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# EEEL Strategic Plan

## FY08

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October 1, 2007

## Forward

Planning plays an important role in the Electronics and Electrical Engineering Laboratory (EEEL). Through the development of annual Division-level strategic plans, all staff have the opportunity to help set the technical direction of the Lab. Through the publication of yearly forecasts, staff can gain insight into the current and anticipated metrology needs of the semiconductor industry and law enforcement and security communities. And through this Lab-level strategic plan, I am able to communicate my priorities as the Director, and to share the priorities of NIST and the Department of Commerce.

I hope that all EEEL staff will take advantage of the planning process to engage with their peers and management in meaningful discussion about the direction of our research program, and I hope that staff will further use these plans to help align their projects and careers with the Lab's priorities. Additionally, I hope our plans provide our stakeholders and customers with an understanding of our goals and values, and motivate increased communication on how we can better serve the community.

I have attempted to keep this plan strategic and fought the temptation to add tactical or operational details. As a result, this document intentionally remains at a very high level, and thus has not changed dramatically from the version published in 2006.

I strongly encourage your feedback and suggestions.

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 a brief 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). 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, while attempting to leverage the ACI to address the metrology needs of EEEL's customers. 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 increase our investment in science. 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. We will work to disseminate and transfer EEEL developments. In support of all our goals, we will nurture a culture of innovation, scientific excellence, open communications, and collaboration.

Strategic plans by their nature often do not change from one year to the next. This is the case this year in that the changes are modest. One change that might be noticed is simply in format. The "Goals" in last year's plan have been integrated into the planning discussion at the end of this document, instead of being highlighted throughout. In general, the goals and intentions of this plan are very consistent with last year's plan with some changes in emphasis.

## Introduction

The Electronics and Electrical Engineering Laboratory of NIST is one of the world's pre-eminent organizations in the field of electromagnetic measurements. We provide measurement services, including traceability, directly to industries which fuel our Nation's economy, and develop world leading measurement science which supports innovations 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 is 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 have 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 measurement capabilities 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, listed 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 a 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. They continue to be:

- 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 mission.

## EEEL Mandates

EEEL refers to its 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 defines us as an organization, and is essential to EEEL remaining 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. EEEL is committed to supporting its mandates at all costs. A current list and further explanation of EEEL's mandates are given in Appendix A.

## EEEL Planning Cycle

The publication of this document represents the completion of the second full implementation of the EEEL strategic planning cycle. This process is 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 entire annual EEEL planning cycle is presented in Appendix B.

## 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 launched the *American Competitiveness Initiative (ACI)* in 2006. 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 in science and technology.<sup>1</sup>

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 proposed increase represents \$50 billion in new funding, of which NIST may receive several hundred million. The ACI has provided NIST a 17% increase in the first two years. The following table shows the ACI increase in the NIST budget in FY07, and that proposed for FY08.

Year	Scientific and Technical Research Services (STRS)	Construction of Research Facilities (CRF)
FY07	\$49.9	\$22.1
FY08 (requested) <sup>2</sup>	\$44.4	\$57.0

ACI Increases to NIST Budget (\$M)

The ACI is a tremendous opportunity to move the mission of NIST forward, and EEEL will actively engage in NIST-wide initiative development to identify compelling new opportunities to impact U.S. innovation and economic competitiveness.

<sup>1</sup> [www.whitehouse.gov/news/releases/2006/01/20060131-5.html](http://www.whitehouse.gov/news/releases/2006/01/20060131-5.html)

<sup>2</sup> The FY08 ACI request includes unfunded ACI initiatives from FY07

## Administration Guidance on Federal R&D Priorities

The Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) released revised guidance on selecting and conducting federal R&D programs in their “FY 2009 Administration Research and Development Budget Priorities” memorandum of August 14, 2007.<sup>3</sup> This year’s guidance again highlights the ACI and continues to instruct 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”; goals which closely match the NIST mission statement.

The memorandum encourages R&D in the following specific technical areas: homeland security and national defense, energy and climate change, advanced networking and information technology, the National Nanotechnology Initiative, understanding complex biological systems, and the environment. Much of the guidance in these areas remains unchanged from the 2006 memorandum. The guidance continues to prioritize research on “instrumentation and methods for nanoscale characterization and metrology”, and the dissemination of new technical capabilities to “help industry advance nanofabrication and nanomanufacturing.” The memorandum also states that energy R&D should “support progress in two interconnected areas: energy security and greenhouse gas emission reduction.”

Concerning security, this year’s guidance places new emphasis on nuclear threats, including enhanced detection of radioactive materials and mitigating the impact of an attack. It emphasizes the advancement of verifiable biometric identification tools, and encourages the study of emergency preparedness and response.

The memorandum includes slightly greater emphasis on R&D for the environment, linking energy research with global climate change, and making new specific recommendations for the study of ocean-based indicators of rapid climate change. This year’s guidance also calls greater attention to interagency collaboration in support of a next generation air transportation system, and to understanding the “science of science”, which refers to the globalization of science and technology, and improving science-based policy decisions.

## Strategic Trends Facing the World Economy

Thomas Friedman<sup>4</sup> and others have 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 significantly impacting many of our customers. We need to recognize the global considerations that influence our customers’ business models and look to see how we can support them.

<sup>3</sup><http://www.whitehouse.gov/omb/memoranda/fy2007/m07-22.pdf>

<sup>4</sup> *The World is Flat: A Brief History of the Twenty-First Century* by Thomas L. Friedman



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.

## 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.

One of the results of these pressures has been a unifying effect on the NMIs of Europe. The newly formed European Association of National Metrology Institutes (EURAMET), which replaces EUROMET as the European Regional Metrology Organization as of July 2007, not only carries out key comparisons and other activities to support mutual confidence in their region’s measurement capabilities, but has an additional function of procuring and directing funding for measurement research across Europe through its European Metrology Research Programme (EMRP).<sup>5</sup> With this directed, multinational research, EURAMET is likely to have a powerful impact on worldwide metrology. NIST must identify ways to most effectively interact and work with this extensive and evolving organization.

### NIST Engagement in Worldwide Metrology

An 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. China represents an important future market, and will be a resource for science and engineering excellence in the future. The Administration has made outreach to China a priority, as have many of our industrial customers. We need to continue to interact with the National Institute of Metrology (NIM), the NMI in China, in ways that are beneficial to both NIST and NIM.

NIST and EEEL also play an important role in the Sistema Interamericano de Metrologia (SIM), the Regional Metrology Organization of the Americas. 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

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<sup>5</sup> <http://www.euromet.org/euramet/euramet.html>

the members' measurement capabilities. Since most of the countries represented by SIM members have developing economies and thus lack resources for measurement science, NIST participation in SIM is essential to that organization's success. Additionally, SIM provides EEEL with an opportunity to expose developing economies to U.S. measurement instrumentation. A strategy for effective engagement with SIM is essential for NIST and EEEL. At this point Europe has more influence in some of the region than does the U.S.

## Strategic Trends at NIST

### ATP to TIP

In September 2007, Congress voted to eliminate NIST's Advanced Technology Program (ATP) and to establish the new Technology Innovation Program (TIP). TIP will competitively fund efforts to "*address critical national needs through transforming the Nation's capacity to deal with major societal challenges*". Similar to ATP, TIP will award grants to individual companies or joint ventures, but in contrast to ATP it will not fund large companies, does not require a commercialization plan, and allows for the funding of other federal labs. NIST is ineligible to compete for TIP funds, and the program will not provide intramural funding to the NIST laboratories. ATP will be formally reorganized to form a more efficient structure tailored to TIP needs, and TIP will likely establish rotating positions open to NIST and other agency staff.

### Facility Additions in Boulder

The plans to build new high tech laboratory facilities at NIST in Boulder are progressing in a very positive way. These plans represent an extraordinary opportunity for EEEL to advance many of our world leading research programs that are based in Boulder.

### OMP Expands Semiconductor Industry Support to Include Grants Program

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 publishes an annual Strategic Forecast, which is shared with the other NIST Laboratories and can be found at <http://www.eeel.nist.gov>.

With the FY07 budget, OMP's role was expanded to include providing funding to the Nanoelectronics Research Institute (NRI). This collaborative effort will increase NIST's interactions with many of the institutions leading the country's efforts to advance nanotechnology applications. Additionally, the potential for new FY08 funding of OMP to support "Beyond CMOS" research represents new opportunities for NIST to provide critical metrology support to the semiconductor industry.

## 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, EEEL staff have recently received the Flemming and APS Keithley awards, and NIST was nationally recognized for organizing the first Robocup “nanogram league” demonstration competition. Additionally, EEEL has been honored to have four 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.

#### “Bottom Up” Technical Innovation

Our best technical ideas 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 address 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.

In an effort to enhance cross-Division interactions and better leverage this “bottom up” innovation, EEEL recently instituted six Brainstorming Teams to critically evaluate potential roles for EEEL programs in the areas of measurement services, metamaterials, energy, nanoscale electromagnetic measurements, bioelectronics & healthcare, and beyond CMOS technologies. The output of these teams will help direct EEEL’s future plans in these technological areas.

#### 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 help attract and retain excellent staff in EEEL. The 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 and provides ready access to Washington, D.C.’s world-class museums and arts. It is also located within an intellectual and scientific environment with strong collaborative interactions with multiple universities, significant high-tech companies, and other government agencies, particularly in the areas of biosciences, defense, and security. Within and among these different technical and cultural environments, strong multi-disciplinary collaborations are often formed both within EEEL, and with other NIST Laboratories and outside collaborators.

## 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. There has been a trend in recent years 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.

EEEL is a world leader in the redefinition of the SI. Our staff have been in the forefront of redefining the kilogram, and were recognized with the Department of Commerce Gold Medal in 2006 for their "landmark measurement of Planck's constant leading the world toward a new definition of the international system of units."

## World's Best Measurement Services

EEEL offers the world's most comprehensive suite of electromagnetic measurement services. This is still true despite the need to selectively terminate some services in recent years for budgetary purposes. The advent of new funding for measurement science through the NIST Measurements Services Advisory Group is an excellent opportunity for advancing measurement services within EEEL.

## Leadership in 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.

## Excellence in Addressing Homeland Security Needs

EEEL is 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 the detailing of staff to the Department of Homeland Security.

As part of EEEL's strategic planning process, OLES provides 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 is shared with all of NIST's Laboratories.

## Weaknesses

### 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 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. 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.

### Succession Planning

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 leadership skills are now relatively thin across all of the EEEL Divisions and Offices. We are also not as deep in our technical staffing as we have been in the past. In recent years EEEL often has not replaced retiring technical personnel, leaving us sparsely staffed in some important areas. Nonpermanent staff are playing an increasingly important role in our success, and their departure from NIST can also leave strategic gaps in our technical programs.

## The Plan

The preceding section of this document discussed the strategic climate that is influencing 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 certain directions but not to describe the pathways for getting there.

### **Being World Class**

EEEL will either be world class in everything we do or strive to be world class in short order. If others have superior capability, we will consider stepping aside as it is not our fundamental purpose to compete. For those capabilities we are committed to maintain, we will invest the resources to achieve technical excellence.

### **Promoting Innovation and Excellence**

EEEL needs to increase its exposure to high-risk, high-payoff technical areas that will drive future innovations. We must be willing to take risks to achieve excellence. To do this, we must ensure that staff 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 their imagination and cultivate their creative ability.

### **Investing in Science**

EEEL needs to invest wisely in science. We need to recognize that major science successes attract and help us retain high quality staff, bring significant recognition to NIST, and place EEEL in a more solid position for the future. We will fund these areas for success and strive to obtain the highest level world-class recognition (e.g. a Nobel Prize) for EEEL.

### **Supporting the 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 will leverage the American Competitiveness Initiative to support the customers of EEEL programs.

### **Setting Priorities**

The EEEL mandates represent the Laboratory’s commitment to achieve full success of those defining tasks. We will choose these tasks wisely, and constantly re-evaluate our choices. For EEEL to continue to be successful, the input of our staff is essential. We will strive to support all staff in contributing to and influencing the technical plans of EEEL, and we will provide as many opportunities as possible to develop visionary ideas.

### **Balancing 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 “applied” we are of little use to our customers and we become irrelevant.

### **Advancing the SI**

As one of the preeminent laboratories in the field of electromagnetic measurements and standards, EEEL 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.

EEEL will continue to support the electronic kilogram project whose goal is to improve the SI by eliminating the last artifact-based standard. We also support other promising electrical research areas that potentially will influence the realization of the SI, such as Johnson noise thermometry to impact a redefinition of the Kelvin, and the manipulation of single physical units of nature (such as photons, electrons, and flux).

Support for the SI can be costly, perhaps more than EEEL or NIST can bear alone. We must foster strategic collaborative relationships with other NMIs to share the responsibility and cost of such efforts. EEEL has assumed the responsibility to lead a worldwide strategic planning effort in electromagnetic metrology. This planning process has identified the world’s major electrical-based metrology challenges and potential collaborators, including EEEL, who are willing to work together to address them.

### **Expanding International Outreach**

International outreach is important to the success of EEEL 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 on complex scientific frontiers and strengthen international partnerships to accelerate the progress of science across borders.”<sup>6</sup>

We recognize that the dissemination of EEEL-developed metrology expertise and technology benefits both the metrology community and EEEL. By having other NMIs use measurement techniques and instrumentation developed by EEEL, our reputation for attracting new staff and guest researchers is enhanced, as is the possibility for productive collaborations. EEEL will determine the most effective methods for distributing our metrology developments to the world.

Additionally, EEEL will continue to support the Sistema Interamericano de Metrología (SIM) Regional Metrology Organization, which comprises 34 Western Hemisphere countries. We will do our best to provide the most effective traceability support possible to those SIM countries that need it most. We will also continue to focus on outreach to China’s NMI, NIM. By providing them needed support at this time, we may provide the basis for future collaborations as NIM’s capabilities increase. 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 21<sup>st</sup> 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

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<sup>6</sup> <http://www.whitehouse.gov/omb/memoranda/fy2007/m07-22.pdf>

partners. 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.

### **Contributing to 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 will be strategically engaged in the development and adoption of documentary standards consistent with our technical expertise and industry priorities. Divisions and Offices must develop coherent plans for effective and efficient participation in documentary standards activities.

### **Providing Measurement Services**

Measurement services are important to EEEL and our customers. We must and will continue to provide high quality, traceable services, and we strive to be a good supply chain partner. 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. We will prioritize our measurement services in light of decreasing resources and in accord with the NIST assessment of the US Measurement System.<sup>7</sup> We will work toward providing ever more efficient delivery of services. We must explore new internal funding sources to improve our measurement services and the delivery of those services.

### **Expanding 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.

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 nanomagnetics, we must work collaboratively and collegially to minimize duplicative efforts and leverage each other’s resources. EEEL has articulated its nanotechnology vision to guide EEEL in advancing a coherent program in this area (see Appendix C). We will advance our nanotechnology programs while continuing to collaborate with others with complementary capabilities to build world class nanotechnology capability at NIST. Consistent with our critical core competencies, EEEL should provide leadership for the new nanofabrication facility being planned for Boulder.

### **Expanding 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. EEEL has an essential role to play in the support of biosciences with key enabling electromagnetic metrology. We have a history of opportunistically applying our existing electromagnetic metrology capabilities to bioscience measurement problems. In

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<sup>7</sup> <http://usms.nist.gov/>



recent years, we have increasingly addressed bioscience measurement needs through a variety of new strategic thrusts, including bioelectronics and biomedical imaging. For EEEL to continue to grow into this expanding research field, it is critical that we present a coherent plan to the rest of NIST and to the outside community. In response to this challenge, we have developed a vision for EEEL's role in meeting the measurement needs in the area of bioelectronics that is presented in Appendix D. EEEL will use this vision to guide a cohesive biosciences program through the development of new initiatives, the redirection of resources, and building partnerships.

### **Staffing Strategically**

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.

We will 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 will make increased use of NIST associates who play a critical role in our success. We need to continue to proactively find new means, such as the "EEEL Distinguished Associate Award", to ensure that all our staff are recognized and valued for the vital contributions they make. While the use of nonpermanent staff gives us flexibility in our technical program development, when possible and strategic, we should look for opportunities to convert exceptional associates to full time status.

### **Developing the Next Generation of Leaders**

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, perhaps over many years in anticipation of potential openings.

### **Working Collaboratively**

Excellent collaborations do occur within EEEL and we will continue to optimally organize and expand these efforts as appropriate. For EEEL to flourish, a culture that nurtures and rewards teamwork and collaboration must exist. We are staffed too thinly to tolerate any lapses in technical cooperation, collaboration or coordination among our staff.

## Impact of The Plan

The EEEL FY07 Strategic Plan was the Laboratory's first explicit high level strategic plan in recent history. It purposely did not include implementation guidelines, leaving the specifics of implementation to the Division and Office management. The following are a few examples of how the plan was implemented throughout the Lab:

### *International Outreach*

EEEL had more than a dozen trips to China in FY07 and on September 12, 2007 signed NIST's first agreement with China's National Institute of Metrology (NIM) on a collaborative workplan for the coming years.

EEEL led the way in providing traceability to Costa Rica and Panama and provided technical assistance to a number of other SIM countries.

### *The SI*

Our support of the SI is evidenced by our successes in single photon physics and the world's best measurement of Plank's constant with uncertainty nearly low enough for a redefinition of the kilogram.

### *Innovation and Excellence*

Investment in science has increased via new Initiative and Competence funding, providing us with new opportunities to obtain increased recognition for our staff. The number of staff receiving Department of Commerce and NIST recognition this year was impressive, with 10 to receive Gold Medals, 2 to receive Silver Medals, and 4 to receive Bronze Medals. In addition, this year our staff are being recognized with the Stratton, Astin, Condon, EEO/Diversity and Flemming awards. When our staff receive such strong federal recognition, it often facilitates even greater recognition from the broader scientific community.

Towards some of the plan's goals we made modest progress:

- We have invested in improvements in the internal use of information technology, with many more improvements envisioned.
- Effective communication is a particular challenge in EEEL since our research staff are geographically split almost evenly between our Gaithersburg and Boulder campuses. We have improved management team coordination through additional face-to-face meetings for top EEEL management.
- There has been satisfactory progress on all of the mandates.

## Call for Input

The publication of this Strategic Plan represents the culmination 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. 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 any of the staff in the EEEL Headquarters Office.

## Appendx A: 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 these 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

### **High Priority**

- 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 2008:

- 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

## Appendix B: Planning for Success

The following steps comprise the annual EEEL 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.” Any suggested changes to the list of Mandated EEEL tasks are considered.
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.

## Appendix C: EEEL Vision for Nanotechnology

EEEL's mission is 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." Electronics is a ubiquitous technology, enabling critical measurements and providing foundational instrumentation for diverse technology areas such as semiconductor electronics, optoelectronics, electromagnetics and bioelectronics. Advances in nanotechnology are driving measurements to smaller scales, and new electromagnetically based measurement science is required to enable novel nanoscale devices, tools, and processes. This provides substantially new challenges and equally rewarding opportunities for driving innovation.

EEEL possesses unique core competencies that address many of today's nanoscale metrology challenges:

- Measurement science and technology from DC to lightwaves with rigorous traceability including uncertainty measurements;
- Quantum-based electronics and photonics expertise for developing primary standards;
- Fabrication and characterization of micro- and nano-scale devices.

EEEL employs these competencies to meet future needs in nanoelectronics and in those nanotechnologies that are enabled by electronics. Active programs include nanoscale electromagnetic sensors and measurements; standards that exploit single electrons, photons, spins, and quantized effects; measurement tools that exploit quantum dots, nanowires, photonic crystals and superconductor nanodevices; and semiconductor (including compound) and beyond-CMOS nanostructures. To most effectively support technology innovation, EEEL nanotechnology programs are strongly aligned with at least one of the following three objectives:

- Advance measurement sciences that fall within the EEEL mission
- Support the national priorities that EEEL can most effectively address within its core competence
- Support critical measurement needs within electronics and electronics-enabling industries such as the semiconductor and optoelectronics industries

EEEL will strive to strengthen its critical core competencies to advance innovative nanotechnology programs in support of the NIST mission.

## Appendix D: EEEL Vision for Bioelectronics and Healthcare

EEEL's mission is 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." Electronics is a ubiquitous technology, enabling critical measurements and providing foundational instrumentation for diverse technology areas such as semiconductor electronics, optoelectronics, electromagnetics and bioelectronics. The growing convergence of electronics and medicine has made medical applications one of the fastest-growing segments of the electronics industry. Electronic-based methods for control and analysis enable affordable, portable, integrated, reliable, and personalized high-throughput medical measurements. The next generation of technologies can only be achieved through multidisciplinary advances in biochemistry, biomaterials, biophysics, and bioelectronics.

EEEL's vision in the biosciences is *to leverage our vast expertise in the quantitative electromagnetic and condensed matter sciences to provide the measurement infrastructure to underpin increased innovation in the biosciences and healthcare.*

EEEL has three core competencies:

- Measurement science and technology from DC to lightwaves with rigorous traceability including uncertainty measurements;
- Quantum-based electronics and photonics expertise for developing primary standards;
- Fabrication and characterization of micro- and nano-scale devices.

EEEL's expertise in measurement science and fabrication is required to address important bioelectronic metrology challenges. Quantitative electromagnetics moves biological measurements from qualitative to quantitative footing and enables the development of traceable bioelectronic measurements at cellular, molecular, and smaller scales. Micro- and nano- fabrication technologies are required to develop platforms to manipulate and study systems and processes on biologically relevant length scales.

EEEL employs its competencies to meet the metrology needs in the biosciences through programs in:

- Micro-nano-technologies for biological systems, including microfluidics and cellular microenvironments
- Nanopore technology for proteomics, genomics, and homeland security applications
- Quantitative bioimaging and medical instrumentation
- Interactions of electromagnetic fields with biological systems

To most effectively support technology innovation, EEEL programs are strongly aligned with the following objectives:

- Advance measurement sciences that fall within the EEEL mission
- Support the national priorities that EEEL can most effectively address within its mission
- Support critical needs for electronic- and optoelectronic-based measurements for the biosciences and healthcare.

EEEL will leverage its critical core competencies to advance innovative bioscience and healthcare programs in support of the NIST mission.