
EEEL Strategic Plan

FY07

October 1, 2006

Forward

Planning, whether operational or strategic, has always been part of the culture of NIST's Electronics and Electrical Engineering Laboratory (EEEL). Historically, the planning was most often directed towards how we should best serve a particular industry as it evolves. EEEL also developed guidelines for the selection of projects, which included criteria such as "fit to mission," "probability of success," and "impact if successful." Operational plans primarily at the Division level have been required since the inception of EEEL. In recent times, following some tough budget years for the Laboratory, we embraced "bottoms-up" strategic planning for our Divisions. That is, with strong staff input, our Divisions developed plans for maximum short term and long term (5 to 10 years) impact. What was missing was an effective high-level strategic plan to guide the entire Laboratory. The publication of this Strategic Plan represents the culmination of the first full year's implementation of our EEEL planning cycle. I have attempted to keep this plan strategic and fought the temptation to add tactical or operational details. As a result, this document remains at a very high level and offers very little specific guidance. I sincerely hope that the document, despite its lack of specificity, will be useful to our EEEL family. Certainly the guidance it contains should be considered by the EEEL management team at all levels.

As mentioned above the intent is to update this document annually. Your feedback is, of course, welcome.

William E. Anderson

Director, Electronics and Electrical Engineering Laboratory

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Executive Summary

This strategic plan for NIST's Electronics and Electrical Engineering Laboratory (EEEL) sets goals and provides guidance on the Laboratory's priorities and future directions to support U.S. innovation and industrial competitiveness. This guidance document is an important part of our strategic planning process, which involves all of our Divisions, Offices and staff. While the primary audience is our Laboratory management and staff, this plan is also intended for customers and stakeholders to encourage their input and advice as we work to address critical electromagnetic measurement issues in industry, government, and the worldwide metrology community.

To achieve our vision to be the world's leading electromagnetic measurements and standards laboratory, we must sustain a culture of world class excellence. We must also effectively partner with others to maximize our impact and to fulfill our mission to promote U.S. innovation and industrial competitiveness in the global economy.

This strategic plan provides an overview of the Laboratory and identifies our critical core competencies and priority "mandates" that help define us as an organization. The plan then discusses the strategic environment and influences external to EEEL, such as the American Competitiveness Initiative (ACI), the Administration's priorities for Federal research and development, and changes at NIST (strategic and otherwise), including the creation of the Center for Nanoscale Science and Technology (CNST). It also includes a discussion of the implications of strategic "flattening" trends in the world economy on our measurement services and other programs. The plan provides an evaluation of our internal Laboratory environment and our strengths and challenges. All of this information provides the context for the next section, "The Plan."

The section called the "The Plan" provides guidance on what these strategic influences mean for EEEL. We will continue to align our research programs with Administration priorities and will strongly support the ACI to advance NIST's mission. We are committed to being world class in everything we do, maintaining a balance between advancing our core electromagnetic measurement capabilities and addressing the specific measurement needs of our customers, including continuing improvement of our measurement services. We will fulfill our share of the worldwide responsibility to advance the SI (from the French *Le Système International d'Unités*) system of units, for example by funding the continued development of the electronic kilogram to eliminate the last artifact-based standard. To support U.S. industry and to promote beneficial collaborations, we will strategically increase our international outreach to Systema Interamericano de Metrologia (SIM) and China. To help support these goals, we will nurture a culture of innovation, scientific excellence, open communications, and collaboration.

Introduction

The Electronics and Electrical Engineering Laboratory of NIST is one of the world's pre-eminent organizations in the field of electromagnetic measurements. It directly provides measurement capabilities including traceability to industries providing hundreds of billion dollars to our Nation's economy, and also provides key measurement capabilities required to support innovation at the frontiers of science in areas as diverse as nanotechnology, biotechnology, and even astrophysics. Serving such a large community means that there is no shortage of customers to benefit from our work, and that we must choose our programs and activities wisely to have maximum impact. This document, which will be

updated annually, is first and foremost a message to our staff on where the Laboratory's programs will be moving in the next few years. It is also meant for our customers and stakeholders so they can see where we are heading and provide advice and feedback on our intended course.

Laboratory Overview

Vision

To be the world's leading electromagnetic measurements and standards laboratory.

Our vision is crafted to inspire our staff to be world class in their areas of research and services. Given our broad scope of work for a wide range of customers, it is hard to justify investing our limited resources to make second-best or redundant contributions. Where our contributions are not unique or world-leading, there should be a plan in place on how to become world class in short order. Where our contributions are world class, we should continually challenge ourselves to advance the frontiers of electromagnetic metrology, particularly in areas that will have significant impact on U.S. innovation and competitiveness. Achieving this vision will require us to engage with the broader international metrology community, both to rigorously compare metrology capabilities to ensure that NIST measurements are internationally accepted, and also to coordinate and collaborate with other National Metrology Institutes (NMIs) to achieve common goals. And, of course, we will need to partner with other organizations in the private and public sectors to have maximum impact.

Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards and technology, primarily for the electronics and electrical industries, in ways that enhance economic security and promote our quality of life.

Our mission statement is consistent with the NIST mission focus on innovation and industrial competitiveness to enhance economic security and quality of life, but with a focus on the industries that EEEL historically has supported. However, our customer base includes all members of industry, government, and the scientific enterprise that could benefit from improved electromagnetic metrology. With internal funding and through strategically leveraging other agency funding, our staff has demonstrated a remarkable ability to maintain a strong focus on providing services and programs to meet today's needs while developing the fundamental electromagnetic metrology to establish future services when they are most needed.

Values

Integrity

...within our organization and in our interactions with our stakeholders

Impact

...through leadership in measurements and standards for our customers and the Nation

Excellence

...in all of our undertakings

Our values, in priority order, reinforce and extend our vision and mission. First, as a foundation for all of our actions and relationships, our value of *integrity* requires us to be open and honest with each other and with our customers. Second, our value of *impact* reinforces our commitment to fulfill our mission by producing significant and timely outputs with meaningful outcomes that benefit the Nation. To help maximize our *impact*, we are committed to thorough evaluation of our projects in relation to meeting our customers' needs. Third, our value of *excellence* means that our goal is to perform work of the highest quality, consistent with *integrity* and with maximum *impact*. Our commitment to world-class *excellence* propels us to achieve our vision to be the world's leading electromagnetic measurements and standards laboratory.

Critical Core Competencies

Our "critical core competencies" are the strengths and foundation upon which we build our core programs:

- Rigorous traceability including measurement uncertainties for electromagnetic measurements delivered to customers
- Quantum-based electronics and photonics expertise for development of primary standards
- Micro- and nano-fabrication capabilities

This is not a static, unchangeable list, and it is not intended to include every competency of EEEL, but rather it recognizes our core strengths that need to be maintained, enhanced and exercised for EEEL to meet its core mission. Our critical program areas, referred to as "mandates" since they define the essential activities of EEEL, are described later in this document.

External Environment (Opportunities and Threats)

Strategic Trends in Government

The American Competitiveness Initiative

In recognition of the key role of federal investment in research and development (R&D), the White House has launched the *American Competitiveness Initiative, (ACI)*. With about 5 percent of the world's population, the United States employs nearly one-third of all scientists and engineers and accounts for one-third of global R&D spending. As the global marketplace changes, it is hoped that the ACI will help the U.S. maintain a leadership role.¹

¹ www.whitehouse.gov/news/releases/2006/01/20060131-5.html

The centerpiece of the ACI is the intention to double over 10 years the sum of the budgets of the National Science Foundation, the Department of Energy's Office of Science, and NIST core programs, the key Federal agencies that support basic research programs in the physical sciences and engineering. This increase represents \$50 billion in new funding, of which NIST may receive several hundred million. The ACI is a tremendous opportunity to move NIST's mission forward, and EEEL will actively engage in NIST-wide initiative development to identify compelling new opportunities to impact U.S. innovation and economic competitiveness.

Goal: *Position EEEL to support the objectives of the President's American Competitiveness Initiative.*

Administration Guidance on Federal R&D Priorities

The Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) provide guidance on selecting and conducting federal R&D programs in their "FY 2008 Administration Research and Development Budget Priorities" memorandum of June 23, 2006.² The document provides both general guidance and Administration priorities in selected R&D areas, and it is recommended reading for all staff. The memorandum highlights the ACI and also instructs agencies to "advance fundamental scientific discovery to improve future quality of life" and to "support high leverage basic research to spur technological innovation, economic competitiveness and new job growth"; these goals closely match the NIST mission statement.

It is important to recognize that this OSTP/OMB memorandum is directed to all of the Nation's federally funded R&D enterprises and that each agency is to support Administration R&D priorities *within the scope of its mission*. For example, the memorandum instructs agencies to "enable potentially high payoff activities that require a Federal presence to attain long-term national goals, including national security, energy security, and the next generation air transport system." There may be pressing national needs that EEEL is most qualified to meet, and while these situations are usually unique, we should always be prepared to meet such needs.

The memorandum also instructs Federal agencies to "enhance the health of our Nation's people to reduce the burden of illness and increase productivity." There are several Federal agencies involved in healthcare-related research, and thus we should look for unique NIST and EEEL opportunities to contribute, particularly in areas in which our expertise is requested by the National Institutes of Health (NIH) and other key agencies. Administration guidance relevant to NIST and EEEL in the area of nanotechnology is that high priority should be given to research on "instrumentation and methods for nanoscale characterization and metrology," and to the dissemination of new technical capabilities to "help industry advance nanofabrication and nanomanufacturing," and research on "human health and environmental issues related to nanotechnology." In all of these programmatic areas, there is a need for inter-agency coordination and cooperation and we should look for appropriate interactions with key driving agencies outside of NIST.

² <http://www.whitehouse.gov/omb/memoranda/fy2006/m06-17.pdf>

Goal: Contribute to national priorities as reflected in the OSTP/OMB "FY 2008 Administration Research and Development Budget Priorities" memorandum of June 23, 2006.

Strategic Trends Facing the World Economy

Thomas Friedman in his book, The World is Flat, has argued that barriers to global production have decreased due to the confluence of new technological advances such as high bandwidth communications, pervasive computing, the Internet, and other factors. The result is that businesses can make use of worldwide talent and supply chains to maximize their profits. For the consumer it generally means reduced prices. For workers it means that they may be competing with others around the world, and thus need to be continually improving their skills.

This "flattening" of the world economy is having major impact on U.S. businesses. Friedman provides many examples of how those who take advantage of this flattening benefit at the expense of those who do not.

Strategically our organization needs to consider the impact of this "flattening" in at least four different ways. First, we need to be cognizant of this trend, which is impacting many of our significant customers. We need to recognize the global considerations that influence our customers' business models and look to see how we can support them. Second, we need to understand that these companies are "supply chain" conscious. In delivering our services, such as our calibrations and other tests, we need to see ourselves as a member of their supply chain and be aware of the impact our services (and the time to deliver those services) may have on them and their other partners. We also need to support the documentary standards that our customers require to facilitate their globally distributed operations. Third, we need to ensure that our usage of information technology is world class as it is essential that we develop systems that allow us to interact and collaborate with the best systems in use by industry. And fourth, we need to recognize that this provides us an opportunity, perhaps even a mandate, that we take advantage of this "flattening" in enabling worldwide collaborations if we are to continue to fulfill our mission.

Goal: Adapt the way EEEL does business, and the business EEEL does, to help our customers be competitive in the "flat world."

Goal: Expand domestic and international collaborations in support of the EEEL mission.

Goal: Bring EEEL into the 21st century in developing information technology solutions for internal and external collaborations.

Strategic Trends in World Metrology

Declining Resources for NMIs Worldwide

Most of the world's NMIs are under some financial stress at least regarding their programs on basic measurements and standards. Whether it is declining budgets overall or pressure to move their resources into other areas such as information technology or biotechnology,

the resources available for electromagnetic metrology at the world's NMIs are most often flat or in decline. Additional complications include the privatization of some NMIs, which deters these NMIs from engaging in “not-for-profit” metrology. While this places a further premium on worldwide collaborative research to maximize resources, it also suggests that some of our potential collaborators may not be reliable partners.

NIST Engagement in Worldwide Metrology

NIST is one of the thirty-four members of the Sistema Interamericano de Metrologia (SIM), the Regional Metrology Organization (RMO) of the Americas. Most of the countries of SIM have developing economies and do not have the most sophisticated measurement capabilities, which the U.S. enjoys. The goal of SIM is to promote and support an integrated measurement infrastructure in the Americas that ensures equity in the market place, improves the quality of life, and facilitates international trade. SIM activities include metrology training, and technical and quality system review of the members’ measurement capabilities. NIST participation in SIM is required if SIM is to be successful in achieving its goal. Additionally, SIM provides us with an opportunity to expose the developing economies to U.S. measurement instrumentation. An international strategy is essential for NIST and EEEL. At this point Europe has more influence in some of the region than does the U.S.

Another area of the world that deserves our attention and active engagement is China. Not only is China’s economy growing dramatically but China is also graduating a significant and increasing number of engineers and scientists, totaling more than the SIM countries put together (using a broad definition of scientists and engineers). China not only represents an important future market but is also a resource for science and engineering excellence in the future. We need to begin to determine how we can best work with the National Institute of Metrology (NIM), the NMI in China.

Goal: Support U.S. industry through effective outreach to and support of the member countries of the Sistema Interamericano de Metrología.

Goal: Expand our outreach to China.

Strategic Changes at NIST

Establishing Mandates

“Establish an objective process to ensure highest priority programs in EEEL are fully funded. This needs to consider national priorities/needs and the unique contribution of NIST.”

William Jeffrey, NIST Director, November 2005

The above directive requires that EEEL:

Align the Laboratory program with national priorities and needs;
Define a process to select our highest priority programs, “the mandates”;
Select and manage these EEEL “mandates”; and
Resource for success these “mandates” by ensuring adequate staff, facilities, and funds are allocated.

EEEL refers to our highest priority programs as “mandates” because they represent critical tasks which the Divisions are required to perform and report on with greater regularity. This subset of our work helps to define us as an organization, and is essential if we are to remain the world-leading NMI laboratory in electromagnetic metrology. Mandates are also selected to help EEEL maintain a portfolio that balances measurement services and measurement science, fundamental and applied research, and short term needs with long range goals, and encompasses both physical artifacts and documentary standards. Mandated tasks are not necessarily the best performing or highest rated or funded efforts within the Laboratory, nor is the list of mandates static from year to year.

Because mandates require a commitment to maintain both internal and external resources to achieve success, they represent a limitation on the Division’s and the Laboratory’s flexibility. Resources must be reassigned if needed to ensure that a mandated task achieves its goals. It is expected that mandates will always represent a discrete subset of EEEL’s portfolio, which can be categorized as follows:

- Mandates
 - “Must do” tasks to stay relevant as an NMI
 - Small subset of EEEL portfolio
 - May be short term or long term
- Solid Middle
 - Represents the majority of EEEL work
 - Established projects, expected to continue for 3-10 years
- Exploratory / early stage / late stage
 - Transition anticipated within the next 3 years
 - Includes both high risk and maturing efforts

Tasks supporting many of our measurement services are also identified as mandates, but these are identified and managed at the Division level for maximum impact.

The following projects (in no specific order) contain tasks, which are considered **mandates** for 2007:

- Electronic kilogram
- Closing of metrology triangle (via single electron tunneling)
- NanoElectronic Test Structures & Methodologies
- Bioelectronics: Single Cell & Molecule Manipulation and Measurement
- Device reliability and metrology
- Single (or integer) photonics
- High-speed measurements
- Quantum voltage (AC & DC)
- Quantum sensors
- On-wafer microwave measurements
- Electromagnetic field measurements and compatibility
- High frequency magnetometry
- Carefully selected portfolio of measurement services managed for success

Goal: Invest in the current and future excellence of EEEL by identifying and appropriately resourcing the Laboratory’s highest priority programs.

Measurement Services

Over the preceding year, NIST in developing its USMS report conducted an assessment of the health of the Nation’s measurement infrastructure, focusing on how well the current

system supports technological innovation. EEEL staff made significant contributions, helping to lead 10 of the 15 workshops held and providing 88 of the 337 gathered measurement need “case studies” – concise summaries of compelling unmet measurement needs. An additional 386 measurement needs were extracted from industry roadmaps.

In sum, the 723 measurement needs gathered are neither comprehensive nor prioritized, but they do represent measurement technology “past due.” This collection, along with traditional industry-focused fact finding, will provide us with the information required to make sure that EEEL measurement services are meeting the priority needs of our customers.

We not only must provide the critical measurement services required by our customers but we must provide them at a cost that they can afford and with a turn-around time that will not compromise their supply chains or other business considerations. We need to explore new ways to provide these services in a cost effective manner.

The NIST Senior Management Board has agreed to fund improvements in our NIST measurement services. Without healthy measurement services, our customers will not fully benefit from the output of our metrology research. This funding will strengthen NIST measurement services in areas consistent with the USMS assessment and other assessments. This new measurement services funding will be an important mechanism to maintain the health of EEEL measurement services.

Goal: Provide the critical measurement services required by our customers in a cost effective manner, and with an improved turn-around time that doesn't compromise quality.

Nanotechnology

It is difficult to talk about innovation without mentioning nanotechnology and the potential it has for broad impact in areas as disparate as electronics to stain-resistant clothing. For NIST and EEEL nanotechnology represents one of our next measurement frontiers and it is essential that we provide the measurement capabilities this area requires to maximize U.S. innovation. With nearly every university, national laboratory, and scientific research organization actively carrying out research in nanotechnology, including the NIST Center for Nanoscale Science and Technology, it is essential that we strategically partner with others while focusing on our mission to provide the electromagnetic measurements and standards that others cannot.

Goal: Articulate a coordinated plan for EEEL's nanotechnology efforts to support industry and advance core nanoscale electromagnetic metrology.

Center for Nanoscale Science and Technology (CNST)

The NIST Center for Nanoscale Science and Technology, when approved, will advance nanotechnology science and industry by providing essential measurement methods, instrumentation, and standards to support all phases of nanotechnology development,

from discovery to production. Located in the new NIST Advanced Measurement Laboratory and including the nanofabrication facility in Gaithersburg, the CNST will likely grow in budget to a comparable size to that of one of the other NIST laboratories. While most of NIST's nanotechnology efforts will be outside of the CNST within the Laboratories, the Center will provide the largest focused nanotechnology program at NIST.

The CNST is a "must succeed" priority for NIST. EEEL staff members are encouraged to support and collaborate with this new Center.

Goal: Support the CNST to ensure its success.

Semiconductor Industry Support

The EEEL Office of Microelectronics Programs (OMP) funds and influences NIST-wide support of the semiconductor industry. To help the Laboratories anticipate the investments, which OMP will make, based on its assessment of industry trends and needs, OMP has published their first Strategic Forecast, which has been shared with the other NIST Laboratories and can be found at <http://www.eeel.nist.gov>. The following are some of the trends highlighted in this report:

- The enormous investments necessary in order to manufacture leading edge semiconductor products has intensified the drive within the industry to form joint ventures. The OMP encourages NIST staff members to increase their involvement with consortia and collaborative clusters, and specifically to maintain and strengthen their collaborations with independent device manufacturers, equipment and materials suppliers, International SEMATECH and the Semiconductor Research Corporation.
- With traditional scaling becoming increasingly problematic, the focus of OMP investment will shift to longer-term issues associated with "Ultimate CMOS" and "Beyond CMOS." These projects will be closely coordinated with the CNST.
- EEEL and OMP have made a strategic investment in the CNST Nanofabrication Facility in the Advanced Measurement Laboratory in Gaithersburg, supporting the purchase of advanced processing and metrology equipment expected to be important to nearly the entire suite of OMP supported projects.

Goal: Help the semiconductor manufacturing industry achieve their technically ambitious goals through developing measurement innovations.

Goal: Facilitate productive interactions between NIST and the semiconductor industry.

Bioscience

While EEEL has contributed to remarkable improvements in metrology for the physical sciences, our mission includes applying measurement science and standards to improve the quality of life. Where the most challenging electromagnetic measurements are required, EEEL needs to be involved. We have a history of opportunistically applying our

existing electromagnetic metrology capabilities to bioscience measurement problems, particularly when we have been asked by key other agencies such as the National Institutes of Health (NIH), for example in electromagnetic radiation exposure protocols. In recent years, we have increasingly addressed bioscience measurement needs through a variety of new strategic thrusts, including bioelectronics and biomedical imaging. In bioelectronics, for example, we have a vision to develop the fundamental metrology of bioelectronic and nanobioelectronic interfaces to processes at the cellular or molecular scale that will enable and support the manufacturers of new test equipment that is used for medical and pharmaceutical research. In response to the strong need for sophisticated diagnostic and treatment methodologies, we have started efforts in important biomedical imaging fields, including magnetic resonance imaging (MRI) and optical coherence tomography (OCT). The healthcare and biomedical communities, including NIH, have welcomed our engagement with these measurement problems, for which we have unique capabilities to address. As we continue to increase our metrology support of bioscience, we need to work closely with the biomedical and healthcare communities to address their most critical electromagnetic measurement barriers to success.

Goal: Work with the biomedical community to address electromagnetic measurement barriers to success in healthcare.

Homeland Security

NIST and EEEL are making an essential contribution to homeland security through providing world class measurements and standards expertise, including improving communications among first responders, measuring biological and nuclear proliferation threats with the best possible sensitivity and accuracy, and characterizing the performance of e-passports to support their implementation by other government agencies. Due to the potentially urgent nature of homeland security needs, EEEL must be prepared to make such efforts the Laboratory's highest priorities should the Nation's security needs demand it.

Located organizationally within EEEL, our Office of Law Enforcement Standards (OLES) provides leadership to NIST in homeland security and is an excellent conduit for NIST to become aware of critical national homeland security measurement needs. OLES staff members manage a significant portfolio of internal and other agency-funded projects and actively participate in inter-agency coordination of homeland security activities, including through detailing of staff to the Department of Homeland Security. These activities and leadership provide an effective mechanism to help NIST coordinate its homeland security efforts and obtain additional other agency funding support.

As part of EEEL's strategic planning process, OLES has provided a Strategic Forecast to identify future needs of first responders and the broader homeland security community, which can be found at <http://www.eeel.nist.gov> and has been shared with all of NIST's Laboratories. Some of the strategic changes that are identified include:

- Significant reorganization and restructuring of the Science and Technology Directorate at the Department of Homeland Security (DHS) to support other DHS operational units, which may provide additional opportunities for NIST to manage and contribute to DHS-funded projects;

- Blurring of boundaries between needs of emergency response communities, such that all first responders are now concerned with ballistic and chemical/biological protection; and
- Increasing importance to first responders and the broader homeland security community of integration and interoperability issues for communications, equipment and other areas.

Goal: Lead NIST in addressing critical national needs in homeland security, and deliver needed electromagnetic measurement solutions.

Joint Research Institutes

NIST has established several strategic partnerships with universities and governmental agencies to further leverage resources in pursuit of common research goals. The success of such partnerships brings added recognition to NIST, as in the case of JILA, a research partnership with the University of Colorado whose faculty includes three Nobel laureates and two John D. and Catherine T. MacArthur Fellows. The most recently established partnership, the Joint Quantum Initiative, is a collaboration between NIST, University of Maryland and the National Security Agency focusing on the understanding of coherent quantum phenomena. Other prominent partnerships include the Center for Advanced Research in Biotechnology and the Hollings Marine Laboratory. EEEL has not been engaged in establishing or participating in joint research institutes, such as those listed above. There may be future opportunities for EEEL and its staff to benefit from formal research partnerships.

Goal: Explore opportunities for and potential benefits of strategic research partnerships.

Internal Laboratory Environment (Strengths and Weaknesses)

Strengths

Our Staff

EEEL staff is world-class. Our best achievements are the result of the expertise and dedication that they bring to NIST. Our staff is well recognized, both within the government and by our external colleagues. For example, in 2006, our gallium nitride nanowire work was selected by the editors of R&D Magazine and MICRO/NANO Newsletter as an inaugural winner of their MICRO/NANO 25 competition, and EEEL has been honored to have three of the Institute's Presidential Early Career Award for Scientists and Engineers recipients since 2000. Our work is published in both respected journals and the popular press, and contributes to industrial innovation and advances in basic science and metrology. To further support our staff's commitment to solve the most important electromagnetic measurement problems facing the world metrology community today, we encourage broad public dissemination of our technological advances and scientific impact.

Goal: Support EEEL staff in achieving the world's highest possible recognition.

"Bottom Up" Technical Innovation

Our best technical ideas nearly always come from scientists and engineers working at the bench, and EEEL has a long history of staff taking initiative to identify and advance new areas of research and measurement support. Our best projects have clearly identified customers, a defined technical plan, adequate resources, and a clear opportunity to contribute to significant problems. These grass roots efforts are often high risk and not all are expected to succeed. We need to support and sustain a collaborative bottom-up culture of technical excellence and innovation, in which we dare to be great.

Goal: Nurture the "bottom-up" EEEL culture of innovation and collaboration.

We Plan for Success

The publication of this document represents the completion of the first full implementation of the new EEEL strategic planning cycle. This process was put in place to help position EEEL for success, to provide our staff an opportunity to influence the direction of the Laboratory, and to give our staff clear information in order that they might proactively align their careers with Laboratory goals.

The following steps comprise the strategic planning process:

- | | | |
|-----------------|--|---|
| October 1 | Publication of the EEEL Strategic Plan | The EEEL Strategic Plan provides directives and goals set by the Administration, NIST Director and the EEEL Director. It also highlights trends within industry or the global metrology community that may impact how EEEL does business. |
| October – April | Divisions Develop Strategic Plans | The development of Division-level plans, consistent with the EEEL Strategic Plan, should provide all staff an opportunity not just to review and critique, but to provide input into the technical direction and local goals of their organization. |
| May | EEEL Program Review | The Program Review provides an opportunity for the EEEL management team to review every project, and to look for opportunities for greater impact or synergy across the Laboratory. This is also the time frame in which EEEL mandates are reviewed for possible changes, and Division Strategic Plans are discussed. |
| August | Progress Report on Mandates and "At Risk" Projects | |

The Division Chiefs must report to the Laboratory Director on their mandated tasks, and any projects that may have been identified as “at risk.”

September Offices Provide Trends and Forecasts

The Office of Law Enforcement Standards and the Office of Microelectronics Programs provide a report on Trends and Forecasts for their sectors. These reports will be shared across NIST to facilitate strategic planning within other Laboratories.

Goal: Develop and communicate Laboratory goals and priorities with all staff, to enable them to maximize their contributions and to proactively manage their own career directions.

Boulder and Gaithersburg

EEEL has a major presence on both of the primary NIST campuses in Gaithersburg, Maryland and in Boulder, Colorado. One of our great strengths is that both locations and communities are nationally recognized and desirable (in their own ways) to help attract and retain excellent staff in EEEL. The scenic Boulder area is enriched by beautiful mountain views and offers exceptional outdoor recreation and athletic opportunities and a strong intellectual and scientific environment with the University of Colorado, NOAA and a multitude of start-ups and established high-tech businesses. Gaithersburg also enjoys a beautiful campus (with resident wildlife) and provides ready access to Washington, D.C.'s world-class museums and arts, and is also located within an intellectual and scientific environment with strong collaborative interactions with multiple universities and significant high-tech companies, particularly in the biosciences, defense, security, and with other government agencies.

Within these different technical and cultural environments, strong multi-disciplinary collaborations are often formed both within EEEL, and with other NIST Laboratories and outside collaborators. These collaborations also span the two campuses.

Preeminent Contributor to Advancing the SI

The International System of Units, universally abbreviated SI (from the French *Le Système International d'Unités*), is the bedrock upon which the world's measurement system rests. It is essential that the SI definitions of the fundamental and derived units keep up with advances in measurement capabilities and needs. The trend in recent years is to define the SI in terms of fundamental constants such as the speed of light used in the definition of the meter. An important exception is the kilogram, the last remaining artifact-defined base unit.

To realize our vision of being the world's leading electromagnetic measurements and standards laboratory, EEEL has responsibility to support the SI. This means that, if we have the capability to improve the SI, we should invest some of our resources for this purpose. But EEEL cannot do it alone. To be effective, we need to collaborate strategically with other NMIs that are in a position to provide similar but complementary investments.

- Goal: Pursue international closure on the issue of redefining the kilogram*
- Goal: Provide the world with needed research and measurement precision to redefine the SI units in terms of fundamental constants of nature.*
- Goal: Collaborate with other NMIs to support the SI*

World's Best Measurement Services

EEEL offers the world's most comprehensive suite of electromagnetic measurement services. This is still true despite dropping some services in recent years for budgetary purposes. While we must continue to provide traceability where needed, we must be strategic in selecting the services we offer in accord with the USMS findings and other input from our customers. We must continue to participate in key comparisons sponsored by the consultative committees of the *Comité International des Poids et Mesures* (CIPM) and regional SIM key comparisons to ensure that EEEL measurement services are recognized worldwide.

- Goal: Provide customers with "measurement solutions" for their highest priority measurement needs.*
- Goal: Strategically participate in key comparisons to ensure international acceptance of EEEL measurement services*

Weaknesses

Aging Facilities

While NIST has been able to construct new facilities, such as the Advanced Measurement Laboratory (AML) in Gaithersburg and the new Central Utility Plant (CUP) in Boulder, many parts of the NIST physical infrastructure including facilities continue to age. As the demand for premium lab space in the AML and in Boulder continues to increase beyond our supply, in addition to advocating for new facilities to meet critical needs, we must be prepared and have effective plans to renovate existing laboratory space. However, this process is slow, requires substantial financial investment, and has the potential to significantly impact and delay ongoing research. EEEL is particularly affected as we have needs on both campuses: for example, our two micro/nanofabrication facilities in Boulder require substantial upgrades, and our radio-frequency metrology laboratories in Boulder require substantial improvement and have unique requirements, including large volume facilities. Roof and heating-pipe leaks have caused extensive damage in Boulder. In Gaithersburg, the Metrology Building has experienced significant problems including flooding caused by leaks in the cooling system, and is high on the list of Gaithersburg buildings slated for future renovation.

Boulder and Gaithersburg Communications

Effective communication is a particular challenge in EEEL since our research staff is geographically split almost evenly between our Gaithersburg and Boulder campuses. Within EEEL we have paid special attention to improving communications between the

campuses, including the use of video teleconferencing, frequent management visits, cross-campus teams such as the EEEL Diversity Team, and inclusion of Boulder staff in NIST-level planning groups. Although we always look for ways to increase the visibility of our Boulder research efforts, our Boulder researchers do not get the same level of attention and "face time" with senior NIST leadership in Gaithersburg, which has an effect on our ability to advocate for programs and influence NIST-level funding decisions, personal recognition through awards, and promotions. For example, it is difficult to find Boulder staff willing and able to accept temporary developmental assignments in Gaithersburg, such as in the Program Office in which they have the opportunity to interact with and become known to senior NIST leadership. Other tangible effects include missed opportunities to collaborate between the two campuses and unequal representation and influence in interagency coordination efforts, which are often centered in the Washington, D.C. area.

Goal: Improve NIST-wide recognition of EEEL Boulder projects and personnel, and enhance cross-division and cross-campus communication and collaboration including short- and long-term visits

Succession Planning and Diversity

As EEEL has filled various vacancies over the past few years, it has become clear that we are not as deep in management talent as we would like to be. Portions of EEEL have been able to successfully develop, train and even export future managers, but we recognize that we are now relatively thin across all of the EEEL Divisions and Offices. Therefore we need to continue to expand our efforts to identify developmental assignments to train the next generation of leaders in EEEL. In addition, we need to look outside of NIST for exceptional candidates and develop relationships with them, typically over many years in advance of potential openings.

We are also not as deep in our technical staffing as we have been in the past. In recent years EEEL has often not "replaced" retiring technical staff, leaving us spread quite thin in some important areas.

As we move forward, it is more important than ever to develop and use all of the talents and capabilities of our staff. The world outside NIST is changing to take advantage of the increased diversity of people and talents, and we need to change with it. With the American Competitive Initiative potentially doubling NIST's budget, we may have the opportunity to grow. As we work to bring in new post-docs and NIST associates and potentially hire new staff, we need to find ways to increase the diversity of our staff and our capabilities and continue to make EEEL a desirable place to work for everyone.

In addition to our permanent staff, we recognize that our nonpermanent staff is playing an increasingly important role in our success. In recognition of this shift, EEEL has instituted a "Distinguished Associate" award to recognize excellence in contributions of our NIST associates. We need to continue to proactively find new ways to ensure that all our staff are recognized and valued for the vital contributions they make.

Goal: Nurture and train the next generation of EEEL leaders and support diversity of people and talents.

Goal: Add technical staff in key areas

The Plan

A previous section of this document discussed the strategic influences external to EEEL. This section focuses on what those and other influences mean for EEEL. The intent here is to stay strategic. The information here is meant to “nudge” us in a certain direction but not to describe the pathway for getting there.

World Class

EEEL will either be world class in everything we do or will be striving to be world class in short order. If others have superior capability, we should consider stepping aside as it is not our fundamental purpose to compete. For those capabilities we are committed to maintain, we need to invest the resources to achieve technical excellence. We should position EEEL for highest level world-class recognition (e.g., a Nobel Prize) in the next decade or so. This means we need to focus, hire the best, and resource these areas for success.

Innovation and Excellence

EEEL needs to increase its exposure to high-risk, high-payoff technical areas that will drive future innovations. To do this, we must ensure that staff on such projects fully understand that failure is often a part of success, and are therefore willing to think beyond low-risk, incremental advances, and take on audacious technical goals that fire the imagination and creative ability of the staff.

American Competitiveness Initiative

EEEL provides the electromagnetic measurements and standards to support innovation in the U.S. Advances in electronics, nanoelectronics, optoelectronics, communications, and many other fields could not be achieved without the precise and often traceable measurements provided by EEEL. We must support NIST in making a strong case for the the American Competitiveness Initiative and its investment in the measurements and standards to support US industry.

Setting Priorities

The EEEL mandates represent the Laboratory’s commitment to achieve full success of those tasks identified. We must choose these tasks wisely, and constantly re-evaluate our choices. They must represent a balanced view of our Laboratory so that we continually develop the capabilities we require to maintain our technical excellence and relevance in the future.

Internal Competitive Funding Mechanisms

All federal R&D agencies are called upon to rigorously evaluate their existing programs and justify new programs, and to “maximize the efficiency and effectiveness of the science and technology enterprise through expansion of competitive, merit-based peer review processes and phase-out of programs that are only marginally productive or are not important to an agency’s mission.” This directive encourages the increased use of competitive processes to maximize our impact. EEEL has already implemented many such processes, including the competitive EEEL Director’s Reserve funding process and a proposal-based process for base funding distribution in some of our Divisions and Offices. However, there is a balance between maximizing impact and maintaining cost-effectiveness, since the proposal and review process can take significant time and resources. We need to evaluate the benefits and drawbacks of our various funding distribution mechanisms to share best practices across the Laboratory. We will also conduct a comprehensive review of the EEEL Director’s Reserve program, which was built into the program when it was implemented.

Core versus Applied

EEEL needs to maintain a balance between conducting the measurement science needed to advance our core capabilities, and developing and delivering services to address the immediate measurement needs of our customers. We need to have a strong science and research foundation to position ourselves to provide the specific measurement tools required by the semiconductor, optoelectronics, and other industries. Without the foundation, we cannot maintain our world class capability. Without the “applied” we are of little use to our customers and we become irrelevant.

The SI

EEEL as one of the preeminent laboratories in the field of electromagnetic measurements and standards has a responsibility among the NMIs to support the SI. While that may seem obvious, recent events suggest that some formerly world class NMIs are discarding that responsibility. EEEL will not.

The electronic kilogram is the prime example of a EEEL project that may dramatically improve the SI by eliminating the last artifact-based standard. While our present measurement capability is probably good enough for a redefinition of the kilogram at this time, it likely will not happen until our results are replicated elsewhere. This is an important lesson. While it may be good to finish “first,” we must make sure that others also finish the race and we may need to help them get there. The “victory” is hollow if the rest of the world will not follow. We must and will collaborate with other prominent NMIs as necessary for our results to have impact.

Other potential SI related areas that EEEL should consider are the potential for Johnson noise thermometry to impact a redefinition of the Kelvin, and our SET related efforts in collaboration with PTB to further close the metrology triangle. Other possibilities might include a countable photon or electron (radiant intensity or current) standard.

Support for the SI can be costly, more than EEEL or NIST can bear alone. We must instead foster strategic collaborative relationships with other NMIs to leverage our work. EEEL has assumed the responsibility to lead a worldwide strategic planning effort in electromagnetic metrology. This planning process will identify the world’s major metrology challenges and identify collaborators, including EEEL, who are willing to work together to address them.

International Outreach

International outreach is important to the success of the Laboratory and the benefits are far reaching whether to open markets for U.S. instrument manufacturers or to build long term relationships with future metrologists around the world. The importance of international outreach is also recognized by the Administration in the directive to “encourage interdisciplinary research efforts and foster advancement, collaboration and innovation on complex scientific frontiers and strengthen international partnerships that accelerate the progress of science across borders.”

Our primary focus will be on the Sistema Interamericano de Metrología (SIM) Regional Metrology Organization (RMO), which comprises 34 Western Hemisphere countries. Many of the countries in SIM have developing economies. EEEL has a responsibility to support the NMIs in these countries wherever possible. We will also focus on outreach to China. By providing them needed support at this time, we may provide the basis for future collaborations as NIM (their NMI) becomes world class. This type of support is not altogether altruistic. Other countries have used outreach to develop markets for their country’s instrument manufacturers. We have the same opportunity to support U.S. industry.

Improved Information Exchange

In order to be a player in the “flat world” EEEL needs to bring its IT capabilities into the 21st century. We need to develop or acquire IT solutions to allow staff to work smarter within the Laboratory and collaborate more effectively with our domestic and international partners. We may need to work with the NIST Chief Information Officer in this pursuit. We also need to help our customers operate in the “flat world” by contributing to standards that facilitate electronic information exchange among geographically dispersed business partners.

Documentary standards

Documentary standards have become increasingly important in the flattening world, and are often on the front lines of enabling U.S. firms to enter global markets. EEEL must be engaged in the development and adoption of documentary standards consistent with our technical expertise and industry priorities, and Divisions must develop strategies regarding their participation in documentary standards activities.

Measurement Services

Measurement services are important to EEEL and our customers. We must and will continue to provide high quality, traceable services, and we should strive to be a good supply chain partner. We must make sure we are meeting the prioritized needs identified in the USMS assessment or by other means, and we must attempt to do this with minimal cost (time and dollars) to our customers. We must explore new internal funding sources to improve our measurement services and the delivery of those services.

Nanotechnology

By the nature of our work to support industries, such as the semiconductor industry, that have long relied on nanotechnology, and through our own micro- and nanofabrication capabilities, EEEL has an extensive nanotechnology portfolio representing a significant fraction of nanotechnology efforts at NIST. We have primarily focused on the areas of nano devices and systems and fundamental nanoscale properties, with additional efforts in nanomaterials and more generally nanometrology and standards. In the area of nano devices, we are continuing to develop and apply nanotechnology advances to support our

own core electromagnetic metrology mission, for example the development of nano-stacked junctions to advance our quantum voltage standards. We also fabricate and characterize nano devices and metrology test structures to support industry, for example in the area of “beyond CMOS” including molecular electronics and spintronics and additional nanomagnetism efforts. As nanotechnology has emerged as a growing field in its own right, we have been increasing our efforts to provide the needed nanoscale electromagnetic metrology to support broad advances. Important parts of this long-term metrology development are nanophotonics measurements and nanoscale high-frequency electromagnetic metrology that is needed to support higher speed chips and devices. A growing area of need is for research to help address concerns about the environmental, health, and safety risks of nanomaterials, and we are responding with optical/electromagnetic nanotube characterization techniques to support the NIST nanotube Reference Material effort.

Nanotechnology is pervasive throughout most of EEEL. That is also true for some other NIST Laboratories and the new Center for Nanoscale Science and Technology. EEEL must be able to clearly articulate our nanotechnology program to interact more effectively within NIST. With the CNST’s broad mission to help “*solve industry’s nanomeasurement problems,*” and with their intention to work in areas such as post-CMOS technologies and nanomagnetism, we must work collaboratively and collegially to minimize duplicative efforts and leverage each other’s resources. We must also continue to collaborate with others with complementary capabilities to build world class nanotechnology capability at NIST.

Bioscience

EEEL has an essential role to support the biosciences with key enabling electromagnetic metrology. While we have begun to address selected high-impact measurement needs, such as in biomedical imaging, we have not fully explored as a Laboratory what it will mean to address the electromagnetic metrology needs of the broad biomedical and healthcare industry as one of the industries we support. EEEL must develop and articulate a vision for its bioscience and health program that will guide us as we work to develop future larger-scope programs to address critical bioscience measurement needs

Homeland Security

In those areas in which EEEL has critical measurement capability, which will impact our homeland security and meet a pressing national need, we must make those efforts a Laboratory wide priority. For example, our critical work to support other government agencies (including the State Department, Government Printing Office and the Department of Homeland Security) with reliable characterization of e-passports falls into this category. In general, EEEL homeland security efforts are well aligned with Administration priorities to increase emphasis on quick and cost-effective sampling and biological/chemical methodologies and novel detection systems (e.g., EEEL nanopore effort for anthrax detection), novel countermeasures against agricultural threats (e.g., EEEL nanowire development of UV sources for water purification applications), transformational capabilities for standoff detection of special nuclear material and conventional explosives (e.g., EEEL gamma ray detector development and THz efforts). In considering where our efforts may have maximum impact to benefit homeland security, EEEL staff members should coordinate with other key agencies, in particular DHS, and to take advantage of OLES connections to the homeland security community where appropriate.

Staffing

We must be strategic in our hiring decisions with the goal of placing EEEL in a strong position for the future. Decisions made years ago have provided EEEL with the

outstanding talent and capabilities it has today. As we venture into new areas we must make increased use of NIST associates. If we are not able to develop world class programs in these new areas, we must have flexibility in our staffing to allow changes in direction. However, when possible and strategic, we should convert exceptional staff to full time status.

Communications

We must continue to develop more open communications within EEEL. Our strategic planning activities must be open to ideas from all of our staff and the resulting plans must be shared with the staff.

Collaboration

Excellent collaborations do occur within EEEL but we must optimally organize and expand these efforts as appropriate. One example that merits collective management attention is our Terahertz efforts, which includes projects in three Divisions and one of our Offices and could benefit from effective organization into a more cohesive program. For EEEL to flourish, a culture that nurtures and rewards teamwork and collaboration must be developed. We are staffed too thinly to tolerate any lapses in technical cooperation, collaboration or coordination among our staff.

Call for Input

The publication of this Strategic Plan represents the culmination of the first full year's implementation of our annual Laboratory-wide planning process. The goals put forth in this Plan not only challenge us to further successes, but are a launching point for continued improvement and dialog within our Laboratory. The strength of EEEL strategic planning is directly proportional to the level of engagement of our staff and our customers and stakeholders. Your feedback on this document, or any aspect of the planning cycle, is always welcome. Feel free to provide feedback to any of our Division Chiefs and Office Directors or to any of the staff in the EEEL Headquarters Office.