REPORT BY THE

Comptroller General

OF THE UNITED STATES

Information On Mission And Functions Of The National Bureau Of Standards

The Subcommittee on Science, Research and Technology, House Committee on Science and Technology, was concerned that the Bureau of Standards appeared divided in carrying out its functions under enabling legislation and subsequent legislative mandates and saw a need to hold hearings on the organic act--the law establishing the Bureau.

GAO identified several matters which the subcommittee may wish to explore during hearings that may help the Bureau carry out its current and future responsibilities. These include

--encouraging Government agencies to have others perform that work which the Bureau is performing but others can do,

--limiting Bureau services provided to industry which are available elsewhere,

--expanding the research grant program,

--possible new productivity and innovation research roles, and

--increasing use of the joint Bureau/university research institute concept.

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COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON D.C. 20548

B-201955

The Honorable Doug Walgren
Chairman, Subcommittee on Science,
Research and Technology
Committee on Science and Technology
House of Representatives

Dear Mr. Chairman:

In response to the subcommittee's request, signed by former chairman George E. Brown, Jr., we reviewed selected aspects of the National Bureau of Standards. Our efforts focused on the specific questions in your request.

This report provides certain information on the Bureau's mission and functions and identifies several possible actions that may help the Bureau carry out its assigned responsibilities. The subcommittee may wish to explore these actions with the Bureau during the hearing expected to be held on the organic act.

We discussed the matters covered in the report with agency officials. Their comments are included where appropriate.

As arranged with the subcommittee office, we will make this report available to other interested parties.

Sincerely yours,

Milton J. Socolar

Acting Comptroller General
of the United States

REPORT BY THE
COMPTROLLER GENERAL
OF THE UNITED STATES

INFORMATION ON MISSION AND FUNCTIONS OF THE NATIONAL BUREAU OF STANDARDS

D I G E S T

The National Bureau of Standards (NBS), part of the Department of Commerce, supports the U.S. scientific and technical community by setting standards for the Nation's physical measurement system and carrying out a number of scientific and technical services for industry and government. Its fiscal year 1980 appropriations totaled about $92.6 million. Additional funds totaling about $72.4 million were received from Federal agencies and others.

BUREAU'S MISSION QUESTIONED

The Bureau's broad and multifaceted statutory mission has prompted concern about the Bureau's ability to carry out its functions in relation to the enabling legislation and the many subsequent legislative mandates. Questions have been raised about how narrow or broad these functions should be and which ones should be emphasized. (See p. 9.)

The law establishing NBS--the organic act--does not clearly state what NBS' role should be. Also, the Bureau has had problems performing all assigned responsibilities because it has not always gotten enough funds and staff. As a result, it has had to reprogram (terminate) ongoing research, which may have caused problems with research planning, continuity of research programs, and scientific competence. In addition, the many activities mandated subsequent to the organic act have resulted in loss of Bureau freedom to decide which programs are most important to the scientific community. (See p. 11.)

According to agency records, about $27 million has been reprogramed since 1974 to carry out legislative mandates. Also, the work that the Bureau does for other Federal agencies, of which 48 percent is required

by specific legislative mandate, may have adversely affected its ability to meet traditional responsibilities. (See p. 12.)

Since 1971, Bureau and other Federal agency resources provided to the Bureau for legislative mandates have increased from $1.6 million to $14.7 million (819 percent) in 1965 constant dollars. Staff years to support this work increased from 50 to 488 (876 percent). However, Bureau direct appropriations during this period increased only from $27.8 million to $31.4 million (13 percent) in constant dollars. (See p. 14.)

Since 1965, funds for Bureau work for other Federal agencies have increased from $15.0 million to $21.1 million (41 percent) in 1965 constant dollars, while Bureau appropriations increased only 18 percent--from $26.5 million to $31.4 million, also in constant dollars. (See p. 15.)

Matters for consideration by the subcommittee

GAO identified several actions that may help the Bureau carry out its current and future responsibilities which the subcommittee may wish to review during planned hearings. Three such matters follow.

--Encourage Government agencies to have others perform that work which can be done outside NBS. (See p. 25.)

--Limit those services it provides to industry that are available elsewhere.

--Expand the limited (about $490,000 annually) Bureau-funded research grant program. (See p. 26.)

Bureau officials acknowledged that they are not opposed to expanding the research grant program from its present level of less than 1 percent to 10-15 percent ($9-$14 million) of the Bureau's budget. Bureau officials also said that transferring to other organizations some of the work the Bureau performs releases resources that can then be used on higher priority work.

BUREAU'S ROLE IN PRODUCTIVITY AND INNOVATION

Congressional concern with productivity and innovation in the economy has stimulated interest in adding new roles or functions to the Bureau that could help improve these factors. The Bureau, through its major function of developing physical standards and measurements, has already had an important influence on productivity and innovation. (See p. 29.) Also, the Bureau has contributed more directly through research it classifies as "research for industrial productivity and innovation."

According to the Bureau, about $24.2 million--$10.8 million of Bureau direct appropriations, and other-agency funding of about $13.4 million--was used for 22 productivity and innovation research projects in fiscal year 1980. (See p. 31.)

Further, the Bureau is expanding its programs dealing with productivity and innovation--by 1985 an estimated $50 million will be devoted to this research, including other-agency funding. (See p. 31.)

Matter for consideration by the subcommittee

GAO believes that new Bureau roles or functions should be adopted only after carefully considering how these added responsibilities will impact on the Bureau's credibility and effectiveness, including its technical competence, third-party objectivity, and the morale and quality of the staff. These characteristics are crucial to the Bureau effectively performing its current roles and should be carefully considered before altering these roles or functions. Examples of possible new research areas are (1) increasing Bureau long-term research aimed at exploring for future technologies, (2) developing an engineering grant program, and (3) developing research capacity to support biotechnology. (See pp. 37 and 38.) Before any new roles are adopted, NBS must ensure that the roles fall within its broad legislative authority.

JOINT INSTITUTE FOR LABORATORY ASTROPHYSICS

The Bureau's Joint Institute for Laboratory Astrophysics is basically an academic institute that studies astrophysics (the physical properties and phenomena of the stars, planets, and other heavenly bodies), atomic and molecular physics, geophysical measurements, and advanced laser measurement techniques. Scientists comprise 138 of the 171 Institute staff. Its financial support comes mainly from the Federal Government.

Institute scientists and their coworkers have published numerous scientific papers (see p. 45) and contributed to commerce. Also, Institute scientists have been granted three patents.

Most members of the five National Academy of Sciences evaluation panels who reviewed Institute operations over the past 5 years rated it good to excellent in many respects. (See p. 44.) Scientific areas mentioned as candidates for other Bureau joint institutes included materials research, fire research, analytical chemistry, radiation research, computer engineering research, chemical engineering, and nondestructive testing and evaluation.

Matter for consideration by the subcommittee

The subcommittee may wish to explore during hearings with the Bureau, expanding the joint Bureau/university method of performing research.

BUREAU'S COMPETENCE-BUILDING PROGRAM

Building Bureau competence, the capacity to carry out duties and respond to new requirements, has been a Bureau priority particularly over the past 2 years--appropriations of $2 million were made for fiscal year 1979 and increased an additional $2 million for fiscal year 1980--because of previous emphasis on responding to over 20 laws requiring short-term research. About

$6.2 million and $8.8 million have been authorized for fiscal years 1981 and 1982, respectively. (See p. 56.)

The Bureau's procedures for evaluating and approving proposed competence-building projects provide for input both from the Bureau and from outside advisors. These projects are designed to conform to its short- and long-range plans, which take into consideration national research needs and the Bureau's need for competence in fulfilling its role in meeting those needs.

AGENCY COMMENTS

In commenting orally on the report, the Bureau concurred with GAO's conclusions and had no major comments. (See p. 6.) Bureau technical comments have been included where appropriate.

Contents

ABBREVIATIONS

CIRES	Cooperative Institute for Research and Environmental Sciences
CRS	Congressional Research Service
DOD	Department of Defense
GAO	General Accounting Office
JILA	Joint Institute for Laboratory Astrophysics
NAS	National Academy of Sciences
NBS	National Bureau of Standards
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
OMB	Office of Management and Budget
OTA	Office of Technology Assessment

CHAPTER 1

INTRODUCTION

The National Bureau of Standards (NBS).was established by the Congress on March 3, 1901 (31 Stat. 1449). This law, referred to as the organic act, initially placed NBS in the Treasury Department, but in 1903 it was transferred to the Department of Commerce. As part of Commerce, NBS reports to the Assistant Secretary for Science and Technology.

The organic act, as amended, authorizes NBS to undertake the following:

--Developing, maintaining, and disseminating standards of physical measurements.

--Determining physical materials' properties and physical constants.

--Developing test methods for materials, mechanisms, and structures.

--Establishing standard practices in cooperation with Government agencies and the private sector.

--Providing advisory services to Government agencies.

The NBS Director, testifying before the Subcommittee on Science, Research and Technology in February 1980, pointed out that NBS had three major roles:

1. Serve as the Nation's central reference laboratory for the development and provision of measurement standards and methods; standard reference materials; and data on the properties of matter, materials, and physical phenomena.

2. Address national problems through the application of physical, chemical, mathematical, and engineering science.

3. Work to enhance the technological and scientific base of the Nation's productive capability by contributing to the development of basic technologies and information which underlie product and process development and innovation.

Because the organic act, as amended, does not impose mandatory requirements on NBS and provides broad authority, NBS has considerable discretion under the act in determining its scientific activities. Numerous other laws, however, have been enacted which direct that NBS carry out certain activities. For example, the Consumer Product Safety Act (86 Stat. 1207) requires the Consumer Product Safety Commission to utilize NBS' resources and facilities to, among other things, perform research and analyses related to injury risks associated with consumer products.

NBS has three major organizational units responsible for its scientific and technical programs: the National Engineering Laboratory, the National Measurement Laboratory, and the Institute for Computer Sciences and Technology. The goals of these major units are shown in appendix I.

Additional research is performed at the Joint Institute for Laboratory Astrophysics (JILA) in Boulder, Colorado--under NBS' National Measurement Laboratory. JILA operates under a 1962 agreement between NBS and the University of Colorado--NBS and other Federal agencies fund most of its scientific research. JILA operations are discussed more fully in chapter 4, and an organization chart is shown in appendix VIII.

Also, NBS has two major administrative organizations. The Associate Director for Programs, Budget, and Finance is responsible for planning, developing, and evaluating NBS-wide programs; developing and carrying out policies on programmatic, budgetary, and financial matters; and developing and executing the budget. Most other NBS-wide administrative functions are the responsibility of the Director of Administration. In addition, some of the Laboratory/Institute staffs carry out administrative and management functions for their respective major operating organizations.

The NBS appropriation for fiscal year 1980 was $92.6 million. During fiscal year 1980, about 44 percent of the work NBS performed was for and funded primarily by Federal agencies. This work totaled about $72.4 million. Also, according to an NBS July 1980 analysis of its research projects underway at that time, about 92 percent of the research was considered to be applied research and about 8 percent basic research. As a result of its research, NBS held about 180 unexpired patents as of October 31, 1980. About 10 new patents have been obtained annually over the past 5 years.

Since 1959 the National Research Council, under a contract between the National Academy of Sciences (NAS) and NBS, has continually evaluated NBS functions and operations. In discharging this responsibility, the National Research Council selects and appoints members to a series of evaluation panels. Members usually serve for 3 years but not longer than 6 years. The scientific disciplines of the members encompass almost all physical science fields.

In appointing members to the panels, the Council attempts to get about 50 to 55 percent of the members from industry and the remaining members from government and academia. Usually, the Council attains this objective or takes action to correct an imbalance.

The NBS organic act provides for the Secretary of Commerce to appoint a five-member Statutory Visiting Committee. The committee is required to visit NBS at least once a year and report to the Secretary on the efficiency of NBS' scientific work and the condition of its equipment. Committee members are prominent individuals from industry and academia and are appointed for a 5-year period.

OBJECTIVES, SCOPE, AND METHODOLOGY

Our review was made pursuant to a January 23, 1980, request from the Chairman, Subcommittee on Science, Research and Technology, House Committee on Science and Technology. We reviewed certain aspects of NBS focusing on (1) the specific questions in the subcommittee's request and (2) matters in which the subcommittee chairman's office orally expressed interest during the review, as follows.

- --Changes, if any, needed in the organic act to enable NBS to (1) perform its functions in relation to the enabling legislation and the subsequent legislative mandates and (2) make a significant contribution to the Nation's innovation and productivity problems. (See chs. 2 and 3.)

- --Resources needed to meet NBS goals. (See ch. 2.)

- --A comparison of NBS' current role with that of other Federal agencies in civilian technology research and development, productivity, and innovation. (See ch. 3.)

- --Potential new NBS roles in innovation and productivity. (See ch. 3.)

--Resources used to carry out legislative mandates and nonstatutory tasks. (See ch. 2.)

--Nonstatutory assignments' impacts on performance of statutory responsibilities. (See ch. 2.)

--NBS' competence-building program, including (1) the basis used to determine the areas in which competence rebuilding is necessary, (2) if the program received funding at the expense of mission programs, and (3) competence funding allocated to basic research, applied research, and other activities since the program began. (See ch. 5.)

--Information on JILA, including (1) how it fits into NBS operations, (2) its contribution to NBS' mission, (3) the amount and use made of its funds, and (4) whether NBS should expand the "joint institute" concept as a means of performing research. (See ch. 4.)

--Information on NBS research grants, including grant amounts and programs involved. (See ch. 2.)

In addition to information on the above matters, the subcommittee requested orally that we provide any other information which we thought would be useful to them during planned hearings. Accordingly, this report contains information on certain matters which we believe the subcommittee may wish to explore with NBS during the hearings. (See pp. 24, 39, and 54.) One of these matters concerned the research and services NBS' customers were obtaining from NBS and whether the research and services were available elsewhere. (See p. 25.) In this regard, we made analyses of responses, other than those reported 1/ previously, to three of the four questionnaires sent in 1979 to a sample (838) of NBS' customers. NBS could not identify the universe of users of its services. Therefore, we sampled a variety of sources, such as mailing lists, members of a professional organization, and other sources. The questionnaire results cannot be projected to the total universe of users of NBS services. However, we have no reason to believe that the responses would be different from those of a statistical sample of all such users.

1/The results of the questionnaires were included in our February 1980 report (see p. 6).

We reviewed various Office of Technology Assessment (OTA), Congressional Research Service (CRS), and National Academy of Sciences evaluation panel reports concerning NBS' mission and/or functions. Some of the issues discussed in the reports are included in this report.

Our work was performed at NBS headquarters and main laboratories in Gaithersburg, Maryland, and at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado. We interviewed key NBS officials and program managers, such as the NBS Deputy Director; Associate Director, Office of the Associate Director for Programs, Budget, and Finance; the Directors of the Planning, Budget, and Program Offices; a former NBS Director and a former Deputy Director; division chiefs; and Colorado University faculty members who were associated with the Joint Institute, one of whom was the former Institute chairman.

We also reviewed various operating procedures and documents including the overall NBS long-range plan and the 5-year Laboratory plans; interviewed Commerce officials including the Assistant Secretary for Productivity, Technology, and Innovation; several NAS scientists and officials; NAS/NBS evaluation panel members; National Oceanic and Atmospheric Administration officials, including an office director; a member of the NBS Statutory Visiting Committee; and the Director, Center for Science and Technology Policy, New York University. We also interviewed several persons from private industry including a consultant from Mitre Corporation; the executive officer of the American Association for the Advancement of Science; and the chief scientist, IBM. In addition, we reviewed the NBS organic act and other specific acts which directly affect NBS operations.

To obtain information on the quality and usefulness of JILA research and the "joint institute" concept as a method of performing research, we interviewed 9 of the 15 NAS evaluation panel members that reviewed JILA operations during the past 5 years--we were unable to contact the other 6 panel members. (See p. 44.)

We believe that the information obtained through interviews, combined with our analyses of questionnaires and our review of NBS' records, reports prepared on NBS by others, and various legislative requirements, accurately describes those aspects of NBS' operations addressed in this report.

We coordinated our work with OTA. Also, we coordinated with CRS in connection with its current efforts to

update the 1971 CRS report 1/ on NBS, which the Subcommittee on Science, Research and Technology, House Committee on Science and Technology, also requested.

AGENCY COMMENTS

We obtained oral agency comments on the report. NBS agreed with the report's conclusions and had no policy problems or problems with the factual information in the report. A few technical comments were made, which we have included where appropriate, to help clarify the report.

PREVIOUSLY ISSUED REPORTS

Within the past 2 years, we have issued two other reports 2/ on the management and administration of NBS which address some of the matters discussed in chapter 2.

1/"National Bureau of Standards--Review of Its Organization and Operations," to the Subcommittee on Science, Research, and Development, House Committee on Science and Astronautics (Sept. 8, 1971).

2/"National Bureau of Standards--Information and Observations on Its Administration" (CED-79-29, Mar. 21, 1979); and "National Bureau of Standards--Answers to Congressional Concerns" (CED-80-49, Feb. 2, 1980).

CHAPTER 2

NBS' MISSION HAS BEEN QUESTIONED

The organic act, as amended, combined with several other legislative mandates, gives NBS a multifaceted mission. The Subcommittee on Science, Research and Technology, House Committee on Science and Technology, is concerned that "NBS appears to be divided as to its function in relation to enabling legislation [organic act] and the subsequent legislative mandates." Also, NBS and others have raised questions about how narrow or broad NBS' functions should be and what function(s) should be emphasized.

The organic act provides NBS with broad, general authority. Under this authorization, NBS has initiated a wide range of scientific activities. Also, the many additional congressional requests, expressed in subsequent legislative mandates, have placed upon NBS a significant number of statutory responsibilities. As a result, NBS has lost some of its freedom to decide which programs are most important to the scientific community. Also, NBS has had problems performing all its assigned functions because resources have not always been provided and its staff ceiling has declined. As a result of the latter, NBS has had to reprogram (terminate) ongoing research to respond to some legislatively mandated functions. This reprograming has apparently caused problems with planning, research continuity, and scientific competence building.

The subcommittee may wish to review during planned hearings NBS' statutory mission and functions to identify problems in obtaining resources and any other problems NBS might have concerning its many responsibilities. Also, the subcommittee may wish to explore with NBS the following matters which may help NBS carry out its current and future responsibilities.

1. Encourage Government agencies to have others perform that work which can be done outside NBS.

2. Limit those services it provides to industry that are available elsewhere.

3. Expand NBS' research grant program.

NBS' MISSION

NBS' statutory mission is broad and multifaceted. According to its long-range plan, NBS may be unique as a Federal agency in having an extremely broad mission that is relevant to nearly every national problem area and economic

sector. Many statutes provide it authority to undertake programs of science, research, and technology. The organic act (passed in 1901), the principal legislation concerning NBS, places no mandatory requirements on NBS; it simply authorizes NBS to perform a variety of functions. The act provides NBS a dual mission: (1) responsibility for standards and measurements and (2) responsibility for providing technical support to other Federal agencies. In addition, other specific legislation has directed NBS to perform certain activities within the scope of the organic act.

The subcommittee in its letter to us expressed concern about NBS' mission and research activities, as follows.

> "NBS appears to be divided as to its function in relation to the enabling legislation [organic act] and the subsequent legislative mandates. On one hand, NBS is to assure maximum application of the physical and engineering sciences through its standards and measurement functions; on the other hand the Bureau is to strengthen and advance the Nation's scientific and technological capabilities and to facilitate their effective application for public benefit.
>
> "1. What changes, if any, in the amended organic act are needed to enable the Bureau to perform these functions?"

The organic act authorizes the Secretary of Commerce, who delegates authority to NBS, to undertake the following functions:

> "(a) The custody, maintenance, and development of the national standards of measurement, and the provision of means and methods for making measurements consistent with those standards, including the comparison of standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions with the standards adopted or recognized by the Government.
>
> "(b) The determination of physical constants and properties of materials when such data are of great importance to scientific or manufacturing interests and are not to be obtained of sufficient accuracy elsewhere.

"(c) The development of methods for testing materials, mechanisms, and structures, and the testing of materials, supplies, and equipment, including items purchased for use of Government departments and independent establishments.

"(d) Cooperation with other governmental agencies and with private organizations in the establishment of standard practices, incorporated in codes and specifications.

"(e) Advisory service to Government agencies on scientific and technical problems.

"(f) Invention and development of devices to serve special needs of the Government."

Other specific legislation has been enacted to supplement the organic act's authority. These additional statutory mandates (see app. III) generally do not give NBS more authority. Rather, they direct that certain activities within the scope of the organic act be performed. As a result of these mandated activities, NBS has lost some of its freedom to decide which programs are most important to the scientific community. Instead, the Congress had focused on national problems and made major policy decisions in science and technology. NBS, however, still has discretion under the organic act to use its scientific expertise to do research it deems important.

Others have also questioned NBS' mission

Questions concerning NBS' mission have been raised several times by NAS 1/ evaluation panels and others. In its 1971 report the Congressional Research Service raised questions about the NBS mission and its functions. The report pointed out that the then-Secretary of Commerce saw the NBS function in a narrow vein "* * * assuring the maximum application of the physical and engineering sciences to the advancement of technology in industry or commerce." The then-NBS Director, however, saw the NBS function in a broader sense: "To strengthen and advance the Nation's science and

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1/The National Research Council, under a contract between NAS and NBS, generally evaluates NBS functions and operations annually through a series of evaluation panels whose members are appointed by the Council.

technology and to facilitate their effective application for public benefit * * *" including industry or commerce, according to the CRS report. The report stated that "It would appear to be important to clarify how narrow or broad should be the goal of the National Bureau of Standards * * *."

Also, a 1978 NAS evaluation panel recognized a problem with the organic act and the NBS mission or role. The panel stated in its report that although the activities of the NBS organizational unit in question were

> "* * * entirely consistent with the NBS Organic Act as amended and with the NBS mission as commonly perceived by those who interact with NBS, the Panel recognizes that the Organic Act perhaps has become outdated and does not directly address rapidly changing technological and research responsibilities of today. Therefore, it recommends that the Department of Commerce and NBS consider how the Organic Act might be updated to reaffirm the current importance of NBS to the nation and to contribute to a clearer understanding of how problem-oriented programs amplify the Bureau's direct usefulness to the nation and thereby enhance the value of the Bureau's contribution to our economy."

In addition, a 1979 NAS evaluation panel also recognized NBS' problem concerning how narrow or broad its role should be and noted that the organic act may need to be revised. The panel's report stated that the panel believed NBS should engage in engineering work in the broad sense rather than pursuing engineering measurements only. According to the report, this required a broad interpretation of the organic act's authority or perhaps some modification of the act.

The act, in our opinion, does not state precisely what the NBS role should be. One panel member told us that some NBS officials interpret the act narrowly and, as a result, restrict engineering work within NBS to measurements. He said that the panel believed the organic act may need to be revised, for "political reasons," to state that engineering work should be done in a broad sense.

The organic act provides broad authority for NBS' performing a variety of scientific functions. The scientific work undertaken at NBS that we reviewed incident to this report did not provide any reasonable basis to question the proposition that such work is within the authority provided by the Congress, either in the Bureau's organic act or in the statutes enacted over the past two decades that have mandated

specific undertakings. Whether NBS' authority would extend to all new programs it initiates to advance the Nation's scientific and technological capabilities will depend on whether the nature and definition of those specific programs fall within the scope of NBS' broad legislative authority.

Still, the mandating by the Congress over the last two decades of various specific NBS undertakings has created problems for the Bureau. As pointed out in our February 1980 report 1/ to the Senate Committee on Commerce, Science, and Transportation and its Subcommittee on Science, Technology, and Space, although we could find no inconsistency, conflict, or substantial duplication among the various statutes that authorize NBS to perform research, questions have been raised both within and outside the Congress about the problems these mandated activities have caused within NBS.

NBS' MANY RESPONSIBILITIES MAY HAVE CREATED PROBLEMS

NBS has had problems performing all its required activities due partly to its multifaceted mission and decreasing staff ceiling. Also, statutes have provided little if any guidance concerning the resources that NBS should devote to its multiple functions, and NBS has not established specific criteria for balancing its resources among its functions. To perform its many functions, NBS has sometimes had to reprogram (terminate) ongoing research. The reprogramings may have created problems concerning planning, research continuity, and scientific competence. (See pp. 18 to 20.)

The Office of Technology Assessment in a March 1978 report 2/ stated that "NBS' mission is divided and has been expanded beyond the organic act." It pointed out that "Our analysis reveals that the most crucial factor affecting NBS performance is internal and external confusion regarding its role and mission." The report stated that the organic act provides two roles for NBS and mentioned subsequent legislation which (1) specifically directs NBS to perform certain technical activities and (2) directs the Secretary

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1/"National Bureau of Standards--Answers to Congressional Concerns" (CED-80-49, Feb. 2, 1980).

2/"Selected Papers on the National Bureau of Standards: A Case Study Within the National Laboratories Assessment" to the Chairman, Subcommittee on Science, Technology, and Space, Senate Committee on Commerce, Science, and Transportation.

of Commerce to perform certain technical activities which are assigned to NBS. In addition, the report stated that the kinds of activities allowed at NBS were determined by budgetary decisions made by the Office of Management and Budget (OMB) or the Department of Commerce.

Concerning the NBS technical support functions to other agencies, the report stated that (1) although many believe these functions should derive only from the NBS standards and measurements role, the organic act allows much broader interpretation and (2) subsequent legislation not only utilized this to expand NBS activities beyond standards and measurements but also authorized NBS assistance to the private sector in such areas as flammability research. As a result of this "variety of definitions" of its mission, NBS, according to the report,

--has had difficulty addressing all the activities it has been asked to perform;

--has no clear sense of priority as to which activities, if any, require more attention; and

--is unable to continue to serve as the Nation's lead laboratory for measurement sciences and standards and also respond adequately to the technical service support demands of other Federal agencies, the Congress, and indirectly, the private sector.

LEGISLATIVE MANDATES AND WORK FOR OTHER FEDERAL AGENCIES

Legislative mandates other than the organic act and the work that NBS does for Federal agencies (other-agency work), about 48 percent of which was also mandated in 1980, have detracted somewhat from NBS' ability to meet its more traditional responsibilities. While NBS' staff ceiling for work funded by all sources has decreased slightly since 1965 from 3,163 to 3,131, its responsibilities and spending for legislative mandates through other agencies have increased sharply.

We were asked to answer the following questions concerning NBS' legislative mandates and work that it performs for other agencies.

"The Bureau, over the years, has developed into a laboratory guided by its organic act missions and other legislative authorities to perform work for outside agencies.

"1. To what extent has manpower and other resources (in constant dollars) been used by the Bureau to carry out the legislative mandates and the outside, non-statutory tasks since 1965?

"2. To what extent have outside non-statutory assignments detracted from the Bureau's capability to meet traditional statutory responsibilities?"

Legislative mandates

As previously mentioned, the Congress in recent years has passed a number of laws giving NBS specific responsibilities for standards and technical functions in addition to the functions authorized under the organic act. These mandated functions have not been carried out without some NBS sacrifice. Because the Congress has not always provided funds to perform these functions, NBS has had to reprogram some of its ongoing base research (about $27 million since 1974) to enable it to meet its legislative responsibilities. This reprograming may have had a negative effect on NBS research capabilities because NBS has not been able to develop necessary competencies. (See p. 55.) In addition, long-term basic research has been reduced to some extent to accommodate the shorter term mandated research.

Like the NBS multiple mission problem, the problems created by lack of funding for NBS-mandated functions have also been recognized. The 1971 CRS and 1978 OTA reports, as well as the May 1980 House Committee on Science and Technology report authorizing NBS' appropriations for fiscal year 1981, mentioned the mandated activities and some of the resulting problems. For example, the CRS report questions whether the Congress was

> "being penny-wise in adding to the work of the Bureau by legislation such as that directing advances in fire research and safety, but then delaying on Bureau requests for funds to implement its responsibilities * * *."

In another instance, the report mentions that in recent years a major portion of the NBS appropriated funding increases had been used to fund functions assigned by the various acts and that according to testimony at appropriation hearings, this had adversely affected NBS' capability to meet its traditional statutory responsibilities. The report asks, "Is there a danger that the Bureau's activities

will become too thinly spread, leading to management difficulties, and neglect of its basic functions of measurements and standards?"

We also noted that NBS in recent years used a major portion of its appropriated funds to carry out functions assigned under various acts. Since 1971, 1/ NBS' and other Federal agency resources provided to NBS and applied to legislative mandates have increased, in constant dollars, 2/ from $1.6 million to $14.7 million (819 percent). Also, staff years spent on this work increased from 50 to 488 (876 percent). However, NBS' direct appropriations, in constant dollars, increased only from $27.8 million to about $31.4 million (13 percent) since 1971. (See app. IV.)

The OTA report points out that the addition of the many new mandated programs and the growth of work performed for other agencies without a proportionate increase in staff, resulted in a decline in basic research at NBS. Also, the report stated that (1) many of the mandated programs were reassigned to NBS by Commerce or required that NBS perform work under the direction of a "lead agency" 3/ and (2) NBS had responded to these new assignments by reprograming staff and funds to meet legislative deadlines.

The House Committee on Science and Technology's report points out that in those cases where the Congress mandated tasks but did not provide the funds to carry them out, NBS has had to approach the related lead agency for the needed funding if it did not reprogram existing research resources.

1/According to NBS records, very limited spending for mandated work took place before 1971--16 of the 20 mandates affecting NBS were enacted after 1971.

2/Derived from statistics from the Bureau of Economic Analysis, U.S. Department of Commerce. Implicit Price Deflator for Federal Employee Compensation based on 1965 dollars. (See app. IV.)

3/An OMB-designated agency that is charged with a specific mission and is the primary source of funds to support all activities concerning that mission, whether carried out by the agency or by others.

Our February 1980 report outlined the problems NBS has experienced with the OMB lead agency policy--that NBS' ability to do its job had been hampered because the lead agency did not always provide funds to NBS. We recommended that, if the Congress decided to amend or revise the NBS organic act, the language make clear the areas in which NBS was to have lead agency responsibility. When the House Committee on Science and Technology authorized NBS' fiscal year 1981 appropriations, it recognized the problems caused by the lead agency policy and the legislatively mandated tasks required of NBS. The committee, for example, reported that the mandated activities have merit in general but not at the expense of ongoing programs. The report further states that specific funding for such mandated activities should be provided either by the lead agency or through congressional authorization and appropriation of such funds to NBS. Similar views on the mandated activities are contained in the Senate Committee on Commerce, Science, and Transportation's report on NBS' authorizations for fiscal years 1981 and 1982.

NBS work for other Federal agencies

Other-agency assignments may have detracted somewhat from NBS' capability to meet its more traditional responsibilities. As previously mentioned, NBS' staff ceiling since 1965 has decreased from 3,163 to 3,131 while NBS has been given more responsibility. Also, NBS' planning, continuity of work, and competence are adversely affected by the emphasis on short-term, other-agency work, of which about 48 percent ($28 million) can be attributed to specific legislative mandates.

Funds from other agencies since 1965 have increased in constant dollars from $15.0 million to $21.1 million (41 percent) while NBS' direct appropriations in constant dollars have increased only about 18 percent--from $26.5 million to $31.4 million. (See app. IV.)

NBS estimated that during fiscal year 1980, work funded by other organizations, primarily Federal agencies, accounted for about 44 percent (about $72.4 million) of all its work. The percent of other-agency work was reported to be about 45 percent in fiscal year 1979. In NBS' two major laboratories, the National Measurement Laboratory and National Engineering Laboratory, other-agency work in fiscal year 1980 accounted for 29.6 and 54.1 percent, respectively, of

the research funded. The percent of other-agency work in one center 1/ in the National Engineering Laboratory was about 85 percent, according to a 1980 NAS evaluation panel report.

During authorization hearings in February 1980, the Subcommittee on Science, Research and Technology, House Committee on Science and Technology, questioned the balance among NBS functions, the adequacy with which NBS responded to the functions, and the internal balance of the work in response to needs. A member of the NBS Statutory Visiting Committee testified that balance among these functions was an issue of concern and that the Visiting Committee would advise that NBS do less other-agency work. He pointed out (1) the difficulty of trying to manage research for which 40 percent of the funds were completely at the discretion of outside agencies and (2) the uncertainty of continuity.

According to NBS policy, any proposed other-agency work must meet at least one of the following criteria before NBS can accept it.

1. Acceptance by NBS establishes traceability of measurements to national standards. This covers other-agency work related to the basic responsibility stated in the organic act authorizing NBS to undertake "the custody, maintenance, and development of the national standards of measurement."

2. The private sector cannot or will not develop test methods for materials, mechanisms, and structures related to items the Government purchases or that are important to the public interest.

3. Support services to other agencies are authorized or mandated by specific legislation other than the organic act.

4. A contract placed outside the Federal Government would result in an unavoidable conflict of interest. Much of the work NBS performs for regulatory agencies falls under this criterion.

1/The largest organizational unit within the two major laboratories, consisting of several divisions/offices.

5. Requirements for accuracy of physical constants and properties of materials cannot be met by other sources.

6. NBS' unique capability is required for support services to other agencies.

7. Other-agency use of a private sector source would cause significant and intolerable delays in providing services.

8. Other-agency use of a private sector source would cost the Government more. NBS policy is that it generally will not accept work solely because it will be less costly to the sponsor.

Generally, work that NBS does for other agencies is classified as applied research. Also, according to an NBS official, most other-agency work is technical, problem oriented, and short term, usually turning over within 1 year.

The organic act provides that NBS furnish services to support other Federal agencies. According to an NBS analysis of all its research projects underway as of July 1980, about 48 percent (about $28 million) of NBS' other-agency work can be attributed to specific legislative mandates. Some of the problems that these legislative mandates have created within NBS were mentioned previously. (See p. 13.) The statutes mandating that NBS perform work for other agencies and the dollar amounts NBS received for performing this work in fiscal year 1979, and expects to receive in fiscal year 1980, are included in appendix III. As shown in this appendix, the largest reimbursements to NBS in fiscal year 1980 resulted from work done under the Federal Fire Prevention and Control Act of 1974, as amended ($7.9 million), and the National Energy Conservation Policy Act (about $3.2 million).

According to the NBS Director, each year NBS provides technical support to more than than 100 Federal agencies; over the years the Department of Defense has been a "major client." We noted that in recent years the Department of Energy has become by far the major client of NBS, accounting for $20.3 million or about 32 percent of all NBS other-agency work. The top 10 other agencies for which NBS is doing work and the dollar amounts of the work follow.

NBS Other-Agency Funding
for Fiscal Years 1977-80

Agency	Fiscal year 1977	1978	1979	1980
	(millions)			
Department of Energy/ Energy Research and Development Administration	$10.2	$15.2	$16.6	$20.3
Department of Defense	9.9	11.7	12.1	11.3
Environmental Protection Agency	1.7	1.7	3.3	4.7
Federal Emergency Management Agency	-	-	-	a/4.3
Department of Health and Human Services (formerly HEW)	2.5	3.1	3.0	3.4
Department of Commerce	7.7	7.4	7.5	a/2.8
Department of Justice	1.2	1.1	1.2	2.8
Department of Transportation	1.6	1.4	1.8	2.5
National Aeronautics and Space Administration	1.6	2.0	1.7	2.3
Department of Housing and Urban Development	3.7	2.7	2.7	1.7

a/Fire Administration funding transferred from Commerce to the Federal Emergency Management Agency.

Appendix IV shows in constant and current dollars the overall amounts that NBS has used to perform other-agency work since 1965.

Although NBS other-agency work may be considered desirable on one hand--it helps resolve problems of the mission-oriented agencies that in turn may be addressing national problems/needs--it also may create problems within NBS concerning (1) planning, (2) continuity of research and staff, and (3) building scientific competencies. The latter are generally associated with long-term research and are needed to ensure that adequate technical support can be provided to the other Federal agencies and the private sector.

The NBS Director testified before the Congress in February 1980 that there was always a problem with other-agency work in that the other agencies were somewhat reluctant to support NBS long-range work; they have immediate problems that they want NBS to address. According to NBS, this emphasis on short-term problems adversely affects its long-range planning. The fiscal year 1979 evaluation panel report on the National Engineering Laboratory points out the panel's concern for the high percentage of other-agency work within some NBS organizational units and the impact this has on long-range programs. For example, the report states that other agencies funded at least 90 percent of the $18 million spent in fiscal year 1979 on energy programs in the National Engineering Laboratory. This percentage, according to the report, shows the importance of this Laboratory's work to the Government, but it presents a danger that the Laboratory might become a "job shop" for other agencies and lose the ability to independently undertake needed long-term programs.

In addition, an NAS evaluation panel member, in response to a question concerning the extent of NBS' role in serving the needs of all Government agencies, stated during NBS hearings in February 1980 that unless there was a basic standards program within NBS, it would not be able to adequately serve the other agencies. Also, the panel member said that if NBS did too much work applicable to Government needs, its primary mission would be lost.

NBS' long-range plan states that its management tries to keep other-agency work in the 35-45 percent range, although there was no analytical basis for any particular optimum ratio. The plan cautions, however, that a problem would ensue if this work grows to 50 percent of NBS' total effort. For the time being, NBS appears to believe that because it normally has requests for significantly more other-agency work than it can do within its personnel ceiling, the ceiling will continue to stabilize the level of this work.

The problem that other-agency work creates with NBS' research continuity is illustrated by a General Services Administration official's acknowledgment that his agency's annual funding of NBS work until 1980 had been "erratic." NBS acknowledged that "in some instances" work for other agencies had caused a problem--when the work being done for another agency neared completion, NBS had to decide where to use the staff resources being released. NBS estimated that between 6 and 8 percent of its appropriated funds--$5.6 to $7.4 million in fiscal year 1980--has to be reassigned in this manner.

The House Committee on Science and Technology's May 1980 report authorizing NBS' appropriations states that to ensure that NBS can provide technical support to Federal agencies, it must maintain "general technical competence" to respond to emerging national needs. The report states that NBS' ability to respond directly to mandated responsibilities, other Federal agency needs, and industry and public needs is determined by the basic technical capability of the NBS staff and a planned program of long-term research.

Actions being taken to resolve problems caused by other-agency work

Two congressional committees have recently recognized NBS' problems concerning other-agency work. To help resolve these problems, NBS has started obtaining longer term commitments from the agencies. According to its officials, NBS had entered into "memoranda of understanding" for longer term work with about 20 agencies as of February 1980. These longer term commitments will, NBS believes, help to formulate its long-range plan and provide more continuity of work, which will also help to build up and sustain needed competence. These arrangements may also help the other Federal agencies anticipate their long-term needs and problems concerning standards and new technologies.

Also, NBS has started (in 1979) a program to help rebuild its scientific competencies to respond to mandated responsibilities and needs of other Federal agencies, industry, and the public. One scientific expert said that this program would restore a declining flexibility and increase NBS' freedom to plan and think in new directions. The program is discussed more fully in chapter 5.

RESOURCE ESTIMATES TO CARRY OUT LONG-RANGE PLAN

According to one of the major NBS laboratory's 5-year plans, two trends--the computer revolution and the increased use of modeling 1/--will have a major impact on the way NBS provides its services to the Nation over the next decade. The plan states that these rapidly moving developments will require expanded capabilities and services in several areas.

1/Includes physical science modeling emphasizing fluid dynamics and certain electrical behavior in semiconductor devices, methods for applying and evaluating large-scale discrete mathematical models, and various statistical modeling.

Neither NBS' overall long-range plan nor the 5-year plans for two of its three major laboratories address manpower and financial resource requirements. However, based on programs in its long-range plan, NBS did develop rough estimates of direct appropriation requirements for 1985 ranging from about $89.3 million to $169.0 million.

We were asked to provide information on NBS resource requirements, as follows.

> "After reviewing NBS's current short-and-long-range plans, what financial, physical, and manpower resources will be required to meet the Bureau's present goals in the areas of competence building, operational equipment, facilities, and funding, as well as the expanded goals mentioned in questions 1 and 2 [see pp. 62 and 63]?"

To carry out planned activities, the National Engineering Laboratory's 5-year plan (fiscal years 1980-85) shows that by 1985 it will need an estimated $105.4 million (in constant 1980 dollars) and 1,233 staff, compared to the fiscal year 1980 estimates of $70.9 million and 977 staff--an increase of $34.5 million and 256 staff. These estimates represent increases of 49 percent in funding and 26 percent in staff. A breakdown of the increases by source of funds and specific program areas follows.

Expected Changes in Funding
for National Engineering Laboratory Programs
Fiscal Years 1980-85

Source of funds	Program area	Fiscal year 1980	Fiscal year 1985	Percent change
		(millions)		
Direct appropriation	Productivity	$12.4	$ 29.5	138
	Safety	4.7	9.9	111
	Energy	1.6	2.6	63
	NBS services	3.6	7.2	100
		22.3	49.2	121
Reimbursable	Productivity	16.2	19.9	23
	Safety	13.8	18.9	37
	Energy	15.1	13.8	(9)
	NBS services	3.5	3.6	3
		48.6	56.2	16
Total		$70.9	a/$105.4	49

a/Does not include $0.2 million for general purpose equipment.

The overall long-range plan states that NBS' "broad charge as custodian of the Nation's measurements and standards continues to define an array of needs and technical opportunities far larger than its resources." The long-range plan does not specifically address NBS resource requirements, stating that this was a topic confined to the 5-year plans of the three major laboratories. As mentioned, however, only one of the three laboratory plans contained these requirements.

The NBS-wide long-range plan states that for NBS to carry out its broad mission in a resource-constrained environment requires very careful resource management. In July 1980 NBS developed for each program category in the plan, tentative budget projections to accompany the long-range plan. According to NBS, some projections are arbitrary but are accurate enough to give an indication of the level of effort needed. Also, these projections are for direct appropriations only. NBS' projections for fiscal years 1980 and 1985 follow.

NBS Funding Estimates for Planned Programs

Program	FY 1980	FY 1985 Low (note a)	FY 1985 High (note b)
	(millions)		
Basic Measurement and Standards	$18.3	$19.6	$ 26.5
Enhanced Development & Utilization of Materials	14.6	14.9	22.1
Changing Measurement Applications from Advanced Electronics	6.4	10.4	14.2
Improvements to Industrial Productivity and Innovation	11.5	12.7	42.7
Increased Measurement Support for Equitable Regulation	5.6	6.0	14.2
Technological Support to Energy Development	3.1	3.5	3.5
Enhanced Federal Information Processing	11.2	11.9	21.9
Collaborative Programs with Other Federal Agencies	4.1	4.5	5.8
Other	5.2	5.8	18.1
Total	$80.0	$89.3	$169.0

a/Approximate projections which show low to no growth.

b/Includes anticipated initiatives.

CONCLUSIONS

The organic act, as amended, combined with several other specific legislative mandates, gives NBS a multifaceted mission. NBS and others, including OTA, CRS, and NAS evaluation panels, have raised questions about NBS' many functions and what function(s) should be emphasized.

We noted that NBS has had problems performing all its assigned responsibilities because resources were not always provided to carry out new work specified by legislative mandates. As a result, NBS has had to reprogram ongoing research to carry out some of the mandates. This reprograming may have adversely affected NBS' planning, research continuity, and competence.

Two congressional committees have recognized some of NBS' problems concerning its mission or functions, specifically those concerning the other Federal agency and mandated work. The Subcommittee on Science, Research, and Technology may wish to review during hearings NBS' statutory mission and functions to identify problems in obtaining resources and any other problems NBS might have concerning its many responsibilities, such as those pointed out by OTA, CRS, and NAS evaluation panels. Also, as requested, we have identified other matters, as follows, that may help NBS carry out its many responsibilities, which the subcommittee may also wish to explore with NBS during planned hearings.

MATTERS FOR CONSIDERATION BY THE SUBCOMMITTEE

Three matters which the subcommittee may wish to explore with NBS during hearings on the organic act are the possibility of (1) NBS encouraging Government agencies to have others perform that work which can be done outside NBS, (2) limiting the services NBS provides to industry that are available elsewhere, and (3) expanding NBS' research grant activities. Other issues--possible new NBS research roles concerning productivity and innovation and expanded use of the "joint institute" concept--are discussed in chapters 3 and 4, respectively.

NBS is doing work and providing services that are available elsewhere

NBS is performing some activities for Federal agencies and others, such as industry, that the private sector is apparently capable of doing, including research and services. Questionnaires 1/ we sent to users of NBS research and testing services in 1979, the results of which were included in our February 1980 report, showed that industry and Federal agencies acknowledge that a significant part of the research and/or services they had NBS perform were also performed by others.

Also, the House Subcommittee on Science, Research and Technology during authorization hearings in February 1980, raised the point that private organizations had expressed some concern about any Government agency providing to other Government agencies services or products that private industry could provide. In this regard, one questionnaire we sent to 206 users of NBS research and testing services in 1979 showed that a significant amount of the research and services they obtained from NBS was available elsewhere. For example, 48 (57 percent) of the 84 Federal agencies--the primary user group--responding to one question said that the kinds of research/testing that NBS did for them was also done by others. Most said they used NBS primarily because of the quality of the research/testing obtained; several also said that NBS' credibility was a major reason.

Of the 119 industry responses to a question in another questionnaire on NBS calibration 2/ services, 80 (67 percent) said the calibrations that NBS performed for them "during the

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1/To obtain users' reactions to and opinions on NBS services, a series of four questionnaires were sent to a sample of NBS' customers totaling 838--206 customers for research and testing, 200 for calibrations, 245 for standard reference materials, and 187 for standard reference data. NBS could not identify the universe of users of its services. Therefore, we sampled a variety of sources, such as mailing lists, members of a professional organization, and other sources. The questionnaire results cannot be projected to the total universe of users of NBS services. However, we have no reason to believe that the responses would be different from those of a statistical sample of all such users.

2/Calibrations are to ensure that instruments and devices conform with preestablished NBS standards.

past 2 years" were available from other sources. Most said they obtained calibrations from NBS "to ensure traceability" and/or because they believed NBS calibrations were "superior."

A third questionnaire sent to users of NBS' standard reference materials 1/ showed that about 46 percent (33) of the primary user group (industry) that responded to one question said that the reference materials they obtained from NBS "during the past 18 months" were also produced by others. About 29 percent (21 respondents) said that during the 18-month period they obtained from others standard reference materials available at NBS.

NBS officials acknowledged in February 1980 that NBS had on occasion transferred activities, such as calibrations, to States and regional groups. According to these officials, transfer of services from NBS to others is essential to dispersing accurate measurements, and NBS resources can then be devoted to higher priority measurement problems arising from changing technology.

The subcommittee may wish, therefore, to explore with NBS the possibility of (1) encouraging Government agencies to have others perform that work which can be done outside NBS and (2) limiting the services it provides to industry that are available elsewhere.

Expand grant program

The Federal Grant and Cooperative Agreement Act of 1977 (41 U.S.C. 501) provides that Federal agencies will use a procurement contract whenever the principal purpose is the acquisition of services for the direct benefit or use of the Federal Government. Grant agreements are to be used when the principal purpose is the transfer of money, property, services, or anything of value to a recipient in order to accomplish a public purpose of support or stimulation authorized by Federal statute. NBS makes research grants of about $2,491,000 annually--only $491,000 is NBS-funded--primarily for three programs.

--The Extramural Fire Research Program, which is administered under section 18 of the Federal Fire Prevention and Control Act of 1974 (15 U.S.C. 278f). Under this program NBS' Center for Fire Research,

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1/Actual materials in their solid, liquid, powdered, or gaseous state certified as to their chemical composition, chemical property, and/or physical property.

which obtains funds from the Federal Emergency Management Agency, grants about $2 million annually to support the Center's fire research program.

--NBS precision measurement grants totaling $150,000 annually are awarded to academic scientists for work in precision measurement and fundamental constants--areas important to measurement science. Two new grants of $25,000 each are made annually, renewable at NBS' option for 2 additional years. The program is funded from the NBS Director's reserve fund.

--A grant is made annually to fund visiting scientists at the NBS/University of Colorado Joint Institute for Laboratory Astrophysics. This grant totaled $341,000 in fiscal year 1980.

Additional grants other than for research totaling $447,866 in fiscal year 1980 were made by NBS' Office of Standard Reference Data to support data compilation and evaluation centers. Also, a $57,250 grant was made to support a data advisory board and committee. In addition, other agencies' funds were used to make grants totaling $203,797 for data compilation and evaluation.

NBS officials expressed the belief that an expanded grants program could be beneficial in expanding NBS' scientific efforts. Also, other advantages cited were:

--A synergistic reaction between NBS in-house programs and grantee programs.

--Ability to attract the best scientific talent available.

--The provision of resources to encourage training students in areas useful to NBS.

These officials also stressed the importance of maintaining NBS' position as a research laboratory by restricting the grants program to a relatively small percentage of its resources--10 to 15 percent ($9-$14 million) was suggested. Also, one of the officials said that any increase in the grants program should include an increase in resources to fund the program. Otherwise, resources would have to be diverted from in-house programs, thereby negating the advantages of an increased research grants program. In addition, the official stressed the importance of retaining, as an in-house activity, work on measurement standards--where NBS must often act as an independent third party.

CHAPTER 3

NBS' ROLE IN PRODUCTIVITY AND INNOVATION

In response to the growing concern about the Nation's rates of productivity and innovation, 1/ the House Subcommittee on Science, Research and Technology is exploring the possibility of adding new roles to NBS that would contribute to improving productivity and enhancing innovation. Specifically, the subcommittee is interested in (1) NBS' current role and involvement with other Federal agencies in the areas of civilian technology research and development, productivity, and innovation, (2) identifying potential new roles for NBS, and (3) assessing the NBS organic act to determine what changes, if any, would be needed to add new roles to NBS.

Our investigation of the subcommittee's concerns revealed that the broad wording of NBS' organic act provides no explicit basis for defining the relationship of its statutory mission to productivity and innovation roles. Also, potential conflicts exist between any new roles and several organizational characteristics that make NBS an effective institution. Given the importance of many of NBS' current functions, we believe new roles that would significantly impair its ability to perform these functions should be avoided.

Before new roles are added, we believe it essential to understand what role NBS currently plays in productivity and innovation and what impact new responsibilities could have on its ability to fulfill its current roles. In considering new roles for NBS, this chapter examines the following:

1/Productivity, as used here, is a measure of output per unit input. Many factors affect productivity, including the weather, the state of the business cycle, the education and experience of the work force, and the amount of capital available for each worker. However, in this chapter, advancing technology will be the factor given almost exclusive attention as a means to increase productivity.

Innovation, as used here, is a developmental process which begins with the generation of a new idea and results in the commercial introduction of new products and processes. The only forms of innovation that affect productivity are the new processes and new products (advancing technologies) used in manufacturing processes and in services.

--NBS' current contribution to productivity and innovation.

--Organizational characteristics essential to NBS' effectiveness.

--Potential new NBS roles affecting productivity and innovation.

--Implications of new roles for the NBS organic act.

NBS ACTIVITIES CURRENTLY MAKE A UNIQUE CONTRIBUTION TO PRODUCTIVITY AND INNOVATION

Current NBS activities that affect productivity and innovation may be divided into two categories: support of the science and technology infrastructure, 1/ and research more directly targeted to affect productivity and innovation. Research that supports the science and technology infrastructure has important effects on productivity and innovation, although these effects are indirect and often long term. Research with a more readily observable impact on productivity and innovation is underway at NBS in automation, chemical engineering, and electronics.

Supporting the science and technology infrastructure

Much of NBS' work supports the science and technology infrastructure. Examples of NBS' contributions to the infrastructure include providing standards, developing testing and measurement procedures, disseminating scientific tables and equations, and generating formal communication mechanisms in the form of scientific journals, symposia, and peer associations.

By supplying standards and testing procedures, NBS assists the private sector with such industry functions as

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1/The science and technology infrastructure, as used here, refers to the underlying foundation of scientific and technical knowledge, instrumentation, and organizational networks upon which the Nation's scientific and technical community depend. The organizational networks facilitate the dissemination of scientific and technical knowledge, which is essential both in the creation of that knowledge and in its effective use. The term "infrastructure" thus refers both to the social network through which knowledge is created and used and to the knowledge itself.

(1) controlling product quality, (2) selecting materials, (3) designing production processes, (4) reducing transaction costs, and (5) protecting workers and the environment (via designing environmental monitoring instrumentation). Through providing such services, NBS has continually contributed to industrial productivity and innovation, but its effect is usually indirect in contrast to the effect of a direct change on a production line. These indirect effects are often complex, long term, and somewhat obscure.

As an example of research with an indirect impact on productivity and innovation, NBS might design a new device for calibrating tolerances more accurately in manufacturing machined parts. This device would monitor the variation in dimensions of the machined parts. Parts within the specified tolerances would be accepted, while the others would be rejected. As a more accurate instrument for gauging dimensions, it should improve the productivity of the manufacturing process both by rejecting fewer parts that actually fall within acceptable tolerances and by accepting fewer parts that actually fall outside of acceptable tolerances. In the first case, productivity is improved through conserving resources; in the second case, by enhancing the quality of the final product--the machined part has a higher probability of effectively performing its function.

In the above example, the impact on productivity might seem less obvious than for an invention such as a new drill press with a faster cutting rate that would directly increase the speed at which those machined parts could be manufactured. However, though more subtle, the effect on productivity of devices such as more precise measurement instruments may be just as beneficial as technologies with more readily perceived productivity impacts. 1/ We believe this insight is fundamental to understanding how the type of research NBS performs affects both productivity and innovation.

1/NBS has recently contracted with Charles Rivers Associates to verify empirically the economic impact of its standards and measurement activities. Also, the NBS Planning Office has recently completed two short papers, "The Impacts of Private-Sector Standards on Industrial Innovation and Growth" and "The National Bureau of Standards Support of Industrial Innovation and Growth," both of which attempt to establish a framework for analyzing the economic impact of NBS activities.

Programs with a more direct impact on productivity and innovation

Although most NBS research can be classified as having indirect effects on productivity and innovation, NBS is currently expanding some programs that may have a more direct impact. Explicit concern for productivity and innovation has been shown since NBS' reorganization in 1978, when these concerns first appeared as an NBS program activity. This program activity, called Research for Industrial Productivity and Innovation, cuts across all NBS major organizational units.

Many of the research projects under Research for Industrial Productivity and Innovation existed before this title was created. A careful examination of the descriptions of the research projects included under it (see app. V) reveals that the nature of the research remains the same--developing standards and measurement and testing procedures--even though the rationale for carrying on the research is couched in terms different from other NBS work.

Other NBS research, such as materials or energy-related research, could arguably be included in the productivity and innovation budget category. However, we have not attempted to determine the degree to which individual research projects affect productivity and innovation since such an undertaking is beyond the scope of this report.

Currently there are 22 research projects in progress under Research for Industrial Productivity and Innovation, divided into three general classes: discrete batch manufacturing technology (automation); continuous process technology (chemical engineering); and electrotechnology (electronics). These projects are listed in appendix V with estimates of funding from NBS and other agencies and a brief description of their potential productivity impacts. In 16 of the 22 research projects, other Federal agencies provided funding greater than, or equal to, that supplied by NBS. As of September 1979, NBS had committed $10,754,000 (11.6 percent) of its fiscal year 1980 budget to productivity and innovation research, while other Federal agencies had committed an additional $13,350,000; but given the nature of other-agency funding at NBS, budget commitments are only estimates and should be treated as such. The total funds for this activity ($24,104,000) represent about 15 percent of all NBS funds received in fiscal year 1980, including funds received from other agencies. This category of research is projected to increase to approximately $50,000,000 by fiscal year 1985 (includes both NBS and other-agency funding).

The various research projects listed in appendix V are intended to improve productivity through the optimal utilization of advanced technologies. Such projects improve productivity by maximizing output per unit input of raw materials, energy, and human capital, and by minimizing negative effects such as environmental pollution and safety hazards. NBS helps industry make optimal use of advanced technologies by developing standard reference materials, mathematical models, testing methods, and prototype testing equipment, as well as by generating measurement data.

Research in automation

NBS has undertaken a number of projects in discrete batch manufacturing technology that are designed to increase productivity in the manufacture of mechanical parts. Maintaining high levels of productivity requires instrumentation to detect and correct operating malfunctions, especially in industries involving electronics, such as semiconductors, computers, and telecommunications. In such industries, increasing miniaturization of products, such as integrated circuits, increases the risk that relatively small errors in a manufacturing step can ruin an entire batch of a product. Quality control instrumentation that detects a malfunction early in a manufacturing sequence, and intervenes quickly and selectively to correct whatever malfunction exists, maximizes productivity and helps achieve the goal of automated manufacturing by enabling the production process to operate continuously.

Research in chemical engineering

In continuous process technology, NBS is pursuing research on parameters (specifications such as operating temperature) that affect the overall design of manufacturing plants and equipment. The productivity of manufacturing systems can be increased if better data is available on such characteristics of the production process as temperature, pressure, and turbulence. With this data, equipment can be designed to meet the performance standards necessary to optimize the manufacturing process. For example, knowing the optimal temperature and pressure of a specific chemical reaction can help an engineer design a containment vessel with precisely those parameters, thereby avoiding a design which would use excessive energy and/or materials.

Research in electronics

Designing electronic devices that neither produce excessive electromagnetic interference 1/ nor are overly susceptible to it is an example of research NBS is undertaking in electronic technology. NBS research in electromagnetic interference illustrates a way to increase productivity by minimizing the negative effects of specific technologies. If, as in the case of electromagnetic interference, a component of a system produces effects which reduce the effectiveness of the overall system, then the productivity of that system is reduced.

NBS HAS DEVELOPED ORGANIZATIONAL CHARACTERISTICS THAT ARE ESSENTIAL TO ITS EFFECTIVENESS

When considering new roles for NBS, we believe it essential to realize that NBS possesses characteristics as an organization that are crucial to the effective performance of its current roles. Four of those characteristics are responsiveness as an organization, technical competence, third-party objectivity, and capacity for strategic assessment.

Responsiveness as an organization

Since its establishment in 1901, NBS has gone through a series of major changes in program focus that demonstrate its responsiveness as an organization. During World War I, NBS responded to an acute shortage of optical glass by actually producing that material, and in World War II, when the demand for NBS-invented proximity fuses could not be met by private manufacturing firms, NBS became a major producer.

NBS was heavily engaged in military research for the Department of Defense (DOD) from World War II through the Korean War. In the early 1950s the Congress questioned the wisdom of having NBS receive up to 85 percent of its budget from projects initiated by other Federal agencies (principally DOD). The House Appropriations Committee recommended that the percentage of other-agency funding be reduced and that the lost funding be replaced with direct increases

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1/Electromagnetic interference is the unwanted coupling of two or more electronic circuits that can inhibit proper functioning of the circuits. Where electronic equipment is used heavily, such as in banks or intensive-care units, it can seriously impair the normal operations of a coordinated system of electronic equipment.

in the NBS budget. That policy was adopted, and since the 1960s NBS has maintained other-agency funding at levels of 40-45 percent.

The concern of the early 1970s was for research targeted at social needs such as building safety, consumer product safety, and air and water quality. NBS promptly responded to such social needs as consumer product safety, and research was undertaken before the establishment of the Consumer Product Safety Commission. After a period of providing increasing service to other Government agencies, NBS now appears to be moving toward greater support for industries such as electronics, energy, manufacturing, and materials. Providing research support to specific industries is not a new function for NBS; it has done so since the 1920s for such sectors as the paper and pulp industry and the dental industry.

Technical competence

In contrast to other Federal laboratories, NBS is not oriented primarily toward direct support of a specific industry or a particular Government mission. Rather, NBS supports the science and technology infrastructure. To do so, NBS employs individuals from a wide range of disciplines. As a consequence of this institutional orientation, NBS is often the only Federal laboratory having the broad scientific expertise necessary to examine technical problems that cut across several scientific disciplines. Acceptance of NBS' technical competence by outside groups is shown by the increasing demand for NBS to perform more work that supports the science and technology infrastructure, such as the development of advanced calibration instrumentation.

Third-party objectivity

As the Nation's central reference laboratory for standards and measurements, NBS adheres to a policy of sustaining objectivity in its relationships with industry and other Government laboratories. Internally, NBS is very sensitive to being recognized as neutral. It displays that sensitivity in its reluctance to become involved in programs which, while politically popular, might strain its relationship with the private sector. For example, NBS has been concerned that its recycled oil project, which develops test methods to characterize recycled oil for specific end uses, has been interpreted by some observers as competing with industry efforts in that area. In addition to being criticized for possibly competing with industry, NBS can also be criticized for establishing too intimate a relationship with an industry or an individual firm. Such an intimate relationship could be

viewed as a conflict of interest, wherein public resources could be used to promote the interests of a given industry or firm.

NBS management seeks to avoid both types of criticism by maintaining an awareness of the delicate balance that must be struck between NBS' need for independence as a standard reference laboratory and its need for responsiveness to industry needs. Two of the strategies NBS employs to maintain its reputation for neutrality are avoiding the later stages of product development and shunning regulatory roles that could bias its judgment.

NBS' distinctive policy toward product development derives from an organizational attitude of being an objective arbitrator of issues dealing with scientific standards. At NBS, product development is usually not taken as far as it is in other Federal laboratories, where the usual policy is to continue developing a new technology to the point of pilot demonstration. Development at NBS usually ends with an early-generation prototype, a few steps prior to pilot demonstration. Then other Federal agency or private sector laboratories are left to continue development.

By avoiding regulatory responsibility, NBS enhances its image as an objective third party. NBS does supply standards and testing procedures to various regulatory agencies, such as the Environmental Protection Agency and the Occupational Safety and Health Administration, but it does not take on the responsibility of setting standards in these areas. As an interested observer, NBS often provides technical advice to standards-setting bodies, but according to NBS officials, it does not become involved in the politically sensitive matter of prescribing standards.

Capacity for strategic assessment

The combination of NBS' planning process with mechanisms for obtaining advice from independent persons and organizations gives it a growing capacity to identify appropriate and timely roles. Under the direction of the Office of Management and Budget, NBS created a central Planning Office in 1978 to coordinate the planning activities of the major operating units and to undertake a more anticipatory, active approach to planning. One of the Planning Office's objectives is to strategically assess developing technologies to identify areas where NBS inherently has a comparative advantage in research. NBS' comparative advantage is specific to those technical fields in which it has a well-developed expertise and the industry involved does not. A comparative advantage also results

from researching multiple problems that may require a broad range of expertise that is usually not available in individual firms but does exist at NBS. The Planning Office selects research areas targeted to meeting national needs (such as advanced energy technologies).

In addition to the Planning Office's work, a number of mechanisms exist at NBS that provide information and feedback regarding NBS research. For example, a research associate program brings private sector scientists and engineers to NBS for discrete periods of time. This inflow of working personnel provides another means of exposure to industry's needs and interests. Appendix VI contains a listing of recent corporate participants in this program.

POTENTIAL NEW ROLES MUST BE CAREFULLY ASSESSED

Proposals for additional contributions that NBS can make to help increase productivity and enhance innovation can be grouped into two categories: (1) marginal adjustments to current activity levels and (2) significant program departures. These proposals should be examined for their possible impact on the credibility and effectiveness of NBS--how will these proposals affect NBS' responsiveness as an organization, its technical competence, its third-party objectivity, and its capacity for strategic assessment? The following discussion focuses on the five most frequently proposed new roles and lists some of the advantages and disadvantages of adopting them. Sources of these proposals are people in industry, academia, and other Federal agencies, as well as NBS personnel.

Marginal adjustments

Formal designation of technology transfer agents

Officially designating selected NBS personnel as technology transfer agents to specific industries would be one way of enhancing NBS' sensitivity to the problems of applied engineering science. These technology transfer agents would represent NBS in the industrial environment by transferring NBS technology to the private sector and by bringing industry problems into NBS. Although numerous informal relationships exist between NBS professionals and their industrial peers, there is no formal institutional focal point to which industry can transmit its problems. In order to maintain neutrality, the formal designation of technology transfer agents would have to be implemented in a way that would allow NBS' work to remain targeted at industry-wide needs and not the problems of a single firm.

The existence of a more formal technology transfer mechanism could be designed to enhance both NBS' ability to communicate effectively with industry and its own research in engineering science.

Targeted exploratory research

Increasing NBS' long-term exploratory research would be another marginal adjustment for NBS. Industry is generally receptive to the idea of NBS undertaking applied research which is not aimed at designing a specific product but which lays the groundwork for future technologies. For example, NBS research on corrosion-resistant coatings should provide information necessary to develop improved coatings. Targeted exploratory research should pose no threat to industry and would fulfill NBS' traditional role of supporting the scientific infrastructure. For example, while NBS' competency program undertakes long-term exploratory research in the interest of NBS' institutional health (see ch. 5), the competency program also generates technical knowledge of use to industry.

Operating a limited engineering grants program

A consensus exists within the research community associated with NBS that additional grant activity focused on engineering or applied research would stimulate the development of new technologies. An expanded grants program equal to 10 to 15 percent of NBS' funds, aimed at profit and nonprofit laboratories, could be initiated to have outside organizations perform more research. This issue was addressed in chapter 2.

Significant program departures

Biotechnology as a legitimate NBS research area

NBS' movement into a new disciplinary area could result in a substantial change in its research direction. Biotechnology--use of data and techniques to study living organisms--has traditionally been ignored at NBS in favor of physics, chemistry, engineering, and other disciplines historically related to standards and measurement work. With the emergence of biotechnology as the basis of a viable and important industry, NBS is beginning to reassess life sciences as a legitimate area of concern. Deliberations on potential NBS contributions to biotechnology are still in a preliminary phase, and according to NBS, no policy actions will probably be forthcoming before late 1981 or early 1982.

NBS expects that if it does choose to become involved in biotechnology, it will apply its expertise to meet traditional needs for standards, testing procedures, and measurement instrumentation. The need for such services may force NBS to undertake this work either on a self-initiated basis or through the pressure of other agencies that either set regulations or conduct research in this area (such as the Environmental Protection Agency, the Food and Drug Administration, the National Institutes of Health, and the Department of Agriculture).

Support for embryonic, high-technology organizations

A second suggestion made by those whom we interviewed which could significantly modify current NBS policies was that NBS play a "nursery" role for new technologies and organizations. Under this proposal NBS would provide a supportive environment in which technological concepts could develop into viable products and/or in which embryonic organizations could form to propagate those products. We question whether NBS could consciously generate such spinoff organizations and, perhaps more importantly, whether a publicly funded organization should attempt to perform such a function. Attempts to use NBS as a "staging area" for new technologies and/or organizations, particularly ones oriented to the private sector, could jeopardize many of NBS' fundamental institutional characteristics, such as its noncompetitive relationship with the private sector and its neutrality in providing standards. Spinoffs should therefore be accepted as fortuitous events without conscious attempts to plan institutional mechanisms to duplicate those events.

AUTHORITY FOR NEW ROLES

The broad wording of NBS' statutory functions covers an enormous range of undertakings, probably including some new initiatives relative to productivity and innovation. However, the organic act provides no explicit basis for defining the relationship of NBS' statutory mission to productivity and innovation initiatives. None of the broadly worded purposes, functions, and objectives specified in the organic act provide details of the arrangements NBS may undertake with private industry to accomplish NBS' mission. For example, whether the proposal that NBS support embryonic, high-technology organizations falls within the scope of the organic act is exceedingly unclear.

CONCLUSIONS

The National Bureau of Standards serves as the Nation's technical reference laboratory. To fulfill this role as an arbitrator of issues involving scientific standards, NBS must maintain the respect of the scientific community in both the Government and the private sector. NBS' credibility depends on its recognition as both a scientifically competent research organization and a neutral ground where technical issues can be resolved. Lacking both enforcement responsibilities and a particular industry focus, NES is in a uniquely noncompetitive relationship with other Federal agencies and industry. This noncompetitive position, combined with NBS' technical competence, enables NBS to effectively perform its role as the Nation's technical reference laboratory.

NBS' work affects productivity and innovation both indirectly and directly. NBS research that supports the science and technology infrastructure, such as providing standards and developing testing and measurement procedures, affects productivity and innovation indirectly by assisting private industry with quality control and with worker health and safety. Research with more directly observable impacts on productivity and innovation is underway in automation, chemical engineering, and electronics. NBS expects to double its research expenditures in these latter areas from about $24 million to $50 million by 1985.

Internally, NBS has generated a significant capacity to assess its current and future research roles. This capacity is based primarily on its multistep planning process and its numerous channels of communication with outside observers.

MATTER FOR CONSIDERATION BY THE SUBCOMMITTEE

New roles or functions for NBS should be adopted only after carefully considering how added responsibilities will affect NBS' current performance as the Nation's technical reference laboratory. Changing socioeconomic and political needs may require NBS to adopt new roles such as those identified in this chapter. However, if new responsibilities are added to NBS, additional funding and staff should also be provided to avoid a deterioration of the vital technical services it already supplies. Before any new roles are adopted, NBS must ensure that the roles fall within its broad legislative authority.

CHAPTER 4

NBS' JOINT INSTITUTE FOR LABORATORY ASTROPHYSICS

The Joint Institute for Laboratory Astrophysics represents a concept which may be worthy of expansion. Scientists from the National Academy of Sciences who served on panels that evaluated JILA operations rated JILA good to excellent in many respects. However, we believe a more precise statement of mission and goals and research planning is needed for future joint institutes to ensure relevance to NBS' mission. Also, questions should be answered concerning (1) who will manage the research, (2) scientists' tenure, and (3) how the research quality can be evaluated.

We were asked to examine

--how JILA fits into NBS operations,

--the amount and application of NBS funds provided to JILA,

--how JILA contributes to the overall NBS mission, and

--whether NBS should expand the "joint institute" concept as illustrated by JILA.

JILA: A FEDERAL/ACADEMIC RESEARCH FACILITY

JILA, established in 1962 by memorandum of understanding between NBS and the University of Colorado, is an independent research institute on the university campus. Primarily, its work concerns atomic and molecular physics, geophysical measurements, advanced laser measurement techniques, and astrophysics. 1/ JILA is basically an academic institute supported mainly by the Federal Covernment. NBS alone will provide about 36 percent, or $1.7 million, of JILA's fiscal year 1980 funds. NBS provides an additional 11 percent ($0.5 million) through contracts with other Federal agencies. JILA's funding is discussed in detail on page 42.

Both NBS and the university provide JILA permanent positions to be filled by senior scientists. Also, through a grant to the university, NBS provides a Visiting Fellows Program under which about 10 distinguished visiting scientists can be brought to JILA for up to a year. In addition, NBS

1/The science of the physical properties and phenomena of the stars, planets, and all other heavenly bodies.

provides an executive officer to direct JILA's administrative affairs.

Organization

Of the 171 staff at JILA, 138 are research scientists who are either permanent Ph.D. staff (1) or JILA Fellows (26), Visiting Fellows (12), Postdoctoral Research Associates (47), graduate students (42), or other senior research scientists (10). The remaining 33 staff members are engineering, mathematical, and technical support staff (16) or administrative, clerical, and supply support staff (17). (See app. VII.)

JILA is run jointly by NBS and the university through the 26 JILA Fellows (scientists)--15 from NBS and 11 from the university. The Center for Absolute Physical Quantities' 1979 annual report states that the permanent Ph.D. staff, or the 26 "Fellows of JILA," form a collegial JILA governing body which sets JILA policy, subject to review by the NBS Director and the university president. (See app. VIII for JILA organization.) The principal officer of JILA is the chairman of the Fellows, who is responsible for operating JILA within the policy limits set by the Fellows. The chairman is elected for a 2-year term. An executive committee assists the chairman with policy matters, and the executive officer handles administrative matters that the chairman delegates. Of the 26 JILA Fellows, 11 are full-time university faculty from the Departments of Physics, Chemistry, and Astrogeophysics; 14 are NBS Quantum Physics Division employees; and 1 is an NBS employee in the Time and Frequency Division. All NBS Fellows (scientists) hold adjunct appointments in one of the university's departments.

According to the 1979 annual report, the NBS Quantum Physics Division, which operates under the Center for Absolute Physical Quantities at NBS headquarters, was created as the vehicle for NBS' participation in JILA. The division consists of 14 NBS scientists (JILA Fellows) and 8 other staff at JILA. At the time of the April 1978 NBS reorganization, NBS stated that the Quantum Physics Division at JILA would

--engage in atomic and molecular physics research,

--measure natural constants and develop new basic standards,

--maintain active contact with advanced physics research,

--disseminate information to other NBS areas, and

--maintain staff and structure to respond quickly to new ideas and reprograming.

Funding

The estimated fiscal year 1980 funding for JILA is about $4,913,000, as follows.

Source	Estimated funding	Percent of total
NBS direct appropriations	$1,763,000	36
NBS other-agency contracts	533,000	11
National Science Foundation (NSF) atomic physics grant	880,000	18
Research contracts	1,100,000	22
Direct Colorado State funds	594,000	12
Miscellaneous	43,000	1
Total	$4,913,000	100

As shown, in 1980 NBS will provide JILA an estimated $2,296,000: $1,763,000 from direct appropriations and $533,000 from contracts with other agencies. Also, NBS has provided JILA an extensive, fully equipped instrument and electronics shop facility; helped supply the laboratory and office furnishings for the JILA building; and shares equally with the university the cost of operating the building.

Other agencies also contract directly with the university for work at JILA. In fiscal years 1979 and 1980 these contracts will provide about $1.1 million from the following agencies.

Agency	Fiscal year 1979	Fiscal year 1980
	--(thousands)---	
NSF (Astronomy, Aeronomy, and Chemistry)	$ 394	$ 412
Office of Naval Research	136	107
National Aeronautics and Space Administration	200	305
U.S. Air Force	260	198
U.S. Geological Survey	77	0
Miscellaneous	40	78
Total	$1,107	$1,100

JILA's funding over the past 10 years is shown in appendix IX.

CURRENT JILA WORK AND PERFORMANCE

The JILA chairman and the NBS Quantum Physics Division chief at JILA estimated that about 60 percent of JILA's work was basic research, 30 percent applied research, and 10 percent development. They stressed, however, that the distinction among these types of research was not clear.

Because most of JILA's work is theoretical and experimental, its output is difficult to measure. One JILA Fellow told us that the individual researcher was virtually the only person capable of directing or applying his work in a meaningful way in an environment like JILA. He stated that the principal investigator was responsible for ensuring that research results were communicated to other individuals and groups who could apply them.

Generally, the Quantum Physics Division staff's scientific work falls into three areas:

--Collisions in gaseous media.

--Radiating gaseous media.

--Fundamental and precision measurements.

A list of the NBS-funded JILA research projects exceeding $50,000 in fiscal year 1980 is shown in appendix X. JILA/university research projects exceeding $50,000 and funded through university contracts and grants as of June 30, 1980, are shown in appendix XI.

To evaluate JILA's recent performance, we interviewed 9 of the 15 members 1/ of the five National Academy of Sciences evaluation panels that had reviewed JILA within the past 5 years. These nine panel members follow.

1/We were unable to contact the other six panel members.

Name	Position
Dr. Jacques M. Beckers	Director, Smithsonian Multiple Mirror Telescope Institute
Dr. Benjamin Bederson	Professor, Department of Physics, New York University
Dr. Solomon J. Buchsbaum	Vice President, Network Planning and Consumer Services, Bell Laboratories
Dr. Ronald Geballe	Dean, Graduate School, University of Washington
Dr. Dudley R. Herschbach	Professor, Department of Chemistry, Harvard University
Dr. William F. Krupke	Chief Scientist, Lawrence Livermore National Laboratory Laser Program
Dr. George W. Preston	Acting Director, Mt. Wilson and Las Campanas Observatories of the Carnegie Institution of Washington, D.C.
Dr. Arthur L. Schawlow	Jackson and Wood Professor of Physics, Stanford University
Dr. Arthur B. Walker, Jr.	Associate Professor of Applied Physics and Associate Dean of the Graduate Division, Stanford University

These panel members, generally considered to be experts in fields of science related to JILA, expressed favorable opinions of JILA as a scientific institution--all rated JILA good to excellent in its ability to

--recruit effective scientific talent,

--retain scientific talent (one panel member had no opinion on this point),

--provide quality research and services,

--provide timely reporting, and

--choose effective reporting methods.

Several NAS panel members noted the "leverage" (explained below) that JILA provided to NBS while also recognizing that NBS had less ability to actually direct the work performed at JILA. JILA officials estimate that the leverage NBS gets from JILA may "save" it about $3 million which would have to be spent to obtain research equivalent to that it receives indirectly through affiliation with JILA. While employing only 15 Fellows and 9 others, NBS benefits--gains leverage--from all 171 JILA employees. However, we noted that about 80 percent of JILA's non-NBS support comes from other Federal agencies, such as NSF, NASA, DOD, and DOE.

PUBLICATIONS AND OTHER JILA CONTRIBUTIONS

Scientific literature is probably JILA's most visible product. NBS officials said that JILA publishes about 150 papers each year, and since 1962 over 2,100 JILA papers have been published in scientific journals. (See app. XII.) Nearly 250,000 requests for JILA publications have been received since 1962. Data on requests for JILA research papers showed that more requests came from foreign countries than from the United States. For example, analysis of requests for JILA papers and reprints for the period March-June 1980 showed that 688 requests for 3,080 documents were received from foreign sources as opposed to 630 requests for 2,340 documents from domestic sources. The domestic sources of requests included 396 university, 130 government, and 104 industry related. JILA does not make an analysis of the foreign sources, and we were unable to identify the countries from which the 688 requests were received.

Further, of the 165 JILA papers published in 1978, 88 were produced by NBS scientists (Fellows), their students, postdoctoral scientists, or Visiting Fellows; other JILA scientists produced the remaining 77 papers. The 88 papers constituted about 9 percent of the 956 NBS publications produced in 1978. In 1979 NBS produced 712 publications of which 76 (10.7 percent) were produced by NBS/JILA scientists and their staffs.

In addition to the publications, JILA officials said that other indicators of JILA's success included the following.

--Approximately 50 scientists apply for JILA visiting fellowships each year; only about 10 are selected.

--Many laboratories (domestic and foreign) desire to send scientists to spend time at JILA at their own expense.

--Scientists spend 1 to 3 years of postdoctoral work and education at JILA despite usually significantly lower salaries than they might be receiving elsewhere.

--While directly employing only 15 Fellows and 9 other staff at JILA, NBS benefits from all 171 JILA employees.

--Generally, JILA scientists have not had difficulty finding jobs after leaving JILA; many have joined other NBS divisions, other Government agencies, industrial laboratories, and universities.

Still other JILA contributions include patents obtained and commercial applications of its research. According to an NBS official, three patents have been granted to JILA scientists during its 18-year history.

--A distance-measuring instrument (1969).

--A system for wavelength measurement (1979).

--A tunable laser (1979).

In commercial applications of research, JILA officials noted its role in developing

--methods now used by industry for improving high-pressure arc lamps,

--a new method of distance measurement using a satellite,

--a million-watt pulsed nitrogen laser now in commercial production, and

--the concept of a heat-pipe oven now used widely for scientific and practical purposes.

QUANTUM PHYSICS DIVISION'S LONG-RANGE GOALS

The stated objectives of NBS' Quantum Physics Division (NBS scientists at JILA) and affiliated students and post-doctoral scientists are directed toward the objectives of the Center for Absolute Physical Quantities at NBS head-quarters. Specific division objectives as shown in the Center's latest 5-year plan include

--using available technology to provide standards,

--researching areas likely to provide major improvements in definition or use of standards within 5 years,

--providing more accurate state-of-the-art determinations of physical constants,

--providing tests of fundamental physical laws,

--developing fundamental understanding of the behavior of gaseous media and its interaction with radiation,

--providing assistance to other agencies knowledgeable about radiating gaseous media, and

--applying expertise to provide precise measurements of large distances.

The perceived more independent position of the Quantum Physics Division as seen by other NBS divisions raises questions about NBS' control over JILA research. Under JILA's bylaws, scientific and administrative policy is established by the JILA Fellows (NBS Quantum Physics Division and university scientists). Policy is subject to review by the university president and the NBS Director, who receive minutes of all the Fellows' formal deliberations. The JILA chairman is responsible for recognizing impending policy issues and for resolving issues based on a consensus of the Fellows and in consonance with the policies of the parent institutions as determined through discussions with the university president and the NBS Director.

According to JILA tradition, the Fellows have personal responsibility for their own scientific efforts and collective concern for JILA's welfare. But according to the JILA chairman and the chief of the NBS Quantum Physics Division at JILA, the Director of NBS' Center for Absolute Physical Quantities was active in managing JILA's programs, and therefore the Quantum Physics Division was not more independent than other NBS divisions. However, the Center director told us that NBS' management of JILA was mostly by suggestion.

JILA research performed under grants is usually directed by the JILA Fellows who receive written descriptions for research projects commensurate with the grants' objectives. With the advice of the scientific community, they "identify outstanding research opportunities as they arise, * * * identify opportunities to make especially cost-effective capital investments not associated with an individual project," and evaluate "mini-proposals" in consultation with other knowledgeable Fellows.

THE JOINT INSTITUTE CONCEPT

We believe the joint institute concept has merit and may be worthy of expanding to other universities. However, a clear statement of mission and goals and research planning is necessary before beginning other joint or cooperative institutes. In addition, other matters, such as how the research will be managed, tenure of NBS scientists at a joint institute, and how the research results can be judged, should be resolved before beginning new institutes.

Evaluations of JILA

The 1979 National Academy of Sciences evaluation panel said that

> "JILA is an outstanding example of an interdisciplinary organization. In it, physicists, chemists, astronomers and astrophysicists work together in a synergistic environment. Such an arrangement is rare on university campuses, which are normally structured around highly discipline-oriented departments. JILA serves to focus these normally disparate activities, to the mutual benefit of the individual scientists and the University as a whole."

The joint institute concept as illustrated by JILA has also received some criticism because of its academic nature and the physical separation of the NBS JILA scientists from the other NBS organizational units. For example, in 1975 an NAS evaluation panel commented as follows on NBS management problems created by JILA. The Laboratory Astrophysics Division (now Quantum Physics Division)

> "* * * with its strong ties to the University, is unique within NBS and presents some unusual problems for Bureau management. In particular, questions regarding the relevance of JILA to the current NBS mission have been raised, and concern has been expressed that [the NBS division] has become insulated from the rest of NBS as a result of insufficient personnel movement and an 'institutional drift' of JILA."

These comments may have been in response to a 1974 OMB report which concluded that astrophysics was not a part of the NBS mission and recommended that NBS phase out its special and formal relationship with JILA. The OMB report noted that

"Astrophysics (the study of stars and the phenomena of intersteller space) was given high priority in the early 1960s because of the Nation's interest in space and the goal of landing a man on the moon. The Nation's interest in space was the primary rationale for establishing JILA."

* * * * *

"The relationship of NBS activities at JILA to the overall NBS mission is, at best, indirect. * * * NBS can point to cases where the basic research conducted at JILA has supported [its] objectives but these results seem to be incidental rather than the result of a directed effort."

As a result of the OMB report, NBS in January 1975 identified three matters which needed to be addressed.

--The JILA memorandum of understanding needed to be rewritten to reflect appropriate purposes for the next decade.

--The tenure policy--unlimited term of appointment--for Quantum Physics Division scientists (NBS JILA Fellows) stood in the way of rotating qualified NBS scientists into and out of JILA.

--The lack of common scientific direction and management for two centers of atomic and molecular physics at Boulder (JILA and a section of another NBS division) was probably contributing to JILA's perceived "drift" away from the NBS mission.

A senior JILA official noted that a 1976 addendum to the JILA memorandum of understanding had resolved the first issue while the move of the section of the other NBS division to NBS headquarters had partially resolved the third issue. The tenure question has not been completely resolved.

In March 1976 NBS and the university, in response to the OMB criticism, reaffirmed their support of JILA by signing an addendum to the original memorandum of understanding. The addendum expanded the scope of JILA activities and reinforced JILA's mandate for research and advanced training in areas within the missions of both partners. According to the addendum,

> "* * * the purpose and role of the Joint Institute for Laboratory Astrophysics shall continue to evolve and expand beyond the areas of science outlined in the original Memorandum of Understanding."

Concerning the tenure question, a 1976 NAS evaluation panel recommended that NBS staff at JILA be rotated within NBS to eliminate the perception that the staff was unfairly privileged and essentially to get new scientists into the organization. The panel's report stated that

> "* * * the unconventional (by NBS standards) location and organization of JILA and the emphasis on astrophysics in the * * * Memorandum of Understanding between NBS and the University have led to the perception in other parts of [NBS] that JILA scientists are unfairly privileged compared with others within [NBS] and that JILA has not adjusted its priorities to reflect the changing requirements of the NBS mission."

A senior JILA scientist told us that the vitality and success of JILA depended strongly on the large flow-through of senior and junior scientists.

Several JILA scientists said that few other NBS scientists had their same interests or expertise and they preferred that visiting scientists come to JILA from academia and institutions other than NBS. However, the Quantum Physics Division chief told us that the perception of elitism and the issue of NBS tenure at JILA had been alleviated somewhat through management efforts and the adoption of the JILA position on "Tenure of Fellowship." According to a resolution adopted by JILA Fellows in 1976, JILA's parent bodies (NBS and the university) should apply the same personnel review and reassignment procedures to each JILA staff member that would apply if that person were in another NBS or university organizational unit.

We noted that 4 of the 15 NBS scientists at JILA were assigned in 1962, and 8 have been in residence for the past 12 years. As a result, the average age of the NBS JILA staff has increased from 35.9 years in 1963 to 45.5 years. However, one NAS evaluation panel member we interviewed stated that this trend was not unique to the NBS JILA staff but was shared by most institutions which had experienced rapid scientific staff expansion in the 1960s.

University faculty members told us that there was a need for orderly rotation of NBS scientists who might have lost interest in the academic aspects of JILA. A faculty member

said that they were concerned about the lack of involvement in academic functions of a small minority of the NBS staff.

In response to this concern, we noted the tenure of the NBS scientists at JILA and the number of graduate students or postdoctoral scientists who were affiliated with them as of August 1980. As shown below, only 6 of the 45 students and postdoctoral scientists are affiliated with the 4 most senior NBS scientists, whereas 16 students and postdoctoral scientists are associated with the 4 least senior (5 years or less) scientists.

NBS scientist	Years as a JILA Fellow	Number of affiliated students and postdoctoral scientists
A	3	1
B	4	9
C	5	2
D	5	4
E	7	2
F	8	5
G	9	1
H	12	6
I	13	0
J	15	5
K	15	4
L	17	1
M	17	1
N	17	1
O	17	3

Joint or cooperative institutes in other Federal agencies

In addition to JILA in NBS, at least one other Federal agency--the National Oceanic and Atmospheric Administration (NOAA)--has also established joint or cooperative institutes by memoranda of understanding with various universities. NOAA had established seven of these institutes as of September 1980 (see app. XIII)--all within close proximity to NOAA laboratories.

The Cooperative Institute for Research and Environmental Sciences (CIRES), the oldest NOAA institute, is located at the University of Colorado, as is JILA. According to NOAA officials, CIRES' budget is about $3 million annually, of which NOAA provides about $1.5 million. The other six institutes were established within the past 3 years--the most recent one in September 1980 at Colorado State University. NOAA officials said these institutes' budgets range from about $200,000

to $500,000 annually and that six of the seven institutes are funded through NOAA's Environmental Research Laboratories in Boulder, Colorado.

According to NOAA officials, each of the institutes has from 4 to 10 NOAA staff including senior Fellows. The Fellows are appointed as adjunct faculty and, unlike JILA Fellows, are appointed for 3-year terms.

Concerning the research to be performed at the institutes, a "typical" arrangement is for an advisory board appointed by the parent organizations to have final approval. New research projects may be initiated internally or by request from either parent organization.

NOAA officials told us that CIRES had been very successful, and its other institutes probably stemmed from CIRES. Because the other institutes are less than 3 years old, these officials said it was too early to tell whether they also would be successful. One official said that it takes about 5 years to determine whether such institutes will be successful.

Other possible NBS joint institutes

OTA in its 1978 report (see p. 11) noted that JILA was "highly successful" and "widely praised inside and outside NBS." The report concluded that it would be useful to explore such a joint program in another area of technical pursuit, with a university near Washington, D.C.

A senior NBS/JILA scientist told us that before NBS establishes other joint institutes, the following conditions should exist.

--The discipline to be studied must be one in which high creativity is needed.

--The discipline must be one which is active worldwide so that visitors from around the world will bring their viewpoints and perspectives to bear on both the NBS and the institutions' problems.

--NBS should benefit from the "great leverage" enjoyed through academic ties. Also, the associated university must benefit from having NBS staff on its campus supervising Ph.D. students and teaching courses.

--NBS must be willing to commit a core group of high-quality people on a long-term basis. The staff must be of a quality to attract international visitors and postdoctoral scientists and graduate students who want to work under them.

--The research and work must be of a nature that will lead to suitable Ph.D. theses.

Because of the "great leverage," the NBS/JILA scientist said that it would appear advantageous for NBS to seriously consider supporting joint institutes when the opportunities arise. He identified the following areas as candidates for joint or cooperative research.

1. Materials research.
2. Fire research.
3. Analytical chemistry.
4. Radiation research.
5. Computer engineering research.
6. Chemical engineering (continuous process technology).
7. Nondestructive testing and evaluation.

Another NBS official said that chemical engineering and materials were two areas that he strongly believed could be researched through joint institutes. He said that some discussion with the University of Colorado had already taken place concerning joint research in these areas. Also, he said that NBS had a good relationship with the Colorado School of Mines.

CONCLUSIONS

The joint concept under which JILA was established and operates appears to be a good method of performing research, based on the many positive comments as discussed above. However, we believe that any future joint institutes planned could benefit from a more concise statement of mission and goals and research planning that would ensure relevance to the NBS mission. Also, other serious questions that would confront the formation of any new joint institute include the following.

--Will research be managed by the principal researchers or NBS?

--How should tenure at such an institute be awarded, or would a systematic program of rotation be appropriate for NBS scientists?

--How can the quality of research at a joint institute be objectively judged when only an inner circle of scientists adequately understands the principles being investigated or their eventual significance to society?

Resolving these questions as well as clearly defining the mission and goals of any joint institute would greatly benefit the task of objectively evaluating the institute's performance as well as contribute to the orderly pursuit of scientific knowledge.

MATTER FOR CONSIDERATION BY THE SUBCOMMITTEE

Based on the views of NAS evaluation panel members and NBS scientists and officials, the joint institute concept may be worthy of expansion to other universities. The subcommittee may wish to explore this with NBS during planned hearings.

CHAPTER 5

NBS' COMPETENCE-BUILDING PROGRAM

"The Competence Building program has over the last couple of years been on the Bureau's list of priority programs." The subcommittee, in making this observation, asked us to answer the following questions concerning NBS' competence-building program.

"1. What basis was used to determine the areas in which competence rebuilding is necessary?

"2. Does this program receive funding at the expense of mission programs?

"3. Please identify the ratio and trend of competence funding allocated between basic research, applied research and other activities since the beginning of the program."

NBS defines competence as "the capacity to carry out its duties and to respond to new requirements assigned by the Administration and by Congress, or imposed by developments in industry, Government, and the public." According to an NBS official, the capacity to respond to such assignments is based on the availability of teams of scientists and engineers working at the forefront of research and able to devote their efforts to specific problems as they arise. Any time a group of scientists that had been engaged in research at the forefront of science and engineering is assigned to work on a specific, more narrowly defined problem, some of the competence is depleted. Competence can be rebuilt by returning scientists and engineers to state-of-the-art research in new fields, once their applied tasks are complete, or by adding sufficient resources to build and maintain the level of competence that is equal to the requirements placed on NBS.

Between 1965 and 1978 NBS was required to respond to more than 20 acts which required short-term research addressed to specific national problems in energy, pollution, consumer interests, and efficient use of national resources. To respond to these requirements NBS had to direct existing competence into areas of short-term research, thereby depleting some of its competence--the competence was no longer available to solve future problems in a timely manner.

In September 1977 the chairman of the NBS Statutory Visiting Committee, in his annual report to the Secretary of Commerce, expressed concern that long-range programs were being sacrificed to "salvage" short-term objectives and

cited this as one factor that threatened to bring NBS to an unacceptable mediocrity. A 1978 OTA report (see footnote on p. 11) similarly took note of the problems incurred by NBS in maintaining the necessary competence to respond to future requirements. In addition, the Director of NBS and many concerned scientists began to warn the Congress and the public of the serious threat to NBS' existence as a first-class institution.

In response to these problems, OMB approved a fund "for maintaining competencies and performing basic research in furtherance of the NBS mission objectives." The fund is to be gradually built to a level equivalent to 15 percent of the total NBS resources, both direct and reimbursable. Competency fund appropriations were increased by $2 million for each of fiscal years 1979 and 1980.

The fiscal years 1981 and 1982 NBS appropriations authorization act authorized $6,176,000 for this program in fiscal year 1981--a $2,176,000 increase over the previous year--and $8,794,000 in fiscal year 1982. The program was also retitled the "Technical Competence Fund."

BASIS FOR SELECTING COMPETENCE-BUILDING PROJECTS

Competence-building projects are proposed by "bench level" scientists and engineers at NBS who are conversant with specific areas of science and technology. These proposed projects are then reviewed by the responsible NBS division chief, center director, and laboratory/institute director using the following criteria.

--Potential long-range public/economic benefit.

--Potential for advancing scientific knowledge.

--Match to NBS mission objectives.

The NBS Planning Office's long-term planning effort and the 5-year plans prepared by each laboratory/institute, along with outside sources such as the NAS evaluation panels that normally review NBS programs annually, contribute to a framework within which the proposed competency projects are evaluated. Final selection of competence-building projects is made by the NBS Director.

Following is a list of new competence-building projects NBS started in fiscal years 1979 and 1980 and those planned for fiscal year 1981.

New Competence-Building Projects
Fiscal Year 1979

NBS unit and project title	FY 1979 resources (thousands)	Staff positions
NML (note a):		
Surface Science	$ 400	6
Organic Electrochemistry	300	5
Advanced Neutron Methods	250	4
NEL (note b):		
Wave Optics for Metrology	150	3
Physics of Defects in Semiconductors	350	3
Nonlinear Modeling of Convection and Smoke Dynamics	200	0
Fluid Mixtures Properties	250	2
ICST (note c):		
Abstract Data Models	100	0
Total	$2,000	23

a/National Measurement Laboratory.

b/National Engineering Laboratory.

c/Institute for Computer Sciences and Technology.

New Competence-Building Projects
Fiscal Year 1980

NBS unit and project title	FY 1980 resources (thousands)	Staff positions
NML:		
Physical and Chemical Effects of Ionizing Radiation on Matter	$ 300	5
Picosecond Laser Chemistry	300	4
Synchrotron Radiation Research for Materials Science	250	4
NEL:		
Physics of Compound Semiconductors	200	1
Soot Formation Processes During Hydrocarbon Combustion	200	0
New Techniques in Mathematical Optimization	100	1
Transient Heat Transfer	250	1
ICST:		
Abstract Data Models (added to FY 1979)	200	5
Measurement and Control of Local Area Networks	200	2
Total	$2,000	23

Planned Competence-Building Projects
Fiscal Year 1981

NBS unit and project title	FY 1981 resources (thousands)	Staff positions
NML:		
Quantum Radiometry	$ 400	4
Analysis of Ionization Mechanisms and Ion Structures	400	2
Compositional Mapping	200	3
NEL:		
Gigabit Electronics	100	1
Development of Mathematical Models for Predicting the Performance of Cement Pastes	300	3
Computational Geometry and Geometric Modeling	175	1
Advanced Robot Vision	275	3
ICST:		
Structures for Intermediate Program Representation	150	1
Total	$2,000	18

RELATIONSHIP TO OTHER NBS PROGRAMS

Competence-building projects are funded from a separate line item in the NBS budget, and subsequent expenditures are monitored to ensure that the funds are consumed only for activities related to competence building.

NBS officials perceive the competence program to be an integral part of the NBS mission because the competence projects selected are those which are expected to develop a scientific and technical base enabling NBS to respond to future programs and problems of national importance. In the shorter term, NBS views the competence projects as "pockets" of scientific and technical creativity which aid current mission programs by providing basic information for use in the more applied research of existing programs.

COMPETENCE PROJECTS AS "BASIC" RESEARCH

OMB in its feedback to NBS on the fiscal year 1980 budget informed NBS that

> "Use of monies in this fund is to be restricted to the support of basic research efforts aimed at maintaining NBS staff competence in the basic sciences. Funds are not to be used in support of applied research projects, other agencies' projects, or projects that are industry specific."

According to NBS, the competence-building projects are considered to be basic research in relation to other work it does. However, on a scale in which research with the sole objective of expansion of knowledge represents the most basic end of the research spectrum, the competence building at NBS would be considered more applied because the long-term objectives of each competence project are directed toward an area of applied research perceived to be important for solving future national problems. What research is basic and what is applied is not clear, even to many scientists. As a result, we had no specific basis for determining the type of research NBS was doing under its competence-building program.

CONCLUSIONS

NBS' procedures for evaluating and approving proposed competence-building projects provide for input from both NBS and from outside advisors and are designed to provide conformity with NBS short- and long-range plans. These plans, in turn, take into consideration national research needs and NBS' need for competence in fulfilling its role in meeting those needs.

NBS' competence-building program does not receive funding at the expense of mission programs; it is funded from a separate line item in the NBS budget. Expenditures from the fund are monitored to ensure application of these funds to competence-building projects only.

According to NBS, all competence-building projects are considered basic research in conformity with OMB requirements placed on the program.

LABORATORY AND INSTITUTE GOALS

NATIONAL MEASUREMENT LABORATORY

The Laboratory provides the national system of physical and chemical measurement, coordinating the system with measurement systems of other nations and furnishing essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce. It conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials.

NATIONAL ENGINEERING LABORATORY

The Laboratory provides technical services to promote development and use of technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in developing technological standards and test methods; and provides technical advice and services to Government agencies upon request. It conducts research in support of the specific objectives of these activities; monitors NBS engineering standards activities; and provides liaison between NBS and national and international engineering standards bodies.

INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY

The Institute develops and recommends uniform Federal automatic data processing standards; provides automatic data processing scientific and technological advisory services to Federal agencies; and undertakes necessary research in computer science and technology.

APPENDIX II

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515

January 23, 1980

Honorable Elmer B. Staats
Comptroller General of the United States
General Accounting Office
441 G Street, N.W.
Washington, D. C. 20548

Dear Mr. Staats:

The National Bureau of Standards is the Nation's oldest national laboratory. In the past few years, it has become evident that the Bureau's scientific and technical capabilities need to be strengthened. This year the Committee on Science and Technology, through its Subcommittee on Science, Research and Technology, will be conducting the first authorization hearings held by the House of Representatives on the Bureau in its 79-year history. It is our hope to remedy past neglect and help insure that the Bureau's resources are used more effectively.

During our preparation for these hearings, it became obvious that in 1981 we should conduct an investigation and hold hearings on the National Bureau of Standards' organic act. With this in mind, we should like to ask the GAO to undertake a study of the Bureau which addresses the following specific questions and any other pertinent issues that the Subcommittee should be made aware of:

Goal/Mission of NBS

NBS appears to be divided as to its function in relation to the enabling legislation and the subsequent legislative mandates. On one hand, NBS is to assure maximum application of the physical and engineering sciences to the advancement of technology in industry or commerce through its standards and measurement functions; on the other hand the Bureau is to strengthen and advance the Nation's scientific and technological capabilities and to facilitate their effective application for public benefit.

1. What changes, if any, in the amended organic act are needed to enable the Bureau to perform these functions?

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2. What changes, if any, in the amended organic act are needed to allow the Bureau to make a significant contribution to the Nation's innovation and productivity problems?

3. After reviewing NBS's current short-and-long-range plans, what financial, physical, and manpower resources will be required to meet the Bureau's present goals in the areas of competence building, operational equipment, facilities, and funding, as well as the expanded goals mentioned in questions 1 and 2?

4. What is the extent of NBS's financial investment compared with civilian technology research and development efforts of other agencies? Is this effort sufficient to strengthen and advance science and technology for public benefit?

Basic Missions vs. Other Legislative Functions

The Bureau, over the years, has developed into a laboratory guided by its organic act missions and other legislative authorities to perform work for outside agencies.

1. To what extent has manpower and other resources (in constant dollars) been used by the Bureau to carry out the legislative mandates and the outside, non-statutory tasks since 1965?

2. To what extent have outside non-statutory assignments detracted from the Bureau's capability to meet traditional statutory responsibilities?

Competence Building

The Competence Building program has over the last couple of years been on the Bureau's list of priority programs.

1. What basis was used to determine the areas in which competence rebuilding is necessary?

2. Does this program receive funding at the expense of mission programs?

3. Please identify the ratio and trend of competence funding allocated between basic research, applied research and other activities since the beginning of the program.

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Following our authorization hearings for fiscal year 1981, we may find it desirable to ask that additional questions and issues be included in this study. In that event a follow-up letter will be sent to you, after consultation with members of your staff, identifying such further questions and issues.

I believe that a GAO study of these questions and issues will make a valuable contribution to the Committee's review of the organic act of the National Bureau of Standards. I have asked Mr. John Clements to serve as my direct contact point with you and your staff for this study. In order for this study to be most useful to the Committee, the completed report should reach us no later than December 31, 1980.

During our current preparations for the authorization hearings which will begin next month, we have had the assistance of Mr. Jack Glick of your staff. Mr. Glick's thorough knowledge of the NBS has been most valuable to my staff and myself, and I should like to express to you my thanks for the valuable contribution he has made to our work, as well as for the GAO's willingness to assist us further with the study we are requesting in this letter.

Sincerely,

GEORGE E. BROWN, JR.
Chairman
Science, Research and
Technology Subcommittee

GEB:jc

STATUTES THAT ASSIGN DIRECT RESPONSIBILITY TO NBS (Note a)

Statutes	Funding (thousands) 1979 STRS (note b)	1979 OA (note c)	1980 STRS (note b)	1980 OA (note c)
"Brooks Act" (79 Stat. 1127) (1965)	$10,590	$1,750	$12,729	$1,274
Fair Packaging and Labeling Act (80 Stat. 1296) (1966)	68	-	75	-
Standard Reference Data Act (82 Stat. 339) (1968)	3,133	596	3,150	978
Radiation Control for Health and Safety Act of 1968 (82 Stat. 1173)	425	106	215	210
Consumer Product Safety Act (86 Stat. 1207) (1972)	-	912	-	944
Noise Control Act of 1972 (86 Stat. 1234)	677	178	400	140
Solar Heating and Cooling Demonstration Act of 1974 (88 Stat. 1069)	164	2,969	-	1,009
Federal Fire Prevention and Control Act of 1974 (88 Stat. 1535)	48	7,642	1,482	7,947
Federal Nonnuclear Energy, Research and Development Act of 1974 (88 Stat. 1878)	-	1,080	-	1,758

a/Many of the acts listed place authority with the Secretary of Commerce; however, responsibility under the statutes has been specifically delegated to NBS.

b/Scientific and Technical Research and Services (direct appropriations).

c/Other agency funds provided.

APPENDIX III

Statutes	Funding (thousands) 1979 STRS	1979 OA	1980 STRS	1980 OA
Energy Policy and Conservation Act (89 Stat. 871) (1975)	$1,869	$3,880	$1,281	$2,433
Metric Conversion Act of 1975 (89 Stat. 1007)	54	-	40	-
Energy Conservation and Production Act (90 Stat. 1125) (1976)	-	20	80	156
Resource Conservation and Recovery Act of 1976 (90 Stat. 2795)	1,041	145	1,853	83
Earthquake Hazards Reduction Act of 1977 (91 Stat. 1098)	381	109	390	515
Solar Photovoltaic Energy Research, Development and Demonstration Act of 1978 (92 Stat. 2513)	-	-	-	15
National Energy Conservation Policy Act (92 Stat. 3206) (1978)	94	1,204	622	3,177
Trade Agreements Act of 1979 (93 Stat. 144) (note a)	-	-	-	-

a/No specific appropriations have been authorized NBS to carry out this act.

NBS FUNDING IN CURRENT AND CONSTANT DOLLARS

FISCAL YEARS 1965-80 (NOTE a)

Year	Index (note b)	STRS obligations (note c)		Other agency funding		Other reimbursable (note d)		Funding for legislative mandates: Other agencies		Funding for legislative mandates: STRS (note c)	
		Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
		(millions)									
1965	100.0	$26.5	$26.5	$15.0	$15.0	$ 5.0	$5.0				
1966	105.5	28.0	26.5	15.4	14.6	5.5	5.2				
1967	107.4	29.7	27.7	18.0	16.8	5.9	5.5				
1968	116.6	31.1	26.7	18.8	16.1	6.1	5.7				
1969	123.8	34.6	28.0	20.4	16.5	6.4	5.2				
1970	139.7	38.6	27.6	21.7	15.5	6.9	4.9				
1971	153.6	42.7	27.8	26.0	17.0	5.7	3.7	-	-	$ 2.4	$1.6
1972	172.4	46.5	27.0	29.5	17.1	5.5	3.2	-	-	2.4	1.5
1973	185.5	49.5	26.7	30.4	16.4	4.6	2.5	$ 3.1	$1.7	5.4	2.9
1974	194.8	54.4	28.0	34.4	17.7	5.4	2.8	5.5	2.8	6.3	3.2
1975	209.7	56.3	26.8	41.7	19.9	5.8	2.8	7.4	3.5	11.1	5.3
1976	222.1	58.7	26.4	43.4	19.5	6.4	2.9	8.7	3.9	13.7	6.1
1977	235.3	65.7	28.0	48.6	20.6	6.5	2.8	12.4	5.3	15.1	6.4
1978	252.1	66.5	26.3	55.1	21.9	7.9	3.1	(f)	(f)	(f)	(f)
1979	e/271.2	79.4	29.2	57.8	21.3	9.4	3.5	20.6	7.6	18.5	6.8
1980 Est	e/292.0	91.5	31.4	61.5	21.1	11.1	3.8	20.6	7.1	22.3	7.6

a/Excludes the Central Radio Propagation Laboratory and the National Technical Information Service.

b/Derived from statistics from the Bureau of Economic Analysis, U.S. Department of Commerce. Implicit Price Deflator for Federal Government Employee Compensation.

c/Scientific and Technical Research and Services (direct appropriations), excluding plant and facilities, Experimental Technology Incentives Program, and Cooperative Technology.

d/Includes fee-supported services such as calibrations, tests, and sales of standard reference materials for all customers, including other Federal agencies.

e/Value extrapolated from a linear regression for 1970-78.

f/Information was not available due to NBS' reorganization.

APPENDIX IV

LISTING OF FISCAL YEAR 1980 RESEARCH PROJECTS UNDER BUDGET SUBACTIVITY

"RESEARCH FOR INDUSTRIAL PRODUCTIVITY AND INNOVATION"

Category I: Discrete Batch Manufacturing

Project	Nature of research	Potential productivity effects	Funding		Othe organi
			NBS	Other Federal agencies (note a)	
Mechanical Measurements for Transfer Equity	Provide calibration services for mass, volume, density, and flow rate	Increase measurement accuracy and thereby contribute to reducing the cost of accounting for materials	$ 160,000	c/ : $245,000	
Advanced Dimensional Calibrations	Provide state-of-the-art, high accuracy dimensional calibrations for the manufacturing industry	Ensure quality control and interchangeability of parts	$ 400,000	c/ : $500,000	
Advanced Inspection Technology	Develop improved reference standards, measurement procedures and evaluation techniques for: 1) acoustic testing, 2) surface roughness analysis, and 3) industrial force measurements	Increase accuracy of non-destructive, in-process inspection for properties that determine a product's reliability and working life	$ 272,000	FDA: $ 60,000 NASA: 79,000 DOD: 57,502 $196,502	As
Automation Technology	Demonstrate fully automated manufacturing with on-line dimensional control and inspection	Accelerate use of computer-aided manufacturing by developing interface standardization, dimensional metrology, and computer-based control	$1,032,000	DOD: $244,577 DOE: 10,661 $255,238	Bu
Industrial Acoustics	Develop procedures for acoustical measurements on industrial process machinery; provide calibration services for laboratory microphones and electroacoustical transducers	Improve health and safety of industrial environments; enhance production control via performance monitoring	$ 150,000	EPA: $ 30,000 VA: 120,000 c/: 100,000 $250,000	NI

a/A listing of abbreviations identifying these agencies is included on p. 72.

b/A listing of abbreviations identifying these organizations is included on p. 73.

c/Additional fiscal year 1980 commitments and reserves not yet received by NBS.

Category II: Continuous Process Technology

Project	Nature of research	Potential productivity effects	Funding			Other interested organizations
			NBS	Other Federal agencies		
Turbulence Control	Provide measurement technology and data base for the understanding and control of turbulent flow	Reduce the overdesign, inefficiency, and energy waste that result from an inability to predict the effects of turbulence	$275,000	DOD: EPA:	$ 232,331 99,116 $ 331,447	NASA, DOT
Fluid Dynamics	Maintain, advance, and develop flow measurement standards and technology for clean fluids such as water, air, hydrocarbons	Enable more accurate measurement of the fluid flow rate of interactable or hazardous fluids	$285,000	EPA:	$ 73,371	API, AGA, State and local governments
Thermophysical Properties of Fuels and Industrial Chemicals	Provide reference data and calculation methods for thermophysical properties of technically important fluids and mixtures (e.g., natural gas, ethylene, industrial gases)	Reduce capital costs of process plants by means of improved ability to predict properties of important fluids	$200,000	DOD: DOE: NASA: a/:	$ 100,000 25,066 49,978 324,956 $ 500,000	
Cryogenic Technology for Energy Systems	Provide engineering design data, measurement methodology, and standards for the cryogenic technology for energy systems	Enhance energy utilization via improved process measurement and better materials selection	$500,000	DOD: DOE: NASA: LLL: MA: NOAA: a/:	$ 581,254 91,233 109,779 68,390 80,000 20,000 449,344 $1,400,000	ASTM, ANSI, IEEE, NEMA
Smart Sensors	Develop sensor systems to make reliable measurements of industrial control variables, and incorporate advanced microprocessor/sensor/feedback systems	Enhance energy utilization via improved process control; reduce maintenance costs and improve safety through failure prediction	$880,000	DOD: DOE: HUD: DOT: Treasury: a/:	$ 68,000 13,750 10,000 15,498 14,640 328,112 $ 450,000	NRC, Case Western Reserve U.
Measurement in Thermal Process	Provide scientific and technical knowledge applicable to measurement and control of industrial thermal processes such as combustion, heat transfer, and steam generation	More efficient utilization of energy resources via improved measurement and control of industrial thermal processes	$560,000	DOD:	$ 586,534	EPA, MIT, U. of Oklahoma, George Washington U., Imperial College, Purdue U.

a/Additional fiscal year 1980 commitments and reserves not yet received by NBS.

APPENDIX V

Category III: Electronic Technology

Project	Nature of research	Potential productivity effects	Funding: NBS	Funding: Other Federal agencies	Other interested organizations
Electronic Materials	Develop improved measurement technology to characterize silicon and related oxides	Improve quality control by providing metrology necessary to characterize and control semiconductor materials before and during the fabrication of integrated circuits	$ 770,000	DOE: $ 231,015 DOD: 233,045 a/: 385,940 $ 850,000	NASA, DOT HHS, IEEE, SIA, SPIE, individual firms and universities
Applied Electrical Measurements	Develop improved measurement technology to monitor the transmission of electrical energy	Enhance efficiency and safety (from both mechanical failure and environmental damage) of electrical power transmission	$ 300,000	DOE: $ 950,991 DOT: 36,915 $ 987,906	FDA, EPRI, IEEE, ANSI, IEC, U. of California, U. of Florida, Colorado St. U.
Semiconductor Devices	Develop improved measurement technology to evaluate manufacture of semiconductor devices	Improve quality control by providing metrology necessary both for control and evaluation of semiconductor devices during fabrication and assembly and for inspection and testing of completed semiconductor devices	$ 525,000	DOD: $ 660,389 DOE: 231,545 NASA: 63,614 a/: 189,452 $1,145,000	DOT, HHS EIA, ASTM, SEMI, SAE, IEEE, SIA, SPIE, individual firms and universities
Electronic Instrumentation and Metrology	Develop new physical reference standards and test methods for digital sampling, processing, and synthesis techniques	Reduce the resources invested annually in metrology instrumentation of this type	$ 500,000	DOD: $ 316,855 DOE: $ 145,000 $ 461,855	IEEE, ANSI, EIA, five industry trade associations, individual firms
Electromagnetic Interference and Radiation Hazards Metrology	Develop measurement techniques and standards to characterize electromagnetic interference and other radiation hazards	Minimize negative impacts of specific technologies on health, safety, environment, and electronic system effectiveness	$1,250,000	DOD: $ 809,499 DOT: 79,000 2,056 359,445 $1,250,000	EPA, FCC· FDA, OSHA, EIA, MVMA, AIA, ANSI, IEEE, SAE, NEMA, CEBMA, ERMAC, individual firms and universities
Electromagnetic Properties of Materials	Develop frequency, time, and spatial domain measurement techniques to determine complex electromagnetic properties of selected materials	Improve safety (via monitoring mining operations, and structural integrity of buildings) and enhance natural resource utilization (via monitoring water content of snow packs, soil moisture profiles, coal seam thickness)	$ 200,000	DOI: $ 140,948 DOD: 105,576 DOE: 375,000 $ 621,524	DOA, State of Idaho, Montana St. U., U. of Colorado, Colorado St. U.

a/Additional fiscal year 1980 commitments and reserves not yet received by NBS.

APPENDIX V

Project	Nature of research	Potential productivity effects	Funding		Other interested organizations
			NBS	Other Federal agencies	
Antenna Systems Metrology	Develop measurement techniques and standards for key performance parameters of antennas and associated components	More effective utilization of a natural resource (specific frequency ranges)	$ 480,000	DOD: $ 378,330 a/: 351,670 $ 730,000	
Microwave Metrology	Improve the accuracy and automate calibration instrumentation for microwave equipment	Improve quality control of industrial measurements at same or reduced cost in manpower	$ 805,000	DOD: $ 868,421 HHS: 21,219 a/: 205,360 $1,095,000	IEEE, NCSL, I/JSATP, BIPM
Optical Electronic Metrology	Provide standards and measurement services required to support the development and safe operation of optical electronic systems (fiber optics)	Support the commercial development of an emerging technology (fiber optics)	$ 500,000	DOD: $ 513,385 FDA: 28,000 $ 541,385	ASTM, EIA, ANSI
Time Domain Metrology	Develop measurement instrumentation to acquire and analyze electrical and optical waveforms	Support the commercial development of several emerging technologies including digital communications and pulsed lasers	$ 280,000	a/: $ 470,000	DOD, DOE, NASA, IEEE, OSA, IEC, URSI
Cryoelectronic Metrology	Develop measurement methods and instrumentation to simplify and improve NBS' measurement services	Demonstrate the feasibility of improving the speed, accuracy, and precision of electromagnetic instrumentation that utilizes superconductive electronics technology	$ 430,000	DOD: $ 431,877	IEEE, IIR

a/Additional fiscal year 1980 commitments and reserves not received by NBS.

APPENDIX V

APPENDIX V

Abbreviations for Government Organizations Used

DOA	Department of Agriculture
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FDA	Food and Drug Administration (HHS)
HHS	Department of Health and Human Services
HUD	Department of Housing and Urban Development
LLL	Lawrence Livermore Laboratory
MA	Maritime Administration (Department of Commerce)
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health (HHS)
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OSHA	Occupational Safety and Health Administration (Department of Labor)
PHS	Public Health Service (HHS)
USGS	United States Geological Survey (DOI)
VA	Veterans Administration

Abbreviations for Non-Government Organizations Used

ACM	Association for Computing Machinery
AGA	American Gas Association
AIA	Aerospace Industries Association
ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing and Materials
BIPM	Bureau Internationale de Poids et Mesures (International Bureau of Weights and Measures)
CEBMA	Computer and Business Equipment Manufacturers Association
CIRP	International Institution for Production Engineering Research
EIA	Electronic Industries Association
EPRI	Electric Power Research Institute
ERMAC	Electromagnetic Radiation Management Advisory Council
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IIR	International Institute of Refrigeration
I/JSATP	Industry/Joint Services Automatic Test Project
ISO	International Standards Organization
MVMA	Motor Vehicle Manufacturers Association
NCSL	National Conference of Standards Laboratories
NEMA	National Electrical Manufacturers Association
OIML	L'organisation Internationale de Metrologie Legale (International Organization for Legal Metrology)
OSA	Optical Society of America
OSRD	Office of Standard Reference Data
OSRM	Office of Standard Reference Materials
RIA	Robotics Industrial Association
SAE	Society of Automotive Engineers
SEMI	Semiconductor Equipment and Materials Institute
SIA	Semiconductor Industries Association
SME	Society of Manufacturing Engineers
SPIE	Society of Photo-Optical Instrumentation Engineers
URSI	International Union of Radio Science

NATIONAL BUREAU OF STANDARDS RESEARCH ASSOCIATE PROGRAM: SPONSORS AND PROGRAMS 1970-79

Sponsoring organization	Number of programs sponsored	Number of research associates involved
Aluminum Association	1	1
American Apparel Manufacturers Association	1	1
American Association of State Highway and Transportation Officials	1	a/11
American Dental Association Health Foundation	1	a/88
American Footwear Industries Association	1	2
American Iron and Steel Institute	1	1
American Petroleum Institute	1	1
American Society for Metals	1	1
American Society for Testing and Materials	3	4
Armstrong Cork Company	7	7
Association of Petroleum Re-Refiners	1	1
Atomic Industrial Forum	1	2
Bell Laboratories	1	3

a/Figures are approximate. These programs, which started prior to the period covered by this list, have been characterized by a continuing turnover of personnel, including temporary employees and summer students.

APPENDIX VI

Sponsoring organization	Number of programs sponsored	Number of research associates involved
Bicron Corporation	1	2
Cement and Concrete Reference Laboratory (ASTM)	1	a/44
Collaborative Testing Services	1	a/ 9
College of American Pathologists	1	1
Control Data Corporation	1	1
Cornell University	1	1
Corning Glass Works	1	1
Cotton Foundation	3	4
Dental Division, Bureau of Medicine and Surgery, U.S. Navy	1	4
Dow Chemical Company	3	3
Eastman Kodak Company	1	1
Edison Electric Institute	1	1
Fairchild Hiller Corporation	1	1
Glass Container Manufacturers Institute	1	1
Gypsum Association	4	4
Hewlett-Packard	1	6
Hydronautics, Inc.	1	2
Interdata, Inc.	1	2
International Sugar Research Foundation	1	1

a/See footnote on p. 74.

Sponsoring organization	Number of programs sponsored	Number of research associates involved
JMR Systems Corporation	1	2
Joint Committee on Powder Diffraction Standards	1	a/7
Kennecott Copper Corporation	1	1
Korean Standards Research Institute	1	5
Manufacturers Council on Color and Appearance	1	1
Man-Made Fiber Producers Assoc.	4	4
Martin-Marietta Corporation	1	1
Mineral Insulation Manufacturers Association	1	1
Motor Vehicle Manufacturers Association	1	2
National Association of Dental Laboratories	1	1
National Forest Products Assoc.	1	1
Nippon Steel Corporation	1	1
Optical Manufacturers Assoc.	1	1
PPG Industries	1	1
Proctor & Gamble Company	1	1
Rhone-Poulenc Industries	1	1
Rockwell International	1	1
Scientech, Inc.	1	1
Sears, Roebuck & Co.	1	1

a/See footnote on p. 74.

APPENDIX VI

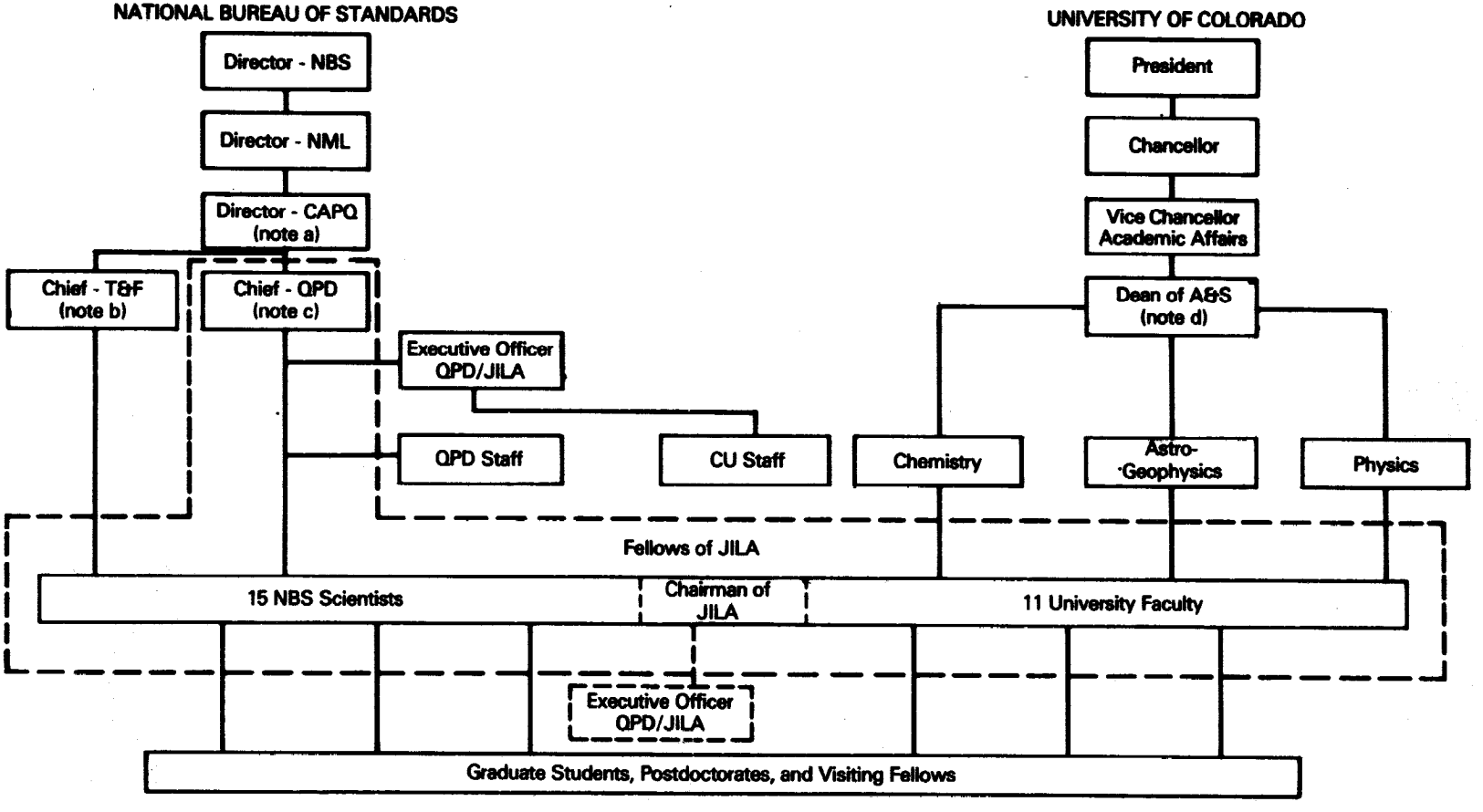
Sponsoring organization	Number of programs sponsored	Number of research associates involved
Skidmore, Owings & Merrill	1	1
Society of the Plastics Industry	1	13
Sperry UNIVAC	2	3
Superconducting Technology	1	2
Technical Association of the Pulp and Paper Industry	1	2
TRW	1	1
Underwriters Laboratories	1	1
U.S. Department of Agriculture	1	1
Upholstered Furniture Action Council	1	1

JILA STAFFING AND FUNDING SOURCES

FOR FISCAL YEAR 1979

	Number of staff	Estimated funds provided				
		NBS	Colorado University	NSF	Other	Total
		(thousands)				
Permanent Ph.D. staff	27	$ 976	$321			$1,297
Other senior research scientists	10			$ 50	$ 50	100
Visiting scientists	12	341				341
Postdoctoral research associates	47			648	568	1,216
Graduate students	42			387	319	706
Engineering, mathematical, and technical support	16	111		128	123	362
Administrative, clerical, and supply support staff	17	314	400			714
	171	$1,742	$721	$1,213	$1,060	$4,736

JILA ORGANIZATION



[a]CAPQ—Center for Absolute Physical Quantities.

[b]T&F—Time and Frequency Division.

[c]QPD—Quantum Physics Division.

[d]A&S—Arts and Sciences.

APPENDIX VIII

JILA FUNDING (OBLIGATIONS), FISCAL YEARS 1970-80
(IN THOUSANDS)

University of Colorado	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980 (estimated)
Direct support (State funds) estimated	$ 419	$ 402	$ 476	$ 476	$ 443	$ 488	$ 475	$ 494	$ 518	$ 561	$ 594
Research contracts (other than ARPA (note a) & NSF atomic physics grant)	290	202	181	334	371	417	597	826	941	1,107	1,100
ARPA (note a)	786	550	466	514	120	120	117	160	170	105	30
NSF atomic physics grant	-	-	-	2	337	506	521	621	740	729	880
Student fellowships	49	20	21	7	-	-	-	-	-	12	13
	$1,544	$1,174	$1,144	$1,333	$1,271	$1,531	$1,710	$2,101	$2,369	$2,514	$2,617
National Bureau of Standards											
Direct appropriations	$ 995	$1,135	$1,193	$1,262	$1,352	$1,434	$1,501	$1,549	$1,627	$1,742	$1,763
Other agency contracts	221	220	225	345	333	393	373	380	508	480	533
	$1,216	$1,355	$1,418	$1,607	$1,685	$1,827	$1,874	$1,929	$2,135	$2,222	$2,296
Total	$2,760	$2,529	$2,562	$2,940	$2,956	$3,358	$3,584	$4,030	$4,504	$4,736	$4,913

a/Advanced Research Projects Agency, part of the Department of Defense.

APPENDIX X

NBS-FUNDED JILA

RESEARCH PROJECTS EXCEEDING $50,000

Project title	Fiscal year 1980 funding
Laser frequency control	$ 148,900
Radiation & energy balance: gas discharge	86,500
Improved measurement methods for long distance	83,900
Transfer of radiation through gaseous media	57,300
Laser spectroscopy of excited states	63,800
Recombination-ion traps	54,200
Radiative and collisional properties	50,400
High energy density discharges	72,700
Gas phase molecular energy transfer	80,500
Atomic collision cross section information center	152,000
Radiometric measurements: solar & stellar astrophysics	87,000
Effects of AC fields on atoms	55,700
High intensity laser absorption	83,000
Gravimeter gravity experiment & telescope development	95,600
Total	$1,171,500

APPENDIX XI

JILA/COLORADO UNIVERSITY

CONTRACTS AND GRANTS EXCEEDING $50,000

AS OF JUNE 30, 1980

Funding agency and project title	Amount
National Science Foundation:	
Atomic Physics Atomic Theory Photodetachment Electron Atom Scattering Plasma Physics Laser Ionization Electron Scattering Saturation Spectroscopy Atomic and Molecular Theory Super Ion Trap Collisional Excitation Eotvos Experiment Low Energy Atomic Physics	$ 880,000
Trapped Ions	164,000
Hot Stars	103,800
Stellar Structure	69,700
O Type Stars	71,000
Theoretical Astrophysics	101,000
Laser State Kinetics	90,000
	$1,479,500
National Aeronautics and Space Administration:	
Data Analysis Solar Physics	$ 66,748
Solar Physics	353,598
Solar Physics	269,000
Solar Physics	100,353
Solar Physics	140,889
X-ray Ultra Violet Emission	139,000
Stellar Chromospheres	129,753
Basic Research in Solar Physics	105,300
	$1,304,641

APPENDIX XI

Office of Naval Research:

Stability of Weakly Ionized Gas Discharges	$ 127,068
Transport Coefficients of Resonating Radiation	291,426
Molecular Continuum Radiation	161,506
Vibration Lasers	115,910
Radiative Collisions	177,978
Precision Beam	162,000
	$1,035,888

U.S. Air Force:

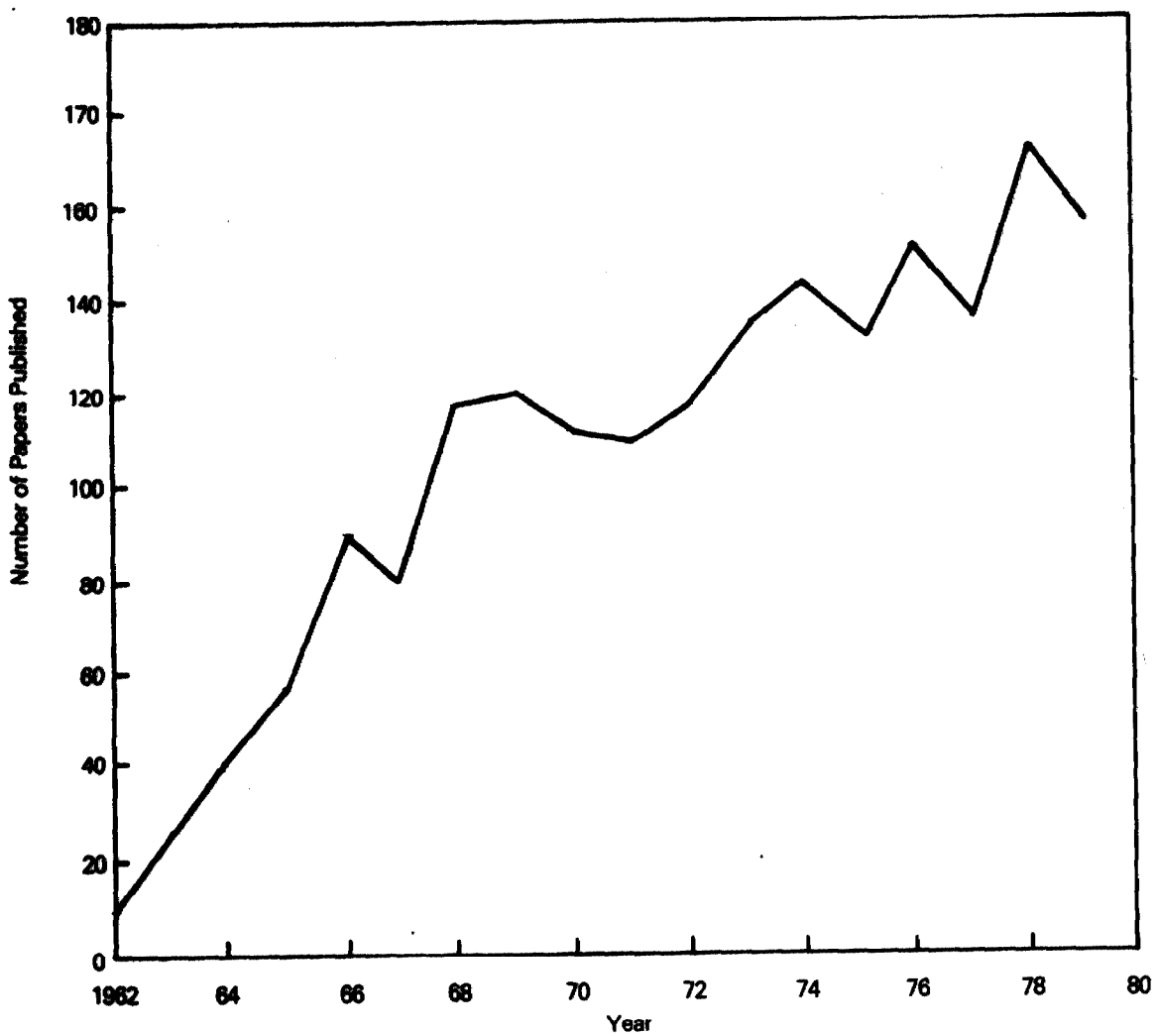
Infrared Chemiluminescence	$ 193,118
Tilt and Strain	360,000
Solar Convection	149,987
	$ 703,105

Solar Energy Research Institute:

Glow Discharge	$ 99,278
Total	$4,622,412

APPENDIX XII

YEARLY NUMBER OF JILA PAPERS PUBLISHED
1962-1979



APPENDIX XIII

NOAA JOINT OR COOPERATIVE INSTITUTES

AS OF SEPTEMBER 1980

Name	University where located
Cooperative Institute for Research and Environmental Sciences	University of Colorado
Cooperative Institute for Research in the Atmosphere	Colorado State University
Joint Institute for Marine and Atmospheric Research	University of Hawaii
Cooperative Institute for Marine and Atmospheric Studies	University of Miami (Florida)
Cooperative Institute for Mesoscale Meteorological Studies	University of Oklahoma
Joint Institute for the Study of the Atmosphere and Oceans	University of Washington
Cooperative Institute for Meteorological Satellite Studies	The University of Wisconsin

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