NBSIR 87-3596

Process and Quality Control and Calibration Programs of the National Bureau of Standards

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, MD 20899

June 1987

Final Report

Prepared for:

The U.S. Congress in Response to Public Law 99.574

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

FOREWORD

Public Law 99-574[1], enacted October 28, 1986, charged the Director of the National Bureau of Standards (NBS) to ask the Bureau's major clients about their needs for research and services related to NBS "process and quality control and calibration programs". This report is in response to that request.

(Excerpt from P.L. 99-574)
PROCESS AND QUALITY CONTROL AND
CALIBRATION PROGRAMS

> Sec. 9 (a) The Director of the National Bureau of Standards shall hold discussions with representatives of Federal agencies, including the Department of Defense, the Department of Energy, the National Aeronautics and Space Administration, the Federal Aviation Administration, the National Institutes of Health, the Nuclear Regulatory Commission, and the Federal Communications Commission, which use (or the contractors of which depend on) the process and quality control and calibration programs of the Bureau, and with companies, organizations and major engineering societies from the private sector, in order to determine the extent of the demand for research and services under such programs, the appropriate methods of paying for research and services under such programs, and with willingness of Federal agencies and the private sector to pay for such research and services.
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> (b) Within six months after the date of the enactment of this Act[2], the Director shall submit to the Committee on Science and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate a report of the Director's findings based on the discussions held under subsections (a), together with recommendations for such legislative actions as may be needed to implement a comprehensive Federal process and quality control and calibration program.

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1 Public Law 99-574, Section 9, Parts (a) and (b), National Bureau of Standards Authorization Act.

2 The National Bureau of Standards was later granted a two-month extension of this deadline.

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EXECUTIVE SUMMARY

General Observations

There has been an explosion in applied science in the last two decades that is manifested in a considerable number of emerging technologies[1]. Computers and robots are revolutionizing the manufacturing industries. Ceramics, polymers, and composites are revolutionizing the materials industries. Biotechnology is revolutionizing the chemical, agricultural, medical, and drug industries. Computers, telecommunications, and optoelectronics are revolutionizing financial, information, and government services and operations as well as manufacturing. New materials that become superconducting at near-room temperature hold tremendous promise for the electric power, medical, and transportation industries.

Movement from basic commodities and materials to higher-value-added products and systems is inevitable and irreversible. Opportunities afforded by the new technologies and challenges from worldwide competition will compel industry to build highly-flexible manufacturing facilities. Customers will benefit from a previously undreamed of variety of products.

The Nation is facing a challenge. Economic competition is increasing throughout the world. The technology-induced rise of new industries and revamping of older industries is taking place in a context of intense global competition. New technologies, new industries, new products and services mean that a new technological infrastructure -- including measurements, test methods, standards, and evaluated data -- has to be constructed and integrated.

The private sector is underinvesting in the science and technology which underlies industrial process design, process control, and quality assurance. Because it is difficult to capture the returns from investment in this science and technology, industry

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[1]Under the direction of Deputy Secretary of Commerce Clarence J. Brown, NBS Director Ernest Ambler recently chaired a Department of Commerce committee to identify emerging technologies and barriers to their expedient commercial application. The Department's report, "The Status of Emerging Technologies: An Economic/Technological Assessment to the Year 2000", is included as Appendix D.

systematically underinvests in its production, to the detriment of national economic growth and international competitiveness.

American firms and Government agencies believe that **implementation of process control and quality assurance in the United States is and ought to be primarily the responsibility of the producers of the Nation's goods and services**, that is, the individual firms, organizations, and agencies. NBS shares this view. No Federal program, no matter how competent or well-meaning, can assume decision-making responsibility for those who take the risks and reap the rewards.

In order to respond effectively to the global competitive challenge, our customers see a need for new measurement services at earlier stages in the product or program development process. This comes at a time when the mechanism for generating these services has become reactive to the product or program needs so that measurement support is often available late in the cycle. This inhibits first-to-market strategies, slows down product introduction, and can cause major setbacks in Government programs.

The National Bureau of Standards also faces a challenge. While measurements and standards for existing technologies and industries continue to require NBS support, new research and services are needed to bring measurement uniformity and compatibility to an array of new technologies. New, emerging technologies have enlarged the scope of measurement requirements; and new kinds of automated processes have changed the scale of measurement support required (e.g., for real-time, in-situ measurement).

Customer Reactions

When asked about the need for a national program for process and quality control, nearly all of the Bureau's industrial customers expressed the view that **the current implementation of the Nation's process control and calibration program, which assigns NBS the role of a central reference laboratory, is the most appropriate national program.**

The firms, Government agencies, and other laboratories we visited **recognize the importance of process control and quality assurance** to their organizations and to the Nation.

Our customers also believe that the National Bureau of Standards plays a unique role with respect to infrastructure support for process control and quality assurance in the Nation. Our customers believe that NBS must provide the measurement foundation needed for process control and quality assurance in the private and public sectors. Many would like to see NBS explicitly designated the lead national laboratory[2] for advanced thinking and experimentation in the measurement science and technology that underlies gains in process control and quality assurance.

Our customers also endorse the Bureau's unique, non-regulatory role that relies on voluntary participation by industry. They believe that NBS should provide technical tools and information to lubricate our free enterprise engine; measurement tools and information which underlie the process control and quality assurance of all firms and facilitate company-to-company consistency in key measurements, but which do not interfere with their proprietary interests.

The customers we visited recognize the symbiotic relationship that exists between forefront research and measurement services. They find the Bureau's measurement services valuable because they are linked to U.S. national standards maintained by NBS. Measurement services are seen as mechanisms for transferring measurement science and theory into practice in industry and elsewhere. Even though a particular service may seem to be provided through relatively routine operations, customers value the fact that each measurement service is built on a sound experimental and theoretical basis, is validated, and is capable of rapid adaptation to high levels of performance.

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[2] "Lead Agency" is the term applied to an agency with a mission that crosses agency lines. A "lead agency's" authorization and funding may require it to perform work for another agency or ask another agency to perform work in furtherance of its mission. At a minimum, a "lead agency" is required to coordinate the activities of all agencies which contribute to its "lead" mission. (See Chapter II for further discussion).

Pricing of Services

Customers showed a high degree of agreement about how NBS research and services should be funded. All believe that the direct costs of delivering services should be paid by the organization that receives the service. If the organization is unable to pay because of some market imperfection, some Government entity should subsidize the purchase, if the service is sufficiently important to the Nation.

If a particular measurement technology exists and has been validated, and a service is developed specifically to benefit a particular industry or agency, **most would be willing to pay "their share"** by having the development costs (amortized over the life of the product or service) added to the direct cost of providing the service or by supplying a "share" of staff, equipment or funding needed for the development. Customers want to be assured, however, that these development costs are directly related to the service they are purchasing and only that service. They are opposed to cross-charging in which high-demand SRMs are priced higher to subsidize the development of other SRMs. They are also opposed to paying for generic development research that might underlie several services.

Both industry and government expressed their **inability to fund the fundamental or generic measurement research and technology** which is required before the final development of a measurement service can be undertaken. Industry, other Federal agencies, and NBS have all become more selective. NBS cannot provide all of the needed measurement support from its appropriation, so NBS is becoming more selective in conducting underlying, fundamental measurement research with its appropriations. Other agencies fund only those measurement activities that directly support their programs. They will not fund underlying measurement research. Firms are willing to pay for services they use directly, but are unwilling to fund generic measurement research or services. Private firms are focusing their R&D on areas with <u>known</u> and <u>predictable</u> profit potential. The times when industry invested broadly in order to have options later are past.

Our customers were unanimous in their belief that the <u>timely</u> availability of measurement research is essential, because it supports the technologies and services needed to meet rapidly expanding international competition, in the case of industry, and mission objectives, in the case of Government. They see such research to be a mandated NBS mission; they expect it to be funded by NBS appropriations at a high enough level to allow services to be available when they need them.

Implications for NBS Services

Demands for NBS measurement services have increased in both scale and scope. Existing measurement services are inadequate because greater accuracies are needed or because the service needs to cover a broader range of temperatures, pressures, frequencies, etc. At the same time, new technologies are creating demands for additional, often entirely new, measurement methods, data, and services.

Today's measurement requirements are also different in kind. Now, more than ever before, dynamic measurements are needed. That is, industry wants to measure some property or characteristic while a process or production line is in motion. It is not economical to stop, make a measurement, and begin again. Furthermore, stopping can alter the process. In addition, now more than ever before, measurement is required in situ. Industry needs the means to verify the measurement performance of instruments, devices, and sensors under use conditions in the production or process stream.

Calibration Services

- Industry needs greater numbers of individual measurements over a diversity of parameters and ranges. Therefore, NBS needs to develop a generic theoretical basis and statistical and other procedures for quality control of measurements by automated systems.

- Because very-high-accuracy measurement capability is being built into commercial devices, NBS needs to develop more measurement standards which are based on the invariant properties of matter which can be used in such devices (e.g., electrical/electronic measurement and test structures on a picosecond time scale).

- The mature technologies need calibration services such as mass, flow, force, temperature, pressure, and optical radiation to be maintained, refined, or advanced.

- The trend toward real-time feedback and modification of process control and quality assurance systems will require different and better sensors, measurement devices, and calibration methods.

- Advances in microwave and millimeter wave technology and applications have created needs to develop and document a variety of measurement methods and procedures.

- NBS needs to work with industry to develop the capability to make and characterize high quality solid state devices that can serve as standards, transfer standards, or transducers for a variety of physical parameters. This promising new technology has the potential to dramatically improve industrial measurements and to provide the U.S. instrumentation industry with a new line of very competitive products.

Standard Reference Materials (SRMs)

- Industrial concern for quality seems to be translating into concern for achieving traceability to NBS, which is increasing demand for NBS SRMs of all types.

- In particular, new, emerging technologies have produced a large and growing demand for new, high-technology Standard Reference Materials (for example, new and renewal SRMs are needed for advanced semiconductors, ceramics, superalloys, nutrition, and advanced physical and chemical metrology). To respond to these needs, the SRM program will need a rapid expansion of its research component.

- "Multi-parameter" SRMs in which both physical and chemical properties are certified for the same material are of especially high priority for the future. For example, an SRM for an industrial plastic needs to be characterized for its chemical composition (polymer, unpolymerized monomer, plasticizer, solvent content, filler, pigment etc) and for its mechanical properties as well.

- U.S. industry has come to rely on NBS SRMs to calibrate "relative" measuring instruments (automated devices which do not measure absolutely). Most firms no longer have any laboratory capabilities of their own to calibrate such instruments.

- Customers believe that tomorrow's highly-automated, multi-component chemical processes will be "optimized" by incorporating standard analytical methods and Standard Reference Materials into "chemometric models" which will control processing. Industry is now pressing for automatic, simultaneous multi-component analyses for many industrial purposes: exhaust gas, medical diagnostics, materials.

Summary of Specific Technical Findings

Measurement-related needs that were identified during recent senior management visits to customers, in documents those customers referred us to, or directly from the users of NBS measurement services are summarized below.

Advanced Materials

- o Design and operation of industrial processes for new, advanced materials such as ceramics, sophisticated metal-alloys, and composites require automated process control to an extent unprecedented in today's manufacturing technologies. These systems will depend on the availability of

  - nonintrusive, nondestructive measurement devices (sensors) that can survive in harsh processing environments; and

  - models and expert systems that incorporate measurement data, test methods, and standards.

  For example, automating these advanced processes will require knowledge of the variability of materials properties versus process perameters fundamental understanding of the relationships between the atomic and molecular structures of materials and their characteristics and performance (e.g., interfacial energies in composites).

- o Methods for analyzing and treating the surfaces of materials are important to a variety of industrial applications. Critical industrial applications will require in-situ diagnosis and treatment of surfaces in harsh environments to assess defects, improve wear, prevent corrosion, prevent stress and fatigue.

- o NBS has received a large number of requests from industry for help in developing a scientific basis (measurement methods, nondestructive tests, predictive models) for assessing wear, durability, and longevity of materials in all sorts of applications and environments. Predictive capability and techniques for improving durability would have significant effects on industrial productivity.

- o Users expect that the speedy development and application of new superconducting materials will depend, in part, on the availability of measurement methods and Standard Reference Materials for identification and characterization, as well as an understanding of process-structure-property relationships.

Advanced Electronics & Semiconductors

- Industry has asked for improvements in the measurement services which assure the measurement of numerous electrical parameters such as voltage, impedance, and current (e.g., new or improved calibration services have been requested for capacitance; magnetic field strength; microwave impedance, low & high power, attenuation, noise, antenna gain, and phase noise.)

- The user community expects new technologies such as Josephson junction technology and superconductivity to lead to the development of new instrumentation and principles for electronic measurement.

- Standards are needed to assure the measurement of semiconductor line width and depth profile and to assure the purity of raw materials used in the chemical production processes of semiconductor manufacture (e.g., Standard Reference Materials such as "known good" and "known defect" wafers; linewidth on wafer; linewidth on X-ray mask; defect size on photomask and wafer; thickness of oxide and metal patterns; internal precipitate concentration, size, and spatial distribution; Gallium Arsenide properties for quality assurance in the production and application of semiconductor devices; minority carrier lifetime; dopant concentration; epitaxial layer thicknesses; carrier density profiles; defect densities; slice flatness; and purity of water, acids, and gases.)

- Measurement methods are needed for manufacturing and evaluating multi-layer semiconductor materials (heterostructures) by chemical beam epitaxy, which combines some of the most attractive features of molecular beam epitaxy and metal-organic chemical vapor deposition.

- Measurement and test methods are needed to assure the measurement of picosecond risetimes and amplitudes of wave propagation on integrated circuits.

Microwave Systems

- Measurement methods, physical standards, and calibration services for numerous electrical parameters in the microwave and millimeter wave ranges are a very high priority to industry (see first "Advanced Electronics & Semiconductors").

- Development of Monolithic Microwave and Millimeter Wave Integrated Circuits (MMICs) will require test methods and standards for the measurement of radio frequency parameters on gallium arsenide semiconductor wafers during processing.

Automation

- To support artificial intelligence applications in factory automation, industry sees a need for generic research in artificial intelligence and robotics. In addition, software standards for computer-aided manufacturing (CAM) systems are needed.

- The user community would like to have guidelines for interfaces, so they will not be dependent on custom, vendor-specific computer networks, software, and workstations.

- Industry sees a need for generic research to develop modeling capabilities for CAD/CAM (Computer-Aided Design & Computer-Aided Manufacturing) that they can use for product development and testing prior to manufacture. Such systems require new quality assurance methodology, methods to verify the accuracy of input data, and a family of application-specific data format standards.

- The complex systems and computing processes that are used in production control, automation, data processing and robotics require additional definition and generic research.

- Specific Calibration Services and/or Measurement Assurance Programs have been requested high-accuracy coordinate measuring machines and for attributes important in manufacturing such as flatness, force, gloss, haze, length (gage block), mass, particle size, surface roughness, and surface finish.

Biotechnology

- As industry begins to bring new biotechnology products to market, the lack of a base of measurement support and research in this area becomes more critical. Industry would like NBS to conduct generic measurement research in biotechnology to create a base of knowledge for the chemical characterization of these new products.

- Industry and the research community need reference materials for immunoassay, for protein sequencing of antibodies used in this technique, and for assessing specific antibody activity in immunoassays.

- New principles of measurement for gas sensing in blood are needed.

- Industry would like NBS to develop complex protein separation techniques for use in "gene fingerprinting" to analyze genetic defects and for use in general protein pattern characterization to detect viruses and cancers in plants and animals.

- Industry needs quality control procedures for enzyme purity and activity measurements.

- Flow cytometry reference materials are needed for cell sorting and diagnostic technologies.

Computer Applications

- NBS customers want additional development, verification, and testing of standards and guidelines for software development, maintenance, and portability.

- Industry sees a need for data interchange standards (physical and logical) for high density computer storage media and systems to facilitate the exchange of media between drives manufactured by a wide variety of suppliers.

- Conceptual designs are needed for advanced information systems used for traffic guidance and control, along with methods for verifying system performance.

Electro-Optics

- New lightwave systems for communications, sensing, and process control in manufacturing have led to requests for NBS to improve, refine, or add new Calibration Services or Measurement Assurance Programs for measurement of power, attenuation, and wavelength; the characterization of fiber-optic sources and detectors; and time domain-reflectometers.

- Calibration Services or Measurement Assurance Programs have also been requested to assure the measurement of ambient and cryogenic blackbodies, laser power, laser beam profiles, and optical fiber power meters.

- Measurement methods and calibration services are also needed for infrared sensors used in satellite monitoring.

- Methods are needed to measure the performance of fiber-optic data communications systems, including switching and multiplexing, determining the location of defective fibers and connectors, and the connectivity of fiber-optic subsystems.

Physics and Chemistry

- Fundamental physical and chemical measurements are the basis of the entire measurement system and many companies visited or receiving services from NBS have expressed the need for continued services, and for service over wider ranges, with greater accuracy, including time-dependent parameters.

- Industry requires sensors, i.e. devices that convert a parameter to be measured into a current or frequency signal. Many such devices will be needed for process control, chemical analyses, control of apparatus and machines; others are needed to transfer accurate measurements from NBS to the manufacturers of instrumentation and from there to the point of use in industry. Industry is seeking closer collaboration with NBS in the development of more sophisticated sensors for fundamental measurements.

- Quality assurance methods and measurement test methods are needed to test components and assure the performance of catalytic converters.

- Tests, Standard Reference Materials, and process control data are needed for assessing the purity of silicon, ceramic powders, and gases.

- Calibration services have been requested to assure vacuum measurement.

- Standard Reference Materials are needed to assure measurements involving basic physical units such as the standard volt, the standard ohm, microlength and atomic scale standards, temperature standards near absolute zero, and density.

- Standard Reference Materials are needed to assure measurements involving specialized chemical quantities such as for part-per-billion constituents in solid state materials; gases and light elements in solid state materials; particle standards certified for inorganic, organic, and isotopic constituents; and standards for compositional mapping.

- Calibration Services and/or Measurement Assurance Programs have been requested for critical parameters of temperature, pressure, and related quantities (e.g., electrolytic conductivity-conductance, improved accuracy for optical fiber thermometry and high-temperature freezing points).

- Measurement Assurance Programs, Standard Reference Materials, and calibration services have been requested to assure measurements made by spectrophotometers to monitor, detect, or control processes (e.g., luminescence, bidirectional scattering ultraviolet, and infrared spectrophotometry).

- To extend the basic length scale to the atomic domain, to provide the metrological basis for the development of nanotechnology devices and production processes, and to improve the design and performance of new devices, customers want NBS to develop fundamental understanding and measurement methods for direct length measurements on microscopic systems of atomic dimension.

- A Measurement Assurance Program for radioactivity measurement has been requested by the nuclear power industry.

- New dosimeters, a Measurement Assurance Program, and calibration services have been requested for industrial radiation dosimeters to extend existing services to electron beams and pulsed fields (e.g., for industrial uses such as food processing, radiopharmaceuticals, medical supplies, electronics, plastics, eleatomers, and composites).

- Methods have been requested for calibrating and characterizing transducers used for the measurement of dynamic (time-varying) forces such as are used to measure rocket and engine thrust, test ordnance, analyze crashes, conduct in-motion weighing, and monitor advanced manufacturing processes.

- Calibration services have been requested for testing the many types of fringe-counting interferometer systems coming into use throughout the dimensional metrology community.

- The angular pointing accuracy required for the Strategic Defense Initiative, plus extensive civilian applications is driving a need for development of a next generation of angular measurement instrumentation with at least an order-of-magnitude improvement over current capabilities.

- One of the most frequently requested calibration services that is not currently available at NBS is the calibration of ultrasound hydrophones that are used to determine the field produced by ultrasonic flaw detectors and medical diagnostic and imaging systems. Many different users have asked NBS to develop measurement techniques and calibration services for ultrasonic contact transducers which are used for industrial and medical ultrasonic measurements. A measurement method is also required for performing the secondary calibration of acoustic emission transducers.

Safety and Health

- o Standard Reference Materials have been requested to assure the measurement of:

  - protein, cholesterol, fiber, vitamin, mineral, toxic metal, pesticide, fungicide, and herbicide content of foodstuffs;

  - eight different enzymes of medical importance, including the certification of each enzyme at three critical levels in human serum;

  - critical levels of all major drugs of abuse in human serum and urine;

  - environmentally important substances for the identification of metals, monitoring of man-made versus natural nuclides, acid rain analysis, detection of organic pollutants and toxic organic gases, and for atmospheric monitoring;

  - substances and attributes related to worker safety and health such as respirator filters, hazardous compounds on filters and surrounding vegetation, and hazardous compounds in human urine; and

  - levels of major therapeutic drugs in human serum for diagnosis and treatment.

Other

- o Industry has asked for Standard Reference Materials to assure the measurement of:

  - color in piece-part manufacturing, pharmaceuticals, agriculture, and transportation;

  - nutrients and minerals (including salt) in soils and water for agricultural purposes;

- o New standards, calibration facilities and training services are needed to improve the accuracy and reliability of barometric pressure measurement to improve the safety and economy of commercial and general aviation.

- o Several Federal agencies and private companies have asked for transfer standards to calibrate devices used to measure radon flux through the ground, floors, and other surfaces.

CHAPTER I: NBS ROLES, PRODUCTS & CUSTOMERS

Introduction

> On the face of it, measurement standards, test methods, and data do not sound very critical when you are talking about national competitiveness. But as one who grew up and made my living working in industry, I can assure you that it is the nuts and bolts details of how you make your product that determine how well it performs, its cost, and ultimately, your success in the marketplace.
>
> Malcolm Baldrige[1]

Sound monetary policy, tax policy, and trade policy; a technologically literate work force; and a robust science base exert a strong effect on the competitiveness of U.S. industry. But on the factory floor where products are made and processes are controlled and in the industrial research lab where processes and products are designed, quality and competitiveness are literally a matter of nanometers, picoseconds, and millivolts.[2] Machinery that works to extremely fine tolerances, components that mesh perfectly into well-crafted final products, and the processes used to create them are coming more and more to depend on cost effective, accurate measurement.

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[1] Malcolm Baldrige, Secretary of Commerce, in Testimony before the Senate Committee on Commerce, Science & Transportation. February 24, 1987.

[2]Nanometers = billionths of meter; picosecond = trillionths of seconds; millivolts = thousandths of volts.

Manufacturing is the key to U.S. competitiveness. Even though the service sector of the U.S. economy is producing more jobs than manufacturing, economists agree that manufacturing, rather than agriculture and the services sector, is the key to curing U.S. international trade problems.[3]

The U.S. faces stiff competition from abroad, and its problems have been developing for many years. According to Jerry J. Jasinowski, Senior Vice President of the National Association of Manufacturers,

> "[The United States] ... had superior manufacturing technology in the 1960s and thought we could continue to run on that ... manufacturing is a very complicated, messy process that does not provide a lot of quick fixes."[4]

In response to a recent survey, members of the National Association of Manufacturers said that they were trying to

> "...cut costs, to improve quality and service, to improve manufacturing processes, to instill a commitment to competitiveness among their employees and to invest more in research and development"

in an attempt to improve their competitiveness.[5] Measurement is central to that task.

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[3]Timothy B. Clark. "The Key is Manufacturing", National Journal, January 10, 1987, pp. 73-78.

[4]Ibid, p. 78.

[5]Ibid., p. 78.

The National Bureau of Standards fills a critical niche in helping U.S. industry produce high-quality, low-cost, internationally competitive goods. NBS works very closely with industry to make sure that essential measurement science and technology is available to meet industry's needs.

Measurement science adds to the pool of basic knowledge that all scientists and engineers use. Scientific advances are often driven by state-of-the-art measurements. New measurements open up new fields for scientific investigation.

Measurement technologies, standards, and data make industrial-research and development more productive by making it easier for industrial scientists and engineers to transform general technical principles into new processes and new product technologies.

In production, measurements, measurement methods, standards and data are crucial to quality assurance and process control. Modern production depends heavily on measurement. In the past, measurement for process control was mostly a static or "snap shot" activity. By contrast, many modern processes require continuous measurement and the ability to respond continuously to measurement change. Similarly, quality assurance was once mostly a matter of inspection to reject defects or select parts for rework. Today, the emphasis is on making it right the first time.

Acccording to Business Week,

> "The typical factory invests a staggering 20% to 25% of its operating budget in finding and fixing mistakes. As many as one-quarter of all factory hands don't produce anything--they just rework things that were not done right the first time. Add in the expense of repairing or replacing the flawed products that slip out of the factory and into the market, and the total burden of 'unquality' can mount to a punishing 30% or more of production costs."[6]

In the most modern production processes, machines are programmed to measure their own attributes, to measure the attributes of the product being processed, and to adjust the process automatically to account for deviations from some ideal.

Measurements, measurement methods, standards and data also help markets develop and grow. New, high-technology products introduce a certain level of risk into the marketplace. Early buyers may be uncertain about the product's attributes or ability to meet their needs. Test methods, test structures and industry standards help new technologies "diffuse" or get into wider use faster by giving both buyers and sellers "yardsticks" to use in assessing the product and its performance. These measurement tools reduce risk or uncertainty, which leads to higher sales,

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[6]"The Push for Quality", Business Week, June 8, 1987, p. 132.

which leads to economies of scale in production, lower costs, and even higher market growth.[7]

The overall economy benefits greatly from measurements, measurement methods, data, and standards but industry tends to underinvest in research leading to measurement science and technology. The first rationale for a national measurements and standards laboratory is based on this economic imperfection: everyone benefits from measurement science and technology, but no one benefits enough to see that the work gets done.

Industry creates many of the test methods and measurement devices needed for their own research, development, production, and marketing. But individual firms and industry groups do not have sufficient economic incentive to create and maintain the overall measurement system needed for the Nation's economic well-being. In general, these specialized technologies do not offer firms an adequate return on the investment required to produce them. The intrinsic nature of measurements, measurement methods, test methods, and data is their self-consistency; their value comes in part from being used throughout an industry or the entire economy.

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[7] "Long-Range Plan of the National Bureau of Standards for FY 1988 and Beyond", September 30, 1985.

Measurement technologies frequently require expensive equipment and highly skilled staff which have limited usefulness to a particular firm or industry. Thus, the measurement-related research of a firm or industry may have <u>insufficient scale to be efficient.</u> Furthermore, individual firms and industries tend to use a limited set of measurement methodologies, but the science and technology of measurement is highly interrelated and can be applied to the problems of many different industries. Thus, the measurement-related research of a particular firm or industry may have <u>insufficient scope to be efficient;</u> the number or range of applications of the research by a single firm may be insufficient to justify the minimum efficient scale of investment in the needed measurement technologies.

The second rationale for a national measurements and standards laboratory is based on the <u>need for equity and uniformity in the marketplace</u> and, thus, for a competitively neutral, technically competent third party in the market to facilitate consensus formation among competitors. Measurement methods, standards and data are critical for conducting and transmitting the results of R&D, for controlling production processes, and for assuring buyers and sellers that products perform as specified. The <u>integrity and efficiency of the free market</u> depends on the development of technically sound, mutually agreeable measurement tools. The presence of a competent, neutral government laboratory can provide the basis for agreement among competitors, without undermining their proprietary technologies.

American industry spends more than $200 billion every year on measurement.[8] As production becomes more automated and highly controlled, measurement is even more important. Why? Because one of the central characteristics of high technology production processes is built-in, on-line, real-time measurement. The result is quality assurance during design and production rather than after production.

How does NBS provide for the common measurement needs of our complex industrial society? It provides tools and reference points that allow industry to trace its measurements back to a common set of national reference standards. NBS also provides advanced measurement technology which allows industry to apply these tools. Some of these tools and reference points include:

- Calibration Services
- Standard Reference Materials
- Measurement Assurance Programs
- Services for the Other Agencies of Government
- Technical Support for Industrial Product Standards

The next section will describe each service briefly.

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[8] Pasquale DonVito. "Estimates of the Cost of Measurement in the U.S. Economy", Planning Report 21, Washington, D.C.: National Bureau of Standards, November, 1984.

NBS Measurement Services

At the beginning of any discussion of measurement services, it is necessary to say plainly that "our services go far beyond the sale of calibrations and Standard Reference Materials. These are important, but they represent only the tip of the iceberg" of the Bureau contribution.[9] An industry request for a new service or, more frequently, an industry description of a problem in controlling some critical measurement, may lead to research that develops entirely new theories and measurement techniques. This research, in turn, can have profound effects on entire industrial processes.

Throughout the evolution of the research, NBS stays in regular contact with all parts of the user community to report on progress and to make sure we are on the right track. NBS also works closely with individual companies to help them decide (1) how they can take our "primary" calibration or Standard Reference Material or Measurement Assurance Program and use it to perform "secondary" calibrations or measurement assurance; (2) how they can embody the new measurement technology into instruments and devices for their own use; or (3) how they can embody the technology into instruments they can develop and sell to others.

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[9] Ernest Ambler. "The State of the Bureau Address," April 21, 1987.

The final calibration or Standard Reference Material then becomes much more than a mere service or product that changes hands. Frequently there are seminars and workshops to explain the significance of the new measurement technique and always there are extensive publications.

The leverage of such a program is tremendous. In the case of NBS' development of a new linewidth standard and Standard Reference Material for the integrated circuit industry, the program cost about $5 million over 14 years (about $350,000 per year). This year alone, savings of over $30 million will be realized on a worldwide sales volume of $375 million in semiconductor device masks, which support $14.6 billion in U.S. semiconductor products.

Thus, behind each measurement service lies a significant investment in time and effort by highly competent and dedicated scientists and engineers in the National Bureau of Standards. The central measurement mission of the National Bureau of Standards is to provide the basis for and the leadership to establish a compatible, coherent measurement system of national scope that is harmonized with the measurement systems of all nations.

Accuracy Requirements of Customers in Relation to NBS Standards

The tens of billions of measurements made in the U.S. economy each year may be categorized as follows: Working Level Measurements, Working Standardization, and Primary Standardization. A particular firm or laboratory may not be certain which level of measurement they need. The choice may be dictated by some other organization (e.g., the Department of Defense or a regulatory agency). In other cases, Measurement Assurance Programs may be formulated by trade groups, professional associations, or standards groups to define accuracy requirements at each level. NBS, as the central reference laboratory, must be knowledgeable about the accuracy required at each level as well as the technology required to achieve that accuracy level.

Working-Level Measurements, the vast majority of all measurements support day-to-day decisions related to production, inspection, health care delivery, public safety, commerce, and trade. Because of their high volume, they need to be low in cost, speedy to perform, and require relatively low levels of specialized training, equipment, or controls. While reliability and accuracy are needed, working-level measurements usually do not require the highest levels of accuracy.

Working Standardization Measurements are used to set and maintain the accuracy of working-level measurements. Accuracy requirements for such measurements greatly exceed those of working-level measurements. Usually they establish a direct link to primary standards. Consequently, they require more specialized training, equipment, and controls. Since they support day-to-day operations, including checking working-level measurements which have gone out of control, easy access is a necessity.

NBS Primary Standardization involves a direct link to national standards and must be of the highest accuracy achievable. Accuracy requirements greatly exceed that for working standardization. Because of the very high accuracy needed, such measurements require specialized personnel, equipment, and operating conditions.

Calibration Services

NBS calibration services link the makers and users of precision instruments to national measurement standards. As the fundamental basis for assuring all physical measurements in the Nation, this measurement transfer system is a critical factor in controlling manufacturing and assembly processes and assuring the quality of manufactured goods.

Firms and other users send instruments or devices to NBS where technicians check, adjust, or characterize the instrument using a measurement process that NBS scientists have specified completely and have demonstrated to be stable, predictable, and tied to national reference standards. NBS currently provides nearly 500 different calibrations, measurement assurance programs, and special tests in seven major measurement areas. About 13,000 tests or measurements were performed on 7,000 different instruments for 1,000 different customers in Fiscal Year 1986. To ensure the skills and procedures needed to transfer precision measurement to the working levels in industry, NBS holds 5-10 technical seminars or workshops each year for 150-200 engineers and high-level technicians who are responsible for measurement and technical support in their own organizations. Fee income from these two activities was $4.7 million in Fiscal Year 1986.

About 80 percent of these calibrations are done for industry, especially those groups involved with product design, research, government procurement, production control, and quality assurance and testing. This relatively small number of NBS-provided calibrations and special tests exert enormous leverage in the manufacturing economy. For example, one large U.S. photographic company relies on photometric and radiometric calibrations by NBS to generate 500 internal standards each year, which in turn are used to produce an annual sales volume of $5 billion. In another case, the 60 calibrations NBS performs each year for the primary standards laboratory of a major U.S. instrument manufacturer, support the company's measurement requirements for its research and development laboratory, for 10 of its technical service centers that repair and calibrate 18,000 instruments annually, and for the company's two manufacturing plants, which calibrate 75 percent of the instruments produced.

Standard Reference Materials (SRMs) are well-characterized, homogeneous, stable materials with specific properties measured and certified by NBS. Produced by NBS since 1906, SRMs are used widely throughout the United States and the world to help develop test methods of proven accuracy, to calibrate instruments and measurement systems used to maintain quality control, to help assure equity in buyer-seller transactions, and to assure the long-term reliability and integrity of the measurement process.

SRMs provide a valuable and economical way of linking laboratory measurements to national standards for large numbers of users in all parts of the country. Very frequently SRMs are cited in voluntary measurement standards promulgated by such groups as the Atomic Industrial Forum, the Society of Automotive Engineers, the Motor Vehicle Manufacturers Association, and the American Society for Testing and Materials. Many firms consider SRMs to be an indispensible tool for their manufacturing processes.

In Fiscal Year 1986, about 40,000 SRM units were sold to about 10,000 customers. The Bureau currently has about 1000 different SRMs available. For example, SRMs are used to establish reference points on the International Practical Temperature Scale, the scale to which all temperature measurements are referenced. The composition of 90 percent of the steel produced in the United States is controlled by measurements based on SRMs. SRMs help improve the accuracy of clinical measurements, including those of glucose, urea, and sodium, that are used by physicians to diagnose and treat disease. The manufacture of virtually all automated clinical analyzers involves reference to NBS SRMs. SRMs serve nearly all sectors of manufacturing including electronics, instruments, computer instrumentation, ferrous and nonferrous metals, mining, glass, rubber, plastics, primary chemicals, nuclear power, and transportation.

Measurement Assurance Programs

These programs help public and private laboratories to improve or verify their ability to make accurate measurements. Measurement Assurance Programs (MAPs) allow other laboratories to test their entire measurement system for accuracy relative to NBS. This is important where very high accuracies are required, because final accuracy of a measurement depends on more than the calibration of a measurement instrument. It also depends on the environment in which the instrument is used, the skill of the technician making the measurement, the measurement procedures used, and similar factors.

Measurement Assurance Programs provide the basis for statistical quality control procedures that industry can use to increase productivity and improve product quality. In setting up Measurement Assurance Programs, NBS works with both individual laboratories and groups of laboratories, who share the cost of the program. At present, NBS offers measurement assurance services in mass; electrical resistance, capacitance, power, and dc voltage; laser power and energy; and temperature.

Technical Support for Industrial Product Standards

NBS provides technical support to the industrial voluntary standards system that specifies the characteristics and performance of devices and materials through measurements and test methods. Our highly competitive industrial economy depends on an extensive system of voluntary organizations, especially voluntary engineering standards organizations, which allow competitors to develop consensus on the minimum set of technical characteristics or requirements to which all competitors will adhere. In the U.S. system, the government does not prescribe which test methods industry will use to manufacture its products, nor does it specify what classification scheme industry should use to describe product characteristics. Industrial committees develop consensus on such questions, publish the results, and then, in most cases, allow individual manufacturers to use the documentary standard or not. But in order for that voluntary, consensus system to work well, there needs to be an impartial, technically competent, organization acting as a competitively-neutral third party to facilitate the consensus process. NBS plays that role in the unique U.S. standards system.

About 450 NBS staff members (about 1/3 of the technical staff) hold 1,444 memberships on over 1,000 voluntary standards committees. NBS staff chair more than 150 committees. Our National Center for Standards and Certification information maintains information on more than 240,000 documentary standards, specifications, test methods, codes, and recommended practices issued by technical societies, professional organizations, trade associations, State purchasing offices, Federal agencies, and foreign national and international standards organizations.

NBS participation in the voluntary standards process serves two functions: (1) NBS provides the link to the national reference system of physical and chemical measurements and methods; and (2) the committees provide one window for NBS on the measurement needs of American industry.

In the next section, we describe the users of the Bureau's services.

Customers

It is a simple fact that everyone relies upon measurements and, to that extent, is dependent on the National Bureau of Standards. The greatest demands on NBS tend to be at the highest levels of accuracy, and that usually implies the highest levels of science and technology. While U.S. industry is the Bureau's primary customer, many other institutions require some level of NBS services. NBS is authorized to perform its functions for the U.S. Government; for international organizations of which the U.S. is a member; for governments of friendly countries; for any State or municipal government in the U.S.; for any scientific society, educational institution, firm, corporation, or individual within the U.S. or friendly countries engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments. NBS is unique among national laboratories in serving such a broad clientele.

One measure of the scope of current NBS interactions with the private sector is shown in Table 1 (following 2 pages). The top R&D-spending firms in the United States are among the Bureau's best customers. Eighty-five of the top 100 R&D-spending firms[10]

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[10]As compiled by Inside R&D, Volume 15, Number 23, June 4, 1986, pp. 3-6.

Table 1. FY 1986 Interaction Between NBS & Top Hundred U.S. R&D-Spending Companies

R&D Spending Rank[1]	Company	Calibration Services	Standard Reference Materials	Standard Reference Data	Visiting Committee[2]	NAS Assessment Panels	Attendance at NBS Conference, Symposia or Workshop	Industrial Research Associates Program	Technical Collaboration	Equipment/Material Donation
1	General Motors (1)[3]	●	●	●			●	●	●	●
2	IBM (5)	●	●	●		●	●	●	●	●
3	AT&T (8)	●	●	●		●	●	●	●	●
4	Ford (4)	●	●	●	●	●	●	●	●	
5	Du Pont (9)	●	●	●	●	●	●	●	●	
6	ITT (25)		●	●		●	●		●	●
7	General Electric (10)	●	●	●		●	●	●	●	●
8	Eastman Kodak (33)	●	●	●		●	●	●	●	
9	United Technologies (16)	●	●	●	●	●				
10	Digital Equipment (55)	●	●				●	●	●	
11	Hewlett-Packard	●	●	●	●	●	●	●	●	●
12	Exxon (2)	●	●	●		●	●	●	●	
13	Chrysler (13)		●						●	
14	Xerox (40)	●	●	●		●	●			
15	Dow (28)	●	●	●		●	●	●	●	
16	3M (47)	●	●	●			●		●	
17	Sperry (63)	●	●	●			●	●		
18	Johnson & Johnson (59)	●	●							
19	Monsanto (53)	●	●	●		●	●	●	●	●
20	Motorola (66)	●	●	●		●	●		●	●
21	Honeywell (56)[3]	●	●	●			●	●	●	
22	Lockheed (36)	●	●	●		●	●	●		
23	Merck (110)	●	●				●			
24	McDonnell Douglas (29)	●	●	●			●			
25	Boeing (21)	●	●	●			●	●	●	
26	Texas Instruments (75)	●	●	●		●	●	●		●
27	Proctor & Gamble (22)		●				●	●		
28	Eli Lilly (119)	●	●							
29	Rockwell International (30)	●	●	●			●	●	●	
30	Allied Signal (37)		●	●		●	●		●	●
31	Control Data (106)		●	●			●	●	●	
32	GTE (Not Listed)	●	●			●	●	●	●	
33	SmithKline (121)		●				●			
34	NCR (89)							●		
35	Goodyear Tire & Rubber (35)	●	●				●	●		
36	Chevron (7)	●	●	●			●		●	
37	Northrop (71)	●	●	●			●			
38	Pfizer (99)		●							
39	Burroughs (72)						●	●		
40	Upjohn (176)		●	●			●			
41	Union Carbide (39)[3]	●	●	●		●	●	●	●	
42	Bristol-Myers (84)		●							
43	Raytheon (60)	●	●	●			●	●		
44	Shell Oil (14)		●	●			●	●	●	
45	RCA (Not Listed)	●	●	●		●	●			
46	American Cyanamid (109)	●	●	●				●	●	
47	Westinghouse Electric (32)	●	●	●		●	●	●	●	●
48	Abbott Labs (116)	●	●					●		
49	General Dynamics (42)	●	●	●		●	●	●	●	
50	Mobil (3)		●	●		●		●	●	

[1] Based on data reported in Inside R&D, June 4, 1986.
[2] Membership on the NBS Visiting Committee and sponsorship of a Research Associate is indicated for the last 10 years.
[3] Numbers in Parenthesis after company name indicate Fortune 500 company rank.

Table 1 (Continued). FY 1986 Interaction Between NBS & Top Hundred U.S. R&D-Spending Companies

R&D Spending Rank[1]	Company	Calibration Services	Standard Reference Materials	Standard Reference Data	Visiting Committee[2]	NAS Assessment Panels	Attendance at NBS Conference, Symposia or Workshop	Industrial Research Associates Program	Technical Collaboration	Equipment/Material Donation
51	Deere (96)		●	●		●	●	●	●	
52	Caterpiller Tractor (52)	●	●	●			●	●		
53	American Home Products (79)									
54	Warner-Lambert (125)		●							
55	National Semiconductor (209)		●							
56	Tektronics (245)	●					●	●		●
57	Amoco (11)	●	●	●				●	●	
58	Intel (251)		●			●	●	●		●
59	Wang Labs (161)						●			
60	PPG (88)		●	●			●			
61	Schering-Plough (189)[3]						●			
62	Texaco (6)		●	●				●	●	●
63	Squibb (180)		●							
64	TRW (57)	●	●	●	●	●	●	●		
65	AMP (223)	●								
66	Standard Oil (24)	●	●	●		●	●	●	●	
67	FMC (120)		●	●				●	●	
68	Gould (233)	●	●	●						
69	Emerson Electric (81)	●	●							
70	Atlantic Richfield (12)		●				●		●	●
71	Amdahl (348)									
72	Data General (269)		●				●			
73	Baxter Travenol (160)	●	●							
74	Syntex (Not Listed)									
75	Rolm and Haas (179)		●	●				●		
76	Eaton (107)	●	●							
77	NYNEX (Not Listed)									
78	General Foods (38)		●	●						
79	Aluminum Company of America (69)	●	●			●	●	●	●	
80	Polaroid (257)		●	●		●				
81	Ingersoll-Rand (145)		●						●	
82	Harris (163)[3]	●	●						●	●
83	Litton Industries (82)	●								
84	Kimberly-Clark (94)									
85	Phillips Petroleum (17)		●	●		●	●		●	
86	Celanese (132)		●	●						
87	General Signal (208)		●							
88	Perkin-Elmer (256)	●	●	●					●	
89	Zenith Electronics (225)		●							
90	Teledyne (122)	●	●				●		●	
91	W. R. Grace (49)		●	●					●	
92	Corning Glass (217)		●	●			●	●	●	●
93	Dart & Kraft (34)									
94	Sterling Drug (202)		●							
95	Colgate-Palmolive (73)									
96	Firestone Tire & Rubber (102)		●					●		
97	Prime Computer (366)									
98	Haliburton (Not Listed)		●							
99	Hercules (147)	●	●	●					●	●
100	Dresser Industries (91)	●	●							

[1]Based on data reported in Inside R&D, June 4, 1986.
[2]Membership on the NBS Visiting Committee and sponsorship of a Research Associate is indicated for the last 10 years.
[3]Numbers in Parenthesis after company name indicate Fortune 500 company rank.

use NBS Standard Reference Materials. More than half of them use NBS calibrations and Standard Reference Data and send staff to NBS conferences. Nearly half participate in technical collaborations with NBS or send Research Associates to NBS to work on mutually beneficial research.

It should be noted that these top R&D spending firms accounted for nearly $39 billion in R&D spending in 1985; 73% of all the privately financed R&D in the Country. Even so, some of the most innovative, cutting-edge firms are too small to appear on Table x (e.g., Genentech, Sun Microsystems, Lotus Development Corporation, LSI Logic, and Convex Corp). Many of these smaller companies are measurement instrumentation companies such as Varian and MTS Systems, to which NBS services and technical data may be especially important.

In addition to the formally structured services and interactions reflected in Table 1, the Bureau carries out many informal discussions and consultations with private sector organizations. It is impossible to quantify the overall level of such consultations with any precision, but NBS technical managers believe that such exchanges (whether by telephone or informal site visits) are among the most effective interactions with industry for purposes of technology-transfer and joint problem-solving.

Even though Table 1 does not reflect the total number of companies with which NBS has significant interactions in Fiscal Year 1986, it demonstrates that NBS programs and services are reaching a significant number of the leading R&D firms in the United States. Such firms will necessarily play a key role in success or failure of the effort to regain international competitiveness in the years ahead.

The Bureau's broad charge as custodian of the Nation's measurements and standards defines an array of needs and technical opportunities far larger than NBS resources. Clearly no single institution can supply all the measurement capability, data, standard materials, or methods for a nation such as the U.S. Firms, standards organizations, educational institutions, and government agencies throughout the country provide a reservoir of science and technology. NBS, through its measurement science and measurement services, provides the links that binds these institutions and their measurement-dependent products into a coherent, compatible whole.

Bureau programs are broadly defined by Congressional and Administration guidance, usually in the form of approval or disapproval of specific programs. These specific programs are based on extensive laboratory-level interactions between users and NBS staff. It is the laboratory-level linkage of which the National Bureau of Standards is most proud. It is these interactions which allow NBS to work directly with the users, from the definition of the problem to the implementation of the solution.

Therefore, although the NBS Director and his senior managers have made a number of visits to industry and government specifically in response to the Congressional charge, NBS also has many diverse mechanisms, cultivated over the years, for assessing user needs . Table 2 shows examples of the high level and diversity of the major services and interactions between NBS and its constituents.

NBS has evolved an approach for most effectively selecting and producing this variety of services and products. It is characterized by a high degree of cooperation, interaction, and cost-sharing with all types of users. Close cooperation in defining needs, conducting research, and disseminating results is a way of life and a "corporate culture" in the technical programs at NBS.

The major components of the NBS user community are described below:

o <u>Large Corporations</u> carry out measurements in many locations and many functions, including process control and quality assurance (both in manufacturing and in the acceptance of components and assembling them), research and development, occupational health and safety, environmental control, and

Table 2. Examples of NBS Services and Interactions

Measurement and Data Services:	
7,000	calibrations performed for 3,000 customers --at a value of $4,600,000.
40,000	units of Standard Reference Materials worth $6,000,000 --sold to 10,000 customers at 32,000 sites
170	testing laboratories accredited in 9 product areas.
22	Standard Reference Data Centers published 3,272 pages of data.
Annual Information Exchange:	
1,600	technical publications
1,000	technical talks presented
115	major conferences held at NBS
600	workshops and seminars held at NBS
11,500	conference attendees at NBS-held conferences
48,000	public inquiries answered
Collaborations with the Private Sector:	
244	technical collaborations with 174 separate U.S. firms --20% with small firms, 80% with large firms
65	firms have loaned or donated equipment
Documentary Standards Support by NBS:	
446	NBS staff active in voluntary standards organizations (1/3 of the technical staff)
1,444	memberships in standards committees
157	standards committees chaired by NBS staff
5,000	annual inquiries answered by the National Center for Standards and Certification Information
Visiting Scientists Working at NBS Annually:	
200	Industrial Research Associates
380	visiting faculty and students
38	postdoctoral research associates
715	guest scientists
Measurement-Related Research for Other Federal Agencies:	
$74	million in 640 individual contracts
Formal Advisory and Oversight Panels:	
188	industry, university & government scientists & engineers on 18 panels reporting to NAS.
5	prominent scientists & engineers & science policy leaders reporting to the Secretary of Commerce.

Examples of Links to National Agenda-Setting Groups:

National Conference of Standards Laboratories
Conference on Radiation Control Program Directors
National Conference on Weights and Measures
National Conference of States on Building Codes & Standards

the purchase of raw materials. Large corporations which conduct significant levels of research and development, have strong direct interactions with NBS and influence NBS research patterns and technology transfer mechanisms. Many have standards laboratories which use NBS primary standards to produce secondary standards for internal use or for sale to others.

- Small Businesses usually carry out measurements in one or a few locations. Their applications are similar to those of large corporations, but usually are more limited owing to a more limited range of products or services. High-accuracy applications may require access to NBS primary standards, while less-demanding applications may depend on secondary standards purchased from private laboratories. Small firms may depend heavily on the voluntary standards process to provide access to measurement and test methods that will support their ability to become suppliers to larger firms.

- Private Testing Laboratories carry out measurements for fees paid by industry, State, local or Federal agencies.

- Hospitals and Clinics carry out measurements in support of medical diagnosis and treatment. (The U.S. health care system carries out measurements in an estimated 100,000 locations.)

- Utilities carry out measurements in support of all operations: purchase of fuels, plant safety and monitoring, plant emissions, coordination of power grids, metering for billing, etc.

- Federal Agencies. Non-regulatory agencies such as the Defense Department, NASA, the National Institutes of Health, and the National Oceanographic and Atmospheric Administration carry out measurements in support of technology development, safety, testing, environmental programs, occupational health and safety. Regulatory agencies such as EPA, FDA, FAA, DOT, and NRC carry out measurements to assess risk, develop regulatory strategy, and enforce regulations.

- State and Local Governments make measurements in support of commerce (i.e., State weights and measures), public health and safety, environment, waste disposal, etc.

CHAPTER II: COMMON CUSTOMER THEMES

During the visits (and in the documents to which we were referred) National Bureau of Standards customers touched on three common themes that relate to the funding of Bureau programs, the pricing of Bureau services, and the Bureau's ability to respond quickly enough to satisfy customer needs.

Lead Agency Status:

Nearly all of the Bureau's industrial customers expressed satisfaction with NBS's role as the Nation's central reference laboratory. They feel this is the most appropriate implementation of a national process control and quality assurance program. Some went further and said that the National Bureau of Standards' lead agency role[11] with respect to the Nation's measurement system should

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[11]The lead agency concept is a well-recognized Government management tool. A lead agency is designated for overall planning and monitoring of Government-wide programs which draw upon the resources and technical capabilities of several agencies. The lead agency is a focal point for formulating objectives and for coordinating activities to achieve the objectives without duplication or gaps. Depending upon Congressional authorizations and appropriations, funding authority may lie fully with the lead agency or may be divided among several agencies. For example, the Department of Energy (DOE) is responsible for all energy programs, including measurement-related programs. When firms from energy-related industries such as the nuclear power industry ask NBS for measurement support, NBS or the industry must ask DOE to fund the work.

be explicitly acknowledged. Many expressed the view that when American industry identifies measurement standards, methods, data, and services required from the Nation's central reference laboratory, they should be able to go directly to NBS, rather than through another agency.

From the NBS point of view, the lead agency principle has been successfully applied in several cases. The designation of a lead agency provides a focal point for coordination and cooperation that is essential for effective, efficient, and concerted national action. However, implementation of the lead agency policy has also led to gaps and delays in the Bureau's ability to meet industry's measurement needs. Often, a designated lead agency declines to fund measurement-related components of a program because (a) they perceive them to be an NBS responsibility; (b) the benefits of the research accrue too widely for them to justify sole responsibility; or (c) they have not budgeted for such work. NBS, in turn, cannot fund the work because (a) the other agency is seen as having the "lead"; or (b) the resources allocated to NBS do not reflect the needs associated with the lead. Many agency missions constrain that agency to fund only part of the measurement-related research needed to solve a major problem (e.g., regulatory agencies do not, as a rule, fund research leading to test methods for industry to use in demonstrating compliance with their regulations). In addition, when other agency sponsors view NBS as a contractor rather than as a partner in carrying out measurement-related research, there is little chance that they will fund the long-term, fundamental research needed to maintain NBS capabilities or create new competence for future measurement problems.[12]

In recent years, other Federal agencies (particularly Department of Defense units and NASA) have required American industry to produce products and components at levels of technical sophistication and quality that challenge industry's process control and quality assurance capabilities. Many of these requirements, <u>which are at the leading edge of tomorrow's commercial requirements</u>, have stringent measurement requirements. Industry expects the National Bureau of Standards to be ready with the measurement methods and services on which they rely. Part of the reason some research and services have not proceeded fast enough is that there are unresolved "lead agency" issues with respect to funding for these programs.

In our discussion, the Bureau's industrial and Government customers expressed the view that it is appropriate for other Federal agencies to pay for project-specific measurements and standards development and services[13], but that measurement-related

[12] There was some customer support for the concept of authorizing NBS to place a surcharge on all research performed on a contractual basis for other Federal agencies to ensure adequate funding for the fundamental base of measurement expertise at NBS. However, many other Federal agencies are not in favor or this approach.

[13] See Table C-1, Appendix C for the levels of NBS income from other Federal agencies.

research that supports industry's general process control and quality assurance needs should be the purview of the National Bureau of Standards. These customers believe that NBS-proposed budget initiatives which are justified on the basis of other agency and industry requirements should not be automatically rejected because of the other-agency connection. Where industry expresses a need and the relevant agencies assert that the work is not duplicative, the work should be considered for inclusion in the NBS budget.

From the industrial customer's point of view, all Government funding comes from a single source, the Federal Treasury. To such a customer it may be "obvious" that some measurement-related program is a Government responsibility and that it ought to have high priority. Therefore, the customer may have little patience with being told to go ask the Department of Defense or NASA to give money to NBS to do the work. Such a process could cause several years' delay, even if successful. The customer wants to be able to come directly to NBS to get a response to his needs. This leads to industry's desire for NBS to be (a) designated a lead agency for process control and quality assurance; and (b) funded directly to provide the measurement standards, methods, data, and services that industry needs for process control and quality assurance.

Cost Recovery and Pricing of Services:

In the 1980s, the Federal Government has placed much greater emphasis on recovering the costs of Government services by charging user fees when individual beneficiaries can be identified and charged. This policy has been applied to many Government services, from entrance fees for national parks to the sale of data.

There is a strong consensus among customers that the direct costs of delivering services -- after the feasibility of offering a service has been proven, and specific customers have been identified, and services are offered on a routine basis (e.g., costs of performing calibration services, cost of producing and distributing Standard Reference Materials) -- should be paid by the organization that receives the service. They believe that the service should be priced at marginal cost. The customer buys a material or sends a device to NBS and receives value added in the form of a direct link to national standards which the customer may use as the foundation for quality assurance.

If a service is developed specifically to benefit a particular industry or agency, many would be willing to pay "their share" by having the development cost (amortized over the life of the product/service) added to the direct cost of providing the service or by supplying a "share" of staff, equipment, or funding needed for the development. If the development is generic in nature or if the service has more diffuse beneficiaries, most firms believe that development costs should be borne by NBS appropriations. Customers are apprehensive about "free rider" issues with such charges. They want to be assured that any development cost associated with a service would be specific to that service alone, not generic or fundamental in any sense.

Under the same constraints, most would be willing to pay "their share" for <u>service upgrades</u>. As technology advances, it is usually necessary to improve services so that they keep pace with the accuracy demands of technology. This may entail upgrading services in the form of new equipment or refined methods which permit the higher accuracies needed. Delivering and upgrading services at the primary standardization level are more likely to require generic measurement research than upgrades at lower accuracy levels.

Customers were unanimously unwilling to pay directly for <u>fundamental or generic research</u> required to undertake development of a service. Such research is risky and entails many costs that are not directly related to service delivery. Fundamental measurement research is primarily concerned with investigating measurement concepts, investigating generic devices for use as transfer standards, and acquiring data related to the concepts or use of such standards. The principal products of this phase of research are publications and other forms of dissemination in the public domain. Such forms of output are highly desirable, since concepts and data are widely applicable in industry, government, and universities. They provide a basis for development of new instruments and devices.

As was described briefly in Chapter I, measurements and standards research and services are carried out by Government (NBS) rather than industry because, in general, industry cannot capture sufficient return on the investment they would have to make to undertake them. Therefore, there is systematic underinvestment by the private sector in measurement-related research and services, despite their importance to competitiveness, to the detriment of the U.S. economy. Measurement-related research and services are considered to be "public goods" to the extent that they have the following characteristics:

- The science and technology is complex, expensive, and time-consuming and therefore requires a significant commitment of resources.
- The skills (personnel) needed to conduct it are frequently different from those required for a firm's proprietary technology development.
- "Economies of scope" exist in the conduct of measurement-related science and technology in that measurement research related to one industry or technology may be highly related to that of another industry or technology. "Economies of scale" exist in that the level and frequency of use of the expensive staff and facilities needed for the conduct of measurement research may be insufficient to elicit adequate investment by a single firm or even a whole industry.
- It is difficult for a private firm to capture an adequate return on investment in such science and technology because part of its value lies in its use throughout an industry or even the whole economy.

- o The results of the research (including services based on the research) must be highly credible among competitors and between buyers and sellers. The results of the research must be regarded as both technically correct and competitively neutral.

On the other hand, measurement research and services are considered to be subject to the same legitimate requirement for recovery of user fees, to the extent that

- o benefits flow directly to an individual beneficiary who can be charged; and
- o no other market imperfection exists that would require the Government to subsidize the beneficiary.

The Bureau's principal goals in setting fees for measurement services are to ensure the availability of needed services while ensuring the appropriate balance of public and private expenditure for such services.[14]

Based on customer reactions and the Bureau's goals, the policy which achieves the overall goals in an optimum manner, and is at the same time consistent with other Federal R&D policies, is one which sets fees to recover the costs of delivering and upgrading a

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[14]It must be noted that many customers expressed the view that the National Bureau of Standards should provide low cost, high quality services for all users. These customers would rather use NBS services, even at higher dollar cost. Therefore, these customers stressed the Bureau's being "cost competitive" with private standards laboratories rather than have NBS adhere to its current policy of discontinuing services when other organizations are able to provide secondary calibrations or reference materials that are sufficiently accurate for working purposes.

"capturable" service, but does not seek to recover the cost of generic research from which the service is but one result.

This balanced approach simultaneously optimizes access, matches accuracy to need, and limits public expenditure on a National standards program. The main concern with this policy is that the span of applications is so large (from purely public to purely private) and the range of organizations is so broad (from large, private enterprises to small businesses or municipalities), that high prices may effectively deny some users who need primary standards direct access to those National standards. One way of providing access would be to place greater emphasis on the creation of high-quality Measurement Assurance Programs to serve those users as well as laboratories that create secondary standards. Such access is needed for good quality assurance and to make certain that suppliers of working level standards maintain high standards.

Measurement & the Current National Concern with Competitiveness:

As might be expected considering the level of attention paid to "competitiveness" in the popular press and in policy circles, many of the Bureau's customers discussed the relevance of measurement to competitiveness and productivity improvements. The principal linkages cited between measurement and these national concerns are discussed below.

Emerging Technologies such as biotechnology, advanced materials, advanced electronics, and flexible automated manufacturing were described as extremely measurement intensive. These new technologies require more measurement in all stages of R&D, processing, testing, and marketing than the more traditional technologies.

While stressing the importance of measurement to the application of emerging technologies, NBS's customers emphasized the importance of continuing to improve measurement standards that are supporting the evolution of the traditional science and technology areas. (No customer told us to stop doing "this" and do "that" instead.)

Many customers described their plans for productivity improvement through automation. Automation depends on the ability to incorporate automated sensing, inspection, and testing. The optimization of processes throughout the economy requires reliable, rapid measurement.

Measurement is the principal tool by which quality is defined. For many Bureau customers, process control and quality assurance are moving from an art to a science; from engineering art to measurement-based science and engineering.

Customers noted that technical regulatory barriers are reduced by the availability of performance standards that are based on objective criteria which can be verified by measurement. Several customers said that a strong U.S. voluntary standards system supported by a reliable national measurement system helps to minimize the need for government regulation. They believe that this system helps to moderate costly and wasteful national "swings" between regulation and deregulation.

CHAPTER III:
NEEDS IDENTIFIED BY SENIOR MANAGEMENT VISITS TO NBS CUSTOMERS

November 1986 - May 1987

As directed by Congress[15], the Director of the National Bureau of Standards (NBS), the NBS Deputy Director, the Associate Director for Programs, Budget and Finance, and other senior NBS managers recently visited several of NBS's major industrial and Government customers.

NBS is appreciative of the time and effort expended by these companies and agencies to brief NBS on their needs in emerging technology areas in general, and their needs for measurement research and services in particular. In many cases these visits serve as kick off meetings that will be followed by more detailed technical working sessions.

Meeting Participants

Customer organizations were selected for visits on the basis of their use of NBS Standard Reference Materials, calibrations and special tests; their collaborations with NBS through joint research or exchange of staff; and their participation on technical over-

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[15] Public Law 99-574, Section 9, Parts (a) and (b), National Bureau of Standards Authorization Act.

sight and advisory committees for NBS. In general, the organizations are large, high-technology, and laboratory-based.

The industry and government leaders who participated in these meetings represented a variety of research, quality control, marketing, and manufacturing functions. Policy-level managers (i.e., vice presidents of firms, heads of agencies or their deputies) as well as metrology or quality assurance managers were present in nearly every case.

The organizations and individuals who attended each of the meetings are listed in Exhibit A, "Senior Management Visits by NBS to Its Customers: Participants."

Discussion Topics

Discussions during these meetings included trends in science and technology, the needs for measurement research and standards, the funding issues of measurement research and standards, and the potential influence of such topics on national competitiveness. See Chapter II for presentation of some of the policy-level themes expressed. Technical findings are discussed below.

These meetings brought out the high value these organizations place on NBS research and services. Customers emphasized the importance of NBS's continuing to provide uniform and accurate measurements to industry and government. They stressed that NBS measurement research, calibration services, and standards need to continue to anticipate the needs of the public and private sectors, in terms of accuracy, range, and technological directions, in both the mature and emerging technologies.

Customers emphasized their need both for more research and services and for coverage of more areas of science and technology.

Trends in the Need for Measurement Research

During these meetings, NBS both confirmed earlier findings and discovered new trends in national needs for uniform and accurate measurement for industrial research, development, production design, and production control. The findings relate to very broad areas of science and technology, including fundamental physical and chemical measurements, advanced materials, advanced electronics, semiconductors, and superconductors, automation, biotechnology, computers, electro-optics, optical fiber data communications, and microwave systems.

Listed below are examples of the scientific and technological areas these customers emphasized during our visits, along with specific requests they made for new NBS research and services or for expansion of current NBS activities. In addition, NBS's current activity in each area is indicated briefly.

Fundamental Physical and Chemical Measurements

- A system of uniform and accurate measurements. Manufacturers of a broad range of instrumentation rely on NBS for the provision of a system of uniform and accurate measurements. This includes electrical parameters (voltage, current, impedance), thermophysical parameters (pressure, temperature, mass), and time or frequency. Manufacturers use these measurements to develop and calibrate instruments for scientific research, process and quality control, and many other applications. The instrumentation industry is concerned that NBS measurement capabilities may not be far enough ahead of industry capabilities in terms of range, accuracy, and time response.

  - NBS is improving its capabilities in several of the areas mentioned above, partly with funds from the Process and Quality Control initiatives.

- Sensors for process control measurements. The instrumentation industry is particularly interested in the development of new sensors, i.e. devices that convert a parameter to be measured - temperature, pressure, density - into an electrical voltage or frequency that is more easily measured with electronic instrumentation. Sensors play a very major role in all process control measurements and in many other applications.

  - NBS has collaborated closely with instrument manufacturers in the past in the development of sensors. This collaboration is now expanding. The Stevenson Wydler Act of 1986 calls for close collaboration between industry and government agencies and sets new rules for the assignment of exclusive rights to industry. NBS is discussing ways for more efficient collaboration and technology transfer with several industry associations and individual companies. NBS is also interested in the development of sensors for use as transfer standards that carry accurate measurements from NBS laboratories into the field.

  - NBS has recently issued a publication describing to industry the opportunities for carrying out joint research and development on a broad range of subjects in NBS laboratories.

- Standard Reference Materials. In industrial practice the verification of measurements made in a production process is often made with standards reference materials (SRM) provided by NBS. In the past these SRM's were mostly characterized for chemical composition. Industry now requires SRM's that are also characterized for related physical properties. For example, SRM's for microelectronic devices must be characterized for (three dimensional) chemical composition and for electrical properties.

- NBS is now developing the microanalytical methods, depth profile analysis, and the software for digital imaging (pictorial display) of the three dimensional composition of microelectronic SRM's.

- For SRM's for industrial plastics NBS is developing methods to determine chemical composition and concentration of leachable organics, such as unpolymerized monomers, plasticizers, and solvents. The same SRM's will also be characterized for their mechanical properties.

o Multi-component analysis methodologies. Multi-component chemical analyses are used in many industrial applications from medical diagnostic measurements to exhaust gas testing of internal combustion engines. Because of the number of needed analyses and the increasing number of elements included industry is beginning to look for simultaneous, multi-component analysis methodologies and suitable SRM's.

- NBS has initiated the development of new Fourier transform nuclear magnetic resonance methods as a prototype for simultaneous multi-component analyses that would require a minimum of time to resolve the composition of fairly complex samples. Other methods should follow: x-ray fluorescence, ion cyclotron resonance, mass spectral analysis.

o Automation of measurements under computer control. Laboratory automation has significantly advanced over the past decade. NBS has worked closely with industry in the development of instrumentation, test methods, and documentary standards for automating measurements under computer control. The next challenge is now to automate some or all of the functions of laboratory technicians in chemical or physical testing laboratories.

- NBS has started a collaboration with a U.S. manufacturer of robots. The goal is to develop the necessary hardware and software to automate a wide range of activities in a typical chemical analytical laboratory.

- o Test methods to determine the durability of materials. Such testing includes the assessment of defects, their causes, prevention, and effects on the reliability and life expectancy of materials. Additionally, the effects of various external agents, on advanced materials, in virtually all environments, require the development of new tests. Test methods and predictive models, which include temperature and humidity variations, high energy radiation, shock, and vibration are needed for advanced materials used in offices, computers, aerospace, and factories.

  - NBS has designed a test program for the study in the effects of defects and lifetime prediction of high density optical storage media.

  - NBS has developed a method for low-cost, high-temperature tensile testing of ceramics to measure the high-temperature strength and deformation behavior of materials for heat engine and heat exchanger applications.

- o Test methods to perform in-situ analysis of surface properties and the treatment of materials, including the effects of stress, fatigue, surface protection, wear, corrosion and interactions (such as adhesion) with other materials. For example, the durability of polymers that are used for structural adhesive bonding, under varying environmental conditions, needs to be analyzed.

  Test methods to evaluate ceramic and composite (metal, polymer, and ceramic) materials, including surfaces, and adhesives, for such properties as viscoelasticity, toughness, flammability, toxicity, rheology, microstructure, and the performance of high temperature materials.

  - NBS has major programs for the development of the measurement science needed to understand the role of toughness and strength on the performance of ceramics at high temperature.

- o The study of polymer structures using small angle x-ray and neutron scattering. The development of sensors for various polymer processing techniques is needed.

  - NBS has pioneered the use of small angle x-ray and neutron scattering techniques to study the structure of a new, potentially important class of polymers, colymer composites, and polymer blends, as a part of a larger program to couple sensors and process models in advancing processing technology. A new, small angle x-ray scattering facility at NBS is available to scientists in industry, government, and universities for cooperative and proprietary research.

- The application of non-destructive evaluation (NDE) methods for the evaluation of process control during manufacturing and in-service inspection of composite (metal, polymer, and ceramic matrices) materials and for the evaluation of precision parts with real-time x-ray systems.

    - NBS is currently a sole source for many NDE standards.

- The study of interfacial energies to evaluate blends of composite materials to provide understanding of both the fabrication processes required to produce high quality materials and the mechanisms by which these materials fail in service.

    - NBS has initiated a program to evaluate the behavior of the interface between the reinforcing material and the matrix material in metal matrix composites, to study the role of the fabrication process.

- The development of integrated processing methods (systems approach involving non-destructive evaluation sensors, process models, and expert systems with computer integration) to facilitate the production of advanced materials in one manufacturing stage and measurement standards for monitoring materials during their manufacture and processing by the user. For example, methods are needed for measurement and process control of fibers in non-woven materials.

    - NBS has initiated a joint effort with American industry to plan, support, and conduct an interdisciplinary program to develop an integrated system for the automated production of rapidly solidified metal powder.

- The characterization and development of reference materials to analyze friction and wear of lubricants and soft films, e.g., hydrocarbons and polymers, especially in "dirty" environments. Techniques are needed for the characterization of friction additives in fuels, which address how fuel properties effect engine design.

    - NBS has an established program to develop measurement methods to study the friction and wear behavior of ceramic materials at high temperatures with and without lubricants.

- The conduct of generic research in the relationship between physical properties and chemical composition of advanced materials. Reference materials that measure both properties are needed for the analysis of advanced materials and fuels/fluids.

- NBS has a major program in the area of rapid solidification processing of metal alloys which results in materials with unique physical properties that are related to the chemical composition of alloys.

Advanced Electronics, Semiconductors, and Superconductors

- o The high accuracy automated calibration of electrical parameters and the development of new instrumentation principles for state-of-the-art electronic measurements.

- o The design and development of semiconductor feature linewidth and depth profile standards.

- o The design of tests and reference materials, in addition to the generation of process control data for the analysis of purity of silicon the analysis of process gases.

- o The measurement and calibration of radio frequency parameters on gallium arsenide semiconductor wafers during processing. These measurements and calibrations are needed due to recent developments in monolithic microwave and millimeter wave integrated circuits (MMICS).

- o The development of methods for manufacturing and evaluating heterostructures, by chemical beam epitaxy. This new technique combines some of the most attractive features of molecular beam epitaxy and metal-organic chemical vapor deposition.

- o The design of calibrations for amplitudes and picosecond risetimes of signals propagating in integrated circuitry.

- o The continued identification, characterization, and understanding of new superconducting materials.

NBS is very aware of many of the needs for measurements in these areas, related to advanced electronics and semiconductors. NBS has continuing high-level contacts with organizations in the semiconductor industries through its ongoing program and therefore is very aware of the measurement needs of the industry and has developed plans to address these needs.

- o The conduct of generic research in artificial intelligence and robotics. Software development is needed for Computer-Aided-Manufacturing (CAM) systems that support artificial intelligence applications in factory automation.

  - NBS has a competence project for knowledge-based computing systems and pattern-recognition systems for generic research which could potentially support this area.

- o The development of guidelines to provide alternatives to vendor-specific computer networks. Currently, multi-vendor computer networks require customization of software, work stations, hardware interfaces, and training.

  - NBS has a competence project in global telecommunications to provide technical solutions for applications of computer networks, nationally and internationally.

  - NBS has competence projects in developing guidelines and standards for computer networks for industry and government.

- o The development of modeling capabilities, used in Computer-Aided-Design (CAD) and Computer-Aided-Manufacturing (CAM) systems, for pre-manufacture product development and testing. Ways of assuring that computer modeling is based on accurate input data are needed. Additionally, quality assurance methods, using on-line design software needs to be developed.

  - NBS conducts generic research in data management, software engineering, and computer security, which includes research related to quality assurance of data.

  - In the areas of Manufacturing Automation Protocol (MAP) and Technical and Office Protocols (TOP) computer communication protocols, which deal with virtual computer to virtual computer communications via local area networks, NBS coordinates users and suppliers in industry and the users in government to promote implementors agreements, thereby, NBS research will reduce the risk of using MAP and TOP and provide lower cost solutions to interconnecting computers in "technical office environments."

- o The continued development of interfaces within CAD/CAM, requires a family of application-specific data format standards.

  - NBS is active in the development of the Initial Graphics Exchange Specification (IGES) for the CAD drafting representation of part geometry, the developing Product Data Exchange Specification (PDES) which deals with concepts such as standardized work elements for process plans and a complete factory system architecture.

- The definition and continued research of complex systems and computing processes. These are used in control and automation systems, data processing, and robotics.

Biotechnology

- The conduct of generic measurement research in biotechnology. Although industry is heavily committed to bringing products to market, the base of support and research expertise do not exist to develop the basic measurement science for chemical characterization of products of biotechnology.

  - NBS has a research effort in measurement support for industrial biotechnology. However, this effort will have to be expanded to meet the diverse measurement needs of industry.

- The development of reference materials for immunoassay and for protein sequencing of antibodies used in this technique.

  - NBS is developing techniques for separations of complex mixtures such as antibody proteins. Separation of such complex mixtures is a prerequisite to issuance of structural reference materials for immunoassay.

- The development of reference materials for assessing specific antibody activity in immunoassays.

  - The NBS research program in chemical characterization of antibodies and related biomolecules would have to be significantly expanded to undertake research in development of reference materials for standardizing and interrelating antibody activity.

- The development of new principles of measurement for gas sensing in blood.

  - NBS has research programs in gas measurements and standards, as well as a small program in clinical chemistry. This specific request identifies a new measurement need that we will have to study.

- The development of complex protein separation techniques for use in gene "fingerprinting" to analyze genetic defects, and for use in general protein pattern characterization to detect viruses and cancers in plants and animals.

- This request would require considerable basic research and competence development by NBS to expand existing efforts in protein separations and digital imaging of electrophoretic gels to the fingerprinting necessary for detection of various health related states.

o The development of quality control procedures for enzyme purity and activity measurements.

- This request for generic measurement science reaffirms a need which is being addressed in the current NBS program of measurement support for industrial biotechnology.

o The development of flow cytometry reference materials for cell sorting and diagnostic technologies.

- NBS currently does not have research activity in this area. NBS has prior experience with fluorescent micro-beads, a related technology. Active involvement in this important area of health measurement would require support beyond that currently available.

Computers

o Continued development and verification testing of standards and guidelines for software development, maintenance, and portability, in addition to advanced application development techniques of computing software.

- NBS has an extensive software standards program, e.g., standards for database management, computer graphics software, and programming languages. NBS has supported the development of the Portable Operating Systems for Computer Environments (POSIX) and is leading the public/private sector development of verification test methods.

o The development of data interchange standards for high density computer storage media and systems. These standards are needed to ensure that systems are physically and logically compatible and therefore facilitate exchange of the media between drives manufactured by a wide variety of suppliers and also between new generations and systems models.

- NBS established and manages the Federal Council on Computer Storage Standards and Technology (FCCSSAT) to provide a forum for the discussion of the user requirements for the design of the Federal Information Processing Standards (FIPS) for data interchange of 12-inch (outside diameter-nominal) write-once-read-many times optical digital data disk media and systems.

- o The development of conceptual designs for advanced information systems, to be used in traffic guidance and control. Methods for acceptance testing and verification of functionality of these systems.

Electro-Optics and Optical Fiber Communications

- o The development of laser power measurements and beam profile characterizations for a wide range of laser power levels and wavelengths. These measurements are needed for the development and testing of a wide range of industrial, military, and commercial laser-assisted systems, including weapon systems, and optical recording, and communications systems.
  - NBS has capabilities in these areas of measurement, but does not have sufficient resources to address all power levels and wavelengths.
- o The development of calibration services for the infrared sensors used in satellite monitoring systems, to assess system reliability and to measure sensitivity and wavelength response.
  - NBS has begun building a cryogenic chamber for the development of this calibration service.
- o The development of performance measurements for fiber optics data communications systems.
  - NBS is already providing comprehensive measurement development for single-mode and multi-mode optical fibers. This effort supports applications in long-haul communications and in local area networks. On a selective basis, NBS is developing measurements for sources, detectors, and waveguides and has requested FY88 funding for developing measurements in modulators, demodulators, and couplers.
- o The development of measurements and test methods for switching and multiplexing schemes in fiber optics communications systems.
  - NBS is participating in the development of Fiber Distributed Interface (FDDI) for the connection of high-performance computers, workstations and storage servers. FDDI is used for the connection and distribution of data through a campus-type environment, over high bandwidth.

- The design of methods for determining the location of defective fibers and connectors in optical communications systems.

  - NBS is developing ways to calibrate commercial equipment of this type and exploring an innovative method for these determinations.

- The development of standards for connectivity of fiber optics subsystems.

<u>Microwave Systems</u>

- The development of measurement methods, physical standards, and calibration services for power, noise, impedance, and other microwave and millimeter wave parameters. These measurements are needed for the optimization of microwave systems and testing to verify that specifications have been met in systems used in the aerospace, instrumentation and communications industries.

  - NBS currently offers a variety of microwave calibration services, but the needs are acute to extend these to higher frequencies and to achieve higher accuracies. We are addressing these needs as rapidly as our available funding permits and we are seeking both other agency and private sector support to accelerate our work.

- The development of new metrology responding to potential industrial development of hardware for microwave and millimeter technology, based on new high temperature superconductors. This may include Josephson junction devices and cooled waveguides.

  - NBS is well versed in superconductor and microwave and millimeter wave technologies.

- For information on Department of Defense applications for microwave metrology, see Appendix C, "Defense Department Needs for Measurement Research and Services."

EXHIBIT A
SENIOR MANAGEMENT VISITS BY NBS TO ITS CUSTOMERS: PARTICIPANTS

NBS/US DEPARTMENT OF DEFENSE (DOD) MEETING
HELD AT NBS, GAITHERSBURG, MD
NOVEMBER 24, 1987

DOD PARTICIPANTS:

Ronald L. Kerber, Deputy Undersecretary of Defense for Research and Advanced Technology (R&AT)

Raymond Siewert, Director, Military Systems Technology

Ted Berlincourt, Director, Research and Laboratory Management

Virginia Castor, Staff Member, Computers and Electronic Technology Directorate

Col. Ted Cress, Military Assistant to Deputy Undersecretary of Defense R&AT

NBS PARTICIPANTS:

Ernest Ambler, Director, NBS

Raymond Kammer, Deputy Director, NBS

Helmut Hellwig, Associate Director for Programs, Budget and Finance

John Lyons, Director, National Engineering Laboratory

Guy Chamberlin, Director of Administration

Lyle Schwartz, Director, Institute for Materials Science and Engineering

Peter Heydemann, Director, Center for Basic Standards

David Jefferson, Institute for Computer Sciences and Technology

Brian Belanger, NBS/DOD Liaison

NBS/US DEPARTMENT OF DEFENSE MEETING
HELD AT NBS, GAITHERSBURG, MD
JANUARY 20, 1987

DOD PARTICIPANTS:

James Cercy, Commanding General, US Army Laboratory Command (LABCOM)

Richard Vitali, Technical Director, LABCOM

Louis Cameron, Director, US Army Research and Technology

Harry Fair, Assistant Director, Defense Advanced Research Projects Agency (DARPA)

General Henry Miley, Jr. (Retired), Director, American Defense Preparedness Association (ADPA)

John Frasier, Ballistic Research Lab, Aberdeen

NBS PARTICIPANTS:

Ernest Ambler, Director, NBS

Helmut Hellwig, Associate Director for Programs, Budget and Finance

Brian Belanger, NBS/DOD Liaison

NBS/AT&T BELL LABORATORIES MEETING
HELD AT AT&T BELL LABORATORIES, HOLMDEL, NJ
FEBRUARY 12, 1987

AT&T PARTICIPANTS:

Robert Lucky, Executive Director,
Research Communications Sciences Division

and staff

NBS PARTICIPANTS:

John Lyons, Director, National Engineering Laboratory

George Sinnott, Associate Director for Technical Evaluation, National Engineering Laboratory

NBS/HEWLETT-PACKARD MEETING
HELD AT HEWLETT-PACKARD, PALO ALTO, CA
FEBRUARY 24, 1987

HEWLETT-PACKARD PARTICIPANTS:

Frank Carrubba, Director, Hewlett-Packard Laboratories

Bernard Oliver, Technical Adviser, Hewlett-Packard Laboratories

Donald Hammond, Associate Director, Hewlett-Packard Laboratories

John Minck, Marketing Communications Manager

Leonard Cutler, Director of Instruments and Photonics Laboratory

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget and Finance

Peter Heydemann, Director, Center for Basic Standards

Judson French, Director, Center for Electronics and Electrical Engineering

NBS/US DEPARTMENT OF DEFENSE MEETING
HELD AT THE PENTAGON, WASHINGTON, DC
MARCH 2, 1987

DOD PARTICIPANT:

Louis Cameron, Director, US Army Research and Technology

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget and Finance

Brian Belanger, NBS/DOD Liaison

NBS/NATIONAL CONFERENCE OF STANDARDS LABORATORIES (NCSL) MEETING
HELD AT NBS, GAITHERSBURG, MD
MARCH 19, 1987

NCSL PARTICIPANTS:

Ed Nemeroff, NCSL President, Datron Instruments

Gary Davidson, Executive Vice President, TRW Corporation/OSG

Pete England, Past NCSL President, General Dynamics

George Rice, Past NCSL President, Rockwell International

John Lee, Chairman, NCSL Government Affairs Committee, Telogy, Inc.

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Alvin Sher, Chief, Program Office

George Uriano, Director, Measurement Services

Elaine Bunten-Mines, Program Analyst, Program Office

Jean Freedman, Program Analyst, Program Office

NBS/GENERAL ELECTRIC COMPANY MEETING
HELD AT
GENERAL ELECTRIC COMPANY, SCHENECTADY, NY
MARCH 27, 1987

GE PARTICIPANTS:

Walter L. Robb, Senior Vice President

Peter W. Dietz, Manager, Engineering Information Systems Branch

Peter C. Juliano, Manager, Polymer Physics and Engineering Branch (PP&EB)

John T. Bendler, Polymer Physicist, PP&EB

Michael T. Takemori, Polymer Physicist, PP&EB

Stuart G. Miller, Manager, Automated Systems Laboratory (ASL)

Lowell W. Bauer, Systems Engineer, ASL

Robert S. Gilmore, Geophysicist/Physicist, Quality Systems Program, ASL

Weiping Wang, Mechanical Engineer, Solid Modeling Program, ASL

Eric Lifshin, Manager, Materials Characterization and Engineering Support Operation (MCESO)

Elizabeth A. Williams, Manager, Organic Characterization Unit, MCESO

Ernest L. Hall, Supervisor, Transmission Electron Microscopy, MCESO

Woodfin V. Ligon, Supervisor, Mass Spectrometry, MCESO

Bernard Gorowitz, Manager, Unit Step Engineering Program, VLSI Technology Laboratory

NBS PARTICIPANTS:

Ernest Ambler, Director, NBS

Helmut Hellwig, Associate Director for Programs, Budget and Finance

John Lyons, Director, National Engineering Laboratory

Donald Johnson, Director, National Measurement Laboratory

NBS/FEDERAL AVIATION ADMINISTRATION (FAA) MEETING
HELD AT FAA, WASHINGTON, DC
MARCH 30, 1987

FAA PARTICIPANT:

Martin Pozesky, Acting Deputy Associate Administrator, National Air Space System Programs

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Peter Heydemann, Director, Center for Basic Standards

NBS/LOCKHEED/TRW/HUGHES/HEWLETT-PACKARD MEETING
HELD AT, LOCKHEED MISSLES SUNNYVALE, CA
MARCH 31, 1987

LOCKHEED PARTICIPANTS:

Al Thompson, Vice President, Operations

Harvey Crosby, Director, Operations Technology

Robert Weber, Manager, Metrology

TRW PARTICIPANTS:

Wendell Seal, Manager, Measurement Engineering

Al Strand, Director of Equipment Management Center

Hartwell Keith, Manager of Calibration Services

HUGHES PARTICIPANTS:

Walter Maquire, Staff Vice President, Quality Management

Ted Mukaihata, Manager, Primary Standards Laboratory of Quality Management

HEWLETT-PACKARD PARTICIPANTS:

Bill Terry, Executive Vice President

John Minck, Marketing Communications Manager

Donald Hammond, Associate Director, Hewlett-Packard Laboratories

NBS PARTICIPANTS:

Ernest Ambler, Director, NBS

John W. Lyons, Director, National Engineering Laboratory

Judson C. French, Director, Center for Electronics and Electrical Engineering

NBS/FORD MOTOR COMPANY MEETING
HELD AT FORD MOTOR COMPANY, DEARBORN, MI
APRIL 3, 1987

FORD PARTICIPANTS:

John McTauge, Vice President, Scientific Research Laboratory

William Goering, Director, Central Laboratories

Dennis Scheutzle, Principal Research Manager, Chemical Analysis Research

D. Baker, Fuels and Lubricants

P. Beardmore, Materials Science

C. Davis, Physics

H. Halloway, Semiconductor Materials

S. Labana, Polymer Sciences

N. Laurance, Senior Staff Scientist, Programming Science and Technology

S. McCarthy, Integrated Circuit Laboratory

R. Pett, Physical Analysis and Technical Services

Margery Roberts, Director, Chemical and Physical Sciences

M. Shelef, Chemistry Department

R. Terhune, Physics

Gordon Willis, Computer-Aided Engineering

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Donald Johnson, Director, National Measurement Laboratory

Lyle Schwartz, Director, Institute for Materials Science and Engineering

Harry Hertz, Director, Center for Analytical Chemistry

NBS/3M COMPANY MEETING
HELD AT 3M COMPANY, ST. PAUL, MN
APRIL 16, 1987

3M COMPANY PARTICIPANTS:

L.D. DeSimone, Executive Vice President, Industrial and Consumer Sector

Lawrence Eaton, Group Vice President, Electronic and Information Technologies Sector

Allan J. Huber, Executive Vice President, Electronic and Information Technologies Sector

Merrill A. Johnson, Vice President, Federal Systems Department

Lester C. Krogh, Vice President, Corporate Research and Development

Manual J. Monteiro, Vice President, International Operations

Krzysztof K. Burhardt, Vice President, Research and Development, Electronic and Information Technologies Sector

Mark L. Anderson, Business Development Manager, Optical Recording Project

Robert L. Bohon, Director, Analytical and Properties Research Laboratory, Corporate Research Laboratories

David F. Clark, Manager, OEM Liaison, Optical Recording Project

Robert J. Clark, Manager, Research and Development Contracts, Federal Systems Department

Dave Davies, Director, Optical Recording Project

Timothy Farrel, Director, Corporate Research Process Technology

Robert P. Freese, Manager, Erasable Media Development

Gerald W. Kottong, Director, Research and Development, Federal Systems Department

Thomas J. Savereide, Executive Director, Corporate Research Laboratories

Ronald Schmid, Director, Engineering Systems and Technology Division

Thomas Wollner, Director, Industrial and Consumer Sector

NBS PARTICIPANTS:

Ray Kammer, Deputy Director, NBS

Helmut Hellwig, Associate Director for Programs, Budget & Finance

James Burrows, Director, Institute for Computer Sciences and Technology

Lyle Schwartz, Director, Institute for Materials Science and Engineering

Curt Reimann, Deputy Director, National Measurement Laboratory

Jean Freedman, Program Analyst, Program Office

NBS/DU PONT MEETING
HELD AT E.I. DU PONT DE NEMOURS, WILMINGTON, DE
APRIL 30, 1987

DU PONT PARTICIPANTS:

Howard Simmons, Vice President, Central Research and Development

Peter Jesson, Director, Physical Services

Ed Chait, Manager, Business Development, Biotechnology Systems Division

NBS PARTICIPANTS:

Ernest Ambler, Director, NBS

Helmut Hellwig, Associate Director for Programs, Budget and Finance

Donald Johnson, Director, National Measurement Laboratory

Lyle Schwartz, Director, Institute for Materials Science and Engineering

Harry Hertz, Director, Center for Analytical Chemistry

NBS/AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES (AAES) MEETING
HELD AT THE AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES,
WASHINGTON, DC
MAY 1, 1987

AAES PARTICIPANTS:

Daniel De Simone, Executive Director

Janis Fritts, Director of Communications

Harry Tollerton, Project Manager of International Affairs

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Burt Colvin, Director, Office of Academic Affairs

NBS/SANDIA NATIONAL LABORATORY MEETING
HELD AT SANDIA NATIONAL LABORATORY, ALBUQUERQUE, NM
MAY 12, 1987

SANDIA PARTICIPANT:

Robert Peurifoy, Vice President for Technical Support

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Ernest Garner, Chief, Office of Physical Measurement Services

NBS/LOS ALAMOS NATIONAL LABORATORY MEETING
HELD AT LOS ALAMOS NATIONAL LABORATORY, LOS ALAMOS, NM
MAY 13, 1987

LOS ALAMOS PARTICIPANT:

Fred Morse, Associate Director for Research

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Ernest Garner, Chief, Office of Physical Measurement Services

NBS/NATIONAL AERONAUTICS AND SPACE ADMINISTRATION MEETING HELD AT NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC MAY 15, 1987

NASA PARTICIPANTS:

George Rodney, Associate Administer for Safety, Reliability, Maintainability and Quality Assurance

Harry Quong, Director, Reliability, Maintainability and Quality Assurance

NBS PARTICIPANTS:

Helmut Hellwig, Associate Director for Programs, Budget, and Finance

Curt Reimann, Deputy Director, National Measurement Laboratory

Howard Yolken, Chief, Office of Nondestructive Evaluation

Jean Freedman, Program Analyst, Program Office

APPENDIX A. CUSTOMER NEEDS FOR CALIBRATIONS & SPECIAL TESTS

June 1987

Introduction

NBS Calibration Services help makers and users of precision instruments achieve the highest levels of measurement quality and productivity. Either directly or indirectly, they link precision equipment or transfer standards to national measurement standards maintained at the National Bureau of Standards (NBS). This linkage is the basis for quality assurance and process control in the manufacture of products as well as in the assembly of complex systems from sophisticated components obtained from a variety of manufacturers. Under the broad umbrella of calibration services, NBS provides nearly 500 calibrations, Measurement Assurance Programs (MAPS) and special tests in seven measurement areas:

- Dimensional
- Mechanical
- Thermodynamic quantities
- Optical radiation
- Ionizing radiation
- Electromagnetic
- Time and frequency.

Types of Services

Calibrations and Measurement Assurance Programs (MAPs) are regularly performed services with pre-established and well-defined conditions. In these services, the measurement process is well-characterized, and shown to be stable and predictable. While calibrations are used to check, adjust or characterize instruments, devices or standards, MAPs are quality control programs for calibrating an entire measurement system. Special Tests are measurements meeting one or more of the following criteria: one-of-a-kind or seldom-calibrated items; measurements or calibration methods for which refinements and/or modifications are still expected.

Users

During a typical year, the largest portion (76%) of services are purchased by American industry. The other major user groups are the Department of Defense (15%), other federal agencies (5%), international customers (2%), hospitals and universities (1.3%), and state/local government (0.7%). Within the industrial sector, customers making products for the Department of Defense (DOD) are the top users of calibration services. This is an anticipated result because of the driving force created by the traceability[16] requirements of MIL-STD 45662 and its effective enforcement by auditors.

User Fees

Calibration services are available to public and private organizations and to individuals. The cost of providing these services is recovered by charging a fee for each calibration performed. These fees range from a low of less than $100 for calibration of a laboratory thermometer to $50,000 or more for special tests of large microwave antenna systems. The customer base of the calibration services is fewer than 3,000. Most customers return their precision equipment or standards every 2-3 years. During

[16] See Exhibit C-1 (page 98) for a brief discussion of "traceability".

fiscal year 1986, calibration services were used by more than 1,000 different customers for a total income of $4.7 million. These calibration services, representing about 13,000 tests/measurements, are then used by manufacturers, commercial metrology and standards laboratories, and government metrology and standards laboratories to support the measurement needs of a large segment of the U.S. economy, a primary goal of the program.

NBS Calibration Needs Assessment

NBS assesses calibration needs continuously using diverse methods. Several important methods of information gathering are direct contact, formal studies, liaison, and literature.

Direct Contact

Perhaps the most dominant source of information is direct contact with customers which is carried out by the entire staff and affects all areas of calibrations on a continuing basis. Direct contact takes many forms, including visits to and from industry, cooperative research projects, consultations with trade associations and standards organizations, workshops, seminars, training courses, guest workers, and research associates. Examples of staff interactions producing a broad spectrum of feedback are:

Participation in National and/or Regional Meetings

American Society for Quality Control (ASQC)
Instrument Society of America (ISA)
Precision Measurement Association (PMA)
Measurement Science Conference (MSC)
National Conference of Standards Laboratories (NCSL)
Promote National Microwave Standards (PNMS)
Council for Optical Radiation Measurements (CORM)
Institute of Electrical and Electronics Engineers, Inc. (IEEE)
Government-Industry Data Exchange Program (GIDEP)
Conference on Precision Electromagnetic Measurements (CPEM)

Annual or Planning Meetings

NBS participates in the annual or planning meetings of the metrology laboratory managers of other government agencies such as the Department of Energy, the National

Aeronautics and Space Administration, and the U.S. Navy. These meetings provide an opportunity for NBS to give an overview and update of its measurement programs, and to receive in return direct feedback on the delivery of services and new measurement requirements.

DOD Liaison

NBS puts special effort into liaison with the Department of Defense, the major user of calibration services within the U.S. government. DOD's calibration requirements are not only rapidly changing but also require long lead times to be in place when new defense systems are fielded. As Defense moves more and more into the high technology and energy technology arena, the measurement requirements are at or beyond the current forefront of measurement science.

NBS Studies

Another valuable source of information in assessing calibration requirements are NBS formal studies seeking detailed information about specific technical fields. These studies yield highly beneficial information in terms of (1) identification of many of the measurement needs, (2) the status and probable development of a technology, (3) industry's view of the NBS role, and (4) impact of the completed work. In general these studies are lengthy tasks requiring up to several years to complete. NBS benefits from a number of formal studies, mostly by other organizations. As an example of an NBS study in progress, the Center for Electronics and Electrical Engineering is evaluating U.S. electronic measurement needs in the frequency range dc to 10 megahertz. To identify those having interest in the field and willing to participate, preliminary circulars were mailed to about 11,000 individuals in industry, academic institutions, and other Government agencies. These recipients had been identified with the cooperation of professional and technical societies as having broad electrical and electronic measurement interests. Some 1,400 individuals responded and accordingly were mailed the questionnaire. Over 500 completed questionnaires and returned them to NBS. The results of this study are undergoing final analysis and review prior to publication, general distribution, and integration into the long range planning process.

Liaison

The technical liaison, marketing and information dissemination activities of the Office of Physical Measurement Services (OPMS) yield numerous group and individual contacts who provide feedback on the delivery of services and requirements for calibrations.

Literature

The open literature yields a vast amount of information which impacts all areas of calibration needs assessment. Both the type of literature and the range of subjects covered in the needs assessment process is extensive and include the technical literature, trade industry literature for economic and technical content, and economic literature to assess impact on productivity and competitiveness.

Customer Services

Seminars/Workshops

Training is a means of providing advice and assistance on measurements and calibrations and, in the long term, promoting measurements consistent with national standards. Participation in regularly conducted workshops and seminars is open to a limited number of persons from measurement and standard laboratories who meet appropriate prerequisites relating to education, work experience and professional activity. Some currently scheduled or recently conducted seminars are:

Seminar	DATE
Precision Thermometry Seminar	10/87 & 3/88
Calibration and Use of Piston Gage Workshop	5/87
Calibration of Ionization Gages Using the Spinning Rotor Gage	5/87
Noise Measurement Seminar	3/87
Workshop on Electrical Measurement Assurance Progs.	3/87
Time and Frequency Seminar	To be Announced

All of the above seminars have been scheduled at least once each year for the past several years, the final determinant being the level of participation. For seminars/workshops requiring hands-on laboratory exposure, participation is limited to 10-15. In other cases the number may be as high as 50 participants. During a typical year, 150-200 participants responsible for engineering and technical support in industry and government will take these seminars. All costs for the conduct of the seminar are paid by the participants.

Exhibits

Technical or professional society meetings represent an opportunity to meet relatively large numbers of users from industry and government, to receive direct feedback, and to disseminate information on the wide range of measurement, standard and cooperative programs available. To date this effort has generated a number of positive responses for information.

FY 1987 Exhibit Schedule

Date	Conference/Location	Attendance	New Contacts
10/86	Instrument Society of America Houston, TX	25,000	500
10/86	Quality Time Expo-West Los Angeles, CA	7,000	400
1/87	Measurement Science Conference Irvine, CA	500	150
3/87	Pittsburgh Conference Atlantic City, NJ	31,000	170
4/87	Quality Central Chicago, IL	25,000	450
7/87	NCSL Workshop and Symposium Denver, CO	500	

Overviews and Briefings

Reports on the status of calibration services and programs in measurement science are given each year, on request, to societies, companies, and educational institutions. These occasions are often used to visit metrology programs and laboratories. Examples of these activities are shown in Exhibit C-2 (page 99).

Formal Needs Assessment by Technical/Professional Societies

One of the most valuable sources of information in assessing the needs for current and new calibration services are the formal studies, reports, surveys and needs assessments of technical and professional societies. These studies are conducted in a variety of ways; several organizations maintain standing committees with major responsibilities for assessing and updating calibration requirements. Brief descriptions of such activities are as follows:

National Conference of Standards Laboratories (NCSL)

NCSL is a non-profit association of laboratories and organizations with a primary goal of advancing the state of the art and practice of metrology through the concerted or cooperative voluntary action of its members. Since its founding in 1961, the NCSL has grown to a membership of more than 700 member organizations from industry, government, and academia. Each member organization appoints a "member delegate" who represents it in NCSL activities. Included among its members are almost all major companies of the defense, aerospace, electronic and other high technology industries.

Along with concerns for the measurement of physical quantities, the calibration of standards and instruments, and the development of standards of practice, the NCSL assesses needs for new or improved measurements. This task is accomplished through a standing committee, the National Measurements Requirements Committee, and results are published periodically. For its 1983 published report[17], this committee surveyed more than 1400 organizations within the United States to assess measurement requirements. Currently, the National Measurement Requirements Committee is updating the 1983 needs assessment as part of a continuing effort to provide a basis for identifying overall needs for major segments of the economy. The updated report[18] is in the final stages of drafting and is still subject to review and approval by the NCSL Board of Directors. This report identifies critical needs in five broad areas of particular importance to NCSL members, reflecting in general a heavy emphasis on needs for defense, aerospace and electronic industries. The findings of the subcommittees making this study are summarized as follows:

- DC - Low Frequency: Capacitance and Magnetic Field Strength are two areas specifically identified for improvement.

- RF-Microwave: Eight parameters are covered in detail with comments on the status at NBS. Of the eight categories, the RF-Microwave Subcommittee has determined that NBS has existing capability to cover most of the requests for Q-meter standards, however, for most areas there is no NBS capability or limited capability to meet the requirements. Some work is in progress but is not expected to reach a point of fruition for several more years. Meanwhile, many DoD programs are proceeding toward full-scale production without new or improved standards to meet perceived needs. Work in this area has been given a number one priority by the subcommittee. Specific areas identified

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17 "National Measurement Requirements Survey", National Measurement Requirement Committee of the National Conference of Standards Laboratories, May 1983.

18 "Report by the National Measurement Requirements Committees (Revised Draft)," National Conference of Standards Laboratories, February 1987.

include impedance, low/high power, attenuation, noise temperature, antenna gain and phase noise.

- Electro-Optics: Critical parameters were reviewed in radiometry/photometry technology, laser technology and fiber optics systems technology. While parameters were not classified by priority, three items were identified for further emphasis in terms of priority by NBS. These are: ambient and cryogenic blackbodies; laser beam profile; and optical fiber power meters.

- Temperature and Pressure: Critical parameters were reviewed but priorities were not established. Two parameters identified as warranting special mention are: electrolytic conductivity-conductance standards and documentation and improvements in the accuracy of optical fiber thermometry and high temperature freezing points.

- Dimensional: This subcommittee covered a number of parameters with no clear distinction in terms of priorities. New requirements were identified for coordinate measuring machines, flatness, force, gloss, haze, length (gage block), mass, particle standards, surface roughness, and surface finish.

The Council for Optical Radiation Measurements (CORM)

CORM is a non-profit organization of professionals and institutions engaged in optical radiometry and spectrophotometry. Among its organizational goals are: (1) assessment of national measurement requirements; and (2) establishment of a national consensus on priorities for these requirements. In its Fourth Report on Pressing Problems and Projected National Needs in Optical Radiation Measurements[19], CORM proposed a multicomponent program to address needs for Measurement Assurance Programs, Standard Reference Materials and new measurement methodologies to correct standardi-

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[19] "Pressing Problems and Projected National Needs in Optical Radiation Measurements," Council for Optical Radiation Measurements, August 1982.

zation deficiencies in broad areas of industrial process and quality control.

Spectrophotometry, one of the principal areas of concern, covers the quantitative application of measurements of spectral transmittance, reflectance, and luminescence, and related quantities, in the near-ultraviolet, visible, and near infrared wavelength regions. This type of metrology is vitally important to many materials-producing and materials-using industries in support of research and development as well as quality control; to clinical and health applications requiring reliable diagnostic tools; and to the analysis of processes and materials important to energy conservation. Surveys estimate that there are more than 50,000 spectrophotometers of various types in facilities throughout the country. The need for standardization is readily apparent when results from only a small fraction of the instruments are compared.

In its report CORM recommended a program to improve services from NBS to the private, state and federal sectors in a manner to assure safety, compatibility and traceability consistent with the economic health of the nation. The proposed program would be carried out in cooperation between a hierarchy of laboratories and NBS. This approach has the advantage of appropriately distributing the burden between the participating laboratories and NBS.

CORM's next in-depth assessment of needs and requirements for optical radiation measurements is currently underway. The report will probably be issued in 1988.

Department of Defense

The metrology requirements of the DoD are published in the "Tri-Service Metrology and Calibration Research, Development and Engineering Plan". This plan documents both the short- and long-range needs for current and future defense systems for fiscal years 1987 through 1991. These as well as other requirements are discussed in Appendix C, "Defense Department Needs for Measurement Research & Services."

The Institute of Electrical and Electronics Engineers (IEEE)

The IEEE Committee on National Measurement in Electro-Technology has undertaken studies[20] in parallel with those of Promotion of National Microwave Standards (PNMS). While the studies are still in progress, the findings to date provide enough information to define general areas of critical need. In general terms, areas of concern are:

- Electrical/Electronic Measurement Technology: All electrical/electronic measurements ultimately relate to the basic parameters of voltage, impedance and current. Sophisticated and advanced commercial electronic instrumentation supporting

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[20] Interim Report, Chairman, Committee on National Measurement Standards in Electro-Technology, Institute of Electrical and Electronics Engineers, February 1987.

numerous quality assurance systems, process and quality control and measurement processes in both industry and government depend upon accurate national standards for traceability and measurement uniformity. As the technology advances rapidly and automation is expanded into all segments of the economy, instrumentation performance capabilities are pushed to new levels. Under these dynamic conditions, research and development are required in all basic areas of electrical/electronic measurement science to improve the accuracy, range and transportability of national standards. Specific areas of primary concern are:

- AC voltage measurements accurate to 5 ppm from 20 KHz, and better accuracy at higher values (1000 v, >1 MHz).

- More accurate (-< 0.1%) four terminal-pair impedance measurements to 60 Hz to 10 MHz.

- Transportable capacitance standards of great stability and resistance to environmental effects.

- Dissipation measurements for standard capacitors at accuracies at 1 ppm and better.

- Calibrations of four terminal standard capacitors at values up to 1 farad at frequencies from 100 Hz to 1 MHz at accuracies -< 0.01%.

- Calibration capability in DC voltage of 0.1 ppm at 10 volts; 1 ppm at 0.01 to 1000 volts. Improved ratio capability in the calibration process.

- Certified confidence of NRC Canada as an NBS surrogate laboratory service at currents up to 4.5 Kamps (AC) at accuracies -< 50 ppm for shunts, or establishment of equivalent NBS service.

o <u>Lightwave Measurement Technology</u>: The ever increasing demand for optoelectronic instrumentation is based upon a need for lightwave systems that perform functions such as communications, sensing and process control of large industrial plants. This emerging technology has very clear and important military and commercial applications. The advanced optoelectronic technologies currently available are of such sophistication that radically new test equipment and measurement technologies are essential to assure performance within specifications. As a result, there are requirements for new approaches to measurement problems encountered in the instrumentation as well as research and development for problems that are not satisfactorily addressed by current approaches. In parallel with these requirements, there is the need to improve, refine or extend existing capabilities. Specific needs include:

- Power measurements of greater accuracy and related primary standards, 1 to 200 milliwatts at 600 to 860 nanometers of wavelength, and from 1 to 8 milliwatts at 1200 to 1550 nanometers.

- Primary standards and techniques for attenuation measurements from 0.1 to 100db from 600 to 1550 nanometers to support a hierarchy of standards to support a field test set measurement requirement of 0.1db/10db.

- Accurate wavelength measurements from 600 to 1550 nanometers and at wavelengths above and below that.

- Measurements to accurately characterize fiber optic sources and detectors and test fibers.

- Methods and techniques for reliable calibrations for state of the art optical time domain reflectometers.

In summarizing National measurement standards and metrology requirements, Jerry Hayes, Chairman, IEEE Instrumentation and Measurement Society Technical Committee on National Measurement Standards in Electro-Technology writes:

"There exists a need for careful documentation and indoctrination lectures describing the newly emerging measurement processes. There also exists a need for training of industry personnel in primary laboratory practices and procedures. There is a wave of retirements taking place in industrial standards laboratories and the integrity of our measurement processes are at risk until new engineers and technicians are trained at the only facility in the U.S. logically equipped and chartered to do so, NBS.

These are but a few of the deficiencies we have identified. We believe they are but the tip of an iceberg of needs. We are aware of several others, but have yet to pin down the specifics in the way of range, accuracy and frequency. Our studies will be directed to identify and report these as we proceed.

We wish to emphasize the great importance that is placed by the measurement community in industry and government on the resolution of these measurement deficiencies. Critical ongoing projects are affected and delayed, future technological developments are impeded, and manufacture of reliable, high quality products is imperiled. We are further concerned about the requirements that will emerge in the future. Continuous and intensive research and development to improve the precision and accuracy of all measurement parameters is imperative as a prelude to technological advancements. We must be moving nationally to measure the 'micro' and the 'macro' of all physical quantities to ever greater accuracies. Electrical-electronic measurements are dependent upon physical-mechanical advances and vice versa. We support advances in all measurement areas as the essential foundation for national measurement technology and the scientific advancements that proceed from it."

NBS Response

The needs assessment process produces an extensive list of parameters and critical areas where industrial needs for measurement methods and services are not being met. Whether an independent study by prominent members of industry and government or the report of a workshop, areas of critical need are usually defined, but priorities, which depend upon many factors, are not always clear. From this wide range of critical needs, many requirements are incorporated into existing NBS programs, or planning processes to develop new programs.

For example, the NBS initiative for "Process and Quality Control Measurements" asked Congress to fund high priority measurement requirements identified through the needs assessment programs of a number of national organizations. In addition to expanding measurement capabilities, this initiative will develop the scientific base for new and improved measurement standards, instrumentation and documentation to transfer measurement technology to the private sector. This program was first funded in FY 1985 at $556,000. In FY 1986 the funding increased by $1,994,000. In FY 1988 an increase of $3,550,000 is pending (see Exhibit C-3, page 100).

Both the calibration community in general and the national organizations presenting formal assessment studies are being kept informed of our progress. This is done through published reports or articles (see Exhibit C-4, page 101) providing information on the exact nature of the requirement, current NBS capability, the status of development, and future plans.

As a complement to these relatively extensive reports, NBS publishes a bi-annual report on changes in calibration services such as improvements in the accuracy of measurements, initiation of new services, and discontinuance or reduction of little used services. Before any service is discontinued, comments are solicited through a general announcement, and all users are notified directly so that they may comment on the impact of the proposed action on their operation. In addition, the Editor of the "NCSL Newsletter" makes space available for NBS to keep its members informed of improvements, breakthroughs or changes in the services offered. Finally, the "NBS Update" publication is an editor's guide to recent activities at NBS of interest to science and technology. This guide is published bi-weekly and widely distributed to editors of technical magazines and newsletters.

Implications for NBS Calibration Services

The results of extensive NBS interactions with industry and government provide guidance on what should be done and feedback on how well current activities are meeting the needs of NBS customers. A representative cross section of identified NBS calibration needs include:

- Barometric Pressure Measurements: Develop new standards, calibration facilities and training services to improve the accuracy and reliability of barometric pressure measurements. This program will impact the safety of commercial and general aviation, leading to reduced operating cost through improved climb patterns and higher capacity in air traffic lanes.

- Quantum Metrology: Develop the capability to make and characterize solid state devices that may serve as standards, transfer standards, or transducers for a variety of physical parameters. This small effort would enable NBS to collaborate with industry and other research laboratories in the exploitation of a new and promising technology that could dramatically improve industrial measurements and would provide the U.S. instrumentation industry with a new line of very competitive products.

- Micrometrology Measurements: Develop the metrology basis for direct length measurements on microscopic systems on the order of atomic dimensions. This effort will: extend the length scale to the atomic domain in terms of national standards; provide the metrology for research and develop of nanotechnology devices and production processes; improve the design and performance of new devices.

- Radioactivity Calibrations: Provide improved calibration services for the community of users and measurers of radioactivity services. Current procedures for data analysis and producing certificates are quite slow and labor intensive. This effort will reduce delays and cost to customers, and also provide a measurement assurance program to the nuclear power industry.

- Dynamic Force Measurements: Develop procedures for calibration and characterization of transducers used for the measurement of dynamic (time-varying) forces. The program will provide high levels of accuracy and precision for calibration and characterization of the dynamic performance of force transducers and force measurement systems over wide ranges of both force and frequency. This project will meet critical civilian and military requirements related to rocket and engine thrust measurement, ordnance testing, crash studies, material and component testing, in-motion weighing, soil mechanics and advanced manufacturing processes.

- Spectrophotometry Measurements: Provide improved measurements, transfer standards and calibration services for luminescence, bi-directional scattering ultraviolet and infrared spectrophotometry. This program will provide uniform measurement scales and transfer standards for widely diverse applications of modern spectrophotometry.

- Dosimetry for High-Dose Applications: Develop new dosimeters, provide measurement assurance services, develop a calibration facility for industrial radiation dosimeters and extend services to electron beams and pulsed fields. This program will provide the measurement services that will improve quality control and economic competitiveness in industrial radiation processing of food, radiopharmaceuticals, medical supplies, electronics, plastics, elastomers, and composites, an industry that is growing at steady rate of approximately 25% per year.

- Radon Transfer Standards: The requirement is for radon transfer standards to calibrate devices used to measure radon flux through the ground, floors and other surfaces. This service has been requested by EPA, DoE and private companies involved in radon measurements in and around homes throughout the country.

- Linewidth Standards for VLSI: Optical and electron microscope standards for thin and thick lines of a variety of materials on a variety of substrates as well as low-voltage scanning electron microscope (SEM) magnification standards. This need has been substantiated by extensive interactions with manufacturers.

- Laser Interferometer Calibrations: For testing the many types of fringe-counting interferometer systems becoming commonly used throughout the dimensional metrology community. This need is verified by customer requests.

- <u>Angle Measurement</u>: A requirement exists for the development of a next generation of angular measurement instrumentation with at least an order-of-magnitude improvement over the current state-of-the-art. The primary driver here is the angular pointing accuracy required in the Strategic Defense Initiative (SDI) program but extensive civilian applications also exist.

- <u>Cylinder and Bore Measurements</u>: The requirements are to extend our ability to accurately measure cylinders and bores by at least an order of magnitude. Prime users will be those developing pressure and microwave impedance standards.

- <u>Force Measurements</u>: The extensive use of load scales for electronic weighing requires development of capability for measurement of the influence of temperature and pressure on force sensor sensitivity, determination of the creep and hysteresis characteristics of force sensors, and the automated calibration of force sensors to high accuracies.

- <u>Vibration Measurements</u>: The requirement is to extend the amplitude and frequency range and the accuracy of vibration measurements needed for experimental model and impact analysis, pointing and tracking systems, and vibration control in a wide variety of civilian and military applications.

- <u>Ultrasound Hydrophones</u>: A calibration service is needed for determining the response of ultrasound hydrophones, used to determine the field produced by ultrasonic flaw detectors and medical diagnostic and imaging systems. This is one of the most frequently requested measurement services which we cannot meet. Use of hydrophones traceable to national standards is written into several ultrasound exposure safety standards. Greater safety and better diagnostics would result from the service.

- <u>Ultrasonic Contact Transducers</u>: About 90 percent of industrial and medical ultrasonics is done by the contact method. The ultrasound field in a solid is the important quantity in this method and yet no measurement techniques, much less calibration services, exist for determining such quantities. This need is recognized by American Society for Testing Materials (ASTM), DOD, FDA and others. Meeting this need would result in more efficient testing and improved product life.

- <u>Acoustic Emission Transducers</u>: A measurement method is needed for performing the secondary calibration of acoustic emission transducers. This need has been recognized by equipment manufacturers, by ASTM and by acoustic-emission practitioners, including those in DoD. NBS currently has adequate capability for primary calibration but development of the next link is needed to support this rapidly growing technology. Meeting this need would result in increased productivity in a wide range of manufacturing industries, including electronics, metal cutting, and chemicals.

- <u>In-Process Sensors</u>: The expanded use of in-process measurement for quality control in manufacturing has lead to totally new calibration requirements for in-process dimension and surface finish measurements as well as more indirect indicators such as acoustic emission and vibration spectra. The Automated Manufacturing Research Facility (AMRF) provides a unique facility for developing these services. Improvements in productivity would be great.

- <u>Power Loss of Voltage Transformers</u>: Develop and document NBS reference measurement capability for measurement assurance program for power loss/power factor (ratio of effective resistance to effective impedance) of voltage transformers. Industry needs access to reference measurement capability traceable to national standards, including means for effective comparison of calibrations of transformer loss-measuring systems. NBS has already developed calibration procedures for these systems, in collaboration with industry. The average annual capitalized cost of transformer losses in the United States is estimated to be about two billion dollars.

- <u>Quality Assurance for Automated Microwave Measurement Systems</u>: Develop generic theoretical basis and statistical and other procedures for quality control of measurements by automated systems. Tasks include verifying systems performance, computational processing of calibration data, and reporting of validated results. Automated microwave measurement systems require capability for operator to ensure that performance of system at time measurement is made meets system specifications and is consistent with system historical performance data base.

- <u>Microwave Impedance Measurements for "TNC" Type Connectors</u>: Develop and document NBS impedance calibration service for "TNC" connectors over the frequency range of 0.1 to 26.5 GHz. TNC connectors are widely used in civil and defense systems that require a compact, rugged, high-quality connector.

- Microwave Waveguide Impedance Standards: Develop and verify performance of waveguide impedance standards over the frequency range 2.6 to 18 GHz. IEEE PNMS "B" priority. These standards are required for NBS waveguide calibration services over the specified range based on the dual six-port automatic network analyzer.

- Noise Figure for Amplifiers: Develop methods and associated documented measurement service for effective input noise temperature for amplifiers used in communications and other microwave systems in the 2 to 4 GHz range. Industry has expressed need for this measurement service traceable to national standards. Service would constitute first step in development of needed reference noise figure measurements and services for a range of frequency bands.

- Low Flow Rate Calibration and Testing: With the growth of high technology comes the need to accurately measure low flow rates. A prime example of these needs comes from the microelectronics industry where the flow of poisonous corrosive gases (such as salines, phosphines, arsines, etc.) has to be measured with high accuracy. Similar requests come from the automobile industry where engine performance testing require accurate measurement of fuel and air consumption.

- Flow Rate Transfer Standards: Design and develop tailor-made flow rate transfer standards which are critically needed to test performance of aircraft engines, aerospace components and liquid fuel driven space engines.

- Slurry Flow Testing: Develop and test slurry meters to measure the dispersed solid phase found in nearly 70% of all process flows. There is need to expand the existing facility, equipped for handling of setting slurries only, by developing the instrumentation and non-intrusive techniques for solid fractions in flowing slurries.

- Characterization of Active Antennas: Develop methods needed to characterize new class of antennas -- active antennas -- in which each element of an array incorporates an active transmitting and an active receiving component. Techniques develop for conventional passive antennas will not be directly applicable, as an active antenna cannot be treated as a reciprocal device. Active antennas offer enhanced control of the beam of electromagnetic energy transmitted by the antenna, increased power in the beam, and greatly increased sensitivity with respect to the received signal. These antennas are finding use of airborne radar and satellite earth resources mapping systems, and offer benefits for future communications systems. In resource mapping, use of an active antenna provides capability for obtaining information not previously available from satellite measurements, as a result of the enhanced sensitivity combined with the capability of the antenna to transmit first a horizontally and then a vertically polarized signal, while receiving in both polarization orientations.

- Dielectric Properties of Materials at Microwave Frequencies: Develop and document NBS calibration services for dielectric properties of materials for electronic and electromagnetic applications, primarily at microwave frequencies. NBS survey results and contacts show strong industry needs for reference dielectric measurements for a wide range of applications, among them substrates for various types of integrated circuits, including microwave monolithic; radomes; lenses for quasi-optical systems; microwave absorbing material, including material commonly used in pyramidal form for measurement systems; and reflectivity issues, including "low-observables".

- Digital Information System Performance Measures: Develop measurement methods and supporting mathematical analyses for determining the quality of high-speed digital data streams in computer and communications systems employing electrical, microwave, or optical means of digital data transfer. Improved measurement methods will support the development and sale of more competitive, high-performance digital products. The new methods will also improve the performance of these systems in service by providing early warning of degradation of signal quality and by providing objective measurements for restoring signal quality.

EXHIBIT C-1
THE CONCEPT OF TRACEABILITY

> "The ideas implicit in the concept of traceability are ancient. The desire for procedures by which measurements made at the working level can be made consistent with an established reference standard can be observed in the building of the pyramids of ancient Egypt, where the length of the pharaoh's arm was defined to be the national standard of length (the cubit). For convenience in disseminating this length unit, this arm's length was transferred to a marked granite rod, which in turn could be compared for consistency with the working measuring rods made of wood that were used by the construction forces."

National Standards, as a necessary basis for accurate measurements, are useful only if they are accessible to those responsible for making measurements throughout the Nation in all sectors of the economy. In principle, National Standards are required to calibrate or otherwise characterize measuring instruments and devices. In practice, the instruments and devices are usually qualified in terms of laboratory standards which, in turn, are qualified in terms of National Standards. Thus, measurements at remote locations, widely distributed and made at different times may be known in terms of units realized on the basis of National Standards through a process which often involves hierarchial levels of intermediate standards. This process with supporting documentation is referred to by the term <u>traceability</u>. A hierarchical system for realizing traceability exists in some form in all developed countries. Traceability may also be achieved through the use of Standard Reference Materials.

In the most general sense, however, traceability means the existence of any systematic process or combination of processes, hierarchical or otherwise, whereby a quantity may be determined in terms of units obtained from any specified standard. Certain measurements of high accuracy are possible, however, without the need for comparison with national artifact standards. For many practical levels of accuracy, intrinsic properties of atoms, molecules and larger aggregates of matter are useful in the realization of units without direct comparison to a national standard.

EXHIBIT C-2

SOME TYPICAL EXAMPLES OF VISITS AND TALKS TO USER GROUPS

Talk: Annual Meeting of the Government-Industry Data Exchange Program, October 1985

Talk: DoE Standards Laboratory Managers Conference, October 1985

Visit: Metrology and Analytical Laboratories, Rockwell International, Golden, CO, October 1985

Talk: Region-9 Meeting of the National Conference of Standards Laboratories, December 1985

Visit: Metrology Laboratory & Facility, John Fluke Manufacturing Company, Everett, WA, January 1986

Visit: Metrology Laboratory, Boeing Aerospace Company, Seattle, WA, January 1986

Visit: Metrology Laboratory, Lockheed Missile and Space Company, Sunnyvale, CA, January 1986

Visit: Metrology Laboratory and Plant Facility, Hewlett-Packard Company, Palo Alto, CA, January 1986

Visit: Analytical Laboratories, Naval Civil Engineering Laboratory Port Hueneme, CA, January 1986

Talk: Butler Community College, Butler, PA, April 1986

Talk: Capital Cities Control Conference, Albany, NY, May 1986

Talk: American Society for Quality Control, Horsham, PA, October 1986

Talk: North Carolina State University, Raleigh, NC, September 1986

Visit: U.S. Navy Primary Standards Laboratory, Coronado, CA, January 1987

Talk: Houston Section of the National Conference of Standards Laboratories, January 1987

Visit: Houston Power & Light Company, Bay City, TX, January 1987

Talk: AT&T Network Systems, Oklahoma City, OK, March 1987

EXHIBIT C-3
PROCESS AND QUALITY CONTROL MEASUREMENTS
PROJECTS REQUESTED IN FY 88

Priority	Project	($K)
1	Frequency Standard R&D	438
2	High-Pressure Measurements	305
3	AC & DC Voltage	441
4	Radon Measurements	246
5	High-Temperature Thermometry	174
6	Low-Frequency Measurements	967
7	Electrical Documentation & Training	255
8	Neutron Dosimetry	246
9	Electrical Resistance Measurements	306
10	Primary Temperature Facility	172
		$3550K

EXHIBIT C-4
NBS PUBLISHED RESPONSES TO FORMAL MEASUREMENT REQUIREMENT STUDIES AND SURVEYS

1. Belanger, B. C., Kirby, R. K., and Simmons, J. D., "NBS Response to the 1982 National Measurement Requirements Survey of the NCSL National Measurement Requirements Committee", NBSIR 84-2847 March 1984.

2. Mielenz, K. D., "NBS Response to the Fourth CORM Report on Pressing Problems and Projected National Needs in Optical Radiation Measurements", NBSIR 84-2889 May 1984.

3. Uriano, G. A., "Update of NBS Response to the NCSL National Measurement Requirements Study: DC/LF Electrical Measurements", NCSL Newsletter, Vol. 26, No. 2, P. 20, July 1986.

4. Uriano, G. A., "Update of NBS Response to the NCSL Measurement Requirements Study: Electro-Optical Measurements", NCSL Newsletter, Vol. 26, No. 4, P. 13, October 1986.

5. Uriano, G. A., "Update of NBS Response to the NCSL Measurement Requirements Study: Temperature, Pressure and Mechanical Measurements", NCSL Newsletter, Vol. 27, No. 1, P 17, January 1987.

6. Adair, R. T.; Reeve, G. R., and Gatterer, L. E., "The Expanding Need for Microwave and Millimeter Wave Calibration Services", NCSL Newsletter, Vol. 27, No. 1, P. 21, January 1987.

7. Uriano, G. A., "NBS Response to 1986 Feedback From NCSL Region 8", NCSL Newsletter, Vol. 27, No. 1, P. 32, January 1987.

APPENDIX B. CUSTOMER NEEDS FOR STANDARD REFERENCE MATERIALS

May 1987

Introduction

Standard Reference Materials (SRMs) have been disseminated by the National Bureau of Standards (NBS) in support of American industry for more than 80 years. Currently, all the operations and production costs associated with providing this service are borne by customers, who during fiscal year 1987 will pay NBS about $5.5 million for SRMs.

SRMs provide a valuable and economical way of linking laboratory measurements to national standards. They are prepared (usually in batch quantities) and certified for the properties of interest in order to provide measurement "benchmarks" for the users. In application, they are used either to calibrate or validate the accuracy of the users' instruments.

For example, steel is produced to close compositional specifications. (Different, but exact, proportions of ingredient elements such as carbon, silicon, chromium, and nickel are required to make steel that is suitable for specific applications.) In order to insure equity in commerce and the quality of final products, producers and buyers of steel need to measure the composition of each lot. To do this efficiently requires that they have accurate benchmarks (SRMs) to calibrate their measurements. SRMs serve this need on both sides of the transaction point and ultimately have a positive impact on quality assurance for the goods produced.

Table B-1 is a summary of the kinds of materials for which SRMs are available. About one-third of the inventory consists of metal alloys certified for chemical composition. Another third covers other materials which are certified for composition. The final third includes materials with certified physical or engineering properties.

Each SRM must pay its own way. As stocks of a given type begin to run low, careful decisions are made to continue or discontinue production based on projected customer ability and willingness to pay development and production costs. In a typical year, supplies of 100-150 different SRMs are exhausted. Of these, about 75 percent are renewed with similar material and 25 percent are discontinued due to declining technological need. Only by discontinuing some SRMs can resources be made available to develop some new ones each year. Where technical need continues, NBS takes pride in maintaining continuity of SRM supply.

Dozens of SRMs are cited in voluntary measurement standards promulgated by such groups as the Atomic Industrial Forum, the Society of Automotive Engineers, the Motor Vehicle Manufacturers Association, and the American Society for Testing and Materials. Industrialists depend on SRMs to assure material measurements that are critical to the success of their business. Usually these critical points are at commercial transaction points, or at places where significant gains can be made in quality assurance.

Table B-1. Standard Reference Material Categories.

Steels	Radioactivity
Steelmaking Alloys	Isotopics
Cast Irons and Steels	Ion Activity
Nonferrous Alloys	Mechanical and Metrology
Gases in Metals	Superconducting
High Purity Metals	Freezing Points
Electron Probe Microanalytical	Calorimetric
Primary Chemicals	Vapor Pressure
Spectrometric Solutions	Thermal Properties
Clinicals	Thermocouple Materials
Biologicals	Magnetic
Botanicals	Optical
Environmentals	Gas Transmission
Industrial Hygiene	Reference Fuels
Lubricating Materials	Resistivity
Fertilizers	Rubber Materials
Ores	Computer Tapes
Minerals	Sizing Standards
Refractories	Color
Carbides	Photographic
Glasses	Surface Flammability
Cements	Smoke Density
Trace Elements	Water Vapor Permeance
Nuclear Materials	X-ray Diffraction

Table B-2 provides just a few of the many instances where SRMs are mentioned in American Society for Testing and Materials (ASTM) standards and vice versa. These have been selected to demonstrate the range of standards supported. The depth of support, especially in the field of chemical analysis of metal alloys, is quite extensive, with several hundred alloy SRMs available for use in conjunction with standard methods of analysis. Many firms consider SRMs indispensible to their manufacturing processes. For example, James Kanzelmeyer, chief chemist at St. Joe Minerals Corporation states:

"The laboratory at St. Joe Zinc Smelter has used standard reference materials from NBS for more than 30 years. Right now we have 128 different SRMs in stock, ranging from environmental standards and reagent chemicals to ceramic materials, ores and minerals, pure metals, and alloys. Just as we check and adjust our analytical balances with a standard set of weights traceable to NBS, we use SRMs to ensure that new methods measure what they are supposed to measure within required accuracy.... Properly used, SRMs provide a means for laboratories to reach agreement on specific measurements. The analyses themselves, if not the interpretation of their significance, can be eliminated as a source of controversy."[21]

James P. McKaveney, manager of analytical services at Occidental Petroleum Corporation, contributed the following comment:

> "At OPC we have long range projects concerned with refining chemicals from coal as well as coal desulfurization; we use a number of SRMs.... Because of large cost increases in recent years, we don't use the large quantities

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21 Standardization News, September 1979, pp. 25-27.

Table B-2. Examples of Support to American Society of Testing and Materials (ASTM) Standards

ASTM Std.	Test	NBS SRM
C 204	Cement Fineness (Blaine)	114n Portland Cement
C 115	Cement Fineness (Wagner)	114n Portland Cement
C 430	Sieve Residue	114n Portland Cement
C 336	Glass Annealing and Strain Points	711 and 717 Glass Viscosity
C 338	Glass Softening Points	711 and 717 Glass Viscosity
C 657	Glass Electrical Resistivity	624 Glass Electrical Resistivity
C 770	Glass Stress Optical Coefficient	708 and 709 Glass
C 829	Glass Liquidus Temperature	773 Glass Liquidus Temp.
D 1238	Melt Flow Rate (Plastic)	1475 and 1476 Polyethylene
D 1505	Density (Plastic)	1475 and 1476 Polyethylene
D 1434	Gas Transmission Rate (volumetric)	1470 Polyester Film
D 1434	Gas Transmission Rate (manometric)	1470 Polyester Film
D 3985	Gas Transmission Rate (coulometric)	1470 Polyester Film
D 1646	Mooney Viscosity	388m Butyl Rubber
D 2268	Chemical Analysis of Fuels	1816a Isooctane
D 3177	Sulfur Analysis in Coal and Coke	2682-2685 Sulfur in Coal
D 4239	Sulfur Analysis in Coal and Coke	2682-2685 Sulfur in Coal
D 2795	Analysis of Coal and Coke Ash	99a Soda Feldspar
E 27	Analysis of Zinc and Zinc Alloys	94c Zinc Base Alloy
E 129	Analysis of Thermionic Nickel	671-673 Nickel Oxide
E 322	Analysis of Steels and Cast Irons	Various SRMs
E 539	Analysis of 6Al-4V Titanium Alloy	173 and 654a Ti Alloy
E 162	Flame Spread Index	1002c Surface Flammability
E 648	Critical Radiant Flux	1012 Flooring Radiant Panel
F 746	Pitting and Crevice Corrosion	1890-1891 Crevice Corrosion

of SRMs that we used about 10 years ago.... I believe both American industry and the federal government need to better appreciate the value of NBS and use it more efficiently.... U.S. industry will require strong support from such agencies as NBS."[22]

Robert J. Bendure, director of research at Armco (Steel), Inc., added:

"For many years, Armco has used NBS standard reference materials to establish calibration points for chemical analysis. The large demand for standards often necessitates use of secondary standards for day-to-day calibration. However, it is extremely important that these secondary standards are calibrated against primary NBS SRMs so that wet and instrumental calibration is traceable to NBS. Unless this is done, measurement of both intralaboratory and interlaboratory accuracy will become increasingly difficult, and resolving differences between suppliers and users as to material composition would become impossible."[23]

Lynn L. Lewis, assistant department head at General Motors Research Laboratories had this to say:

"The automotive industry may appear to be like a duck on water -- calm, unruffled, and moving forward serenely. But I assure you that there is furious paddling beneath the surface! Much of this vigorous activity is concerned with ensuring product quality, conserving materials, and solving environmental problems -- all three of which require SRMs as the keystone in assuring measurement compatibility and integrity.... Our industry's use of SRMs goes back to 1906 when a standard was issued for cast iron in chip form. Our reliance on standards for alloys has grown, and today we depend on more than 90 chip-form and powder-form SRMs, as well as more than 100 solid-form SRMs. All of these standards were issued on

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[22]Ibid.

[23]Ibid.

> the basis of established needs, most of which will continue far into the future."[24]

Perhaps even more revealing of the essential nature of the program are the cries of distress heard when an SRM runs out of stock. In 1985, it was necessary to certify a new lot of SRM 927, Bovine Serum Albumin, an important standard in clinical and nutritional chemistry. The first batch of material purchased to prepare the renewal lot was of unsatisfactory quality, so the reissue was delayed. The following comments were received from Dr. Marvin C. Feil, Project Manager for Allied Corp., Instrumentation Laboratory Division. His comments are typical of the distress suffered by many users of SRM 927:

> "The extended 'out-of-stock' situation for SRM 927 is a major problem for my colleagues and me. The SRMs enable us to ensure the accuracy of our products over long periods of time. Accuracy is so important to us that we use SRMs to validate every lot of material we make. The unanticipated lack of an SRM forces us to use inherently less reliable standards. We depend upon the National Bureau of Standards to provide these vital materials in a timely manner so that we can provide our customers with the high quality products they demand."
>
> "Please do whatever is necessary to provide SRM 927 as soon as possible. Please tell me if I can assist in any way to make SRM 927 available quickly and to ensure an uninterrupted supply of all the SRMs which are so important to my profession, company and industry."[25]

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[24]Ibid.

[25]Letter dated October 22, 1985.

More than 40,000 Standard Reference Materials are sold each year to over 20,000 customers in every state and to numerous overseas laboratories. See map, Exhibit B-1 (page 128). The main reason customers use SRMs is to assure the quality of a wide variety of economically-important measurements. About 1000 different types of SRMs are currently available to support measurements in such areas as:

- Industrial quality assurance
- Efficient energy utilization
- Semiconductor electronic components
- Construction materials
- Mining and metal production
- Petroleum industry
- Environmental protection
- Industrial hygiene
- Health (clinical) analyses
- Agriculture
- Nutritional information
- Support to research laboratories

The set of available SRMs will vary over a period of years as customer demand, technology, and means for assuring measurement quality change.

The Office of Standard Reference Materials (OSRM) attempts to operate in a business-like fashion. The catalog which lists the available SRMs is revised each two years and distributed to about 60,000 potential clients. (Copies can be made available to readers of this report.)

Description of Interactions/Needs Assessment

Because the SRM program must recover all development, production, and distribution costs, its very survival depends on selecting SRMs that customers will buy. Therefore, the Office of Standard Reference Materials is eager to know exactly what customers want and will buy. In order to assess customer needs, OSRM has employed a multifaceted approach using increasingly diverse methods. Direct customer demand, while not the only criterion for producing an SRM, has carried especially heavy weight as a factor in the selection process since the program began to operate on a cost recovery basis. Below are listed (approximately in the order of effectiveness) ten ways OSRM uses to learn about customer needs for Standard Reference Materials:

- Sales Results
- "Brown Cards" Returned by Buyers
- SRM Request Forms
- Technical Committee Advice (Including NBS Divisions)
- Workshops/Seminars
- Exhibits at Technical Meetings
- Monthly Magazine Forum
- Magazine Surveys
- Exchange of Visits/Visitors
- Surveys Prepared External to OSRM

Sales Results

NBS keeps careful records of monthly and annual sales for each SRM type. These data are most important in assessing the need to renew materials which are going out of stock. In addition, they provide valuable information about similar SRMs when considering a new material. Exhibit B-2 (page 129) is an example from the 27-page monthly report titled "Four Year Sales Summary Report," for the end of January 1987. Each report provides year-to-date (YTD) sales for each SRM in comparison with the last four years of its sales history.

"Brown Cards" Returned by Buyers

In FY 1985, OSRM began packing a user feedback card with each outgoing shipment (more than 20,000 shipments per year). These "brown cards," see Exhibit B-3 (page 130), ask customers to comment on the service received and potential new SRM products that are needed. About two hundred are returned to NBS each year. Every brown card is answered and then considered when priorities are set for production.

SRM Request Forms

See Exhibit B-4 (pages 131-132). These forms give customers and non-customers alike an opportunity to provide input to the OSRM priority setting process.

Technical Committee Advice

NBS technical division chiefs are a very important source of ideas about new SRMs, because this input is based on broad connections with the U.S. technical community. Specific advice about industrial priorities for reference materials is received from numerous technical committees, some of which exist solely to provide advice to NBS. The participants on these committees represent their own firms, and their salaries and expenses are paid by their firms. Together the individuals strive to reach a technically correct and competitively neutral consensus on industrial needs for NBS SRMs. Some important contributors to the SRM program are listed below.

- American Society for Testing and Materials (ASTM)
  - -- Comm. S-17 ASTM/NBS Research Associate Program
  - -- Comm. C-14.91 SRMs for the Glass Industry
  - -- Comm. D-22 Methods of Sampling and Analysis of Atmospheres
  - -- Comm. E-13 Molecular Spectroscopy
  - -- Comm. E-29 Particle Size Measurement
  - -- Comm. F-1 Semiconductor Materials
  - -- Association of Official Analytical Chemists
  - -- College of American Pathologists
  - -- International Oceanographic Commission
- Motor Vehicle Manufacturers Association
- National Committee for Clinical Laboratory Standards
- Portland Cement Association
- Society of Automotive Engineers

Exhibits at Technical Meetings

Project managers from OSRM make more than 1000 contacts each year at technical exhibits throughout the country. These contacts keep the project managers closely coupled to the needs of the technical community. Table B-3 shows exhibits for Fiscal Years 1984, 1985, and 1986.

Table B-3. Technical Exhibits for Fiscal Years 1984-86.

Date	Conference	Attend'd	Contacts
10/83	Assoc. of Official Analytical Chemists	1,500	75
3/84	Pittsbgh. Conf. on Analytical Chem.	27,000	900
3/84	Quality Expo, Chicago	8,000	550
4/84	Amer. Chem. Society, St. Louis	9,000	300
6/84	Soc. of Nucl. Medicine, Los Angeles	6,000	200
6/84	Air Pollution Control Assoc.	4,000	200
7/84	Amer. Assoc. for Clinical Chem.	3,000	150
8/84	Amer. Chem. Society	10,000	300
9/84	LABCON Central	3,000	150
Total			2,825

Date	Conference	Attend'd	Contacts
10/84	Quality West	12,000*	500
10/84	LABCON New Eng.	3,000*	150
1/85	Measurement Science	500*	75
2/85	Pittsbgh. Conf. on Anal. Chem.	23,000	900
4/85	Quality Expo	18,000	650
4/85	LABCON West	3,000	175
4/85	Amer. Chem. Society	9,000	300
5/85	Test & Measurement	5,000*	200
6/85	Soc. of Nucl. Medicine	6,000	200
7/85	Rocky Mtn.	2,500*	150
7/85	Amer. Assoc. for Clinical Chem.	3,000	150
Total			3,450

Date	Conference/Location	Attend'd	Contacts
10/85	LABCON Central	3,000	150
10/85	Instrumnt. Soc. of America	20,000*	400
11/85	Quality West	10,500	200
11/85	Eastern Analytical	8,000*	250
1/86	Measurement Science	500	100
3/86	Pittsbgh. Conf. on Anal.	26,000	1,150
4/86	Amer. Chemical Soc.	8,000	300
4/86	Quality Central	22,000	700
5/86	Amer. Soc. of Qual. Control	8,000*	300
6/86	Air Pollution Control Assoc.	6,000	200
9/86	Amer. Chemical Soc.	9,000	350
9/86	Federation of Anal. Chemical Socs.	2,500	150
Total			4,250

*New Exhibit - First time attending this conference.

Workshops/Seminars

Over the past three years, OSRM project managers have participated in more than two dozen workshops, seminars, and symposia. Several of these have been arranged, sponsored, or chaired by them. Often the workshops have been co-sponsored with an NBS technical division. In addition, they have all participated twice yearly in workshops on quality assurance in analytical chemistry conducted at NBS. These workshops annually bring into the Office of Standard Reference Materials about 50 chemists, many of whom are very active SRM users and can provide the office with input on needs.

The workshop/seminar participation by OSRM staff during 1986 are shown in Table B-4, as an example of such activities. Lists of participation in prior years are available on request. These interactions have two goals: to let clients know about SRM availability and to give users all across the country an opportunity to give NBS feedback and describe their needs.

Monthly Magazine Forum

Each month since June 1980, American Laboratory has published a column entitled "Reference Materials," edited by the Chief of OSRM. One of the functions of this column is to solicit customers and needs for SRMs. More than 1,000 letters have been received and responded to in the first seven years of the column. See Exhibit B-5 (pages 133-134) for a sample column.

Table B-4. Fiscal Year 1986 Workshops and Seminars.

Alvarez, R., "Recently Developed NBS Standard Reference Materials for Use in Method Validation and Instrument Calibration," Association of Official Analytical Chemists, Scottsdale, AZ, September 16, 1986.

Alvarez, R., "New NBS SRMs for Environmental Measurement," University of Maryland, College Park, MD, September 26, 1986. Co-sponsored by OSRM.

Gills, T. E., "Reference Materials for Quality Assurance in Geochemistry and Health," Annual Lab Instrument and Equipment Conference, Chicago, IL, October 3, 1985. Half-day workshop chaired by Mr. Gills.

Gills, T. E., "Development of Natural Matrix Standards for Use in the Analysis of Environmental Materials," Rocky Mountain Conference, Denver, CO, August 5, 1986.

Gills, T. E., "Importance of SRMs in Applied Science," Norfolk State University Workshop, NBS, Gaithersburg, MD, August 17, 1986. Co-sponsored by OSRM.

Rasberry, S. D., "Standard Reference Materials in Support of Quality Measurements," Mid-Michigan Section of the Society for Applied Spectroscopy (SAS), Midland, MI, October 8, 1985.

Rasberry, S. D., "A Strategy for Making Enzyme Reference Materials Available," NRSCL Workshop on a Reference System for Clinical Enzymology, Arlington, VA, October 16, 1985. Co-sponsored by NBS, 2-day workshop.

Rasberry, S. D., "Standard Reference Materials for Dimensional and Physical Property Measurements," 1986 Measurement Science Conference, Irvine, CA, January 24, 1986. Half-day session chaired by Mr. Rasberry.

Rasberry, S. D., "Biological Reference Materials from the U.S. National Bureau of Standards - An Update," Second International Symposium of Biological Reference Materials, Munich, Germany, April 24, 1986. Co-sponsored by OSRM.

Rasberry S. D., "Standard Reference Materials," Quantitative X-ray Diffraction Analysis Workshop, NBS, Gaithersburg, MD, June 23, 1986. Sponsored by NBS.

Rasberry, S. D., "Standard Reference Materials for X-ray Fluorescence Analysis," 1986 Denver X-ray Conference, Denver, CO, August 5, 1986. Half-day session arranged by Mr. Rasberry.

Reed, W. P., "Standard Reference Materials: A Program for Good Measurement," Corning Section of the American Chemical Society (ACS), Waverly, NY, September 15, 1986.

Reed, W. P., "SRMs in Chemical Monitoring Systems" Special Symposium on U. S. National Monitoring Strategies at the OCEANS '86 Conference, Washington, DC, September 23, 1986.

Magazine Surveys

In 1983 and 1987 magazine surveys were conducted. See Exhibit B-6 (135-136) for an example. The point of these surveys is to obtain input from the technical community regarding needs for SRMs. One conclusion drawn from the 1983 survey was that NBS should certify and issue solution standards for atomic absorption spectroscopy. Seventy-two types are now available or under development.

Exchange of Visits/Visitors

One source of ideas for new SRMs that is especially important from the perspective of idea quality is exchange of visits. Visits to and from industrial and university scientists, as well as counterpart laboratories abroad are important mechanisms for keeping up with changing technical needs.

Surveys Prepared External to OSRM

"The Market Book"[26] and "Survey of Industries"[27] are examples of externally prepared marketing studies which are useful to OSRM. They are not directlly focused on needs for SRMs, so they cannot be used to set priorities for SRM production. Rather, they indicate general growth areas in use of instrumentation requiring or bene-

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[26]Alpert Research Group, The Market Book, The 1985-1989 Market for Analytical Instruments, Centcom, Ltd., 1 Belmont Ave., Bala-Cynwyd, PA 19004 (1985).

[27]Hord, J., Survey of Measurement Needs in the Chemical and Related Industries, National Bureau of Standards Tech Note 1087 (1985).

fitting from use of SRMs. This provides information helpful to the OSRM staff in setting production priorities.

SRM Formal Needs Assessment Process

The previous two sections of this report have described how input is received from customers regarding needs for SRM research, development, and production. Each year the senior OSRM staff (Chief, Deputy, and five Project Managers) reviews and puts into priority order proposals for more than 200 SRMs. Priority setting is essential because production funds are only available for certifying 125-150 SRMs each year. Standard Reference Materials are only produced following establishment of need by the technical community; they are not made by NBS "on speculation." This tradition stems from production, over 80 years ago, of the first four SRMs in cooperation with the American Foundrymens Society (AFS). The four main stages of the process are:

1. Receiving Input. (Year-round) Input is received, considered, and responded to throughout the year by the senior OSRM staff, as has been described above.

2. Organizing Input. (March-May) A concentrated effort is made during this period to gather data pertinent to each proposed

SRM. Each proposal is assigned a project manager and undergoes technical review by the appropriate NBS technical division.

3. <u>Setting Priorities</u>. (June) One week, usually the first week in June, is used for the seven senior OSRM staff members to meet together with the Director of Measurement services to set the OSRM project priorities for the year. Each project is discussed, usually with the assigned project manager describing the project and defending his preliminary assessment of it.

Formal criteria are used to rate each project. See Exhibit B-7 (pages 137-138). Following a presentation by the assigned project manager, each of the eight staff members rate the project. The highest rating and lowest rating are dropped and the remaining six are averaged to produce a final rating for the project. This rating determines the priority assignment for the project.

4. <u>Writing Budgets</u>. (July) Following careful review of the work of the priority-setting conference, the office chief can produce budgets for SRM research and production activities.

Needs and Priorities

Exhibit B-8 (pages 139-149) shows the result of the priority-setting conference of June 1986 which developed budgets for FY 1987 SRM research and SRM production. In Exhibit B-8, the production budget is labeled "WCF Projects," which means Working Capital Fund Projects. All "WCF Projects" are financed by sales income. "STRS Projects" are development projects supported by Congressionally-appropriated funds under the title "Science and Technical Research and Services." A few highly rated production projects (WCF project listing) received no funding (priorities 1, 2, 3, 7, 40, and 46). These projects were completely funded in fiscal year 1986 but were not expected to be completed by 1 October 1986. Individual projects often require production of more than one SRM. Ratings of zero for all WCF projects below priority 102 mean that the final rating of the project was postponed.

As of March 1, 1987, it appears there will be sufficient production funds (based on sales income projections prepared at the end of February) to reach priority 80 on the FY 1986 production list. Thus, about $2.8 million in projects will be funded and about $1.4 million in possible production projects will be delayed or dropped. For development of new SRMs, funding will be sufficient to reach priority 32 on the STRS list.

SRM Costs -- Who Should Pay?

All costs of producing SRMs and operating the SRM program are paid by customers who buy the materials. Congressional appropriations pay for part of the development costs associated with SRMs. The level of the Congressional support ($0.5 million) is about 8 percent of the total program cost ($6.0 million). Therefore, customers are currently bearing 92% of total program cost.

The Office of Standard Reference Materials has operated for several years under the principle that customers should pay the full costs for SRMs they use. This principle works extremely well for many SRMs. Based on current government policy with respect to user fees, SRMs which cannot pay for themselves should be weeded out of the system, or never made in the first place.

There may be at least two cases where the Government should pay a larger share of SRM development (and perhaps even production) costs. These are SRMs which are vital to specific Government programs and SRMs which are vital to the commonwealth. Some details on each case are given below:

SRMs vital to specific Government Programs

These are mostly related to the military, NASA, and safety in aviation. Sponsorship of the work by specific agencies is difficult and costly to arrange. Due in part to interservice "placement of responsibility" problems, inefficiencies arise in attempting to get other agency sponsorship. Usually, the argument comes back to the point that NBS is the mission agency for measurement and reference materials and, therefore, should finance and control the work. The current rate of SRM development is far too slow in several fields. Table B-5 indicates the fields and the level of program needed to develop SRMs vital to specific government programs.

SRMs Vital to the Commonwealth

Society would benefit from the development of numerous SRMs, but the beneficiaries cannot be marshalled beforehand to provide the necessary capital to produce them. Several examples and the level of program needed to develop them are shown in Table B-6.

Table B-5. SRMs Vital to Government Programs

Description	Number of Types	Est. Cost of Develop. ($, Millions)
Thermal Expansion Materials: From space shuttles to scram jets to twenty-first century automobiles, thermal expansion is of vital importance. Our nation has no SRMs to support engineering and quality production of such components as rocket engine seals. We have no measurement benchmarks for rubber materials such as O-rings. We have no benchmarks for measuring, predicting, and controlling the performance of new plastic and composite materials, which are at the center of the technological future for world-competitive automobiles. 4 SRMs each are needed for rubber, plastic, composite, and metal types.	16	1.6
Composite Materials: The future of aircraft, automobiles, and numerous construction materials is composites. The U.S. has no reference materials for composite materials. SRMs are needed for starting materials and composites incorporating a variety of plastics, ceramics, glass, carbon, and metal components.	20	3.0
Glassy Metals: From transformers and electric motors to nuclear submarine propulsion systems, glassy metal applications may increase 1000% by the end of the century. The U.S. has no reference materials for glassy metals and no plans to develop any. SRMs are needed for composition, microstructure, and physical properties.	8	1.2
Super Alloys: Space stations, SDI, scram jets, ballistic missiles, fighter aircraft, ships and tanks will all rely on accurate formulation of new super alloys now being defined in metallurgical research. NBS has produced a few super alloy SRMs but they are not the latest, highest performance alloys that will move our nation's defense into the twenty-first century. SRMs are needed for the newest alloy compositions.	8	1.2
Semiconductor Devices: Ten years ago, if semiconductors failed in an automobile it only meant the radio would not play. Today it may mean the engine will not run. Ten years from now it may mean the loss of anti-skid braking, loss of collision avoidance system, loss of power, and loss of steering. On-board computers are pervasive in autos, aircraft, rockets and nearly every other motive system more complex than a skateboard. Our nation has very limited reference materials resources to support quality assurance in the production and application of semiconductor devices. "Known good" and "known defect" wafers; linewidth on wafer; linewidth on X-ray mask; defect size on photomask and wafer; thickness of oxide and metal patterns; internal precipitate concentration, size, and spatial distribution; GaAs properties.	25	7.5

Table B-5. SRMs Vital to Government Programs (Continued)

Description	Number of Types	Est. Cost of Develop. ($.M)
Semiconductor Reagents: The raw materials used in the chemical production processes of semiconductor manufacture must be of exceptional purity if quality production is to be assured. Despite the encouragement of such firms as IBM, the U.S. still has no reference materials in this field. Minority carrier lifetime; dopant concentration; epitaxial layer thicknesses; carrier density profiles; defect densities, slice flatness; purity of water, acids, and gases.	20	6.0
Rockwell Hardness: Tank armor, ship plates, bridge decking all have their performance characteristics predicted based on Rockwell hardness. This engineering quantity is a relative measurement that is not currently well-defined metrologically, thus, making the need for reference materials especially critical. NBS has produced no SRMs for Rockwell hardness. A complete set of Rockwell benchmarks is needed.	10	1.0
Tensile Testing: Tensile testing measures material "toughness," resistance to breaking and tearing, in contrast to hardness. Toughness is a vital parameter to high-quality materials design and use. NBS has produced no SRMs for calibrating tensile testers. A set of benchmarks for calibrating tensile testing instruments is needed.	6	0.6
Surface Finish: Piston rings and cylinders, shafts and bushings, bearings and journals--every place where two surfaces slide together--even aircraft skins through the atmosphere, require careful measurement of material surface finish. NBS has developed one SRM for such measurements, but many more are needed. SRMs are needed having defined finishes of constant period and different amplitudes, and constant amplitudes and different periods.	8	1.6
X-ray Diffraction: Additional intensity and wavelength markers are needed and the composition of crystalline phases should be certified for several mineralogical specimens.	20	3.0
Totals	141	26.7

Table B-6. Standard Reference Materials Vital to the Commonwealth

Description	Number of Types	Est. Cost of Develop. ($.M)
Nutrition-Related Materials: SRMs are needed for protein, cholesterol, fiber, vitamin, mineral, toxic metal, pesticide, fungicide, and herbicide content of foodstuffs and prepared diets.	30	6.0
Enzymes in Human Serum: At least eight different enzymes are of medical importance and should be certified at three critical levels in human serum.	8	4.0
Drugs of Abuse in Serum and Urine: SRMs are needed for all major drugs at three critical levels in human serum and urine.	12	6.0
Environmental Materials: Speciation SRMs are needed for several metals; isotope tracers are needed to monitor man-made versus natural nuclides; several new acid rain (including dry deposition) SRMs are needed; carbon dioxide isotopics; residues, waste chemicals, and heavy metals in soil and water; priority organic pollutants in soil, plants, animal tissue and marine biota; organic hazardous wastes; toxic organic gases; benchmark atmospheric monitoring gases.	50	10.0
Industrial Worker Health and Safety: Benchmarks for industrial atmospheres, benchmarks for respirator filters, hazardous compounds on filters and surrounding vegetation, hazardous compounds in human urine.	20	4.0
Advanced Physical Metrology: Standard volt and ohm SRMs, microlength and atomic scale standards, temperature standards near absolute zero, and density standards are needed.	10	5.0
Advanced Chemical Metrology: Generic standards for part-per-billion constituents in solid state materials, gases and light elements in solid state materials, particle standards certified for inorganic, organic and isotopic constituents, standards for compositional mapping.	20	6.0
Color: A complete CIE Lab benchmark color set to support manufacturing, pharmaceutical, agricultural, transportation, and defense industries.	1	2.0
Agriculture: Soils and waters for nutrient and mineral levels, including salt.	10	1.0
Clinical Analysis: Major therapeutic drugs in human serum.	30	4.5
Totals	191	48.5

EXHIBITS

Standard Reference Materials FY86 Service to All Customers (in Units by State)

FOUR YEAR SALES SUMMARY REPORT
01/31/87

SRM NUMBER	SEQUENCE CODE	DESCRIPTION	PACK	BULK	TOTAL	MONTHS PK	MONTHS TL	FY83	FY84	FY85	FY86	****SALES**** 4-YR AVERAGE	YTD UNITS
1573	324491	TOMATO LEAVES	95	51	146	6	9	147	181	174	200	176	64 Problem
1575	324492	PINE NEEDLES	18	433	451	1	44	98	133	137	114	121	60
1577(A)	324510	BOVINE LIVER	859	524	1383	35	56	248	303	295	331	294	116
1577(B)	324510	BOVINE LIVER	0	866	866	0	99	0	0	0	0	0	0
1579	326050	PDR LEAD-BASED PAINT	23	0	23	17	17	13	17	17	17	16	5
1580	326051	SHALE OIL	340	0	340	99	99	37	28	9	7	20	1
1581	326052	PCB'S IN OIL	387	0	387	41	41	143	110	80	109	111	42
1582	326053	PETROLEUM CRUDE OIL	130	213	343	47	99		41	27	31	33	5
1583	326054	CHLOR PESTICIDE ISOOCTANE	196	81	277	63	89			39	35	37	11
1584	326055	PHENOLS IN METHANOL	96	841	937	60	99		30	18	10	19	5
1585	326057	CHLORINATED BIPENYLS	192	152	344	49	87				47	47	9
1586	326056	ISOTOPE LABEL POLLUTANTS	315	625	940	99	99		0	55	3	19	2
1587	326058	NITRATED PAH IN METHANOL	278	169	447	99	99			6	31	19	7
1589	326064	PCB'S IN HUMAN SERUM	10	250	260	3	99				31	31	8
1590	324900	STABILIZED WINE	35	136	171	23	99	23	16	18	16	18	11
1595	324995	TRIPALMITIN	31	477	508	37	99	0	24	8	9	10	1
1599	324101	2 ANTICONVULSANT DRUGS	478	0	478	99	99	44	17	18	30	27	7
1600	423310	MAGNETIC TAPE-CASSETTE	4	0	4	12	12	5	3	4	2	4	2
1614	326390	DIOXIN	71	369	440	11	70			37	113	75	10
1618	326088	VANADIUM & NI IN FUEL OIL	14	628	642	2	97			102	56	79	22
1619	326089	SULFUR IN FUEL OIL 0.7%	183	0	183	27	27	89	65	72	90	79	27
1620(A)	326090	SULFUR IN FUEL OIL 5%	100	0	100	13	13	77	110	90	91	92	34
1621(C)	326092	SULFUR IN FUEL OIL 1%	23	800	823	1	50	180	225	189	193	197	69
1622(C)	326096	SULFUR IN FUEL OIL 2%	30	800	830	1	50	197	206	168	225	199	64
1623(A)	326104	SULFUR IN FUEL OIL 0.3%	24	198	222	2	22	105	100	138	133	119	49
1624(A)	326112	SULFUR IN DIST. OIL 0.2%	47	99	146	3	12	125	135	157	159	144	33
1625	323422	SO2 PERMEATION TUBE-10CM	26	44	70	4	12	85	75	56	50	67	7
1626	323424	SO2 PERMEATION TUBE-5CM	49	5	54	3	3	165	167	183	169	171	19
627	323426	SO2 PERMEATION TUBE-2CM	8	0	8	5	5	13	23	19	21	19	3
629(A)	323450	NO2 PERMEATION DEVICE-10	13	0	13	10	10	21	14	9	17	15	0
630	326130	MERCURY IN COAL	48	1	49	57	59	8	10	13	10	10	1
632(B)	326142	TRACE ELEMENTS IN COAL	86	863	949	5	65	207	114	151	222	174	56
633(A)	326148	COAL FLY ASH	657	0	657	40	40	191	174	220	204	197	69
634(B)	326152	TRACE ELEMENTS/FUEL OIL	132	665	797	12	73	140	133	148	99	130	50
635	326143	TRACE ELEMENTS IN COAL	14	1231	1245	2	99	77	63	57	35	58	12
636(A)	326200	LEAD IN REFERENCE FUEL	34	72	106	10	31	44	29	41	47	40	11
637(A)	326204	LEAD IN REFERENCE FUEL	20	0	20	5	5	23	47	84	34	47	24
638(B)	326208	LEAD IN REFERENCE FUEL	51	173	224	27	99	15	34	5	35	22	-10
639	326119	HALOCARBONS FOR H2O	59	618	677	26	99	29	36	21	22	27	15
641(B)	326360	MERCURY IN WATER-CONCENTR	188	0	188	61	61	24	33	36	54	37	20
642(B)	326366	MERCURY IN WATER-TRACE	2	65	67	0	14	45	47	76	55	56	-3
643(B)	326368	TRACE ELEMENTS IN WATER	150	0	150	7	7	196	177	269	327	242	120
644	326380	PAH GENERATOR COLUMNS	25	0	25	60	60	4	4	7	6	5	0
645	326605	RIVER SEDIMENT	162	0	162	10	10	190	171	207	205	193	52
646	326606	ESTUARINE SEDIMENT	499	472	971	47	93	126	126	120	127	125	43
647	326387	PRIORITY POLLUTANT PAH'S	93	224	317	6	22	121	128	191	224	166	56
648	326610	URBAN. PARTICULATE MATTER	429	0	429	46	46	118	108	110	109	111	40
649	326612	URBAN DUST/ORGANICS	283	6	289	64	65	62	61	35	52	53	25

Exhibit B-3

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

April 1, 1987

[redacted]
Oxford, MS 38655

Dear Mr. [redacted]

Thank you for replying to our customer feedback card--we are trying in every way possible to stay in contact with SRM users.

Your comment with regard to the need for dissolved and total organic carbon and natural organic reference materials was very helpful. It will be forwarded to the project manager of these SRM's, Robert Alvarez, for consideration for future production.

Determining the need for specific SRM's and estimating the sales rate is one of our toughest problems. While we are considering your suggestion, your additional input on one of the enclosed forms could be very useful to us.

Again, many thanks for your suggestion. We hope to be able to respond favorably to it as satisfying customer needs is one of our most important functions.

Sincerely,

W P Reed

William P. Reed
Deputy Chief
Office of Standar
Reference Mater

Enclosure

cc: R. Alvarez

SRM Customer Feedback

This self-addressed mailer is provided in case you need to send us feedback about your SRM shipment

Delivery Problems? NO

SRM Certificate Clear? YES

Suggestions for Better Service?

Suggestions for New SRM's? DISSOLVED & TOTAL ORGANIC CARBON — NATURAL ORGANICS, e.g. CROP RESIDUES

Name: [redacted]

Address: P.O. BOX [redacted]

City: OXFORD

State: MS Zip: 38655

→ WJR → ~~TBG~~ → IDEA FILE

(B) (19)

Exhibit B-4

received 7/7/86

1 Title of proposed SRM AF-600 STANDARD

2 Purpose for which SRM is intended CALIBRATION OF LECO AF-500 & LECO AF-600 INSTRUMENTS

3. Reason SRM would be useful. CALIBRATION OF DEFORMATION TEMPS NOT ONLY MELTING PT OF Ni WIRE

4 Special characteristics and requirements ~~FINE~~

FINE POWDER FOR CONES TO BE MADE

FOR CHECK OF ASTM D1857-68

5 Estimate of present and future demand for proposed SRM:

INCREASING IN STEEL INDUSTRY & ALREADY ~~IN~~ A MARKET IN

POWER INDUSTRY FOR ANALYSIS OF FLY ASH FUSIBILITY

6 Why proposed SRM should be produced by NBS:

7 Other pertinent information:

[redacted] [redacted]

8. Requested by: [redacted]

Telephone ( ) 215-[redacted]

9. Company [redacted] DELAWARE RIVER

PHILA PA 19137

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Office of Standard Reference Materials
Room B311, Chemistry Building
National Bureau of Standards
Gaithersburg, MD 20878-9950

Guide for Requesting Development of Standard Reference Materials

The National Bureau of Standards develops Standard Reference Materials (SRM's) to provide a basis for comparison of measurements on materials and to aid in the control of production processes. The Office of Standard Reference Materials evaluates the requirements of science, industry, and government for carefully characterized reference materials, then directs the production and distribution of these materials.

NBS currently has over 1000 SRM's available, about 100 new ones in preparation, and requests for the development of many more. The demand for new SRM's greatly exceeds the Bureau's capacity to produce and certify these materials. Consequently, requests for new SRM's of limited use are deferred in favor of those that serve a substantial area of interest. In determining which requests receive top priority, NBS relies heavily upon information supplied by industry and interested organizations.

The Bureau welcomes all requests for SRM's. Both the Bureau and potential users would be helped if these requests included as much of the information below as possible.

1. *Short title of the proposed Standard Reference Material.*

2. *Purpose for which this SRM is intended.*

3. *Reason why the SRM would be useful.*

4. *Special characteristics and/or requirements of the material. Include necessary additional information, if more than one SRM is needed for standardization in an area.*

5. *An estimate of the possible present and future (6-10 years) demand for such an SRM in your operations and elsewhere. (National and international estimates are very useful).*

6. *Facts about whether such an SRM (or a similar one) could be produced by, or obtained from a source other than NBS. If so, justify preparation by NBS.*

7. *Other pertinent information to justify the SRM, such as: (a) an estimate of the range of application, economic significance of the measurement affected, and scientific and/or technological significance, including estimates of the impact upon industrial productivity or growth, and (b) supporting letters from industry leaders, trade organizations, interested committees, and others.*

In developing an NBS-SRM, the candidate material must meet one or more of the criteria listed below:

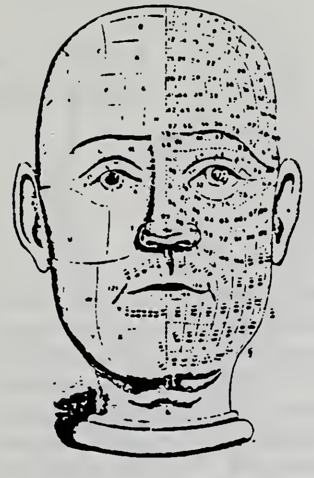
1. *The SRM must permit users to attain more accurate measurements.*

2. *The production of the SRM must not be economically or technically feasible elsewhere,*

3. *The SRM must serve as an industry-wide standard for commerce, provided by a unique neutral source,*

4. *NBS production of the SRM would provide readily available, highly characterized material useful to science, industry, or government.*

NBS has recognized the need to enlarge the scope of the SRM program to include all types of well-characterized materials that can be used to calibrate a measurement system, or to produce scientific data that can be widely used. Input from science, industry, and government assists NBS in continuing to provide Standard Reference Materials that will be valuable in many areas.



Stanley Rasberry, Editor

Reference materials

THE OBJECTIVES of this new column are described on the Editor's Page of this issue. In brief, the column's aim is to report current news about the availability and uses of reference materials. Suppliers of reference materials wishing coverage should write Stanley Rasberry at B-311 Chemistry Bldg., National Bureau of Standards, Washington, D.C. 20234, or call him at (301) 921-2408. While we await contributions, the next few columns will examine the Standard Reference Materials (SRMs) produced at the National Bureau of Standards (NBS).

NBS defines SRMs as materials which "have been characterized by the National Bureau of Standards for some chemical or physical property and are issued with a Certificate that gives the results of the characterization." In accordance with international definitions (ISO), SRMs are the same as Certified Reference Materials (CRMs).

Approximately 1000 SRMs currently available span a range of many different types as indicated in *Table 1*. This month we highlight several recently issued SRMs that are of special interest to industry:

White iron, SRM 3d

SRM 3d is in chip form and is intended for use in checking chemical methods of analysis. It is certified for carbon (2.54%), manganese (0.40%), phosphorus (0.025%), sulfur (0.052%), silicon (1.31%), copper (0.043%), nickel (0.025%), and chromium (0.03%). Additional information is provided for vanadium, molybdenum, and titanium.

The composition of the SRM is similar to that of malleable iron except that all of the carbon is in combined form, rather than some being present as graphitic carbon. Although difficult to machine because of their hardness, the white iron chips offer material of high homogeneity, particularly for calibration of rapid carbon/sulfur analyzers. The issuance of this renewal SRM is the culmination of an important industry-ASTM-NBS cooperative project, with major input from the ASTM-NBS Research Associate Program.

Iron ores, SRMs 690, 692, and 693

Three new iron ore SRMs have been produced to complement the currently available SRM 27f, Sibley Iron Ore. Each of these iron ores has been certified for total iron, phosphorous, and sulfur, as well as the oxides of silicon, aluminum, potassium, sodium, magnesium, calcium, manganese, and titanium. These Standard Reference Materials are: SRM 690, Iron Ore Concentrate (Canada) SRM 692, Iron Ore (Labrador) and SRM 693, Iron Ore (Nimba).

The analytical work leading to the certification of this series of ores was performed under the ASTM-NBS Research Associate Program.

Polystyrene, SRM 1478

SRM 1478 is a linear polystyrene with a certified weight-average molecular weight of 37,400 g/mol. This material also is certified for number-average molecular weight, 35,800 g/mol, and limiting viscosity number at 25.0 °C in toulene, 23.06 mL/g.

The SRM is useful to polymer technologists for calibrating and validating methods for determining molecular weight and molecular-weight distribution. It should be particularly useful as a calibrant for gel permeation chromatography. The SRM also serves as a characterized reference for the measurement of other physical properties of polystyrene.

Glass sand, SRM 81a (high iron) and 165a (low iron)

Renewal SRMs 81a and 165a are two sands used in glass manufacturing. Each of them is intended for use in checking methods of analysis and in calibrating instrumental methods of analysis. Each SRM is certified for Al_2O_3, Fe_2O_3, TiO_2, and ZrO_2. In addition, SRM 81a is certified for Cr_2O_3 content.

Tungsten concentrate, SRM 277

This new SRM is certified for WO_3

Mr. Rasberry is Deputy Chief of the Office of Standard Reference Materials, National Bureau of Standards.

JUNE 1980

Exhibit B-5
(Continued)

content at 67.4 (wt%), and approximate values are provided for calcium, iron, lead, manganese, molybdenum, niobium, phosphorus, silicon, sulfur, tin, and titanium. Additional information is provided for 15 major or minor elements and 19 trace elements. Need for the material was demonstrated by discrepancies in analyses between buyers and sellers of large quantities of similar concentrates, involving millions of dollars. SRM 277 (and improved methodology) should provide the means for assuring fair measurement for buyers and sellers.

Nickel-copper alloy, SRM 882

SRM 882 is prepared in the form of small granules resulting from water atomization. It is a compositional reference for nickel-copper alloys of a type used in industrial applications requiring high strength and resistance to corrosion, including marine and electrical uses. The certified weight percent of four principal elements are nickel (65.25), copper (31.02), aluminum (2.85), and titanium (0.57). Carbon, manganese, sulfur, silicon, and iron are also certified in the SRM.

Futher information is available from Stanley Rasberry. The next column will examine some new SRMs of interest to analysts of environmental and energy-related materials.

Table 1

SRM types produced at NBS

Steels	Isotopics
Steelmaking alloys	Ion activity
Cast irons	Mechanical and metrology
Cast steels	Superconductive thermometric
Nonferrous alloys	Freezing points
Gases in metals	Melting points
High purity metals	Colorimetric
Electron probe microanalytical	Vapor pressure
Standard chemicals	Thermal conductivity
Clinicals	Thermal expansion
Biologicals	Thermal resistance
Botanicals	Thermocouple materials
Environmentals	Magnetic
Industrial hygiene	Optical
Metallo-organic compounds	Gas transmission
Fertilizers	Permittivity
Ores	Reference fuels
Minerals	Resistivity
Refractories	Rubber materials
Carbides	Computer tapes
Glasses	Sizing standards
Cements	Color
Trace elements	Photographic
Nuclear materials	Surface flammability
Radioactivity	Smoke density
X-ray diffraction	Water vapor permeance

Edited by Stanley Rasberry

Reference materials

SURVEY FORM ON NEXT PAGE.

One of the areas hardest hit by cutbacks in federal resources for SRM production has been industrial hygiene analysis. The concern voiced by the American Industrial Hygiene Association and many individual laboratories has helped us redirect some effort to this area, with the result being the SRMs described here. Continued scarcity of resources makes it essential that projects be selected carefully.

You can help us a great deal by completing the survey in this month's column. Your answers will be tabulated and published in the fall to assist all producers of reference materials in planning their production. As this column enters its fourth year, your guidance as to useful topics would also be greatly appreciated.

New industrial hygiene/clinical SRMs

The NBS Office of Standard Reference Materials has announced the availability of a series of four SRMs developed especially for clinical and industrial hygiene analyses. These SRMs should be helpful in toxicology research and for monitoring human exposure to selected toxic elements in the workplace environment. SRM 2670, toxic metals in freeze-dried urine, is a recently developed multielement standard which complements the others in the series and promotes standardization in the multielement analysis of human body fluids. Constituents certified or analyzed are listed in *Table 1*.

SRMs 2670, 2671a, and 2672a consist of freeze-dried urine in 30-mL serum bottles. The freeze-dried urine SRMs are reconstituted by the addition of 20 mL of pure water to each bottle. Each unit contains a set of four bottles, two bottles each at normal and elevated levels. SRM 2676b contains duplicates of membrane filters at three concentration levels for four selected toxic metals. The membrane filters can be easily dissolved in 5 mL of 1:1 nitric acid and diluted with distilled water to desired volumes.

For details contact OSRM, Room B311 Chemistry Building, National Bureau of Standards, Washington, D.C. 20234. Tel. (301) 921-2045.

Mr. Rasberry is Deputy Chief of the Office of Standard Reference Materials, National Bureau of Standards.

Table 1

Freeze-dried urine and metals on filter media SRMs

SRM	Matrix	Constituent certified or analyzed	Approximate availability
2670	Freeze-dried urine	Arsenic, cadmium, calcium, chloride, copper, lead, magnesium, manganese, nickel, potassium, selenium, sodium, zinc	August 1983
2671a	Freeze-dried urine	Fluoride	Available
2672a	Freeze-dried urine	Mercury	Available
2676b	Metals on filter media	Cadmium, lead, manganese, zinc	Available

1983 Reference materials survey

This survey will be used to gauge your needs for new reference materials and topics of interest for future columns. Please copy, complete, and mail the completed copy to:

Stanley Rasberry, International Scientific Communications, Inc.
P.O. Box 827, Fairfield, CT 06430

Check one box in each set of columns for every row that is of interest to you.

Category	A. SRM production			B. Column topics		
	Need fewer	OK	Need more	Cover less	OK	Cover more
By instrument type						
1. Atomic absorption	☐	☐	☐	☐	☐	☐
2. Chromatography, column	☐	☐	☐	☐	☐	☐
3. Chromatography, gas	☐	☐	☐	☐	☐	☐
4. Chromatography, HPLC	☐	☐	☐	☐	☐	☐
5. Electron microscopy (incl. SEM)	☐	☐	☐	☐	☐	☐
6. Electron probe microanalysis	☐	☐	☐	☐	☐	☐
7. Electron spectroscopy	☐	☐	☐	☐	☐	☐
8. Fluorescence	☐	☐	☐	☐	☐	☐
9. Infrared	☐	☐	☐	☐	☐	☐
10. Ion chromatography	☐	☐	☐	☐	☐	☐
11. Mass spectrometry	☐	☐	☐	☐	☐	☐
12. Nuclear magnetic resonance	☐	☐	☐	☐	☐	☐
13. Optical emission (incl. ICP)	☐	☐	☐	☐	☐	☐
14. Optical microscopy	☐	☐	☐	☐	☐	☐
15. pH/Ion specific electrodes	☐	☐	☐	☐	☐	☐
16. Thermal analysis	☐	☐	☐	☐	☐	☐
17. UV/Visible	☐	☐	☐	☐	☐	☐
18. Voltammetry/polarography	☐	☐	☐	☐	☐	☐
19. X-ray diffraction	☐	☐	☐	☐	☐	☐
20. X-ray fluorescence	☐	☐	☐	☐	☐	☐
21. Other ________	☐	☐	☐	☐	☐	☐
By specimen type						
22. Amino acids	☐	☐	☐	☐	☐	☐
23. Biological	☐	☐	☐	☐	☐	☐
24. Botanical	☐	☐	☐	☐	☐	☐
25. Cement	☐	☐	☐	☐	☐	☐
26. Chemicals	☐	☐	☐	☐	☐	☐
27. Clinical	☐	☐	☐	☐	☐	☐
28. Color	☐	☐	☐	☐	☐	☐
29. Environmental	☐	☐	☐	☐	☐	☐
30. Fertilizer/soil	☐	☐	☐	☐	☐	☐
31. Glass	☐	☐	☐	☐	☐	☐
32. Industrial hygiene	☐	☐	☐	☐	☐	☐
33. Metals, ferrous	☐	☐	☐	☐	☐	☐
34. Metals, nonferrous	☐	☐	☐	☐	☐	☐
35. Metallo-organics	☐	☐	☐	☐	☐	☐
36. Nuclear materials	☐	☐	☐	☐	☐	☐
37. Ores/rocks	☐	☐	☐	☐	☐	☐
38. Pesticides	☐	☐	☐	☐	☐	☐
39. Plastics	☐	☐	☐	☐	☐	☐
40. Radioactivity	☐	☐	☐	☐	☐	☐
41. Rubber	☐	☐	☐	☐	☐	☐
42. Other ________	☐	☐	☐	☐	☐	☐

(Optional) Write other ideas or comments here:

____

____

____

____

(Optional)

Name ______________________________________

Company/Institute ______________________________________

Address ______________________________________

____

JUNE 1983

Exhibit B-7

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

March 4, 1986

MEMORANDUM FOR OSRM Technical Staff

From: S. D. Rasberry Stan
Chief
Office of Standard Reference Materials

Subject: WCF Production Priority Evaluation for FY 87 Proposals Given Below

	Maximum Points
1. Impact and User Acceptance Delivery of NBS measurement capability to user community. Unique responsibility - mandated regulations, etc. National concern, economic growth, health, etc. User community track record for purchase and use of SRM's.	30
2. Technical Risk/Track Record of Performers Track record of group working on project (i.e., other work completed on time at, or under, budget). Material stability - measurement problems. Degree of enthusiasm for promoting SRM development and dissemination.	25
3. Type of Proposal Renewal - currently out of stock in area of need (15) Orderly renewal - will go out of stock soon in area of need (12) New - in area of need (10) New - planned multi-year effort-this funding to complete (10) Additional certification data in area of user need (5) Bailout proposal - completes old work (5)	15
4. Fiscal Credibility Total cost to NBS WCF including prior year costs divided by estimated sales. SRM selling fewer than 20 units per year should be rated low.	10
5. Outside Support Ratio of contributions of other groups to WCF costs must be greater than 1.	10
6. Resource Availability Material here Equipment and methods now available Technical staff availability	10

cc: G. A. Uriano
T. D. Siedling

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

March 4, 1986

MEMORANDUM FOR OSRM Technical Staff

From: S. D. Rasberry Stan
Chief
Office of Standard Reference Materials

Subject: Priority Rating Criteria for FY 87 SRM-STRS and Research Reimbursable Projects

We will, as in the past, rate all STRS proposals. In order to be rated, the proposals must adhere to the following:

1. Supports R&D leading directly to new SRM's (usually within one to two years).

2. Supports R&D to solve unforeseen problems arising after production of an SRM starts.

3. Supports SRM development where Center STRS or OA funds are already committed.

For proposals that meet the above criteria, the numerical rating should be determined by applying the following rating system on the basis of 100 maximum points:

1.	Degree of technical risk, scientific or technical challenge, quality, track record, and enthusiasm of people, manpower and equipment availability, etc. For renewed cost centers, degree of technical progress.	up to 40
2.	Outside of Technical Division support.	up to 25
3.	Area of national concern (i.e., health, industrial productivity, energy, consumer interest) and taking into account NBS priorities and measurement delivery missions.	up to 25
4.	Annual cost of proposal (pro-rated with 0 points for proposals over $100K).	up to 10

Please note that the cost limit for the pro-rated score of item 4 above has been decreased to $100K.

cc: G. A. Uriano
T. D. Siedling

E X H I B I T   B-8

Examples of the Results from the Priority Setting Conference

of June 1986

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
1	534.04	Aluminum Mirrors 2003a	0	RWS	100	0
2	534.08	Hi Density Photo Step	0	RWS	100	0
3	652.02	Hi Dens.Mag.Cart. 3217	0	RWS	100	0
4	551.23	S in Fuel Oil 1623a-24a	40	TEG	99	40
5	553.02	Gas Calib. testing	25	TEG	99	65
6	420.01	Catalyst Pkg Lube Oxidat	20	RLM	97	85
7	551.22	Rocky Flts & R.Sediment	0	TEG	96	85
8	553.07	NO/N2 5 10 20ppm 2627-29	51	TEG	96	136
9	511.01	Microcopy 1010a	10	RWS	95	146
10	551.25	T.E. in H2O 1643c	135	RA	95	281
11	552.07	PAH/Acetonitrile 1647a	25	RA	95	306
12	553.03	SO2/N2 50& 100ppm 1693-4	17	TEG	95	323
13	553.04	O2/N2 2% 10% 21% 2657-59	46	TEG	95	369
14	553.08	SO2/N2 1661-2 1693-4	34	TEG	95	403
15	652.03	Tapes 1600 3200 6250	42	RWS	95	445
16	536.02	H-3 Solution 4361-B	25	TEG	94	470
17	551.01	Spectromet.Soln. 2121-34	175	RWS	94	645
18	553.12	SO2 Perm Tube 5cm 1626	36	TEG	94	681
19	440.04	Butyl Rubber Hi Mooney	38	RLM	93	719
20	551.05	River Sediment 1645a	75	TEG	93	794
21	551.1	Spectrophot Filters 930d	48	RLM	93	842
22	552.02	Stability Tstg. Clinical	15	RA	93	857
23	552.03	Stability Tstg. Environ.	15	RA	93	872
24	553.06	CO2/N2 14% 1675	15	TEG	93	887

WCF PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
25	552.05	Bilirubin 916a	15	RLM	92	902
26	652.01	Four Disk Cartridges	10	RWS	92	912
27	727.01	Si Resis.1521-23 2526-29	150	RWS	92	1062
28	511.02	Metals Processing	80	WPR	91	1142
29	511.03	Metals Purchasing	40	WPR	91	1182
30	543.01	Update QA of Coal	15	TEG	91	1197
31	551.21	H in Unalloyed Ti 352c	15	TEG	91	1212
32	553.09	NO/N2 50 100ppm 1683-84	64	TEG	91	1276
33	727.02	Additional Si Production	100	RWS	91	1376
34	420.03	N in Lube Base Oil	25	RLM	90	1401
35	450.01	Coating Thickness	130	RWS	90	1531
36	511.05	Sediment 1645a &RMs/Hg	15	TEG	90	1546
37	536.07	Gd-153 Solution	7	TEG	90	1553
38	543.02	Benzoic Acid 39i	25	RLM	90	1578
39	551.03	Metal Homogeneity	200	WPR	90	1778
40	553.14	H2S/N2 5 15ppm (EPA)	0	TEG	90	1778
41	731.02	SEM Magnification 484	40	RLM	90	1818
42	773.01	DTA 2226 2227 2228	30	RLM	90	1848
43	420.08	XRD Profile 2-theta	45	RLM	89	1893
44	511.04	Agricultural soils (2)	12	TEG	89	1905
45	551.09	Bovine Serum/Inorganics	40	RA	89	1945
46	551.15	(Comb. with 551.03) 348a	0	WPR	89	1945
47	551.16	S in Coal (1%) 2689	25	TEG	89	1970
48	551.18	Pb in Ref.Fuel 1636b-37b	30	TEG	89	2000

WCF PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
49	553.05	CO/N2 25ppm 2635	15	TEG	89	2015
50	522.02	Thermo.Fix.Pt.767a & 768	37	RWS	88	2052
51	522.01	Indium MP Cells 1971	13	RWS	87	2065
52	551.11	Ext'd Abs Filters 1930	25	RLM	87	2090
53	551.2	Unalloyed Zr 358a	25	TEG	87	2115
54	420.09	Cryst. Alpha-alumina	14	RLM	86	2129
55	440.01	Polyethylene Gas Pipe	49	RLM	86	2178
56	536.05	Al-26 Solution 4229-B	19	TEG	86	2197
57	541.01	Thin-film "Marker" (new)	30	RLM	86	2227
58	552.06	Cholesterol 911b	20	RLM	86	2247
59	420.06	Ceramic Particle Size	33	RLM	85	2280
60	430.01	Eddy Current 1861a & 3a	40	RWS	85	2320
61	511.07	Filter Media 2673a-74a	3	TEG	85	2323
62	534.01	X-ray Step Tablets 1001	38	RWS	85	2361
63	534.1	Fluores.Cor.Emis.Spectr.	42	RLM	85	2403
64	536.01	Pu-238 Pt. Source 4906-C	13	TEG	85	2416
65	551.06	Reactor Fuel Charges	25	TEG	85	2441
66	551.12	Ni & Sr Isotopics 986-7	6	RWS	85	2447
67	551.14	Aq.Electrolytic Conduct.	30	RWS	85	2477
68	551.31	Filter Media 2673a-74a	25	TEG	85	2502
69	552.04	PCB's in Sediment	30	RA	85	2532
70	553.17	Thin Film Glass Micropro	38	RLM	85	2570
71	553.18	Thin Film Glass Add'l.	15	RLM	85	2585
72	440.02	Lin.Polyeth. Narrow MW	15	RLM	84	2600

WCF PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
73	420.05	Four-Ball Ceramic Wear	61	RLM	83	2661
74	420.07	Tridymite Quantitative	14	RLM	83	2675
75	534.03	Microcopy 1010a	6	RWS	83	2681
76	534.09	Gray Specular Reflect.	40	RWS	83	2721
77	536.06	Sr-89 Solution 4945-F	7	TEG	83	2728
78	552.09	Fat Sol.Vitamins/Ethanol	22	RA	83	2750
79	552.1	River Sediment 1645a	20	TEG	83	2770
80	553.01	Metals Homogeneity	30	WPR	83	2800
81	714.01	Metals Stat Analysis	65	WPR	83	2865
82	731.06	Documentation 1960 10mu	15	RLM	83	2880
83	534.02	Photo Step Tablets 1008	23	RWS	82	2903
84	536.08	Nat.U & Am-241 & Pu-238	36	TEG	82	2939
85	551.19	H in Unalloyed Ti 354-5a	25	TEG	82	2964
86	420.04	High Boron Glass	10	RLM	81	2974
87	534.05	Gold Mirrors 2011	10	RWS	81	2984
88	534.06	Second Surf Al Mirrors	12	RWS	81	2996
89	511.08	Steel (Vac Remelt) 1092a	5	TEG	80	3001
90	536.03	Cs-137 Pt Source 4207-B	19	TEG	80	3020
91	420.02	Glass Viscosity	15	RLM	78	3035
92	553.11	CO2/N2.1%2%4%1681 2640-1	32	TEG	77	3067
93	534.07	Reflectance Step Tablets	7	RWS	75	3074
94	551.26	Oyster Tissue 1566a	5	RA	75	3079
95	552.08	Deuterated PAH/Solvent	35	RA	75	3114
96	551.24	Cert.Si in Exist. SRM's	36	TEG	73	3150

WCF PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
97	536.04	Be-10 Isotopic Ratio	13	TEG	72	3163
98	420.1	Aqueous Butyltin	20	RLM	71	3183
99	551.27	Total Diet	120	RA	71	3303
100	551.29	Cert. Al in Exist. SRM's	25	RA	70	3328
101	551.3	Micros for Microspectro	35	RLM	70	3363
102	553.1	NO2/Air 250ppm 2653	17	TEG	60	3380
103	440.03	Polystyrene Narrow MW	95	RLM	0	3475
104	450.02	Microhardnes 1893-6 1905	80	RWS	0	3555
105	450.03	STEP Test (Plating)	40	RWS	0	3595
106	511.06	SNM Repackaging	25	TEG	0	3620
107	521.01	Eddy Current 1861a & 63a	30	RWS	0	3650
108	551.02	Aq.Chromatographic 3101	50	RWS	0	3700
109	551.04	Tr.Metals/Filters 2676c	50	TEG	0	3750
110	551.07	Fluoride/Vegetation 2695	0	RA	0	3750
111	551.08	CaCO3	0	RA	0	3750
112	551.13	ICP & DCP Inst. Perform.	20	RWS	0	3770
113	551.17	Be on Filters 2675a	12	TEG	0	3782
114	551.28	Orch.Leaves(Mv to Opns)	20	RA	0	3802
115	552.01	Cocaine in Urine	35	RA	0	3837
116	553.13	Meth/Air 1.35 1.7 2.0ppm	28	TEG	0	3865
117	553.15	CO2/Air ppm	35	TEG	0	3900
118	553.16	C3H8 CO CO2 in N2 (EPA)	0	TEG	0	3900
119	731.01	Documentation 484	12	RLM	0	3912
120	731.03	Precision Rough. 2074-75	63	RLM	0	3975

WCF PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
121	731.04	Documentation Roughness	15	RLM	0	3990
122	731.05	3 Micron Spheres 1962	50	RLM	0	4040
123	731.07	Documentation 1691 .3mu	10	RLM	0	4050
124	738.01	Socketed Ball Bar 2083	0	RLM	0	4050
125	738.02	Photomask 474 475	125	RLM	0	4175
126	753.01	Smoke Toxicity	10	RWS	0	4185

STRS PROJECTS , IN PRIORITY ORDER.

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PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
1	420.05	Pyrite Met.Proc.Biotech	25	RLM	90	25
2	450.02	Solder Coating Thicknes	30	RWS	90	55
3	551.03	Stab.Multielem.Spectro.	5	RWS	90	60
4	551.08	Meth. for Ni at PPB Lev	45	TEG	90	105
5	727.01	Stab.Sheet Res.Prototyp	10	RWS	90	115
6	552.02	Drugs of Abuse in Urine	40	RA	89	155
7	553.03	Meth.for Zero Gas Mixes	50	TEG	89	205
8	552.08	Cholesterol in Serum	20	RA	88	225
9	553.09	SIMS Depth Profiling	30	RLM	88	255
10	522.01	MP Stds Hyperthermia Th	30	RWS	87	285
11	551.01	Hi Ionic Strength pH	30	RWS	87	315
12	551.04	Ion-exchange Separation	25	WPR	87	340
13	552.05	Organics in Tissue	35	RA	87	375
14	553.04	Long-term Stab.SO2 Perm	20	TEG	87	395
15	727.02	3-in. Dia. Resistivity	25	RWS	87	420
16	753.01	Smoke Toxicity	50	RWS	87	470
17	430.01	Hardness (Rockwell)	35	RWS	86	505
18	652.01	Hi-dens.Mag.Tape Carts	10	RWS	86	515
19	731.01	Surface Particle Stds.	40	RLM	86	555
20	773.01	Calib.Proc.DSC & DTA's	12	RLM	86	567
21	552.07	Tr.Org/Food Int.Round-R	15	RA	85	582
22	738.01	Diamond Turned Line	25	RLM	85	607
23	534.01	Fluores.Cor.Emis.Spectr	50	RLM	84	657
24	738.02	Low V SEM Pitch Std.	25	RLM	84	682

STRS PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
25	420.03	Alpha-Beta Si Nitride	15	RLM	83	697
26	551.06	ICP-MS Error Sources	30	RA	83	727
27	420.01	ASTM Research Associate	20	RLM	80	747
28	420.02	Crystallite Size	10	RLM	80	757
29	450.01	Ni-P Electrodep. Foils	20	RWS	80	777
30	551.05	IDMS Meth -- B in steel	10	WPR	80	787
31	551.1	Activity in Biol.Fluids	20	RA	80	807
32	553.01	NO2 & HNO3 Stability	10	TEG	80	817
33	551.02	Multielem.Spectrometric	20	RWS	78	837
34	552.06	Milk Screen/Pollutants	20	RA	77	857
35	420.04	Oxygen in Si Nitride	15	RLM	76	872
36	551.09	Accel. Environ. Studies	30	WPR	76	902
37	553.05	Trace Multi.Organic Gas	50	TEG	76	952
38	440.01	Low Mol.Wt. Polystyrene	30	RLM	75	982
39	551.11	Li Tetraborate Ultratrc	20	RA	75	1002
40	552.01	Pest.PCB Hg/Oyster Tiss	20	RA	75	1022
41	775.01	Liquid Bulk Conductivty	50	RLM	75	1072
42	552.03	Serum Screen/Pollutants	15	RA	73	1087
43	536.01	Be-10/Be-9 Nucl. Dating	45	TEG	72	1132
44	553.08	Low Lev. Dynamic HNO3	53	TEG	72	1185
45	551.07	XRF Fixed Phase Chelat.	25	TEG	70	1210
46	551.12	Total N by NAA	30	RA	70	1240
47	552.04	HPLC Col.Perf. Mixture	20	RA	70	1260
48	553.06	XRF Fixed Phase Chelate	30	TEG	70	1290

STRS PROJECTS , IN PRIORITY ORDER.

PRITY	CONTROL	DESCRIPTION	TOTAL K$	MGR	RTG	CUM K$
49	553.07	C Chemical & Isotopic	35	TEG	70	1325
50	553.02	Diode Laser Gas Meas.	0	TEG	0	1325

APPENDIX C

DEFENSE DEPARTMENT NEEDS FOR MEASUREMENT RESEARCH & SERVICES

JUNE 1987

Introduction

The Department of Defense (DOD) currently accounts for the largest share of the contractual work performed by the National Bureau of Standards (NBS) for other Federal Agencies (approximately 48% of NBS's total FY 1986 other-agency income of $74.5 million). In addition to performing research and development (R&D) under contract to DOD, NBS provided almost $700,000 in calibration services and Standard Reference Materials to DOD in FY 1986. R&D projects performed for DOD ranged from rather fundamental physics and chemistry studies to very applied work such as developing a calibration technique for a particular piece of defense hardware. In addition to serving many different commands in the Army, Navy, and Air Force, NBS often works closely with defense agencies such as the Defense Advanced Research Projects Agency, the Defense Nuclear Agency, and the Defense Communications Agency. NBS has also been in close touch with the Strategic Defense Initiative Office.

Modern high-technology weapons systems often require state-of-the-art measurements for data verification during the R&D phases, for quality control during production, for performance verification during testing, and for critical adjustments during the deployment phase. Quantities to be measured cover the entire gamut of measurement technology--from precision electrical measurements which determine the accuracy of missile guidance systems and laser power measurements to determine the sensitivity of laser warning receivers, to fluid flow measurements used to monitor fuel consumption in high-performance aircraft. The military Services look to NBS for support of this entire spectrum of measurements.

The Army, Navy, and Air Force each operate a major program to provide calibration standards support for testing and maintenance operations.[28] A hierarchical approach is used, with each service operating a primary standards laboratory that relies on calibration services from NBS and in turn provides calibration services to second and third tier operating units. **Through this hierarchy, the calibration of virtually every instrument used in the Army, Navy, and Air Force for precision measurement can be traced to national standards at NBS.** The Services[29] employ nearly 10,000 people at over 1000 calibration facilities world-wide, and perform approximately 3.7 million calibrations annually, all of which ultimately rely on NBS's capability to support the measurement needs of DOD and its contractors.

This close cooperation between NBS and DOD dates back to the early days of the Bureau, but the level of support required today

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28 The focal points within the Services for metrology and calibration issues are: the Army Test, Measurement, and Diagnostic Support Group (Redstone Arsenal, AL); the Navy Metrology Engineering Center (Corona, CA); and the Air Force Aerospace Guidance and Metrology Center (Newark AF Station, OH).

29 The Marine Corps considered the fourth military Service, but calibration support for the Marine Corps is provided by the Navy. Therefore, calibration and standards issues sometimes are discussed as involving only three Services: the Navy, Army, and Air Force.

is the highest of any peacetime era. Table C-1 shows how the DOD component of NBS's other agency funding has grown over the last twenty years. Not only are defense and national security more dependent on science and technology today, but DOD is funding major portions of the Nation's R&D. These DOD-funded R&D programs require measurement support in and of themselves. Military requirements often precede civilian applications of technology by several years, so work performed today by NBS for DOD will often have important implications for civilian technology several years hence.

In light of the importance of our support to DOD, NBS has made a concerted effort over the past five years to improve our ability to respond to defense needs. The Director of NBS and other top NBS staff have met frequently with high-level defense officials to explore how NBS can be more effective in assisting DOD. Top DOD managers have visited NBS to familiarize themselves with NBS programs that support their requirements. NBS managers have encouraged their technical staffs to become more familiar with defense needs and to ensure that NBS's long-range plans properly reflect these needs. The number and diversity of NBS projects undertaken in support of DOD have increased in recent years.

Table C-2 lists significant meetings between the NBS Director and Deputy Director and high level DOD managers over the past three years.

Table C-1. Research Funding to NBS from Other Federal Agencies (1966-1986).

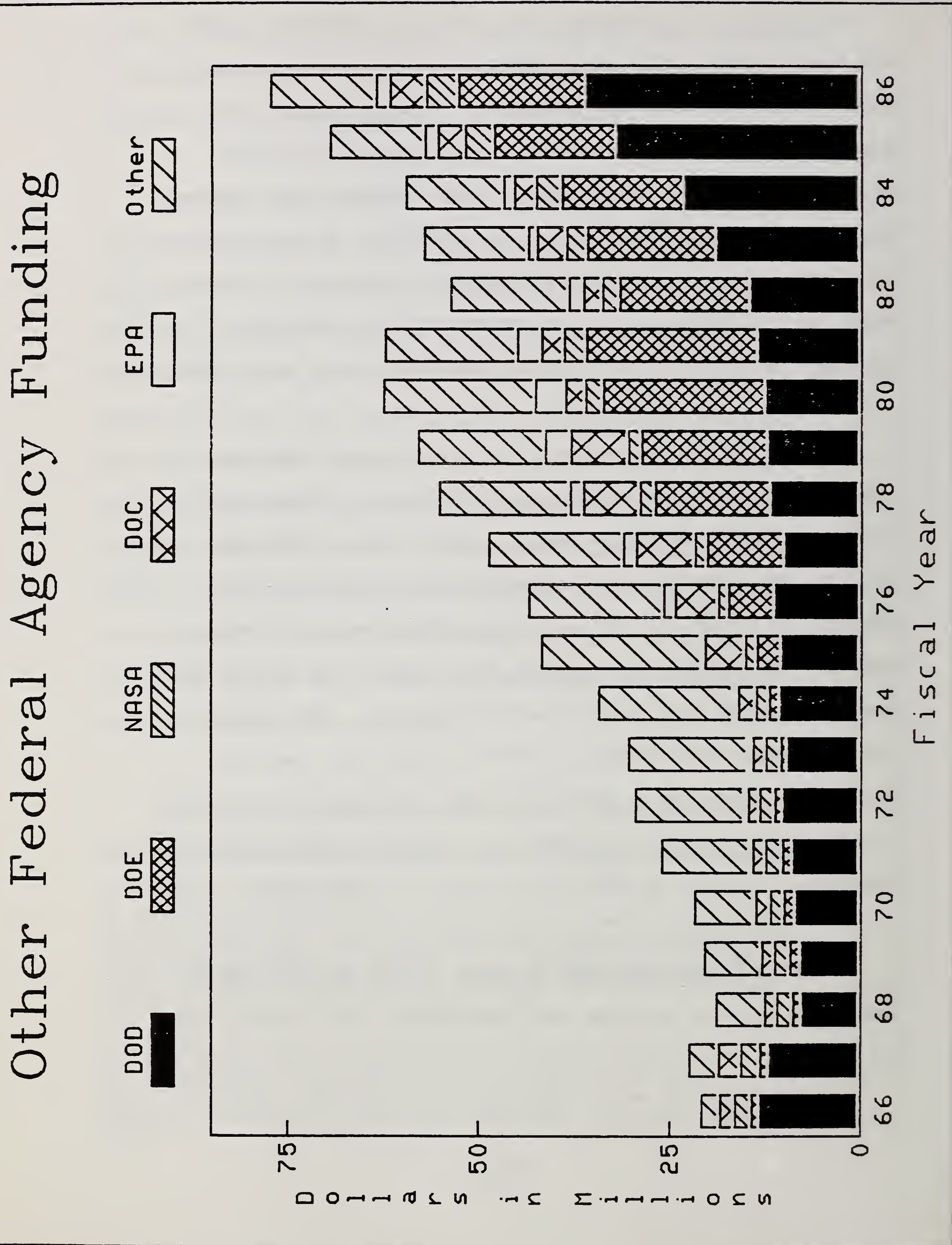

Table C-2. High-Level Meetings to Improve NBS/DOD Communications

April 20, 1985

Dr. Ernest Ambler, Director of NBS
Dr. James Wade, Acting Under Secretary of Defense for Research and Engineering (USDRE)
Dr. Robert Cooper, Director, Defense Advanced Research Projects Agency
Brig. Gen. James Cercy, Commander, US Army Electronics Research and Development Command (ERADCOM)
Mr. Charles Church, Asst. Dir., Technology Planning, HQ US Army

November 15, 1985

Mr. Raymond Kammer, Deputy Director of NBS
Col. Donald Carter, Acting Deputy Under Secretary of Defense for Research & Engineering (Research and Advanced Technology)

January 16, 1986

Dr. Ernest Ambler, Director of NBS
Dr. Donald Hicks, Under Sec. of Defense for Research & Engineering

February 14, 1986

Mr. Raymond Kammer, Deputy Director of NBS
Dr. Ronald Kerber, Deputy Under Secretary of Defense for Research and Engineering (Research & Advanced Technology)

April 24, 1986

Dr. Ernest Ambler, Director of NBS
Dr. Donald Hicks, Under Sec. of Defense for Research and Engineering

June 18, 1986

Dr. Ambler, Director of NBS
Briefed the Joint Logistics Commanders at Hanscom AF Base.

November 24, 1986

Dr. Ernest Ambler, NBS Director
Dr. Ronald Kerber, Deputy Under Secretary of Defense for Research and Engineering

January 20, 1987

Dr. Ernest Ambler, NBS Director
Maj. Gen. James Cercy, Commanding General, US Army LABCOM
Mr. Richard Vitali, Technical Director, US Army LABCOM
Dr. Louis Cameron, Director of Army Research and Technology

As a result of increased contacts between NBS and DOD personnel, the NBS/DOD working relationship is more effective today. A number of important technical people from the Department of Defense have visited NBS over the past three years to present seminars on their technical programs, tour NBS laboratories to learn how our programs support their needs, and discuss cooperation. Table C-3 lists examples of such visitors.

Table C-3. Examples of Other DOD Visitors to NBS

Dr. A. T. Stair, Director, AF Geophysics Laboratory

Dr. Dwight Duston, Deputy Director, Innovative Science & Technology Office, Strategic Defense Initiative Office (SDIO)

Col. Perry Butler, Commander, US Army Test, Measurement & Diagnostics Equipment Support Group, Redstone Arsenal

Col. Pete Miner, Director of Metrology, Aerospace Guidance & Metrology Center, Newark Air Force Station

Mr. Steve Kimmel, Asst. Deputy Under Secretary of Defense for Developmental Test and Evaluation

Mr. Richard Verga, Director, Space Power, SDIO

An additional important mechanism for NBS-DOD communication is the hosting by NBS of DOD technical meetings. NBS encourages DOD and outside groups concerned with defense technology to hold technical meetings at NBS. Such meetings may include tours of NBS facilities and help foster more interaction between DOD and contractor laboratories and NBS. The Joint Technical Coordinating Group on Nondestructive Inspection has, for many years, held the annual meeting of its Standards and Specifications Subgroup at NBS, largely to facilitate consultations between the Services' representatives and NBS's technical experts. In January of this year, the Army and the American Defense Preparedness Association held a conference at NBS called "Technology Forecast for Army Key Operational Capabilities". Furthermore, NBS often co-hosts defense-related meetings at other locations. Examples include the 1984 and 1985 Millimeter Wave Measurement Requirements Seminars held at the Army's Harry Diamond Laboratories (Adelphi, MD) and the 1986 Millimeter Wave/Microwave Measurements and Standards for Miniaturized Systems Conference held at Redstone Arsenal, AL.

In spite of NBS and DOD efforts to develop a more effective working relationship and to improve NBS's ability to respond to rapidly advancing defense technology; NBS, DOD, and DOD contractors continue to be deeply concerned about NBS's ability to provide all of the standards[30] support needed by the Services and defense agen-

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[30]Note that "standards" in this case refers to measurement reference standards, not written or documentary standards. NBS does assist the DOD in developing written military standards from time to time, particularly test method standards. In fact, a long-term collaboration between the Army's Materials Technology Laboratory and NBS continues to produce many of the new and improved military standards for nondestructive testing. However, this discussion focuses instead on the other type of standards, the artifacts or hardware used to determine the accuracy of an unknown instrument or device by comparing it to a well-characterized instrument or device. Thus, for example, a standard for laser power would be an NBS-developed laser calorimeter (power meter) that compares the absorbed power or energy of a particular laser to the power or energy from electrical resistors carrying currents sufficient to cause a temperature rise in the calorimeter identical to that caused by the absorption of laser energy or power. In this way a difficult-to-measure parameter such as laser power can be related to the fundamental electrical units in a meaningful way.

cies and their contractors in a number of technical areas. The "lead agency" issue[31] has contributed to difficulty in obtaining funding either through NBS appropriations or through the DOD budget.

The Joint Logistics Commanders have established a Joint Technical Coordinating Group for Metrology and Calibration[32] (JTCG-METCAL) to foster inter-Service cooperation on measurement and calibration issues and avoid duplication of effort among the Services. NBS works closely with the JTCG-METCAL and its principal subgroup, the Joint-Service Calibration Coordination Group (CCG). (The CCG consists of representatives of each of the Service's Metrology Engineering Centers listed earlier.) For many years NBS has had a Memorandum of Understanding with the Calibration Coordination Group. It covers (1) the calibration services we provide, and; (2) special engineering projects funded by CCG to improve NBS's ability to support their calibration needs. In Fiscal Year 1986 NBS carried out over $3.7 million worth of engineering projects for the Calibration Coordination Group (roughly 10% of the total DOD contracts received by NBS).

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[31] See Chapter II for a more complete discussion of the "lead agency" issue.

[32] "Metrology" is the science of precision measurement.

There is considerable commonality among the Services's measurement requirements, so the Engineering Working Group of the CCG has combined them into an overall plan called the "Tri-Service Metrology Research, Development, and Engineering Plan." Volume 1 of this plan is an overall description of the needs and the rationale for carrying out the measurement R&D needed to address needs. Volume 2 of the plan contains more detailed task statements for the actual work that needs to be performed. The plan is updated every year or two. The most recent edition is dated September 30, 1985; publication of a 1987 edition is planned for later this year. Many of the tasks identified in the current plan would be carried out by NBS (those involving the development of new national standards). Others would be carried out by industrial contractors or by the Services in-house (e.g. those tasks involving the development of "ruggedized" standards and instruments to be used in the field.)

As an example of common requirements, all three Services use lasers for guided weapons, range finding, etc. and hence all three need to measure laser attributes such as power and energy and beam profile to predict system performance and to determine whether lasers meet their specifications. By mutual agreement, a "lead Service" has been designated to accept responsibility for each task identified in the Plan. Designation of responsibility for a given task is based on which Service has the requirement first and/or which Service has the most stringent requirement for the particular measurement.

The new calibration capabilities resulting from R&D sponsored by the CCG are available to all three Services. This inter-Service cooperation has ensured that no duplication of effort occurs in the development of new calibration capabilities. An important assumption in this cooperative mode of operation is that each Service will carry its share of the R&D load. If one Service fails to receive its share of the funding in a given year, the other Services will also suffer and may have to reprogram their funding to avoid having any high priority tasks of interest to all three Services remain unfunded.

The total 5-year metrology R&D requirement identified in the DOD metrology plan is roughly $100 million. Approximately 60 percent of that total would come to NBS were the entire plan funded. Up to now, none of the three Services has received the funding to carry on its share of the tasks identified in the plan.

The preface to the "Tri-Service Plan" (page i) states in part:

> "Metrology and calibration support is absolutely essential to the operation of modern, sophisticated military hardware. Measurement science research and development, however, has not been heavily supported during the period of time which has seen a virtual technology explosion. The national metrology problem has been emphasized by commercial users complaining that the US National Bureau of Standards has failed to provide adequate standards to calibrate existing hardware. Department of Defense (DOD) calibration requirements are significantly more

stringent than those of commercial organizations. In many areas, the total national calibration requirement has been driven by military hardware advances. Naturally, problems are most obvious in those parameters which are newest and most abstract--high frequency microwaves, electro-optics, etc.--but these are not the only areas of deficiency."

Section II of this plan (page 3) notes further:

> "Military systems currently being developed and fielded are demanding calibration support and standards that cannot be provided by NBS or DOD laboratories. This situation, if not immediately rectified, will result in unreliable performance, higher development costs, and a multitude of logistical problems. The use of obsolete, inadequate, or nonexistent calibration standards during weapons system development and acquisition make both the DOD and its contractors unable to legally validate system performance during testing, evaluation, and production acceptance. Inadequate METCAL support after deployment results in degraded weapons system performance, poor reliability, and higher logistics costs. DOD METCAL organizations are unable to maintain confidence in their own test results when it is impossible to compare their most critical measurements to higher accuracy national standards. The technical sophistication of future weapons systems will require significant advances in metrology if they are to be tested, adjusted, repaired, and maintained."

The DOD metrology plan has been divided into seven technical areas. Examples of the needs in each area are given below. This list is not intended to be exhaustive, but rather to illustrate the wide diversity of measurement requirements. Because in some cases, the quantitative relationship between measurement accuracy and weapons system performance is classified, the discussion here is qualitative. NBS is pursuing most of the topics covered in the 1985 DOD metrology plan with CCG support, but in almost every case the level of effort is insufficient to upgrade our capabilities in a timely fashion to meet the needs DOD has identified.

Low power lasers are being used by all of the Services to guide weapons and determine target ranges. Systems such as the Air Force's laser-guided Pave Tac offer higher performance than more conventional missiles. The Army's M-1 tank uses a carbon-dioxide laser range finder. The Navy is putting considerable emphasis on developing a blue-green laser communications system that will permit secure and rapid communications with deeply-submerged ballistic missile submarines. Laser communications inter-satellite cross links are being investigated for the Strategic Defense Initiative. Sensitive laser warning receivers are being developed to alert pilots that they are being irradiated with enemy laser designators. Laser radar is of considerable interest to the SDI for reentry vehicle mid-course discrimination. High power lasers (in excess of 1 megawatt) are being investigated as possible directed energy weapons for the SDI.

In order to develop and test all of the above systems, the capability for measuring laser power and energy and laser beam profile must be in place. NBS has developed laser measurement capabilities for a number of different wavelengths and for levels ranging from the very low levels needed for laser target designators to a 15 kilojoule pulse calorimeter for the Air Force Weapons laboratory. Thus while NBS has developed considerable expertise in laser measurements, and presently offers a variety of laser calibration services, we do not have the capability to provide calibration support to the Services and their contractors at the accuracy levels desired for all of the wavelengths and power levels needed for the systems mentioned above.

The following anecdote illustrates the problems that can arise when inadequate attention is devoted to ensuring the quality of measurements. The X-ray laser program of the Strategic Defense Initiative ran into difficulty near the end of 1985 because of questions about the credibility of test data. Photonics Spectra, a trade magazine, reported in January of 1986 that a Congressional investigation of the controversy was being held to examine "flawed test measurements" within this program and that 29 members of Congress were asking Defense Secretary Weinberger to delay an underground nuclear test to evaluate an X-ray laser "because of supposed flaws in laser power measurement devices."[33] The following month this same magazine continued its coverage of this issue and stated that " . . . beam brightness was greatly exaggerated because of wrongly calibrated measurement equipment."[34]

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[33] Photonics Spectra, January 1986, p. 30.

[34] Photonics Spectra, February 1986, p. 36.

NBS has not had access to the data from these tests, so we cannot comment on whether or not the criticism in the press was justified. Whether or not the criticisms are valid, the point is that credible measurements are crucial to any technical program, and NBS's mission is to help laboratories achieve that credibility. An editorial about the X-ray laser measurement controversy in the November 13, 1985 Los Angeles Times summarizes this point well. After describing the measurements in question, the editor wrote, "The results of scientific experiments can only be as valid as the accuracy of the instruments used to measure them." . . . "It is self-evident that millions of taxpayer dollars should not be thrown away in a test that cannot be accurately and reliably calibrated."

Optical fiber data communication links are being exploited by all three Services. For example, the Navy has found that considerable weight and space can be saved on ships by replacing conventional copper coaxial cables interconnecting computers and monitoring systems with optical fiber cables. The performance of such systems cannot be evaluated unless careful measurements can be made. In order to use fiber optic cables the Navy must be able to measure their performance and locate defective fibers or connectors. Such measurements involve an instrument called an optical time domain reflectometer (OTDR), and the Navy looks to NBS to develop calibration techniques and standards so high precision OTDRs can be calibrated to the desired accuracy levels.

The performance of missile seekers employing infrared (IR) sensors must be measured during production and checked during deployment. Instruments for these measurements must be carefully calibrated. The strategic surveillance sensors (focal plane array IR sensors) required for the SDI monitoring satellites are advancing rapidly, and our ability to measure them accurately is not keeping pace with the ability of the contractors and DOD laboratories to improve their sensitivity. If company A claims that their sensors are 50% more sensitive than those of company B, but neither firm can guarantee that their data are accurate to better than ± 50%, then such comparisons are not meaningful. Extra expense will be incurred when expensive measurements must be repeated. Ambiguous data could cause the DOD to pursue a technical approach that later turns out to be non-optimal. A recent article notes that such sensor systems may contain in excess of 100,000 tiny pixels (picture elements).[35] Calibration, which must be performed in an ultra-cold cryogenic chamber, is a challenge. Unless measurements for IR sensors can be improved, the Department of Defense could well have difficultly determining unambiguously whether a particular contractor has achieved the performance level required by the contract.

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[35] IEEE Spectrum, Sept. 1985. (Note that this issue contains a number of articles on SDI technology--the stringent sensor requirements are mentioned in several places.)

NBS has developed a variety of measurement methods and standards to meet the needs of the defense microwave community to support systems such as navigation, imaging, and fire control radars, communications systems, and electronic warfare devices (e.g. jammers). Good measurements are needed to be able to adjust these systems for best performance and to determine whether or not a given systems meets its specifications. If a contractor claims that a system meets the specification but the DOD measures it and thinks that it does not, lengthy delays and extra expense will be incurred while tests are repeated--perhaps several times to try to resolve the discrepancy.

Until recently most of these systems operated in the microwave region at frequencies below about 20 or 30 GHz. Now these same kinds of systems are being developed and deployed with operating frequencies in the millimeter region--well above the old range. (The millimeter wave region extends from approximately 30 to 300 GHz). Standards previously developed by NBS for lower frequencies cannot be used at these higher frequencies, and new measurement techniques and hardware must be developed. Examples of systems exploiting millimeter waves include space based radar for SDI (60 GHz), the seekers for the Multiple-Launched Rocket System (MLRS) (94 GHz), and a variety of special-purpose covert communications systems and special electronic intelligence systems.

Measurements of interest include power, attenuation, noise, antenna gain, phase angle, and others. The standards available at these frequencies have not kept pace with the calibration needs. For example, the new MILSTAR military satellite communications system has a link operating in a range for which no NBS standards are currently available. Fortunately, the MILSTAR Program recognized the deficiency and recently funded NBS to develop a capability for the frequencies used by MILSTAR. (Note, however, that the MILSTAR funding will not permit NBS to develop a complete calibration capability in these frequency bands--only the minimum necessary to support MILSTAR.) Had this not been done, serious disagreements regarding data on component values and system performance between contractors and subcontractors and between the prime contractors and DOD would undoubtedly have arisen.

Recent emphasis on developing monolithic microwave and millimeter wave integrated circuits (MMICs) has generated an entire family of new measurement problems, such as measuring radio frequency parameters directly on the gallium-arsenide wafers during the processing. NBS has been in touch with the office in DOD concerned with MMIC devices and is now in the process of defining the measurement requirements.

Electrical/Electronic Metrology

The Services own thousands of pieces of general purpose electronic test equipment, such as digital multimeters for measuring voltages and currents, oscilloscopes for viewing electrical signals, and signal generators and spectrum analyzers. Each of these instruments must be calibrated periodically to ensure its continued accuracy. Many of the measurements made on a daily basis for servicing and adjusting avionics equipment, troubleshooting computers and communications equipment, etc. are supported by existing NBS measurement services and standards which must be maintained. At the same time, there are some critical parameters for which state-of-the-art electrical measurements must be made in the field with extremely high reliability. For example, voltage or resistance measurements in the guidance systems of missiles such as Trident and Peacekeeper must be made at accuracy levels comparable to the best that NBS can do in its own laboratories, because the targeting accuracy can be directly related to measurement accuracy.

For measurements such as these, NBS must work with the Services to improve our ability to transfer state-of-the-art measurements made at NBS to the field without losing appreciable accuracy. Frequently, the latest scientific developments must be exploited. For example, NBS has worked with the Navy to develop arrays of thousands of microscopic superconducting Josephson junctions cooled to the temperature of liquid helium (about 450 degrees F below zero). The use of this exotic technology was necessary to achieve much improved accuracy for dc voltage standards in Navy and Navy contractor laboratories. Lockheed, for example, has stated that this new, much improved voltage standard is essential in achieving the desired performance for the Trident missile.

Another recently-developed physical phenomenon, the Quantum Hall Effect, promises similar improvements in field-level accuracy for standards of electrical resistance. Cesium or rubidium atomic clocks are used in Navy submarines in conjunction with their precision navigation systems. One of the factors affecting how long submarines can stay on patrol is the ability of these atomic clocks on board to stay synchronized with atomic time standards on shore. Years ago the requirements of the Navy were considerably less stringent than NBS's ability to measure time. Today this gap has closed and NBS needs to improve its own capabilities if it is to stay ready to meet the military requirements.

Important parameters for this category include force, temperature, pressure, length, angle, and fluid flow. As with the areas above, new military requirements are straining the state-of-the-art.

Space weapons must be tested in evacuated chambers. Future requirements are for accurate measurements of levels of vacuum 1000 times lower than NBS currently supports. Many military systems (e.g. electronics used in space) have requirements for ultra-high reliability. In order to achieve such reliability, the hermeticity of the packaging must be tested. This means that extremely minute leaks must be detected. The development of NBS's new calibration service for leak rate measurements was supported in part by Sandia National Laboratories in order to satisfy measurement requirements for civilian nuclear power applications. However, military requirements for leak rate standards exceed those of the civilian sector by a considerable amount. If leaks cannot be measured accurately, contractors cannot produce systems with assured long-term reliability.

The measurement of angles is conceptually straightforward, however the requirement for precision angle measurement associated with the pointing and tracking requirements of the Strategic Defense Initiative are formidable. One SDI official compared the requirement to being able to point a weapon from atop the Sears Tower in Chicago and hit a particular window in the Empire State Building in New York. NBS's current capability for angle measurement is approximately 1 microradian or an accuracy of about 0.00006 degrees. In order to meet the requirements for SDI, this capability will need to be about 100 times better. Unless NBS can improve the state of the art for precision angle measurement, future tests of SDI pointing systems could produce data of dubious credibility.

Pressure transducers and gauges are ubiquitous in many DOD systems. One might think that pressure measurement is a well-established measurement for which no new exotic requirements are likely to arise, but this is not the case. Army scientists studying ways to improve the performance of large guns such as those used in tanks and howitzers, must measure the pressure transients in the breach of a gun when the weapon is fired in order to understand how the charge burns during the detonation. NBS standards to calibrate the pressure transducers used for such dynamic measurements, where the pressure increases from atmospheric to over 100,000 pounds per square inch in a fraction of a second, are not currently available. The consequence is that it is difficult to compare results from one laboratory with those from another or to be sure that results obtained one month are consistent with those obtained the next.

There is also a need for improved nondestructive testing (NDT) techniques and standards to support the fabrication and maintenance of planes, helicopters, and cruise missiles made of fiber-reinforced composite materials. It is common practice to check ordinary metallic structures for fatigue-induced cracks or other defects that develop during manufacturing and testing by using conventional techniques such as ultrasonics and dye penetrants. NBS has developed a variety of such techniques and calibration standards for them, for example, our ultrasonic reference blocks. Analogous standards for testing composite materials for cracks and\or delaminations do not currently exist. In the absence of adequate standards and test methods, two options are available, neither of which is appealing. Either a very conservative but costly approach is taken where wings, rotor blades, etc. are replaced frequently lest undetected flaws cause problems, or a high-risk posture is adopted where the safety of pilots or the reliability of systems is compromised.

Automated Metrology

Complex automated test equipment (ATE) and complex built-in test systems are commonplace in the Services today. For example, the Navy's new Consolidated Automated Support System (CASS) supports avionics and weapon system electronics of the latest types while greatly reducing the amount of shop space occupied by analogous prior-generation test equipment.[36] CASS is predicted to save the Navy $3 billion in testing costs over its projected 18 year life. Such equipment is required because of the complexity of the multi-function equipment it supports--equipment that in some cases would take days to test, troubleshoot, and calibrate if old-fashioned manual testing were used, where multiple points were checked in each operating range and where the system was checked in all of its possible operating modes. The Navy has asked NBS to help design calibration strategies for CASS. The cost and productivity advantages of equipment such as CASS are significant, but adequately verifying the performance of these powerful multi-purpose systems is a formidable task.

Built-in test systems must perform accurately because errors can be costly. A system that fails to detect a genuine problem can compromise a mission, whereas a system that continually triggers false alarms can be a logistics nightmare and result in large unnecessary expense. Recent articles about false alarm problems with the electronic diagnostics for the B1 bomber (80 false alarms per flight have been reported) and the large costs associated with

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36 "Navy's CASS to Cut Operating Costs", Defense Electronics, March 1986, pp. 131-134.

eliminating this and other problems ($1.5 billion being requested for upgrades to the plane) illustrate the point.[37]

While most of the work in developing ATE verification techniques is the responsibility of the producers of the electronic systems, both the Services and contractors look to NBS to help from time to time, both because we have expertise in this area and because we are a neutral third party and can, therefore, be objective in helping to resolve disputes between a Service and a supplier of ATE. (For example, NBS recently assisted the Air Force in investigating diagnostics problems with the F-15 aircraft.) One of the areas where NBS has special capabilities is the impact of measurement error in defining the minimum number of test points that must be examined to verify that a particular system is performing properly. More work is needed on the basic theory and practice of tracking errors in complex ATE systems.

The digital revolution has generated demanding new requirements previously unheard of. For example, NBS has had to develop the capability to calibrate analog to digital and digital to analog converters. Virtually every modern sensor or transducer used in automated defense systems generates an analog signal that must be accurately converted to a digital signal for processing. It is obviously important to be able to characterize this conversion process and quantify the errors introduced by the conversion.

A particularly demanding measurement challenge is automated nondestructive evaluation of precision parts during manufacture. Real-time X-ray radiography holds great promise for meeting this need. NBS recently held a workshop with representatives of the Services and defense contractors to define standards and calibration requirements for this new technology. Funding to develop these standards and measurement services remains a problem, however.

Analytical Metrology and Systems Metrology

These final two categories discussed in the DOD metrology plan are important to the Services. They involve such issues as designing equipment to minimize calibration requirements, determining optimum calibration intervals, designing Service calibration capabilities for rapid deployment in wartime, etc. While NBS does occasionally help with these issues, the role of NBS in these topics is considerably less than in those previously mentioned, and thus these topics will not be addressed in this report.

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37 "Officials Say Air Force Understates B1 Problems", Washington Post, February 26, 1987, p. A6.

The Lead Agency Issue

The "Lead Agency" policy[38] of the Federal Government has presented some particular difficulties in securing adequate funding for NBS to support DOD's metrology needs.

The Department of Commerce and the Office of Management and Budget (OMB) expect DOD to reimburse NBS for research undertaken to support DOD metrology needs. DOD budget officers and the DOD managers who are developing systems that require new or better standards generally act on the assumption that the science and technology which underlies the national measurement system is the Bureau's responsibility, particularly as DOD needs are often the forerunners of general industrial needs. Therefore, when DOD does underwrite NBS measurement research, it budgets only for the incremental cost of providing traceability[39] to this underlying base of science, engineering, and measurement techniques. DOD managers assume that such research which upgrades the capability of the national central reference laboratory (NBS) is a part of the Bureau's legislative mandate and should be funded from NBS appropriations.

Thus, even though there is no dispute about the importance of

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[38]See Chapter II for a more complete discussion of "traceability".

[39]See Appendix A. "Customer Needs for Calibrations and Special Tests", Exhibit A, for a discussion of the concept of "traceability".

the work, there remains ambiguity about who should budget for this area of generic measurement research in support of DOD's needs.

DOD's industrial contractors expect NBS to provide the measurement science and technology they rely on for traceability to national standards. From their perspective, all the funding comes from the Federal Treasury, so it does not matter who funds the work. What does matter to them is that they are able to come to NBS to get the measurement tools they need, when they need them.

Because of the importance of measurement to the DOD mission and because NBS has been unsuccessful in acquiring additional appropriations for fundamental and generic research driven by DOD requirements, the DOD Calibration Coordination Group (CCG) has attempted to secure funding in DOD's budget to permit NBS to develop broader capabilities. Their "Tri-Service Metrology Research, Development, and Engineering Plan" calls for a total program amounting about $10 million per year for 5 years, but their funding to NBS in recent years has amounted to only about $1 million per year per Service.

NBS's Response to DOD Needs

Where NBS has existing expertise that can be brought to bear on defense problems, the work is consistent with the NBS mission, and the appropriate DOD office is willing to transfer funds; NBS gives the work high priority. For example:

- The Navy has provided support in recent years for NBS's Automated Manufacturing Research Facility (AMRF) because they intend to apply this technology to achieve dramatic increases in productivity in piece-part manufacturing at Navy shipyards and depots.

- The software approaches developed for the hierarchical control system used in the AMRF are similar in many ways to the hierarchical controls that will be needed for SDI battle management, and so NBS's Center for Manufacturing Engineering is working with the Army Strategic Defense Command to help them develop benchmarks for SDI battle management software.

- NBS has received funding from the Army Strategic Defense Command to develop a cryogenic test chamber for infrared radiometry required to support the SDI.

- By virtue of its design, NBS's new accelerator, the microtron, lends itself very well to driving a free electron laser (FEL), and so, with SDI funds, NBS will be developing a FEL facility that will be available to SDI and other researchers.

- NBS is assisting with the DOD's new Computer-Aided Logistics Support Project (CALS).

Early Identification of Standards Needs

Once measurement requirements have been identified and the funding is available, significant lead time may be required for NBS to respond. When a new standard or calibration service is required for a measurement that is beyond the state of the art, it often takes two or three years and sometimes much longer for the capability to be developed. DOD program managers often are not aware of the time required for research that underlies a standards or calibration need. Therefore, they frequently do not ask for help until an immediate solution is needed.

To avoid long delays, it is important that DOD be able to anticipate new standards requirements and notify NBS in advance of the need. NBS scientists and engineers, because they are experienced in standards development for DOD, also monitor technical progress in relevant areas to try to anticipate long-range DOD needs.

There are mechanisms that require DOD project managers to report standards needs. However, reports are not likely to be filed until managers recognize that they have a problem. The most demanding requirements occur in highly classified areas, where the number of people familiar with the technical details is intentionally kept as small as possible.

The individual Services are tasked to attend to measurement and standards requirements. The Office of the Secretary of Defense in the Pentagon has no staff member with full-time responsibility for monitoring the adequacy of measurement standards. Within the Services, Calibration Coordination Group members are part of the logistics function, so they are functionally separated from the developers of new weapons systems, which is where new measurement requirements originate.

NBS and CCG have discussed with DOD possible ways of improving early identification of measurement and standards needs that may require NBS research. Several possible approaches have been proposed, involving modifications to DOD and Service regulations and instructions. The Office of the Secretary of Defense (OSD) is currently studying possible changes in organization or operation to better address metrology concerns, but the results of that study are not available at this time.

APPENDIX D

FINAL REPORT

THE STATUS OF EMERGING TECHNOLOGIES:
AN ECONOMIC/TECHNOLOGICAL ASSESSMENT TO THE YEAR 2000

U.S. DEPARTMENT OF COMMERCE

May 1987

The Department of Commerce has concluded, in a review of emerging technologies and their future impact on the economy, that American businesses lag behind many of their foreign competitors, especially the Japanese, in exploiting technological breakthroughs.

The review was ordered by Deputy Secretary Clarence J. Brown in April 1986 to identify the new technologies that will lead to new products or processes, analyze their commercialization, and recommend means of reducing the barriers. It is based on an assessment by technical experts and agency heads within the Department, under the leadership of Dr. Ernest Ambler, Director of the National Bureau of Standards. They studied scientific and industrial plans and the commercialization process here and abroad.

Once the list of technologies was determined, the experts determined their probable contribution to the gross national product by the year 2000. While recognizing this as an imprecise measure requiring some subjective forecasting, the Department believes it to be the best proxy to judge economic impact. Although the technologies are ranked in terms of high, moderate or low impact, the terms are relative; all are expected to play a significant role in future growth.

Identifying the technological opportunities and their probable economic effect is not difficult. The real problem facing U.S. companies is converting these opportunities into real economic success. The review's primary focus is upon identifying ten barriers to commercialization and making recommendations for overcoming them. The recommendations require action by all sectors of American life, sometimes unilaterally and occasionally together.

The barriers to commercialization are also ranked in order of importance. The two most important are inadequate tax incentives and the high cost of capital. The remaining barriers include two that require actions by individual companies. The Department found that there is a lack of integration and communication among functions within companies, and it also cites companies for being too complacent and dependent on the domestic market for growth opportunities.

The recommendations include fostering participative management by employees, training managers in the production process, eliminating provisions in foreign tax laws that discriminate against U.S. products, and updating business school curricula. They also reiterate recommendations of President Reagan's competitiveness initiative, such as those regarding improving export controls, reforming product liability and tort laws, and lifting antitrust restrictions.

Since the list of technologies was determined, there have been significant and highly publicized breakthroughs in the field of superconductors -- materials that have zero electrical resistance. Several developments must be achieved before their economic potential can be realized, particularly an improvement in the current-carrying capacity of these materials. Until it is known whether this is possible, superconductors should be considered a <u>potential emerging technology</u>.

The accompanying appendices describe in detail the technologies, barriers, and recommendations.

APPENDICES

Table 1

EMERGING TECHNOLOGIES

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
1. Advanced Materials			
A. Ceramics (high performance structural and electronic ceramics)	Better high temperature strength-to-weight properties	Heat engine components, turbine blades, heat shields	Automotive & aircraft engines
	Better dielectric & optical properties	Electronic substrates, integrated optics	Electronic components
B. Polymer Composites	Higher strength-to-weight ratio	Structural components	Aerospace, automotive, ind. const.
(high strength fiber reinforced plastic resin)	Design flexibility because of spatial asymmetry	Structural components	Aerospace, automotive, ind. const.
C. Metals (rapid solid-ification, & metal matrix composites)	Improved strength & high-temp performance	Structural components Super conducting components	Manufactured components
	Improved magnetic properties	Electro-magnetic equipment	Electrical machinery
2. Electronics			
A. Advanced Microelectronics	Improved performance in speed, size	Semiconductor devices	Electronic & optical components & systems
(enhanced VLSI and VHSIC chips)	Improved magnetic properties	Information storage	Information processing
	Higher efficiency photovoltaic conversion	Solar cells	Energy generation

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
B. Optoelectronics (optical fiber and light wave processing)	Improved performance in speed, size, capacity, and security	Electronic equipment, information processing	Communications & computers
	Higher density information storage	Computer systems of all sizes	Computers
C. Millimeter Wave Technology	When replacing radio systems it frees RF spectrum for other uses	Voice & data communication systems	Telecommunications carriers & corporate use for private circuits
3. Automation			
A. Manufacturing (computer integrated and flexible systems)	Flexible reconfiguration of production processes	All manufacturing processes	All manufacturing
	Integrated control of all production operations		
B. Business and Office Systems (computer applications within an organization)	Efficient information storage, retrieval, & exchange	Networking, word processing, & data base management	All organizations
C. Technical Services (computer applications in the provision of commercial services)	Efficient high-volume information storage, retrieval & exchange	Information retrieval and distribution, data base management, education and training	Financial services, electronic mail, telecommunications, professional service

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
4. Biotechnology			
A. Genetic Engineering	Improved diagnostic and therapeutic drugs	Health Services	Medicine, Pharmaceuticals
(design & production of highly selective agents)	Improved plants, pesticides, & animal supplements	Foods and pesticides	Agriculture Food processing
	Neutralize pollutants	Environmental control processes	Chemical manufacturing & treatment
B. Biochemical Processing	Improved control of chemical processes, outputs, and yields	Chemical separations and reactions, biosensors	Chemical manufacturing
5. Computing			
A. Computing Equipment	Faster, lower-cost computing	Information processing and computer control	Potentially all.
(supercomputers, parallel processing, computer arch.)			
B. Artificial Intelligence Techniques	Improved computer replication of human judgment	Information processing and computer control	All applications using computers
(includes expert systems, natural language, and robotic control)			

Technology	What does it do new or better?	Applied to what products or processes?	Used by What Major Industries?
6. Medical Technology			
A. Drugs (other drugs are included in category 4 - Biotechnology)	Improved immunology and treatment	Health Services	Medicine, Pharmaceuticals
B. Instruments & Devices	Improved diagnostic and therapeutic systems	Magnetic Resonance Imaging & CAT scanning, radiation treatment	Medicine
7. Thin Layer Technology (semiconductor applications also are included in Electronics)			
A. Surfaces & Interfaces	Improved control and yield of chemical reactions	Chemical catalysis	Chemical manufacturing, food processing
	New electronic & optical properties	Semiconductor devices, surface modification and coatings	Electronic components, computers
B. Membranes	New chemical properties, better chemical separation techniques	Chemical separations	Chemical manufacturing, food processing

Table 2

EMERGING TECHNOLOGIES RANKED BY ECONOMIC IMPACT

Group A (Highest)	Advanced Materials; Composites Biotechnology; Genetic Engineering Electronics; Optoelectronics Electronics; Advanced Microelectronics Computing; Computing equipment Automation; Manufacturing
Group B	Automation; Business and Office Systems Biotechnology; Biochemical Processing Medical Technology; Drugs Advanced Materials; Ceramics Automation; Technical Services Computing; Artificial Intelligence Tech. Medical Technology; Devices
Group C	Thin Layer Technology; Membranes Advanced Materials; Metals Thin Layer Tech.; Surfaces & Interfaces Electronics; Millimeter Wave Technology

Table 3

GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

1. High costs of capital funds in the U.S. relative to foreign competitors.

2. Tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations).

3. Poor integration of manufacturing, design, and R&D functions.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

5. Complacency and dependence on the domestic market.

6. Restrictive trade policies in foreign markets.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, drug approval regulations, and occupational health regulations).

8. Export controls on advanced technologies and high-technology products.

9. Restraints and uncertainty caused by product liability and tort laws.

10. Anti-trust restrictions against cooperative ventures for marketing or production methods. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

APPENDIX B

DETAILED DESCRIPTIONS OF GENERIC BARRIERS TO ACHIEVING MAXIMUM ECONOMIC BENEFITS FROM EMERGING TECHNOLOGIES

1. High costs of capital funds in the U.S. relative to foreign competitors.

   Higher interest rates, lower debt-equity ratios, cultural practices, and tax laws combine to make the effective cost of capital funds for U.S. firms up to twice as high as their Japanese competitors. For example, U.S. savings rates, as a percentage of GNP, have historically been, and continue to be, among the lowest of developed countries (and about half that of Japan). Recent declines in the value of the dollar relative to foreign currencies have reduced some capital cost differentials, but the above factors combine to keep that differential high.

2. Tax incentives for U.S. companies relative to foreign competitors to deploy emerging technologies (including the stability of tax regulations).

   Foreign countries continue to employ a variety of incentives to encourage the growth of new technologies. These range from subsidies for the conduct of R&D to import protection of the products derived from the new technologies, at least in their early marketing stages. U.S. firms receive few such subsidies. Some predict that recent changes in the tax law will have a stultifying effect upon venture capital, thus denying U.S. firms access to a previously major source of funding for new high-technology firms.

   Frequent changes have made it difficult for U.S. businessmen. Drafting of regulations often lag behind legislation significantly. These changes and delays have created an air of uncertainty in business planning: uncertainty is always an anathema to the businessman.

3. Poor integration of manufacturing, design, and R&D functions.

   For rapid movement of new technologies through the functions of R&D, design, product development, and production, it is necessary to have effective communication among these functions. Lack of willingness and opportunity of key technical staff to move with the emerging technology from R&D into manufacturing, for example, has been common in U.S.

organizations, although much improvement has occurred in recent years. A contributing factor in the U.S. has been the lower status, reflected in lower salaries and recognition, given to manufacturing relative to other branches of engineering.

Lack of cooperation and integration among institutions in the U.S. is just as important a barrier as among functions within a firm. For example, more rapid application of new technologies could be the result of closer coupling of firms to technical activities in Universities and Federal laboratories, and from intercompany cooperation to jointly address generic or structural technical problems of a longer-term nature. In this category would fall the classic Government research (carried out by NBS, NOAA, and NTIA) to provide technical data and standards that industry needs to design reliable new products/processes, but single firms do not have the incentive, expertise, or funds to develop themselves.

The Japanese are said to be particularly strong in integrating functions; this may partly account for the rapid speed with which their firms introduce new products into the market. Rotation of staff among these functions in Japan also helps this integration process.

4. Inadequate laws, regulations, and enforcement protecting intellectual property rights in the U.S. or overseas.

U.S. businesses rely upon strong intellectual property protection to realize the benefits of emerging technologies. In fact, the rate of development of emerging technologies may well depend upon patents as incentives and security for R&D or marketing investment, and upon trademarks to build and protect reputations for quality. Barriers exist where laws, regulations or enforcement procedures are inadequate. When innovation is neither rewarded nor encouraged, markets are either forfeited, left untapped, or are underdeveloped. Examples of domestic barriers include (1) the inadequacy of the statutory 17-year patent term for certain agricultural and pharmaceutical products which are subject to extensive premarket testing, and (2) the absence of effective protection for process patent holders against imports of products made abroad under the patented process.

On the international front, it is well recognized that many countries do not offer adequate intellectual property protection and, in some cases, actually sanction abuse of intellectual property rights. This would include, for example, a nation's outright appropriation of foreign-owned technologies or of creative and artistic works. This robs the inventor or creator and, of course, the associated business concern of any possibilities of realization of world market potential.

5. Complacency and Dependance on the Domestic Market

This barrier encompasses the attitudinal problems generated by the size and ready availability of the U.S. market for new products and services -- the lack of an immediately apparent need to compete with Japan and other countries head-to-head in the international marketplace. American companies, separately and in joint ventures, must aggressively seek export opportunities abroad and anticipate challenges in the U.S. from new foreign competitors. This barrier also encompasses the attitudinal differences toward "risk taking" between U.S. and Japanese firms and the cultural differences in approaches to production and marketing. The Japanese preference is to produce and market technological improvements in small increments, thereby gaining a foothold and experience in the marketplace. The U.S. approach is to complete as much research and development as possible before producing and marketing a new product which "leapfrogs" existing technology.

6. Restrictive Trade Policies in Foreign Markets

Restrictive trade policies take many forms -- laws, regulations and practices -- with an overriding consequence of protecting a home market from foreign products. Although most of these policies are sponsored by governments, business practices and social mores may also act as significant trade barriers.

Direct Government Practices are one type of policy affecting trade. Included here are:

- Tariffs and other import duties designed to protect a domestic market rather than to raise revenues.
- Import licensing designed to create uncertainty, delays, and discrimination for foreign products.
- Government procurement (i.e., buy national products)
- Product development and export subsidies programs.

Indirect Government Practices are a second type of policy. Included here are:

- Standards codes, testing, labeling, and certification requirements which interfere with market availability and acceptance of foreign products.
- Local or domestic content (e.g. rules or origin)

requirements on foreign products which adversely affect technology and process innovations.
- Market reserve policies that designate certain markets for domestic products only.
- Disregard of intellectual property rights by foreign governments which undermine the ability to exploit markets with new products.

<u>Non-trade and Non-government Measures and Practices</u> are a third type. Included here are:

- Public health and safety laws that indirectly restrict the importation of foreign products.
- Local and national distribution systems that discriminate against foreign products through interlocking relationships among manufacturers, wholesalers, and financial institutions.

7. Federal or State regulations on corporate activities intended to protect the public health and safety (e.g., building codes, environmental laws, occupational health regulations, and drug approvals).

Emerging technologies generally require, somewhere in their development and production, some form of environmental and/or health clearance or regulation. This will occur on the Federal or State levels depending on which of the Federal regulation(s) apply.

Those technologies involving large-scale use of new materials, particularly in the broader electronics categories, will have to continue to meet the existing water, air and disposal requirements. In the case of new and exotic materials, such as the new semiconductor compounds (e.g. Gallium Arsenide), OSHA regulations are constantly being revised to protect against potential hazards, while EPA has control of various emissions through clean air and clean water legislation.

Solid waste reclamation also will enter into the cost of using new technologies. Disposal of new composite materials as scrap in products that have reached the end of their useful life, will impose a new set of costs and possible barriers. The present case of what to do with worn-out lead storage batteries is a good example of what might happen to a higher technology material with end-of-cycle toxicity.

For those technologies involved in medical and health care, regulations covering production, product certification, standards, OSHA considerations and disposal add to the burden of time/testing, as well as to the cost of meeting stringent health and environmental standards. The current issues surrounding the regulation and testing of genetically-altered naturally occurring organisms is a prime example of an emerging technology in the early stages of development.

The costs and time delays involved are further exacerbated if competing countries have less stringent certification and environmental requirements. Technologies in those countries are often put into production faster, thus putting U.S. suppliers at a competitive disadvantage. There are several recent examples in the pharmaceutical industry of the effect of these differences.

8. Export controls on advanced technologies and high-technology products.

While the need for control of the export of technology for purposes of U.S. national security has been clearly established, the costs attributable to "over-control" are also now becoming more apparent. That is, the Executive Branch's inability to decontrol goods and technology -- that are no longer strategic or are available from foreign competitors--is now seen as inhibiting our ability to remain technologically superior to our international competitors as well as contributing to the erosion of our defense industrial base . The Department of Commerce is trying to establish interagency procedures that will facilitate the decontrol to take place as Congress intended.

9. Restraints and uncertainty caused by product liability and tort laws.

With increasing frequency, claims are made that innovation and ability to compete are retarded in the U.S. by product liability and tort laws. The resulting uncertainty and instability have brought about a need for reform. Reasons include:

- -- A patchwork of 50 different state laws on product liability. Cases based on similar facts, but tried in different states, can produce strikingly different and contradictory results.
- -- The enormous transaction costs for all parties involved in litigation.
- -- The high costs of insurance for product-liability related protection.

Over the past 20 years our product liability law has moved away from fault as its basic guiding principle. The Commerce Department has taken the position that as a matter of fairness to manufacturers and as an incentive to them to construct new and safe products, businesses should generally be held liable only for behavior based on fault.

10. Anti-trust restrictions against cooperative ventures for marketing or production. There may still be perceived barriers against cooperative R&D, but legal restrictions against procompetitive R&D were eased by legislation in 1984.

Many U.S. anti-trust restrictions have been in place, substantially unchanged, for over 75 years. In these times of strong foreign competition and worldwide markets, U.S. firms are at a disadvantage when compared to foreign firms not subject to such strong, legal strictures. Production economies not envisaged when the original laws were enacted are now possible. These economics permit firms jointly to build and operate facilities at lower cost, thus improving world-competitive positions. Facilities housing flexible automated manufacturing systems are one example, but other shared facilities are also possible. Joint production by large firms, joint marketing of the products, and mergers of such large firms are subject to close scrutiny by U.S. Federal agencies, even though they may increase efficiency. This is viewed as an anachronism, particularly in the light of foreign practice.

Cooperative funding of procompetitive R&D was eased by changes enacted in 1984 which, among other things, reduced damages to be assessed to losses actually incurred. These changes are still not as widely known as they might be, with the result that some cooperative U.S. ventures are not being undertaken in fear of anti-trust prosecution.

APPENDIX C

RECOMMENDATIONS OF METHODS TO OVERCOME BARRIERS

BARRIER: HIGH COST OF CAPITAL IN THE U.S. RELATIVE TO FOREIGN COMPETITORS

Efforts to reduce Federal budget deficits should continue because of negative effects of the high deficits on capital markets and on interest rates.

State and local level efforts to meet local capital needs should be encouraged. The creation of venture capital pools would help increase the availability of capital for the new, high-risk developments that sometimes have very large innovation and competitive payoffs. Investment rebates and other incentives might also be used.

Actions should be taken to increase aggregate savings in the U.S. Additional tax incentives (beyond the recent tax reform), direct appeal to savers, and other actions could increase savers willingness to save rather than consume. Increased savings levels are necessary to help increase capital supply and lower interest rates. The U.S. savings level is much lower than in competitor nations.

BARRIER: TAX INCENTIVES FOR DEVELOPMENT OF NEW TECHNOLOGIES

In order to encourage rapid commercialization of technological advances, any future changes in the tax law should focus on the incentives available for long-term investment in all factors of the production, marketing, and distribution processes. Changes in cost recovery provisions should not force U.S. companies into a competitive disadvantage. American businesses must have confidence that major tax changes will not be made repeatedly.

The tax laws of foreign countries should be analyzed to determine if they discriminate against U.S. products being sold there. Discriminatory effects should be alleviated through negotiation or, if necessary, compensated through legislation.

BARRIER: POOR INTEGRATION OF MANUFACTURING, DESIGN, AND R&D MARKETING FUNCTIONS

All managers should have a grounding in the basic production process of the company. Beyond this, managers should receive cross-functional training so they have at least a minimal appreciation of finance, personnel, technology development, marketing, as well as production.

Top management must foster attitudes throughout management staff that foster flexibility, change, innovation and adaptability.

Business schools must update curricula to train business students in the total process -- from R&D to marketing and servicing. Business students must see any particular specialization within the fullest context of what is required for corporations to achieve maximum productivity.

BARRIER: INTELLECTUAL PROPERTY PROTECTION

Industrial firms in the U.S should take great care in transferring their technology and other intellectual property to foreign firms. For protecting the competitiveness of the nation as a whole, firms should establish safeguards against non-economic transfers.

Export control procedures should be changed to include intellectual property protection agreements and concerns, so that sales by U.S. firms are protected and enhanced.

Insist other nations protect U.S-owned intellectual property. Treaties, reciprocal agreements, tariffs, and other mechanisms used by the U.S. government in dealing with other nations should incorporate strong intellectual property provisions. U.S. laws could be strengthened to insure reciprocity and to prevent unapproved imports of products made abroad by processes patented in the U.S. Enforcement in other countries is often the weakest link in the protection process.

Ownership of rights stemming from collaborative research should be clarified. The goal is to eliminate uncertainty and thus maximize the incentives to rapidly commercialize technological developments by U.S. firms. Similarly, actions should be taken to assure that ownership rights and other benefits from Federally-funded research flow to U.S. organizations.

Ways should be sought to obtain payments from foreign graduate students for the intellectual property they benefit from while doing research in the U.S.

BARRIER: COMPLACENCY AND DEPENDENCE ON THE DOMESTIC MARKET

We must foster entrepreneurial risk-taking. Several steps can be taken. Promote greater ownership by executives of corporate stock so that executives become owners, not simply managers. Include employees in "participative management" so that more decisions are made by those closest to production operations. Incentive systems must be improved so that more employees feel they have a greater stake in the success of the company.

Shift emphasis in our business schools so that executive responsibilities are taught more within the context of "owners" responsibilities rather than "management" responsibilities.

We must promote a greater sense of the "common good" so that government, management and labor interact on a basis of achieving positive goals rather than on the historic adversarial basis.

We must foster the awareness that there is no longer anything such as a purely "domestic" market. What we think of as the U.S. domestic market is, in fact, part of the global market. Thus as soon as a product leaves the shipping dock, it has hit the world market, even if it is only being shipped across town. This perspective must permeate all management levels.

BARRIER: RESTRICTIVE TRADE POLICIES IN FOREIGN MARKETS

Adaptability to foreign preferences should be improved by U.S. firms. The result should be U.S.-made products that better meet the special preferences of consumers in other nations and better performance in the marketing/distribution systems overseas. Increased exports and reduced trade deficits are the obvious goal.

Foreign languages should be introduced earlier into the U.S. educational process, so that our citizens will have a greater ability to understand foreign needs/preferences, and have an increased ability to successfully do business overseas.

BARRIER: FEDERAL AND STATE REGULATIONS FOR PROTECTION OF HEALTH AND SAFETY

Wherever possible, domestic regulations (from such sources as EPA, OSHA, FDA, and SEC) should be reduced and simplified in order to minimize their negative effects on industry's use of new technology. In some cases, foreign competitors have an advantage of less stringent or loosely enforced regulations.

A better balance should be achieved between the desirable safety goals of domestic regulations and the economic costs to U.S. manufacturers and businesses. In addition to the added costs, firms often have the application of new technology or marketing of new products delayed significantly. In the current global economy, we should recognize that economic viability is as important a national goal as public safety. The key is to balance these goals in a meaningful way.

BARRIER: EXPORT CONTROLS ON ADVANCED TECHNOLOGIES AND HIGH-TECHNOLOGY PRODUCTS

The January 1987 President's Competitiveness Initiative directs the Cabinet to review the export controls program and provide recommendations to achieve the following:

- Decontrolling those technologies that offer no serious threat to U.S. security;
- Strengthening enforcement controls on those technologies that could harm U.S. security;
- Eliminating unilateral controls in those areas where there is widespread foreign availability;
- Reducing the time required to acquire a license by at least one-third and implementing a fair, equitable, and timely dispute resolution process;
- Seeking agreement with our allies for concrete actions to be taken which will make export control procedures more uniform and enforcement more rigorous;
- Seeking overall to level the competitive playing field while strengthening multinational controls over products and technologies that can contribute to Soviet military capabilities; and
- Recognizing the continued improvement in U.S./People's Republic of China (PRC) relations and the commitment of the PRC to protect sensitive technology, and working with our allies to further liberalize high technology trade with China.

BARRIER: RESTRAINTS AND UNCERTAINTY CAUSED BY PRODUCT LIABILITY LAWS

The January 1987 President's Competitiveness Initiative proposes several methods to overcome this barrier. Proposed legislation would:

- Retain a fault-based standard of liability;

- Eliminate joint and several liability except in cases where defendants have acted in concert;
- Limit noneconomic damages to a fair and reasonable amount;
- Provide for periodic, instead of lump sum, payments of damages for future medical care or lost income;
- Reduce awards in cases where a plaintiff also is compensated by other sources, such as government benefits;
- Reduce transaction costs by limiting attorneys' contingent fees to reasonable amounts on a sliding scale; and
- Encourage litigants to resolve more cases out of court.

BARRIER: ANTI-TRUST RESTRICTION AGAINST COOPERATIVE VENTURES

The January 1987 President's Competitiveness Initiative proposes several methods to overcome this barrier. The statutory proposals include:

- Amending Section 7 of the Clayton Act to distinguish more clearly between pro-competitive mergers and mergers that would create a significant probability of increased prices to consumers;
- Limiting private and Government antitrust actions to actual (rather than treble) damages, except for damages caused by overcharges or underpayments;
- Removing unwarranted and cumbersome restrictions on interlocking directorates;
- Clarifying the application of U.S. antitrust laws in private cases involving international trade; and
- Requiring that any antitrust claims remaining against other defendants after a partial settlement in a case be appropriately reduced.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This report responds to Public Law 99-574, which directed the NBS Director to ask the Bureau's major clients about their needs for research and services related to NBS "process and quality control and calibration programs"; and to report findings and recommendations to the Bureau's Congressional authorizing committees.

NBS found that American firms and government agencies believe that implementation of process control and quality assurance are and ought to be primarily the responsibility of the producers of the Nation's goods and services; and that to respond to global competitiveness, measurement services are needed at earlier stages in the product/program development process. Greater accuracies and broader coverage are needed for existing measurement services, and new technologies are creating demands for additional, often entirely new or different services.

In general, customers are willing to pay costs directly related to the delivery of NBS services, but are opposed to subsidizing basic or generic research that might underlie several services. They see such research to be a mandated NBS mission, they expect it to be funded by NBS appropriations, and they expect services to be available when needed.

Finally, the report lists customers' specific measurement-related needs in a variety of technical areas.

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