which semiconductor devices shrink to half their previous size every three years and measurement advances depend on microscopes that "see" individual atoms. NIST conducts research on fundamental measurement techniques and technologies that individual companies typically have neither the technical ability nor the resources to conduct on their own. While each company needs these new measurement technologies and standards, once developed, the benefits extend to all. A company paying for such research could not expect to recoup its costs—and it would be paying for research that would benefit not only itself and its customers but also its competitors.

The aggregate effect of NIST facilities inefficiencies on the U.S. economy is large. More than a dozen economic impact studies of NIST programs have been conducted in recent years. These studies covered a broad range of NIST programs, including work on optical fibers and electromagnetic interference, on real-time control system architecture and integrated services digital network (ISDN) technology, on power and energy calibration services, on software conformance services and software error compensation, on optical instrument and radiopharmaceutical calibration, and on several projects related to the semiconductor industry. The benefit/cost ratios determined for the programs studied ranged from 3 to 1 to more than



100 to 1. In other words, for every dollar spent on NIST research in the studied areas, benefits of $3 to more than $100 were realized by the U.S. economy. (See graphic U.S. Economy Depends on NIST Measurements.)

Another way to evaluate the economic benefit of NIST programs is to consider the social rate of return, defined as the effective annual impact of these programs on the initial industries to benefit from the technical infrastructure transferred. The median social rate of return for the programs studied is 144 percent. This can be compared to a National Bureau of Economic Research estimate of roughly an average 50 percent return for new technology investment projects launched in the private sector and to a Harvard/MIT estimate of a "hurdle rate" of about 12 percent for investments in the economy as a whole.

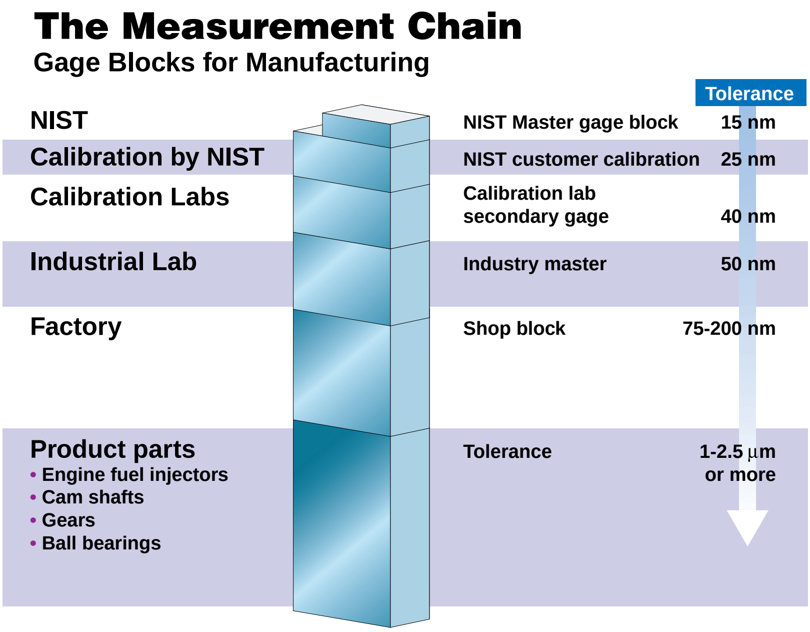
Direct appropriations for NIST laboratories represent less than one-half of 1 percent of the federal government's investment in research and development, and yet they have played a critical supporting role in the unprecedented success of U.S. industry and science over the last 50 years. With this modest investment, NIST laboratories have provided the measurement knowledge needed to stay ahead of industry's needs and to keep the economy growing.

In addition, NIST provides the essential elements of neutrality and credibility to the nation's measurement system. NIST maintains basic and derived units of measurement such as length, mass, time, and voltage and transfers accurate realization of these quantities through thousands of reference materials, calibrations, and standard test methods. As a non-regulatory federal agency with a 96-year track record for technical competence and impartiality, NIST also develops measurement methods and testing procedures accepted by both vendors and users, regulators and industry, prosecutors and defense attorneys alike.

In a 1995 letter to Congress written on behalf of 25 American Nobel laureates in physics and presidents of 18 scientific societies, Norman Ramsey of Harvard University said **"NIST's laboratories carry out the basic research that is essential for advanced technology**. They provide the know-how to maintain and improve our measurement and calibration capability in areas such as time, power and materials, and health and medicine. **It is unthinkable that a modern nation could expect to remain competitive without these services."**

STRATEGIC OUTLOOK

The primary mission of NIST's Measurement and Standards Laboratories is to provide technical leadership for the nation's measurement and standards infrastructure by creating and maintaining the best possible measurement system for U.S. industry and science. In practice this means that NIST researchers strive to "see" things so small that they



have never been “seen” before and to measure things that have never been measured—to explore at the outer limits of scientific and technical capabilities.

In many cases, NIST researchers serve as a technical scouting party for the rest of the research and development community. Before a product can be made to a higher quality, with better performance, there must be reliable ways to measure the quantities that determine that higher quality.

NIST researchers’ goal is to establish this “measurement infrastructure”—ways to measure reliably everything from length, to time, to mass, to electric current—before industry or science hits a roadblock in its pursuit of a better product or new understanding of the way the world works. In this way, NIST research helps foster technological innovation, the driving force for about 50 percent of U.S. economic growth.

NIST must be the best at measuring a whole range of quantities because the accuracy of any measurement decreases each time it is transferred. Just as a photograph gets fuzzier every time you make a copy of a copy, measurements lose accuracy and precision as they are first transferred from NIST to secondary, private calibration laboratories, then to individual company and university laboratories, and finally to the factory floor. A ruler, whether it measures millimeters or nanometers (billionths of a meter), can be only as accurate as the template used to make it. NIST's job is to provide U.S. manufacturers and scientists with “gold standard” templates that, in turn, help produce the highest quality products and research. (See Measurement Chain graphic.)

In short, the NIST Measurement and Standards Laboratories’ vision of its role—as established by its interdisciplinary Laboratory Council—is to be “the world’s leader in measurement, standards and data, recognized for its impact on the U.S. economy.”

As science and technology become increasingly sophisticated, NIST’s job has become correspondingly more difficult. When the NIST laboratory facilities were built in Boulder, Colo., in the 1950s and in Gaithersburg, Md., in the 1960s, measurement accuracies were typically in the part-per-thousand level or at most in the part-per-million level in research laboratories. Today, even products costing just a few dollars, like photographic film, are measured with accuracies of tens of micrometers (millionths of a meter). NIST researchers, in turn, are accurately measuring length with uncertainties of just a few nanometers. This kind of precision is equivalent to measuring the distance from Washington, D.C., to Los Angeles to within a few widths of a pencil.

At the same time, NIST chemists are working on determining the chemical composition of materials at the zeptogram level (10^{-21} of a gram). A zeptogram is to a gram what the mass of a man is to that of the entire moon. In other words, measuring chemical composition at the zeptogram level is like being able to find a man-sized object within something as large as the moon and determining the precise amounts of carbon, oxygen, nitrogen, etc., in the man’s body. Other NIST researchers work at the level of femtoseconds (10^{-15} or quadrillionths of a second) or in microKelvin (millionths of a single degree of temperature). The outlook for the future is for more diverse and ever smaller frontiers.

To ensure that NIST’s laboratory research is targeted at the areas likely to produce the greatest economic benefits, Institute experts work closely with U.S. industry in technology planning efforts. Examples include:

- The National Technology Roadmap for Semiconductors[9];
- Technology Vision 2020: The U.S. Chemical Industry[10];
- The Next Generation Manufacturing Initiative[11];
- CORM Sixth Report: Pressing Problems and Projected National Needs in Optical Radiation Measurements [12]; and the
- Action Plans for Achieving High Priority Construction in the Residential Sector.[13]

In addition, working with industry representatives and university experts, NIST also recently assessed priority measurement needs in 10 rapidly emerging high-technology areas—from nanotechnology to biotechnology to digital libraries. A sampling of NIST laboratory frontier measurement goals in support of U.S. industry and science includes:

- Standard Reference Materials certified by NIST that would allow the semiconductor industry to map contaminants of silicon wafers at the nanometer level;
- a subatomic ruler that can measure accurately distances smaller than a single atom over distances as large as 10 centimeters;
- "intrinsic" definition of the kilogram based on extremely accurate measurements of electric current that could dramatically improve mass measurements in the nuclear processing, pharmaceutical, and advanced materials industries;
- an atomic clock 100 times better than NIST-7, the current official U.S. timekeeper, (already accurate to 0.2 millionths of a second per year) to support continued advancements in accurate control and guidance of spacecraft and precision navigation with Global Positioning Satellites; and
- precision measurements of surface shape accurate to sub-nanometer levels in support of next-generation semiconductors made with extreme ultraviolet rather than visible light lithography.

All of these goals either cannot be achieved or will be achieved substantially more slowly without improved NIST facilities, resulting in high costs to industry and science from delayed availability of NIST results.

NIST takes special pains to ensure that its activities and facilities are highly leveraged. In addition to careful planning with industry and universities (as well as sister laboratories in other countries and professional societies), NIST makes substantial use of Cooperative Research and Development Agreements with industry and guest researchers who rely on the Institute's laboratory facilities.

In a similar way, NIST researchers have made regular use of special facilities at other institutions in the United States and around the world whenever feasible to conduct experiments not possible in its own laboratories. For example, when NIST lacked both the facilities and the right equipment to perform highly accurate 1 meter and longer step gage calibrations for industry, it established a cooperative effort with the Department of Energy's Y-12 Plant in Oak Ridge, Tenn. These calibrations are now conducted at the Y-12 plant under the supervision of NIST researchers. This plan requests funding for those facilities NIST needs to fulfill its mission that are not available elsewhere.

NIST's ability to accomplish its ambitious research goals bears directly on growth in U.S. jobs in the years to come. Research by the Economics and Statistics Administration shows that employment grows about 13 percent faster in plants that use advanced technology compared to those that do not. These plants are much more likely to implement advanced technology if NIST has provided the measurement infrastructure to make its use more reliable through traceability to national units of measurement. If the United States does not continue to pave the way for technologies of the future, other countries will pick up the slack and U.S. industry and science will suffer competitively.

Other nations looking to the United States to understand what drives economic growth have concluded that infrastructural industrial and science support through national measurement laboratories matters a great deal. High-technology industries in Germany, Japan, France, and other industrialized nations already are receiving the competitive benefits of modern facilities from their counterpart NIST organizations. Even more telling, the rapidly developing economies in Latin America are eagerly developing their NIST-like research competence and facilities. Mexico, Colombia, and Brazil recently have completed construction of new laboratories with better environmental controls than those available at NIST. Ecuador has new measurement science buildings under construction, and Venezuela is in the planning stages to do the same.

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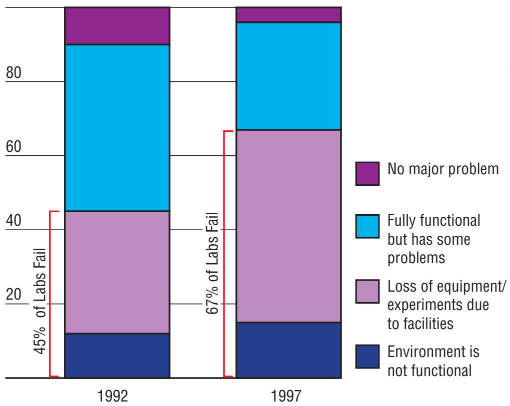
[9] Semiconductor Industry Association, 1994, 206 pp.
[10] American Chemical Society, American Institute of Chemical Engineers, Chemical Manufacturers Association, Council for Chemical Research, Synthethic Organic Chemical Manufacturers Association, 1996, 91 pp.
[11] Agility Forum, Leaders for Manufacturing, Technologies Enabling Agile Manufacturing, 1997, 76 pp.
[12] Council for Optical Radiation Measurements, 1995, 33 pp.
[13] National Association of Home Builders Research Center, 1997, 68 pp.



Facility Adequacy Scores:

Based on detailed surveys of technical obsolescence in 1992 and 1997, SHG Inc. found that "continued neglect of NIST facilities has dramatically affected the ability of laboratory and technical space users to conduct measurement research." Sixty-seven percent of NIST facilities now fail to meet performance needs compared with 45 percent in 1992.

INADEQUATE FACILITIES

If the nation needs a NIST that continually pushes back measurement frontiers, then what does NIST need to do its job? It needs a high-caliber scientific and technical staff and state-of-the-art instruments and facilities. NIST has high-quality human resources. Many NIST researchers are among a handful in the world conducting frontier measurement science studies. Most recently, a NIST researcher was awarded the 1997 Nobel Prize in Physics for his groundbreaking work in trapping and cooling atoms. In most cases, NIST has the instruments it needs. Institute scientists and engineers, in fact, frequently must build their own instruments to extend measurement capabilities not previously available.

NIST does not have the facilities it needs. NIST laboratory facilities in both Gaithersburg, Md., and Boulder, Colo., are largely inadequate to the task of modern measurement research. (See Appendix D.) NIST's Gaithersburg site was built about 30 years ago and includes 34 buildings located on 234 hectares (578 acres). Its Boulder field site was built about 45 years ago and consists of 16 buildings on 84 hectares (208 acres). There have been few new additions or renovations to either site.

Two previous NIST reports (*Report on the Facilities of the National Institute of Standards and Technology, March* 1992, revised April 1993) have documented the severe technical obsolescence and deteriorating conditions of NIST's facilities. A comprehensive review of NIST facilities in 1992 by SHG Inc.[3] found that "42 percent of NIST's Gaithersburg laboratories and 59 percent of laboratories at Boulder fail to meet system performance levels required by current scientific and engineering programs." A detailed assessment by Henningson, Durham, and Richardson Inc. (HDR) in 1996[14] confirmed these findings.

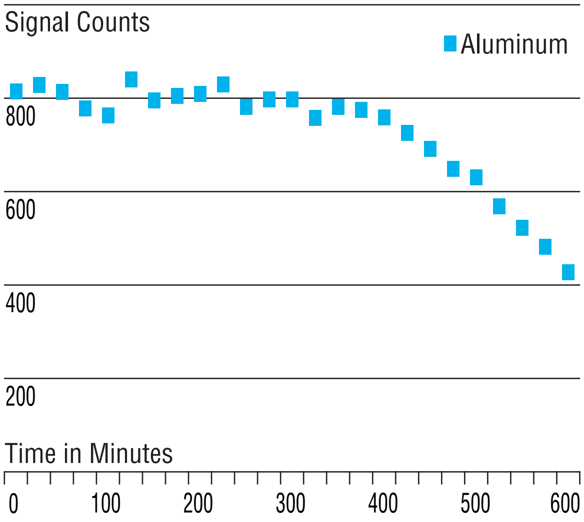
A further "retrace" study by SHG in 1997[4] found that the performance gap between the capabilities of NIST research facilities and the technical needs of its programs has grown to the point that 67 percent of NIST laboratory space now fails to meet program needs. (See chart, Facility Adequacy Scores.) This study also concluded that several NIST buildings and programs "were severely compacted and overcrowded resulting in safety hazards and unsafe egress."

Based on benchmarking with industrial and government R&D laboratories, the new SHG study recommended that the average amount of laboratory space per NIST researcher be increased from about 27 net assignable square meters (290 net assignable square feet) to 37 nasm (400 nasf). This translates to about 15,000 nasm (161,000 nasf) of additional space needed to accommodate all NIST programs on the Gaithersburg campus and about 4,300 nasm (46,000 nasf) of additional space needed on the Boulder campus.

The independent analysis of facilities investment alternatives completed in June 1997 by Booz·Allen found that, "Without intervention, the performance deterioration caused by the facilities inadequacies will impede, if not invalidate, NIST's ability to maintain standards in weights and measures, and to facilitate the development and application of new technology and the advancement of basic science."

NIST's external oversight committee (Visiting Committee on Advanced Technology) has urged repeatedly that funding for facilities upgrades be given top priority because improved laboratory space is "crucial to NIST's ability to meet the nation's scientific and technical needs in the next decade and beyond." Groups representing industry and education, such as the American Society of Mechanical Engineers, the Semiconductor Industry Association, and the American Association of Engineering Societies, have urged Congress to fund NIST's facilities upgrades because they view these improvements as crucial to

[14] HDR, Earl Walls Assoc., CRSS Constructors, *Long-Range Facilities Plan, 1996 Update, Vol. 1*, 1996, 434 pp.



Effect of Temperature Change on Experiments:

Changes in temperature can dramatically affect chemical composition data collected by X-ray spectrometry and other methods. The chart above shows variation in an X-ray signal for aluminum in post-mortem brain tissue from an Alzheimers's patient. Though the concentration of aluminum in the sample stayed the same, a temperature change of several degrees C over the duration of the 10-hour experiment caused the number of counts (which at constant temperature are proportional to concentration) to drop almost in half. NIST researchers must routinely collect data over long time frames in order to measure low concentrations of elements in delicate samples.

NIST's ability to support U.S. industry with high-technology measurements.

After 30 to 45 years of deterioration, NIST's current buildings do not meet the standards set for them when they were new, let alone modern standards required for a precision national measurement laboratory.

Examples of current facilities failures include:

■ Black soot particles emitted by the ventilation systems of all NIST's Gaithersburg General Purpose Laboratories due to deteriorating insulation materials in air ducts that regularly ruin sensitive optical components and semiconductor samples, while substantially increasing the cost of NIST research in key areas.

■ Inadequate vibrational control that smears circuit features during semiconductor fabrication, lowers the resolution of atomic microscopes, and slows research progress or prohibits needed projects from even being attempted.

■ Regular, momentary power outages in Gaithersburg (20 to 30 times per year) and spikes and dips in voltage that can damage sensitive lasers, high-pressure vacuum systems, and other lab equipment and seriously degrade the quality of computer-collected data.

■ Regular, at times lengthy, outages at Boulder caused by high winds affecting the site's overhead transmission lines.

■ Swings in temperature averaging ± 2 degrees Celsius for most Gaithersburg labs and reaching as high as ± 6 degrees Celsius in some Boulder labs that substantially lower research productivity, degrade the quality of data, and increase the cost of NIST research. (See temperature chart.)

■ Inadequate humidity control in Gaithersburg General Purpose Laboratories (± 20 percent) and no humidity control in the majority of Boulder laboratories, which regularly causes sensitive measurement research to be shut down during certain seasons and shortens the life span of expensive laser and microscopy equipment.

■ Limited accessibility for the disabled and limited fire safety egress due to overcrowded laboratories that do not meet codes required for new construction.

Unless NIST can move forward with the needed construction and renovation soon, these problems will escalate in the next three to five years. Meanwhile, progress will be slowed substantially or stalled completely in precision dimensional standards, atomic resolution microscopy, wave-guide materials measurement, calibration of extremely high electrical resistance levels, nanometer-level chemical mapping, and a host of other projects due to a lack of adequate laboratory environmental controls.

For more than a decade, NIST facilities have been handicapping NIST researchers' efforts to efficiently provide the best possible measurement services to U.S. industry and science. A representative list of the many other ways in which NIST's inadequate facilities adversely affect U.S. industry and science *today* includes (see Appendix D for examples):

■ inability to provide the semiconductor industry with standards for ultratrace wafer contamination and thin-film thickness;

■ backlogs of up to one year for important reference materials needed by the healthcare, food processing, and energy and power industries;

- delays in the delivery of pressure and temperature calibrations to the pharmaceutical, jet engine, semiconductor, utility, and other industries;
- setbacks in providing “nanoscale” standards for the $60 billion data storage industry; and
- delays in delivery of antenna calibrations for satellite communications and radar operations.

The inadequacy of NIST’s facilities now has reached the point where many Institute researchers routinely spend as much or sometimes more time devising ways to “beat the building”—to isolate their experiments from uncontrolled environmental influences—as they spend on solving specific measurement problems. In many precision measurement areas, NIST has purchased expensive air-handling systems, enclosures for temperature control, and instrument shielding to try to limit these environmental problems. It has employed every stopgap measure at its disposal, including constructing “rooms within rooms” and building measurement instruments like Russian nesting dolls with multiple shells for temperature, vibration, and air-quality control. Often these environment control systems take up valuable laboratory space, exacerbating overcrowding on both campuses.

NIST researchers without the physical laboratory space available for such specialized equipment have resorted to extraordinary measures, e.g. covering their laser tables with plastic sheeting or “Plexiglas,” conducting more than 50 percent of their measurements after hours to minimize vibration from others working in the building and to improve temperature stability, and fashioning homemade filters for their laboratory air vents. None of these measures—even the most expensive options available to individual laboratory spaces—can provide the quality of air, temperature stability, vibration control, power, and humidity control required and that will be available with new construction or the kind of major renovation NIST plans for its General Purpose Laboratories.

These are patchwork solutions for a much larger problem. Without additional new construction and major renovation of its facilities in both Gaithersburg and Boulder, NIST gradually will cease to be able to meet the needs of the nation’s highest technology industries and scientific research. **The cost will be slower innovation rates; higher costs for defense, semiconductor, and other high-end products; and lowered global competitiveness for U.S. industry.** Ultimately, the standard of living for average Americans depends upon our industry’s capabilities, and our national measurement system makes an important difference in improving these capabilities.

NIST has done everything possible to reduce costs. The construction of the ACSL is being accomplished through an innovative simultaneous design/build contract. The planned Advanced Measurement Laboratory (AML) has only half the space recommended in 1991 by an independent assessment of program needs by building consultants, SHG Inc.

Continued neglect of NIST’s facilities needs will not save money. Each year construction and major renovation are delayed, the current buildings become less functional. Immediate safety and systems capacity needs that must be addressed to protect NIST employees and allow continued building operation consume a larger proportion of funding. **Each year conditions continue to deteriorate, the U.S. public receives less return for their annual investment (about $400 million[15] in FY 1998) in NIST laboratory efforts.** NIST researchers are forced to devote more and more of their time and resources to controlling experimental environments rather than conducting actual measurement research and passing their results on to industry and science.

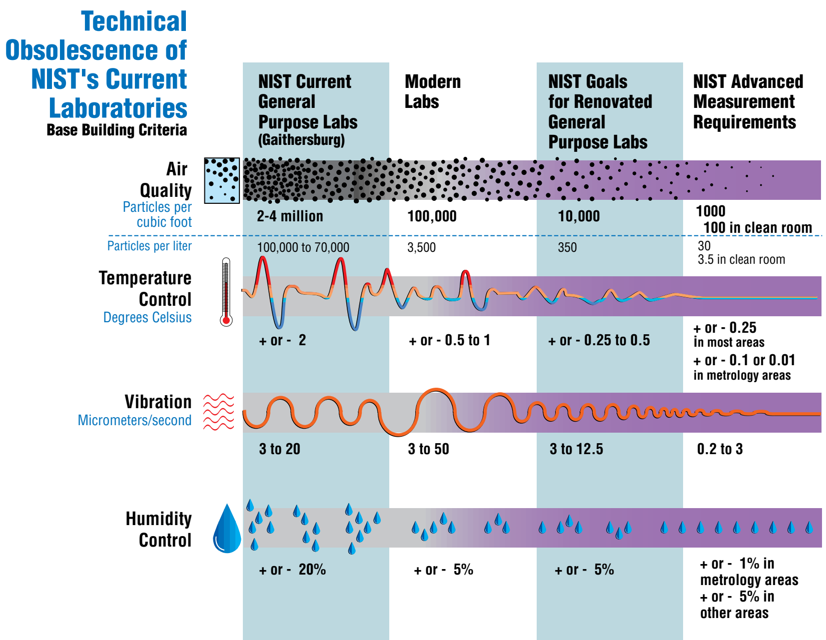
Meanwhile, other countries that already have invested in their measurement laboratories will be moving ahead, providing their industries with a competitive advantage over American firms. A recent NIST benchmarking study of measurements and standards laboratory programs in Germany, Japan, and Brazil found that all three countries recognize the importance of metrology for economic growth, industrial and scientific leadership, and competitiveness. All three recently have increased their funding for measurements and standards programs and all have strong construction programs for laboratory facilities substantially better than those currently available at NIST. In some cases, buildings or facilities built as recently as five to ten years ago already are being renovated.

The United States is the world's most advanced industrialized nation with the highest standard of living, but our competitors are catching up fast. The U.S. industrial and scientific communities cannot afford to settle for a second-rate measurement system.

[15] Includes direct appropriations, funding from other agencies, and reimbursable fees.

CURRENT PLAN AND PRIORITIES

Taking into account a wealth of information collected since 1991 (see Appendix A), NIST produced this 1998 Facilities Improvement Plan. In developing its 1998 plan, NIST took a fresh look at a wide range of alternatives for meeting its facilities needs.[5] An extensive set of planning data and possible scenarios were provided to Booz·Allen to assist with their independent development and analysis of the economic costs, both short- and long-term, of a variety of alternatives for meeting NIST's facilities needs.[5] The final plan has been developed to minimize construction costs, long-term life-cycle costs, as well as costs to the economy from further delay. In addition, NIST sought to meet a number of other objectives stated in the Executive Summary.



This Facilities Improvement Plan assumes no growth in NIST staffing levels. It gives highest priority to maintaining the safety and health of NIST staff and continued operation of current programs through adequate safety and systems capacity upgrades, maintenance, and major repairs of existing capital assets and infrastructure support systems. It gives second highest priority to addressing severe technical obsolescence and mounting safety issues caused by aging laboratories.

Included in Administration budgets requests, past, current and outyear estimates are:

- completion of the Advanced Chemical Sciences Laboratory in Gaithersburg (fully funded with previous appropriations); and
- construction of an Advanced Measurement Laboratory (AML) in Gaithersburg.

Completion of this program of new construction will result in approximately 20 percent of NIST's laboratory space meeting the criteria of modern laboratories or better. (See Technical Obsolence Chart.) If the failure rate of the remaining laboratories can be maintained at the 67 percent level or below, the overall failure rate of NIST's facilities might be expected to decrease from the 67 percent found in the most recent SHG study[4] to somewhere in the vicinity of 50 percent.

SPACE ANALYSIS

In 1991 and again in 1997, detailed analyses of NIST's available office and laboratory space were conducted for NIST by SHG Inc[3,4]. These studies found that several NIST buildings and programs were "severely compacted and overcrowded resulting in safety hazards and unsafe egress." SHG recommended that laboratory space per researcher be increased from about 290 net assignable square feet (nasf) per person to about 400 nasf. SHG based its recommendation on benchmarking with other government and industry R&D laboratories.

The NIST Gaithersburg and Boulder sites currently have 591,000 net assignable square feet (nasf) of office space and 770,000 nasf of laboratory space. These totals include about 86,000 nasf square feet of leased office and laboratory space off campus (NIST North). The Institute has a total of about 3,600 staff members requiring office space, of which about 2,630 require laboratory space. These totals include a conservative estimate of the office and laboratory space requirements of the more than 1,000 guest researchers, post-doctoral researchers, industry collaborators, contractors, and others whose full- and part-time work on the NIST campuses is critical to the success of its ongoing research programs. Dividing the total nasf by the number of staff members produces a current (FY 1998) average of about 160 nasf per person of office space and 290 nasf of per person of laboratory space.

The current NIST office space per person is slightly above the 153 nasf of office space (including conference rooms, storage areas, etc.) recommended by the General Services Administration.[16] The current NIST laboratory space per person is substantially below the level of 400 nasf recommended by SHG Inc.

HOK Consulting made a separate review of NIST space requirements in October 1996[17] at the request of the Department of Commerce. HOK found that there was "minimal space currently available" on the NIST Gaithersburg campus. It concluded that implementing a recommendation made by the Department of Commerce Inspector General's Office in August 1996 [18] to immediately vacate a large portion of NIST North would "severely impact the functionality and performance of the program's operations. Therefore, no part of Bldg. 820 (NIST North) can be vacated at this time."

NIST North originally was built and leased to provide swing space for NIST laboratory programs that would be displaced due to renovation of the Gaithersburg General Purpose Laboratories. In 1993 when plans for NIST North were made, NIST had already received $107 million in construction funding and expected to receive quickly the remaining funding needed to carry out its construction and renovation program. Congressional appropriations were not provided as expected, however. In the meantime, NIST was in the process of moving substantial numbers of employees from its administrative, technology services divisions, and its Information Technology Laboratory into NIST North. Some of these employees moved from temporary trailer space, which was then surplused or was needed for supervising construction of the ACSL. Another group, which did not require "wet" laboratory space, moved from the NIST Technology Building. This freed up laboratory space urgently needed by other NIST programs due to the overcrowded conditions documented by SHG. The laboratories and offices vacated in the Technology Bldg. have now been filled with other programs that have, in some cases, waited years to get the space they need.

NIST's Information Technology Laboratory currently has a substantial number of staff vacancies due to a nationwide shortage of computer specialists and technicians. The Laboratory is also starting a new program with the National Security Agency and has plans for another new program with the University of Maryland. Once these vacancies and new programs are fully staffed, NIST North will be 95 percent occupied. For the moment, the primary current need for NIST North is to relieve overcrowding. Consequently, NIST has shifted payment of the $3 million per year rental fee to its overhead funds, as recommended by the DOC Inspector General's Office.

Upon completion of the ACSL and AML, NIST will have increased its inventory of lab space to approximately 370 nasf per person.

NIST's Longer-Term Goals

NIST's Facilities Improvement Plan proposes to alleviate current overcrowding in laboratories, while providing the much higher quality laboratory environments needed for NIST research to meet the needs of U.S. industry and science. Implementation of NIST's long-term plan will result in about 183,000 nasf of additional modern laboratory space and 84,000 nasf less office space, leading to an average of about 140 nasf of office space per person and an average of about 360 nasf of laboratory space per person. These are reasonable goals given that the General Services Administration guideline is 153 nasf of office space per person and that SHG recommended that NIST provide approximately 400 nasf of laboratory space per person.

In preparing its long-term space analysis, NIST relied upon the following underlying assumptions:

■ The number of NIST staff members remains constant.

■ Square footage numbers for "office space" include areas for both workstations and for support areas such as conference rooms, storage areas, photocopier rooms, etc.

■ Each General Purpose Laboratory in Gaithersburg and each independent wing of Building 1 in Boulder will be renovated all at once. Partial renovations are substantially more expensive, time consuming, and less safe.

■ Renovated buildings contain substantially less assignable office and laboratory space than unrenovated buildings. The addition of larger, more efficient air handling systems, service corridors, disability access,

[16] General Services Administration, *Federal property Management Regulations, Temp. Reg. D-7*, Aug. 2, 1991
[17] HOK Consulting, Building 820-NIST North—Space Study, Oct. 1996, 31 pp.
[18] DRC Report IPE-8377-1, August 1996

and other factors needed to improve control of the building environment cuts back on the available space for laboratories and offices.

- Soon after the AML is available, the Metrology Bldg. is assumed to begin major renovation and therefore is not included in the available space in the year renovation begins. Each time a renovation is complete, renovations would begin on a new building and its square footage is removed from space available. Thus NIST's available laboratory space increases when all buildings have been renovated.

- By the end of renovations, NIST would no longer maintain temporary space (i.e. trailers).

- For planning purposes, the proportion of laboratory to office space in each of the General Purpose Buildings or each wing of Bldg. 1 remains the same before and after renovations are complete. NIST may increase the amount of laboratory space compared to office space in some buildings if there is a cost-effective way to do so.

- NIST would use the combination of NIST North, the ACSL, and the AML to create enough laboratory swing space to renovate one complete GPL at a time. NIST North will be vacated after all GPLs have been renovated.

- The vacant space created when the National Oceanic and Atmospheric Administration moves out of Boulder's Bldgs. 1 and 24 in 1999 will provide the opportunity to create good on-grade laboratory space from space currently being used for offices. It will also create swing space that will allow NIST to renovate a complete wing at a time in Bldg. 1.

MAINTENANCE PRIORITIES

The facilities projects included under this category of funding are related to keeping NIST's current buildings in good working order, providing a safe working environment, or delivering sufficient and reliable utilities and other services to laboratories. (See Appendix B for descriptions of 12 categories of SCMMR projects.) Normal day-to-day maintenance costs are excluded from this category. NIST has consistently placed the safety and health of its employees and visitors as its highest facilities improvement priority. In addition, NIST sites suffer from severe systems capacity problems such as inadequate ability to deliver chilled water to high-technology laboratories and antiquated electrical systems. Finally, there are large numbers of maintenance and major repair projects such as replacement of 30- to 45 year-old roofs and replacement of failed emissions control systems.

Over a 25-year period beginning in 1965, appropriations for building maintenance and improvement remained essentially flat in constant dollars. At the same, time, the buildings' advanced age produced a substantial backlog of urgent safety, capacity, maintenance, and major repair projects (SCMMR). Since 1993, NIST has received a total of $80 million dollars in appropriations for SCMMR projects. Projects paid for with these appropriations have included installation of a fire safety sprinkler system in the 11-story Administration Bldg; construction of a hazardous waste materials handling facility; increased capacity for Gaithersburg's central utility plant and systems (including additional chillers, cooling tower cells, and pumping systems); upgrades to sewer lines, water lines, and electrical distribution systems; replacement of steam manholes, and structural repairs to NIST's 750-seat auditorium.

While progress has been made, only a small fraction of a backlog of needed SCMMR projects totaling about $400 million (at the end of FY 1997, in FY 1999 dollars) has been addressed. Over the next 5 years, NIST hopes to achieve a significant reduction in the most urgent components of this backlog. Estimated five-year expected costs in FY 1999 dollars for currently known projects are shown below. NIST has prioritized its SCMRR projects based on multiple factors such as importance of the project to life safety, probability of imminent failure, compliance with applicable regulations, impact of the project on litigation exposure, and importance for meeting NIST's program needs.

Given NIST's current substantial backlog of projects, prioritization necessarily depends on an up-to-date assessment of current facility conditions and the amount of funding available. Appendix C presents specific project priorities for $16.7 million in SCMMR FY 1998 funding appropriated and released at the start of the fiscal year in October 1997 (Phase 1), for $15.3 million in FY 1998 funding specified by Congress to become available with submission of this NIST Facilities Improvement Plan (Phase 2); and for $16.7 million in funding requested by the Administration for FY 1999 and outyears FY 2000 through 2003.

NIST will use the additional funding requested in the President's FY 1999 budget as shown in the table below to continue addressing the most urgent projects in the backlog. These include a wide range of projects such as continued upgrades to fire safety systems,

Planned Safety, Capacity, Maintenance and Major Repairs (SCMMR) Projects ($ in Thousands)

Project Categories	FY 1998 Total	FY 1999+ Four Years
Architectural Repairs Replacements	1,250	5,180
Central Utility Plant Expansion/Replacements/Upgrades	5,350	1,736
Civil and Site Environmental Repairs/Replacements/Upgrades	800	2,808
Conveying System Repairs/Replacements	0	1,336
Energy Conservation Projects	600	8,012
Exhaust Air Filtration System Repairs/Replacements	6,550	1,336
Handicap and Accessibility Projects	1,350	1,568
Hazardous Materials Projects	1,230	4,826
Mechanical-Electrical System Replacements/Upgrades	6,520	29,300
Site Alarm System and Fire Safety Upgrades	500	3,644
Site Utility System Replacements/Upgrades	7,350	22,656
Structural Repairs/Replacements	500	1,168
Totals	**32,000**	**83,570**

***Note**: Spending in FY's 1999 and beyond is in FY 1999 dollars and is projected using established project priorities for FY 1998. Project priorities are adjusted when necessary to meet changing demands and/or funding levels.*

removal of hazardous asbestos materials, replacement of boilers or antiquated electrical switch gear, repairs to roofs and roads, and improvements in access for the handicapped.(See Appendix C for detailed lists of these projects.) Many of these projects have been deferred in previous years to the point where they present risks for safety, critical failures, or non-compliance with building codes. To the greatest extent possible NIST will coordinate its spending on SCMRR projects with the new construction and renovation priorities discussed below to avoid major repairs to buildings scheduled for near-term renovations.

NIST's Longer-Term Goals

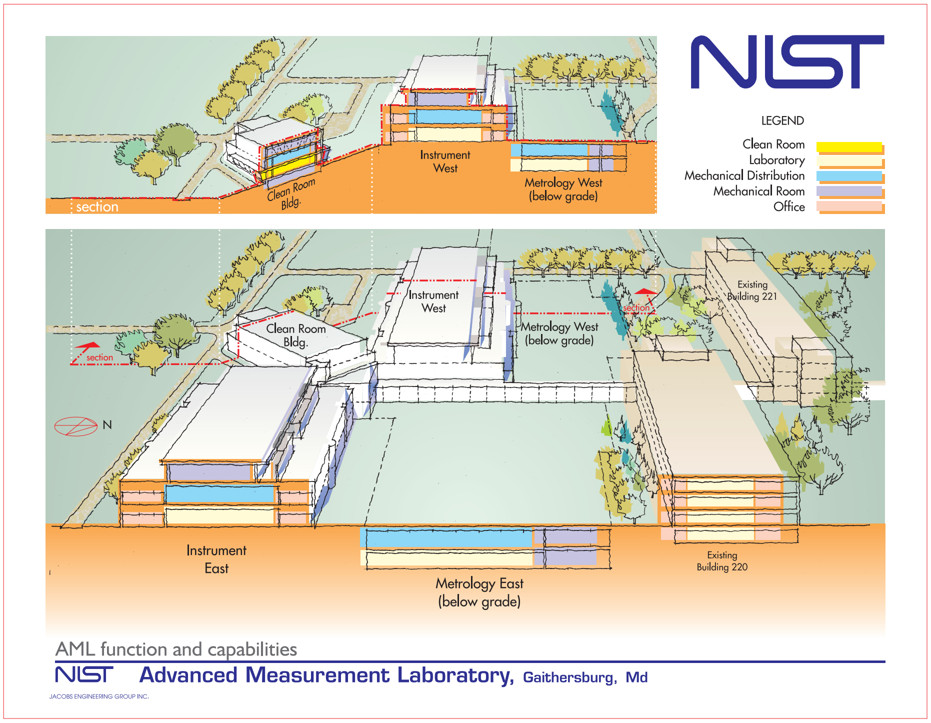
NIST facilities planners believe that the proportion of SCMMR projects in each category is likely to remain relatively stable over the next 10 years. An annual SCMMR budget of about $16.7 million, as included in the Administration's outyear estimates, approaches the GSA standard level at 1.5 percent of federal capital facilities replacement value. However, because of the advanced age of NIST facilities, the Institute will be able to attack only its most urgent SCMMR problems, and the backlog of projects may continue to grow. NIST's long-term goal is to reach a level of SCMMR funding in line with industry standards for high-technology laboratories and Booz·Allen's recommendations [5] of about 4 percent of facilities replacement costs, or about $50 million per year (FY 1999 dollars). Booz·Allen's business case analysis recommended[5] that DOC and NIST "increase annual reinvestments in capital assets in the form of SCMMR projects to an annual rate in the range of $48 million (constant FY 1999 dollars.)" The study recommended an additional investment of $18.7 million for 15 years to "buy down" the approximately $400 million in backlogged SCMMR projects. These recommendations were based on what Booz·Allen calls two different "generally accepted methods used to estimate appropriate levels for this expenditure." In addition, Booz·Allen cites a recent study[19] that suggests that NIST's backlog of deferred SCMMR projects (as a percentage of its facilities replacement value) is several times higher than the average for 34 public research colleges and universities. NIST supports Booz·Allen's analysis.

NEW CONSTRUCTION PRIORITIES

NIST's Facilities Improvement Plan proposes new construction only when existing facilities cannot be cost-effectively renovated to meet the technical needs of critical NIST measurement research programs.

NIST's current plans for new construction include the following in priority order:

[19] APPA: The Association of Higher Education Facilities Officers, The National Association of College and University Business Officers, and Sallie Mae, *A Foundation to Uphold: A Study of U.S. Colleges and Universities*, 1996, pg. 43.



- completion of the Advanced Chemical Sciences Laboratory (ACSL) in Gaithersburg by early 1999 (fully funded with previous appropriations), and
- construction of an Advanced Measurement Laboratory in Gaithersburg.

Advanced Measurement Laboratory

Since 1991 and the first detailed assessment of NIST's long-term facilities needs, it has been clear that no currently existing building on the Gaithersburg or Boulder campuses or elsewhere can be retrofitted economically to the high levels of environmental control needed by NIST's most advanced physics, chemistry, electronics, engineering, and materials science research projects. (See examples, Appendix D.)

Individual U.S. industrial or other government sites may have substantially improved air quality, temperature control, vibration isolation, power stability, or humidity control than currently available controls in NIST's facilities. However, few have strict control in all of these areas simultaneously as NIST needs and plans through construction of the Advanced Measurement Laboratory. (See AML drawing.) In addition, while some of these other U.S. facilities were intended to deliver superior levels of temperature or vibration control, for example, actual measured values in these laboratories do not always meet original design specifications.

It is not possible to retrofit economically an existing building to meet the exacting requirements of NIST's most advanced research due to the need for:

- extremely low levels of vibration (a velocity amplitude of 3 micrometers per second or less);
- large volumes of air to produce the necessary temperature control of ± 0.25 degree Celsius or better;
- very good air cleanliness (1000 particles per cubic foot/350 particles per liter or less); and
- excellent humidity control (to ± 1 percent in advanced metrology areas).

The current ceiling heights in all of the Gaithersburg General Purpose Laboratories are set by the structural frames of the buildings. There is no room within the confines of the set floor-to-floor heights to include enough new air-handling equipment to reach the required temperature control and air-quality levels. While some improvement in vibration levels is possible through isolation of mechanical equipment in a retrofitted building, the exceptionally low levels needed for NIST atomic-based measurements require a building specifically designed to achieve this goal.

Both the SHG 1997 retrace project and the Booz·Allen business case study recommended that NIST build an Advanced Measurement Laboratory in Gaithersburg without delay.

With facilities appropriations received to date, NIST has completed an architectural and engineering design and supporting research for the AML at a cost of $17 million. In conjunction with HDR and vibration experts, Acentech Inc. (see Appendix A), NIST has conducted detailed experiments in temperature and humidity controls and in vibration isolation. It also has constructed full-scale mock-ups of laboratory and office modules on the Gaithersburg campus to test and improve critical elements in the design of the AML.

The design process has included participation by key NIST scientists who are experts in building environmental controls as well as researchers expected to be users of the new building. The information gathered through these studies has greatly improved confidence that the building can meet its ambitious design specifications.

NIST's plan is to build the AML in a single phase beginning in FY 1999 (using the advanced appropriation requested in the President's FY 1999 budget), and to complete it in 44 months at a total project cost of $218 million. For construction of the AML, NIST plans to use an integrated project team of government staff and contractors to manage this project. The Director of Administration, as the Program Manager with overall responsibility for the NIST's capital assets program, will assign procurement specialists and a project manager with support staff. A budget analyst will be assigned. The Director of the Boulder Laboratories has responsibility for (a) representing the researchers, and (b) planning NIST's long and short-term facility needs. Contract staff will include an Architect/Engineer (A/E) and, potentially, a construction manager (CM).

In order to better focus on value and mitigate risks to the government, NIST generally prefers to select the construction contractors via a Request for Proposal (RFP). Under the RFP approach, risk will be managed through a formal risk assessment process whereby each offeror will be evaluated against the quality of its reference check results, past performance information, experience, financial soundness and current vs. historical work backlog. Integrated project teams, consisting of experts in all pertinent disciplines, will participate in the evaluation of proposals and award decisions. Construction contract documents for this project will include detailed construction specifications and drawings, and all contracts are planned to be of the firm fixed price type. The contract will require the contractor to adhere to a contract schedule that will be used as the basis of payment for work in place. Detailed information on the AML cost estimate, contract strategy, program management, and cash flow and major milestones during construction can be found in Appendix E.

To lower appropriations needed in any one year, NIST considered the option of phased construction of the AML in three self-sustaining sections. While technically feasible, this option has a number of substantial drawbacks, including additional cost. Phasing construction would require a substantial redesign. Phasing also raises the cost of AML construction to $283 million (FY 1999 dollars) and extends the completion date about three years. Since the currently envisioned building consists of five independent wings, excavating and laying foundations for each subsequent portion of the building will be much more difficult, expensive, and disruptive to important ongoing research than if underground wings and adjacent foundations were constructed at the same time.

Booz·Allen analyzed both the single-phase and a three-phase AML alternative. They concluded that the $218 million AML cost estimate was within a reasonable range, and they also concluded that the three-phase alternative would increase total costs by $50 to $90 million, consistent with the above. "Thus," it concluded, "our recommendation is to construct the AML in a single phase."

The AML is designed to be a shared resource for the entire Gaithersburg campus and the industrial and scientific community that works closely with NIST. Research groups from any of the NIST laboratories may be assigned space in the AML if they have a technical need for tight environmental controls. Currently, the programs with the greatest need for AML space are research areas such as precision engineering; atomic-scale physics; micro-chemical analysis; microelectronics processing and materials analysis; acoustics, mass, and vibration measurements; pressure and temperature measurements; chemical kinetics; and photonic materials. With the evolution of technology to smaller, faster products, however, the demand for the limited AML space should continue to increase.

The AML will include five different sections joined by a central corridor that connects them to the current Metrology Building. There are two different metrology sections in the planned AML. "East Metrology" includes those areas of atomic physics, mass measurements, or other research that require excellent isolation from vibration sources as well as good air quality and temperature and humidity control. The "West Metrology" section will include NIST research and calibrations using coordinate measuring machines and other metrology instruments that need good vibration isolation and temperature control but that also create some vibration due to the fact that parts of the machines must move while measuring artifacts.

Vibration

Very strict attention will be paid to maintaining good vibration isolation for these metrology spaces. Both metrology sections will consist of single floor buildings constructed entirely below grade level. The roofs of these areas will be covered with soil to minimize disturbance to the building from wind and vibrations transmitted through the soil. The space above the metrology area will be planted with minimal care shrubbery and reserved as a quiet zone. Building mechanical systems such as motors, air-handling units, and uninterruptible power supplies will be isolated from these areas. Even refrigerated vending machines, which have been shown to generate significant vibration in laboratory settings, will not be allowed in these areas.

In addition to the above measures, the AML metrology laboratory spaces will include several types of vibration isolation foundations. Measurements made in a mock-up foundation lab constructed at NIST have provided detailed information on the benefits of different vibration isolation schemes. These experiments have included comparing vibration isolation at various frequencies for isolated concrete slabs, concrete slabs floated on air springs with passive vibration controls, and concrete slabs floated on air springs with active computer-controlled cancellation of vibration. The results have shown that for certain highly demanding research areas, especially atomic-level measurements and atomic manipulation, active canceling of vibration offers the best achievable vibration control for frequencies both above and below 10 Hz. The AML metrology modules have been designed to provide the greatest flexibility to meet industry's needs today and in the future. This includes provisions for active vibration damping to be turned off if necessary for specific experiments and for modules on simple slabs to be retrofitted economically for active air springs if the need arises.

The AML also will include two sections of Instrument Laboratories. These will each include one floor of laboratory space, above ground, on well-isolated concrete slabs on grade. Both sections will house research projects that use a wide variety of electron microscopes, laser/optics equipment, high-vacuum chemical reactors, and other instruments requiring stringent vibration control and excellent temperature, humidity, and air-quality control. Adjoining the instrument labs will be two floors of office space for researchers working in the AML.

Clean Room

Finally, the AML will include a Clean Room section that offers one floor of aboveground laboratory space. The Clean Room will be similar to those certified as class 100 with 3.5 or less particles per liter. While this is not as good as current high-performance industry semiconductor fabrication facilities (typically class 10 or better), the AML Clean Room will be adequate to perform the measurement R&D required by NIST programs. Areas of class 10 space will be achievable in the AML Clean Room through dedicated enclosures, so that this level can be reached when necessary. In addition, the AML Clean Room will be designed to be upgradable to class 10 in the future, should the need arise. The Clean Room will house projects by research groups in semiconductor processing, materials evaluation, and length measurement. It also will be a user facility for sample preparation or fabrication needed by many groups housed in the adjacent metrology and instrument laboratories of the AML.

High-Bay Areas

To accommodate the increasing need for high-bay areas due to larger laboratory instruments, AML laboratory modules can be adapted to ceiling heights as high as 7 meters (22 feet). This adaptability stems from the fact that mechanical systems will be isolated above the ceiling or away from instruments in each of the AML's three different types of spaces. By isolating mechanical systems above and away from experiments, the AML's design will improve vibration control within the lab modules, provide for regular maintenance without disturbing sensitive instruments, and improve the safety and productivity of research. (Drawings or models of the planned AML appear to have two floors rather than one in the instrument and Clean Room areas due to this added level for mechanical systems. Such features increase the flexibility of the labs for future use and help prevent obsolescence.)

Air-Handling and Temperature Control

The extra floor for mechanical systems is also necessary due to the large volume of air that must be drawn through the building spaces to achieve the required temperature, humidity, and air quality. Temperature control for most areas of the instrument and clean room wings will be ± 0.25 degree Celsius. Laboratories requiring control to ± 0.10 degree Celsius or ± 0.01 degree Celsius will be located in the metrology areas. These labs will be configured as “rooms within rooms” and will have dedicated air-handling units. These levels of temperature control have been confirmed through an extensively tested, full-scale, operating test module onsite. Achieving such temperature control depends on larger volumes of air circulating than normal to minimize temperature differences in various parts of a room. This means that instruments cannot be "packed to the rafters" as is typically the case in today's smaller, NIST laboratories in the Gaithersburg General Purpose Laboratories. Sensitive instruments must have sufficient open space surrounding them to maintain even temperatures throughout the room.

Those projects with the strictest temperature stability requirements will need to be controlled to better than ± 0.01 degree Celsius. These projects typically involve precision dimensional metrology where the slightest expansion of a material due to a temperature change will degrade measurements. Even projects requiring ± 0.1 degree Celsius control will entail fabricating special enclosures for instrumentation. These instruments will be controlled remotely since even an operator's body heat can change measurements substantially.

Usable Floor Space

While the "footprint" of the AML on schematic drawings of the NIST campus looks large, the actual "net assignable square meters" is substantially less than it appears. Two areas are below grade and three are above grade, but none of the five areas includes more than one floor of laboratory space. The total "net assignable" space in the AML is about 19,500 square meters (210,000 square feet.) About 13,000 square meters (140,000 square feet) of the building is research laboratory and office space-an area about 1½ times the area currently provided by one four-level Gaithersburg General Purpose Laboratory.

However, for a variety of reasons, fewer projects will be able to occupy this space than occupy equivalent square meters in the current General Purpose Labs. These reasons include: greater space needs (estimated at about 20 percent) for the precise temperature control described above, greater space to allow access to people with disabilities as required by codes not currently met in Gaithersburg labs (estimated at 6 percent), and the fact that some of these projects will need substantially more space than currently available due to building enclosures and remote access rooms (needed for monitoring and controlling experiments) to achieve even tighter controls than the base building provides.

NIST's Longer-Term Goals

NIST's longer-term goals for new construction include the following in priority order:

- improved utility services and distribution system in Boulder, and
- improved and expanded clean room facilities in Boulder.

Boulder Utilities and Distribution

When the NIST Boulder site buildings were being built in the early 1950s, Colorado was considered an ideal climate—relatively low humidity, steady mountain breezes, and summer temperatures rarely above 32 degrees Celsius (90 degrees Fahrenheit). NIST Boulder laboratory buildings were built with individual building systems rather than a more economical and efficient central utilities plant. However, such individual systems vary in capability and are less maintainable and reliable than central plant systems. Furthermore, the increasingly sensitive work performed at NIST in Boulder would benefit from location of large vibration-causing equipment away from the laboratories. Systems delivering laboratory services such as chilled water, steam, and compressed air also are individual and not centrally provided.

As a consequence of that original decision, utilities at the Boulder site today are a hodgepodge of different, often inadequate systems, and a number of areas remain with no air conditioning at all. While this may have sufficed in the 1950s, 1960s, and even 1970s, the dawn of the computer era—and a whole array of sophisticated scientific instrumentation—has made the lack of centrally distributed, high-quality air, temperature and humidity control, and power supplies a costly, major burden on research productivity for more than a decade.

For example, researchers working in Boulder's Building 1 have measured temperature swings of up to 6 degrees Celsius in a 24-hour period, which substantially reduces the accuracy of data collection on lightwave materials crucial for fiber-optic-based communications. Boulder's advanced research efforts suffer from the same types of technological obsolescence and aging of facilities as Gaithersburg laboratories described above only conditions in Boulder are worse because these buildings are older and receive considerably less reliable utility service. (See examples, Appendix D.)

Simply having reliable air conditioning and heating will prevent people in offices from opening their windows and introducing large quantities of dust that damage sensitive instruments and cause temperature and humidity fluctuations throughout the building. The availability of the centralized utilities also will provide better quality and more reliable power. A new central plant, in combination with full renovation of

Building 1, would permit researchers to control such swings to ± 0.5 degree Celsius.

Boulder Clean Room Space

According to laboratory consultants Earl Walls Associates (EWA), rapid obsolescence of Clean Room space is an accepted fact of life in the semiconductor industry. The rapidly shrinking size of circuit features and associated needs for cleaner, more controlled space cause U.S. semiconductor companies to plan on chip processing buildings becoming obsolete and replacing them with new ones about every five years.

Boulder researchers working on voltage standards, nanoscale cryoelectronics, superconducting electronics, magnetic recording metrology, and other areas currently use extremely overcrowded and outdated clean room space in Building 1. Part of this space was renovated in 1993 and is designed as class 100. But the critical photolithography section is 10 years old and is only designated as class 1000. This level of air cleanliness is inadequate for the complexity of circuits NIST fabricates in the facility. The voltage standards program, for example, conducts research on improved circuit design for high-accuracy voltage microchips used in aerospace, semiconductor, and other high-technology industries. This group regularly fabricates circuits with submicrometer lines, some with 38,000 junctions on chips about 12 millimeters (one-half inch) square. A single chip may take as long as two weeks to fabricate. A speck of dust that falls on a chip being printed can ruin two weeks of work and require a costly refabrication.

Temperature and humidity controls, power quality, and vibration levels in the current facility also are inadequate. Small changes in temperature and humidity affect adhesion and development times for the photolithography process, just as larger temperature changes can speed up or slow down development times for conventional photographic films.

The overcrowding problem has reached the point where current equipment in the Clean Room sits directly next to other equipment with no space in between. Nothing new can be installed in the room without first taking something else out. Work surface spaces are so cramped that researchers sometimes inadvertently ruin their colleagues' work by spraying incompatible solvents too close to circuits under fabrication or by dislodging particulates from the floor that then land on circuits.

RENOVATION PRIORITIES

No major renovation projects are included in the President's FY 1999 budget or outyear projections, and so all such projects fall in to the category of NIST's long-term goals.

Many more NIST projects need tight environmental controls than there will be space in the AML or the Boulder clean room facilities to put them. These programs would move into renovated General Purpose Laboratory space or renovated wings of Bldg. 1.

All seven of the General Purpose Laboratories on NIST's Gaithersburg campus require major renovations. All are about 30 years old and suffer from severe deterioration and obsolescence of major systems as described above.

Following completion of the AML, NIST plans call for the Metrology Building (220) to be the first General Purpose Laboratory renovated. Similar in design to the Physics Building (221), it provides four floors of laboratories and has the lowest natural vibration levels on the campus in its basement laboratories. (The Chemistry Building has three floors with no basement.) The Metrology Building is closest to the site of the planned AML and, once renovated, will provide easy access to the AML for research groups most likely to collaborate with AML-based projects. In addition, a number of the current projects in the Metrology Building are slated to move to the AML, opening up space that can be renovated. The remaining occupants will be moved temporarily to the nearby Physics Building (where additional space will be vacated by projects moving to the AML).

With minor repairs made with SCMMR project funds, the Chemistry Building also can provide laboratory “swing space,” due to vacancies from completion of the ACSL and AML. The absence of "wet chemistry" being conducted by this set of NIST research groups will allow them to temporarily continue research in the Chemistry Building beyond the time that would be feasible for NIST's chemistry programs.

The availability of temporary laboratory space would allow the entire Metrology Building to be renovated simultaneously, a major requirement for protecting the safety of NIST researchers, keeping costs as low as possible, and for causing the least disruption to important ongoing measurement research. Like most buildings built in the 1960s, the building contains asbestos insulation and floor tiles that must be removed and treated as a hazardous material to avoid endangering the health of occupants. Renovating an entire building at once also is required because most of the current occupants of the Metrology Building need good to excellent vibration control to conduct their research. Measurement research and construction equipment are fundamentally incompatible, especially within the same building.

The Metrology Building would be gutted completely, including the exterior facade. This is necessary in order to install completely new air-handling systems with electronic controls, to provide service corridors for duct work, cabling, and plumbing systems for gases and chilled water to improve building maintenance and better maintain temperature controls, and to provide a modern "skin" for the building that is less prone to air and thermal leaks. Laboratory exhaust systems also will need to be replaced and may require some structural building changes; however the lack of potentially explosive acids and the lower quantities of chemicals typically used will simplify greatly this process compared with the problems presented by the current Chemistry Building that required construction of the ACSL.

Once renovated, the Metrology Building would provide base building air quality of about 10,000 particles per cubic foot or about 350 particles per liter—not as good as the AML but still very good by modern laboratory standards. Temperature control will range from ± 0.5 degree Celsius to ± 0.25 degree Celsius in certain specialized modules. Vibration will be minimized by strict attention to the placement and isolation of mechanical systems. Humidity control will improve from approximately ± 20 percent to ± 5 percent.

After renovation, about 4 percent of the laboratory space will be lost to service corridors for cabling, ductwork, and mechanical systems. Approximately 6 percent will be lost to larger aisles and doorways needed to comply with current regulations on disability access. This is therefore a loss in building area of approximately 10 percent. Finally, the June 1997 SHG Needs Assessment Report recommends that NIST's space usage be decompacted to better align NIST research space usage with industry standards.

The end result is that fewer research groups will fit in the renovated space than occupy the current buildings. Notwithstanding such loss of area, NIST researchers would have the dramatically higher quality space needed to provide industry with the quality and turnaround times on calibrations and other research U.S. industry needs to stay competitive.

As research groups move into the renovated Metrology Building from their temporary assignments in the Physics Building and Chemistry Building, space would become available to renovate the entire Physics Building. Criteria for this building are planned to be identical to those for the renovated Metrology Building.

Despite the fact that Boulder's Building 1 was finished in 1954, it still can provide quality research space with major renovation. Its basic layout of six largely independent wings provides a large amount of space with relatively good natural vibration characteristics. Most of the building's current vibration problems are caused by aging and poorly located mechanical systems-problems that can be reduced when the building is renovated as planned with service corridors alongside the outside of the building to house such systems.

The construction of a new building on the Boulder site for the National Oceanic and Atmospheric Administration should provide NIST with about the equivalent of one full wing (about 50,000 net square feet) additional space in Buildings 1 and 24 by the end of FY 1999. This vacant space will serve as laboratory swing space, thereby allowing entire wings of the building to be renovated at once. This approach (the same one proposed for Gaithersburg) minimizes safety hazards from asbestos removal and reduces disruption to research programs by requiring no more than two moves per program. In addition, NIST plans on performing a limited renovation of the high bay areas of Building 4. This will allow the Instruments Shops Group to move out of wing 3, freeing up additional laboratory swing space.

Upon completion of the renovation of Boulder's Building No. 1, control of air cleanliness, vibration, humidity, and temperature is planned to be similar to that for the renovated Gaithersburg GPLs as described above.

ANNUALIZED BREAKDOWN OF COSTS

Developing accurate annualized breakdowns of costs for NIST's Facilities Improvement Plan is complex. With release of the first two phases of the FY 1998 appropriation, NIST will be able to continue a concentrated attack on the growing backlog of safety, capacity, maintenance and major repairs projects and update the design of the AML. With approval of the FY 1999 budget and advanced appropriations, it will be possible to begin AML construction in FY 1999 and to have an estimated completion date of late FY 2002. (See Appendix F for a schedule of spending on SCMMR projects and the AML consistent with the President's FY 1999 budget.)

NIST's Longer-Term Goals

NIST's longer-term facilities planning necessarily extends beyond the five-year time frame of the President's budget and outyear estimates. NIST's ultimate goal is to increase spending on SCMMR projects until a steady level of about $50 million (FY 1999 dollars) is reached. In its economic analysis study, Booz·Allen recommended that NIST allocate $18.7 million yearly (FY 1999 dollars) for the next 15 years to "buy down" the current backlog of SCMMR projects, in addition to spending $48 million yearly (FY 1999 dollars) on SCMMR projects to prevent the backlog from growing. Booz·Allen based its recommendation on "generally acceptable methods used to estimate appropriate levels for this expenditure" for research facilities.

In addition, NIST hopes to undertake a program of major renovations of its General Purpose Laboratories (GPLs) following completion of the AML. Completion of the AML and relocation of personnel into the new building will create vacant space in Gaithersburg. This space will form the mainstay of "swing space" that would allow the start of major renovations on the Gaithersburg campus, beginning with the Metrology Bldg. and followed by the Physics Bldg. Additional major renovations to the remaining Gaithersburg GPLs (Chemistry, Materials, Polymers, Technology, and Building Research) would follow.

Improvement of utility services and a distribution systems in Boulder would be followed by improved and expanded clean room facilities. Next would come limited renovation of Bldg. 4, renovation of Bldg. 1's wings 3 & 4, wing 6, wing 5, spine, wings 1 & 2, as well as renovation of Bldg. 2 and Bldg. 24.

For a detailed breakdown of the estimated costs required to accomplish these projects in priority order see Appendix G. Maps of both sites are provided in Appendix H that identify those buildings that would be affected in NIST's long-term Facilities Improvement Plan.

The goal of this extended program of new construction and renovation would be to bring at least two-thirds of NIST's laboratory space up to the level of modern laboratories. If the failure rate of the remaining laboratories can be maintained at the 67 percent level or below, the overall failure rate of NIST's facilities might be expected to decrease to somewhere in the vicinity of 20 percent.

The Administration recognizes the importance of the facilities improvement needs addressed in this report, and this need is clearly articulated in the Commerce Department's Strategic Plan. However, the long-range time table provided in this report should be regarded as a planning guide rather than a firm request for a specific funding level in any given year. As always, annual Administration funding requests will depend upon a continuing reassessment of priorities that balances NIST construction, renovation, and maintenance needs against other funding requirements for NIST, the Department of Commerce, and other executive branch agencies.