Operational Plan
Electronics and Electrical Engineering Laboratory
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Introduction

With world-class staff, a solid history of achievement and close ties to customers, the Electronics and Electrical Engineering Laboratory is well positioned to address the electronics industry's measurement needs in the coming years. EEEL is a critical resource to a wide range of industrial sectors, primarily serving microelectronics, telecommunications, and industrial equipment manufacturers. The Laboratory is a reliable provider of fundamental electrical measurements, leading the world in measurement capabilities such as resistance and voltage. EEEL is also building the foundation to support future metrology needs, as it strives to meet industry's requirement for nanoscale accuracy in the development of beyond-CMOS alternatives, next generation telecommunications systems and ultra-dense magnetic storage. EEEL also invests a small percentage of its resources to address high-impact technology challenges, such as quantum computing and provably secure quantum communications, where the Laboratory's distinctive expertise and facilities provide unique opportunities for progress. In 2004, for example, the development of a new class of microrefrigerators by EEEL researchers was featured on the covers of both Physics Today and Applied Physics Letters. EEEL is also recognized for its security contributions, serving both the homeland security and law enforcement communities. With support from its Office of Law Enforcement Standards, EEEL made headlines with its investigation of first responder communications at demolition sites.

EEEL delivered world-class results in 2004 despite having to operate within a very difficult fiscal environment, and while staff were adjusting to new positions within a restructured organization. As described in the 2003 EEEL Operational Plan, EEEL implemented a new organization, which became official in November 2003. This leaner, more efficient structure has contributed to greater collaboration among staff and positioned the Laboratory to remain solvent in FY2004 even when faced with over $2M of unexpected earmarks, cuts, and rescissions. Since the cuts were larger than even worst-case planning scenarios anticipated, the reorganization did not provide the comfortable operating margin it was designed to deliver. FY2005 is expected to be equally challenging, given the difficult environment for raising external funds and the minimal cushion of carryover the Laboratory will have available.

Continued flat and shrinking budgets are threatening the Laboratory's ability to maintain its global leadership in a number of areas. Progress is being impeded by the inability to make timely hires, to re-fill vacancies, to upgrade or in some cases even maintain research facilities. This impact is especially felt in fundamental metrology research, where EEEL cannot afford to fully participate in key efforts such as the development of a new calculable capacitor or research in ac quantum Hall effects. The world is catching up to NIST in single electron current sources, and there are several calibration services that are in danger of becoming obsolete as EEEL struggles to find the resources to accommodate industry's changing needs.

Broad Support of NIST Strategic Objectives

Through its commitment to understanding and meeting the needs of the industries it serves, EEEL not only contributes to the core metrology mission of the Institute but also aligns itself with the NIST strategic goals in nanotechnology, biosystems and health, information/knowledge management, and homeland security. EEEL continues to make the Institute's most substantial investment in nanotechnology, in such areas as the development of quantum-based standards, high-speed data storage, support for current semiconductor fabrication processes, beyond-CMOS alternatives, and the development of standards for NanoElectroMechanical Systems (NEMS) manufacturing practices. The EEEL Office of Microelectronics Programs currently invests practically its entire annual $12M budget in nanotechnology.

EEEL has brought its unique skill set to bear on biosystems and health challenges, growing its investment in this area with $1.3M of new starts in 2004 and 2005. EEEL initiated two new efforts that promise advances in medical diagnostics: a multi-OU collaboration to develop highly sensitive magnetic sensors; and the development of optical coherence tomography. These new efforts complement ongoing contributions to health-related goals, such as calibration of laser and display-based medical equipment; development of measurement techniques to support NIH studies of the potential health effects of electromagnetic fields radiating from cellular telephones; and development of a measurement platform for metrology at the cellular level in the competence-building Single Molecule Manipulation and Measurement (SM^3) program.

EEEL continues its support of information and knowledge management advances through its contributions to industry roadmaps and standards for the effective communication of product data across the electronics supply chain. EEEL also contributes to the nation's information and telecommunication infrastructure by providing metrology support of network equipment, and by providing international leadership of broadband wireless standards development.

EEEL contributes to homeland security directly through its technical program, and through funding provided by the Office of Law Enforcement Standards (OLES). EEEL homeland security efforts include first responder communications, chemical sensing, concealed weapon detection, critical infrastructure protection, and a new project to develop advanced gamma-ray detectors for nuclear nonproliferation monitoring. OLES provides leadership and effective management of a full suite of primarily DHS- and DoJ-funded programs supporting homeland security and first responders. In addition, OLES serves the criminal justice community: it has been in the forefront of computer forensics, and was called on in 2004 to apply rigorous procedures to the Attorney General-initiated investigation of protective armor failures.

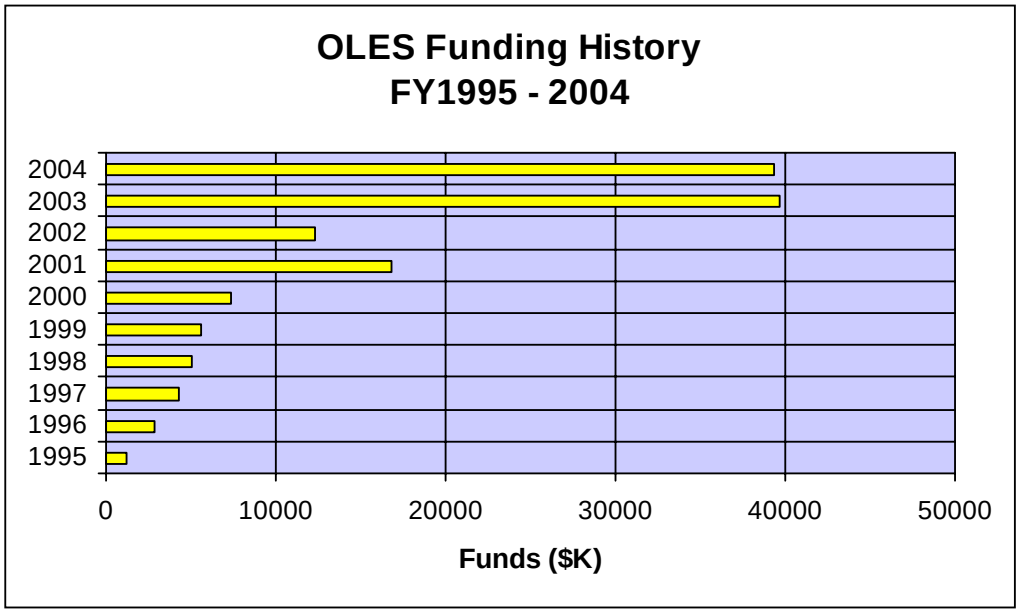
Strategic Shifts

The following are important factors influencing the performance and direction of the EEEL Technical Program.

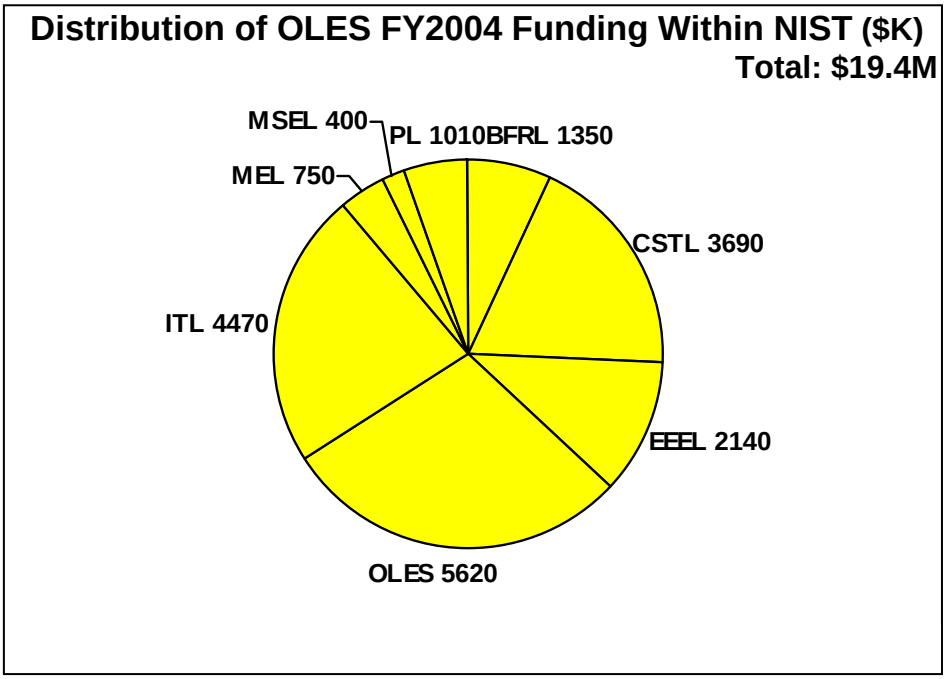
Growth of the EEEL Office of Law Enforcement Standards (OLES)

Due to increased national focus on security, OLES has been trusted with the management of a significant and growing homeland security portfolio. With an annual budget that has grown to $39.5M in 2004 and for the first time includes $3M in STRS, OLES now provides the NIST Laboratories with more funding than does the ATP intramural program. With its strong relationships with DoJ and DHS, OLES provides NIST an effective interface to these important sponsors.

The following graph highlights the rapid growth of the OLES budget in the last few years.



The next graph provides the distribution of OLES FY2004 funds within NIST. Although the EEEL technical program includes resources and expertise relevant to the OLES portfolio, EEEL Divisions are not the primary NIST recipients of OLES funding. The Laboratory intends to more aggressively market its homeland security capabilities in 2005 and 2006, expanding its homeland security portfolio.



The EEEL Reorganization and its Benefits to Collaborations

One of the objectives of the EEEL reorganization was to facilitate collaboration within the Lab, and to position each Division to more effectively attract and manage OA support. The new organization trimmed total overhead by approximately $2.5M, allowing a greater percentage of resources to be applied directly to services and research. EEEL now operates with a third fewer Divisions and Groups, and eleven fewer support and administrative positions.

The new structure removes organizational barriers to collaboration in a number of significant areas. The Quantum Electrical Metrology Division not only spans Boulder and Gaithersburg, thus setting a new model for cross-campus interaction in EEEL, but organizationally combines the Boulder-based development of new voltage and single-electron-tunneling-based capacitance standards with Gaithersburg-based efforts including the delivery of the calibration services. The Electromagnetics Division now combines radio-frequency and magnetics efforts, allowing better alignment of technically related efforts. The Infrastructure for Integrated Electronics Design and Manufacturing project was moved into the Semiconductor Electronics Division, which is allowing gains in supply chain standards for electronics manufacturing to be extended to the semiconductor engineering chain.

Increased Commitment to Outreach

Partnerships with OA sponsors are essential, both to provide a diverse funding base and to maintain an operational link with key customers. There are several examples across the Laboratory of highly successful OA collaborations, where the deliverables

support both the sponsor's needs and the EEEL mission. One the best examples is the Quantum Electrical Metrology Division's Quantum Sensors Project which develops cryogenic sensors for a wide range of applications. Over $2M of this Project's $3M budget is provided by OA sponsors, most of which are in the astronomical community. Enthusiastic support for this project was clearly expressed in a letter from the American Astronomical Society to both NIST and Congress.

The EEEL reorganization brought to light the variation across the Laboratory in attitudes towards cultivating external sponsors, and in experience and comfort level in approaching potential funding agents. EEEL management has proactively taken steps to bolster and develop the skills needed to maintain robust OA relationships. The Laboratory posts monthly financial reports on the internal EEEL website, providing visibility of solvency strengths and weaknesses at the Group level. Divisions have established mentoring efforts where staff with proven track records coach others on best practices for acquiring and maintaining OA support. Commitment to OA relationship-building is factored in to individual performance plans (although success is never made a performance requirement), and management is communicating with staff on how the financial health of a given project impacts plans for the future. These efforts are beginning to show positive results.

The following table shows that the Lab recovered from a 2003 dip in OA as a percentage of budget. This 3% recovery is especially significant given the particularly challenging environment for obtaining new OA funding. Budget cuts in agencies across the Government are eroding available resources and thereby creating greater competition for those funds. Some traditional OA sponsors have changed priorities, making current externally supported programs less certain to be continued. For example, EEEL has benefited from long-term NASA funding for advanced x-ray detectors, and has more recently worked with NASA to improve microwave radiometry. However, support for these efforts may suffer as NASA redirects funds to meet new priorities, such as future manned Mars missions.

OA Funds as a Percentage of Laboratory Budget

FY	Budget ($M)	OA (%)
2004	55.8	20.3%
2003	54.8	17.2%
2002	56.1	20.0%
2001	53.7	20.3%
2000	49.6	20.2%

Notes:
1. OA includes non-Federal Government sources.
2. OA does not include calibration income.
3. Table excludes all OLES funding except for that received by EEEL Divisions.

Increasing Importance of Non-Permanent Labor

Similar to the renewed emphasis on acquiring OA support, EEEL is also striving to control costs through continued aggressive use of contractors, students and guest researchers. The effective use of non-permanent staff can provide an immediate positive impact on budget. The Semiconductor Electronics Division, for example, now employs 40 student and guest researchers in addition to its 42 permanent members, and the Electromagnetics Division employs 64 non-permanent staff to complement its 59 permanent staff members. EEEL also took the initiative to establish a new contract mechanism for procuring outside scientific and technical services in Boulder, which is also being used by other Boulder Divisions.

Global Metrology Environment

The traditional mission of the NIST Laboratories is to provide the metrology support and infrastructure needed by its customers, including industry, academia, and government. At the heart of this responsibility is the realization and representation of the SI and their derived units; the scaling of these units, in some cases over twenty orders of magnitude; and the delivery of this metrology by way of measurement services, such as calibrations, data, reference materials, and special tests.

Ultimately the bedrock on which the NIST Laboratories rests is this core metrology capability. It defines NIST and provides a mission unique from other science agencies and academia. The NIST Laboratories in this capacity have provided the nation with metrology capability equal to or better than anywhere else in the world.

Unfortunately, this Operational Plan shows a continuing decline in investment in core metrology. Principally, this is due to the fact that the limited new resources received are not directed towards core metrology or at least not traditional core metrology. (Investments in metrology related to nanotechnology and biosystems are extremely important for the nation's future but are not providing support for the other more traditional metrology needs.)

With reduced support for core metrology and CIPM's Mutual Recognition Arrangement, which enables other NMIs to sell their services to U.S. customers, NIST's world class core metrology program is being challenged. For example, European NMIs under similar financial stress have partnered with one another to share responsibilities for providing measurement services to their region. NIST does not have the same opportunities to do this in North America, although EEEL has redirected some customers in the high voltage area to Canada.

EEEL remains committed to providing broad core metrology support for its customers, and will endeavor to continue this in the future.

Fluctuating Demand for Calibration Services

Industry calibration requirements are constantly changing, and it takes vigilance and resources to maintain both relevance and a competitive position in the markets served by EEEL. The Optoelectronics Division, for example, had positioned itself well to meet industry's needs for component-level services, and is now working to address new needs for system-level measurements. Because the demand for its services is relatively inelastic, that Division is able to recover much of its indirect costs through calibration fees, while the other EEEL divisions cannot reduce prices enough to meet competitive pressures from other National Metrology Institutes. The Mutual Recognition Arrangement provides calibration customers more options for service, and many are opting for lower-cost alternatives – even at the cost of accuracy.

The following table shows a relatively consistent level of demand for services across the Laboratory, but fails to reflect the variations across services. One significant example of this is the EEEL voltage calibration service. The calibration income from this service has fallen from a high of $200k/year to less than $50k/year over the last 10 years. This is primarily due to the development and dissemination of Josephson Voltage Standards, which can be viewed as a great EEEL success, but this success now requires significant restructuring of an existing calibration program.

Reimbursable Funds as a Percentage of Laboratory Budget

FY	Budget ($M)	Reimbursable (%)
2004	55.8	6.1%
2003	54.8	5.7%
2002	56.1	5.3%
2001	53.7	6.3%
2000	49.6	5.4%

It is important to note that the relatively constant reimbursable income does not keep pace with the growing salaries of the calibration staff, thus requiring more STRS subsidy or a commensurate reduction in staff.

Beyond CMOS

The CMOS (Complementary Metal Oxide Semiconductor) FET (Field Effect Transistor), which is the current basis of ULSI (Ultra-Large-Scale Integration) circuits, is beginning to show fundamental limits associated with the laws of quantum mechanics and the limitations of fabrication techniques. The Semiconductor Industry Association's (SIA's) International Technology Roadmap for Semiconductors (ITRS) shows no known solutions in the short term for a variety of future advanced technological requirements including gate dielectric, gate leakage, and junction depth. Therefore, it is expected that

entirely new device structures and computational paradigms will be required to augment and/or replace standard planar CMOS devices.

Beginning in 2000, the Semiconductor Electronics Division started the Nanoelectronic Device Metrology (NEDM) Project in the CMOS and Novel Devices Group. The overall goal of the NEDM Project is to develop the metrology that will help enable new nanotechnologies (such as Si-based quantum devices, molecular electronics, and organic thin-film transistors) to supplement and/or supplant conventional CMOS devices. This involves determining the critical metrology needs for these exploratory technologies. The NEDM Project now accounts for approximately 1/3 of the CMOS and Novel Devices Group and has significant competence and OA resources. EEEL intends to continue transitioning more of the Group into this area as conventional CMOS technology reaches its limits.

One specific goal of the NEDM projects is to develop test structures and methods to measure the electrical properties of small ensembles of molecules reliably. Another targeted goal is to develop the precise metrology and characterization methods required for the systematic characterization of Si-based nanoelectronic devices. A third goal is to develop an integrated and interdisciplinary suite of sophisticated measurement capabilities to enable correlations between organic electronic device performance and the structure, properties, and chemistry of critical materials and interfaces.

AML Nanofabrication Facility

To continue to respond to U.S. science and industry's needs for more sophisticated measurements and standards in the face of heightened global competition, NIST has constructed one of the most technologically advanced facilities in the world—the Advanced Measurement Laboratory, or AML. The NIST Nanofabrication Facility (NF) is one of five buildings in the AML at the Gaithersburg, MD campus. The AML Nanofabrication Facility will provide researchers at NIST the ability to fabricate prototypical nanoscale test structures, measurement instruments, standard reference materials, and electronic devices. It provides Gaithersburg researchers with new opportunities to partner across OUs and with external collaborators, and to accelerate research through rapid prototyping of device designs. This investment strategically positions NIST to remain a world leader in nanotechnology standards, and with its external partners, to be at the center of technology breakthroughs. Making the Institute's largest investment in nanotechnology, EEEL has a tremendous amount to gain from the NF, and has also contributed leadership and resources to its planning and management.

The NF will be operated as a shared access user facility for all NIST staff and associates. This means that the staff of NIST and its partners, subject to provisions, training, and user fees, will be permitted to independently operate the equipment. The tools will be operated in a manner such that a wide variety of materials can be processed. Unlike other nanofabrication facilities, the NIST AML NF is unique in that it is located next to the most advanced metrology tools in the world, and its focus will be on fabricating nanoscale structures necessary for metrology and standards in support of the

semiconductor, nanotechnology, biosystems and health, and homeland security industries.

NIST has invested in a complete suite of new equipment (capable of processing 150 mm wafers) that will be installed over the upcoming year. This includes furnaces (2 banks of 4 tubes each), LPCVD (poly, nitride, LTO), rapid thermal annealer, 3 reactive ion etchers (SF_6/O_2, Metal, Deep), 3 metal deposition tools (thermal, e-beam, sputterer), contact lithography (front- and back-side alignment), e-beam lithography, focused ion beam, and numerous monitoring tools including FESEM, spectroscopic ellipsometer, contact profilometer, 4-point probe, and microscope with image capture.

The NF will offer Gaithersburg researchers the same benefits currently afforded by the Boulder Fabrication Facility, which has enabled Boulder staff to fabricate novel devices that are unique. The Boulder Facility is used by nearly every NIST Division at that site, and supports many of NIST's most advanced achievements in areas as diverse as Johnson noise thermometry, quantum computing and communication, atomic clocks, single photon detection, Josephson array voltage standards, and microcalorimetry. The Boulder Facility is integral to the success of NIST's world-leading research in quantum computing, providing researchers with the means to fabricate both ion traps and Josephson junction qubits. The Facility has provided the only means available to the National Science Foundation to fabricate the superconducting detectors needed in their search for dark matter. At the first Colorado University / NIST PREP Postdoc Symposium in Boulder in 2004, over 60% of the posters presented were based on work performed in this Facility.

EEEL Investing in Biosystems and Health

Bioscience broadly defined has been identified by EEEL as a high priority, strategic growth area for the Laboratory. EEEL will be making significant strides in the coming years in a number of high-impact biosystems and health areas. Currently there are significant EEEL efforts in the biosystems related areas of (1) competence building in single biological molecule manipulation and measurement through a cross-OU collaborative effort, (2) bioelectronics work with NIH which will interface biological systems to integrated circuits, and (3) DNA separations for forensic applications for the Department of Justice.

2005 Stops and Starts

Resources for core metrology continue to be a major concern in the coming years. EEEL efforts in biosystems and nanotechnology are growing significantly, homeland security efforts are growing modestly, IT / knowledge management efforts are staying flat, while core metrology efforts are shrinking substantially. While new starts for FY2006 are unclear at this point, it is expected that core metrology will shrink by an additional $480K. About $440K of current homeland security efforts are expected to conclude, although it is anticipated that this decrease will be offset by about $600K of OA growth from new programs in this area. It is also anticipated that EEEL IT efforts will acquire an additional $300K of OA funds in FY2006. Note that the following table assumes the continuation of nanotechnology initiative funds at the previously established levels.

	Start (OA)	Start (STRS)	Total Starts	Stops (STRS)	Stops (OA)	Difference (start - stop)
2004						
Nanotechnology	0	425,000	425,000	817,000		-392,000
Biosystems	400,000	600,000	1,000,000	0		1,000,000
Homeland Security	200,000	0	200,000	100,000		100,000
IT/Knowledge Management	0	0	0	0		0
Core Metrology	0	575,000	575,000	1,650,000	150,000	-1,075,000
2005						
Nanotechnology	533,000	3,180,000	3,713,000	1,600,000		2,113,000
Biosystems	0	300,000	300,000	0		300,000
Homeland Security	750,000	350,000	1,100,000	0		1,100,000
IT/Knowledge Management	100,000	100,000	200,000	100,000		100,000
Core Metrology	0	500,000	500,000	1,305,000		-805,000

Resources

Anticipated Changes in Other Agency Sources

EEEL does not anticipate major changes in OA sponsors for 2005 and 2006, although increased effort will be made to diversify funding sources. The Laboratory anticipates new or increased DARPA funding in areas including quantum dot lasers, coherent communications, and power electronics. Small increases are expected in NIJ money for bio-NEMS work. EEEL plans to prove itself to be of greater value to homeland security efforts in general, and to attract increased homeland security funding.

Anticipated Staff Changes

Plans for converting post-docs or making other strategic hires have been primarily on hold throughout 2004 due to budget constraints. EEEL is at risk of losing the opportunity to convert at least one of its highly qualified, diverse post-docs, who has agreed to extend their stay temporarily. It is hoped that 5 to 10 permanent hires can be made in 2005 and 2006 to provide needed support in growth areas, such as MEMS and power electronics.

Alignment of EEEL with NIST Strategic Directions

The following tables provide various perspectives on current and planned EEEL investments. Table 1 highlights the significant and growing investment that EEEL makes in nanotechnology, which is expected to increase by 6% in 2005. Homeland security is another strong growth area for the Laboratory, with a planned 9% increase in 2005. Investment in biosystems and health also shows a modest growth in the coming year, and investment in IT remains essentially flat. Core metrology is expected to see continued erosion in both OA and STRS in the outyears.

Table 2 highlights the emphasis which EEEL places on measurement science and measurements and standards. Table 3 highlights the broad spectrum of customers served. While much of the EEEL technical program is targeted to the microelectronics, industrial equipment and telecom industries, nearly every industry tracked in this table benefits from EEEL operations. The customers labeled as "other" are in general other government agencies, or refers to work so broad in nature as to be difficult to assign to any one sector. Technical efforts were assigned to only one customer or activity type in Tables 2 and 3.

Note that the totals from each table are not exactly equal due to several factors: Table 1 double counts a minority of projects due to their significant contributions to more than one SFA; in Tables 2 and 3, administrative funds have typically been assigned customers but not an "activity type." Also note that 2003 data does not follow directly from previous EEEL Operational Plans, since SFA activity was counted very differently in previous years. This plan assumes a much narrower definition of Homeland security based on recent guidance from OMB, and doesn't include telecommunication hardware efforts in the Information / knowledge management total.

Table 1: OU Program Funding by Type of Technology

	FY2003		FY 2004		FY 2005		FY 2006	
	STRS $	OTHER $	STRS $	OTHER $	STRS $	OTHER $	STRS $	OTHER $
NANO-TECHNOLOGY	10,570,772	6,166,452	10,731,494	5,960,357	12,579,846	5,674,137	12,750,724	5,684,137
BIOSYSTEMS AND HEALTH	1,962,534	614,310	1,992,420	623,665	2,293,006	576,895	2,313,901	576,895
INFORMATION/ KNOWLEDGE MANAGEMENT	1,603,493	140,744	1,627,912	142,887	1,798,843	127,887	1,677,116	427,887
HOMELAND SECURITY	2,607,145	2,526,250	2,646,645	2,564,721	3,137,845	3,264,721	2,639,662	3,864,721
CORE METROLOGY	20,965,254	10,623,826	17,934,268	10,785,610	17,006,907	9,807,269	16,808,711	9,672,644
OTHER			922,200	842,039	933,033	842,039	944,028	842,039

Table 2: OU Program Funding by Type of Activity, FY 2005

Type of activity	STRS $	Other $	Total $
Data and informatics	$1,369,032.00	$167,500.00	$1,536,532.00
Harmonized measurements and standards to facilitate international trade	$736,382.50	$571,367.00	$1,307,749.50
Management and technology tools to improve business performance	$0	$0	$0
Measurement science	$16,655,297.40	$7,544,379.10	$24,199,676.50
Measurements and standards	$10,058,578.95	$3,655,193.00	$13,713,771.95
Measurements and standards for regulatory implementation	$3,711,956.50	$1,938,266.00	$5,650,222.50
Technology development	$2,392,669.65	$4,068,921.90	$6,461,591.55
Total	$34,923,917.00	$17,945,627.00	$52,869,544.00

Table 3: OU Program Funding by Primary Area of Application, FY 2005

PRIMARY AREA OF APPLICATION	STRS $	OTHER $	TOTAL $
AEROSPACE/AERONAUTICS	$1,127,870	$1,626,245	$2,754,115
AUTOMOTIVE	$130,180	$75,000	$205,180
BIOMATERIALS	$48,000	$0	$48,000
BUILDING PRODUCTS AND MATERIALS	$48,000	$0	$48,000
CERAMICS	$154,500	$0	$154,500
CHEMICAL AND ALLIED PRODUCTS	$48,000	$0	$48,000
COMPOSITES	$48,000	$0	$48,000
COMPUTER EQUIPMENT	$930,570	$996,336	$1,926,906
COMPUTER SOFTWARE	$0	$0	$0
CONSTRUCTION	$0	$0	$0
DRUGS AND PHARMACEUTICALS	$48,000	$0	$48,000
ENERGY (ELECTRICITY PRODUCTION AND SALES, FOSSIL FUELS)	$2,238,380	$1,243,389	$3,481,769
ENVIRONMENTAL TECHNOLOGIES AND SERVICES	$450,000	$308,997	$758,997
FIRE SAFETY	$0	$0	$0
HEALTH AND MEDICAL PRODUCTS/SERVICES	$1,632,040	$40,929	$1,672,969
HOMELAND SECURITY (LAW ENFORCEMENT, FORENSICS, ETC.)	$3,674,900	$2,289,399	$5,964,299
INDUSTRIAL AND ANALYTICAL MEASUREMENTS	$4,095,040	$3,054,971	$7,150,011
INFORMATION SERVICES	$69,000	$0	$69,000
INFORMATION SYSTEM NETWORKS	$113,960	$0	$113,960
METALWORKING EQUIPMENT	$0	$0	$0
MICROELECTRONICS	$15,033,130	$5,623,574	$20,656,704
NONFERROUS METALS	$48,000	$0	$48,000
NUCLEAR MATERIALS	$0	$0	$0
PLASTIC MATERIALS AND RESIN	$48,000	$0	$48,000
PROCESSED FOODS AND BEVERAGES	$0	$0	$0
PRODUCTION MACHINERY	$0	$0	$0
SECURITY AND PRIVACY (INFORMATION AND COMPUTER)	$0	$0	$0
STRUCTURAL SAFETY (INCLUDING EARTHQUAKES)	$0	$0	$0
TELECOMMUNICATION SYSTEMS AND SERVICES	$4,415,370	$1,501,611	$5,916,981
OTHER	$1,601,000	$1,051,179	$2,652,179
TOTAL	$36,541,969	$17,811,629	$54,353,598

Coordination With Other OUs

EEEL work addresses a number of interdisciplinary challenges, and EEEL could not meet its goals without the collaboration of other NIST OUs. The two Offices managed by EEEL, OLES and OMP, provide good examples of the Laboratory's commitment to mission-focused collaboration. The majority of funding provided by each Office supports work outside of EEEL, and both Offices make significant investments in support of the NIST SFAs. The OLES Director leads the NIST Strategic Working Group in homeland security, and has assigned several of her staff to lead and contribute to HS SWG activities. As mentioned above, OLES has become NIST's most significant source of non-STRS funds. OLES provides an indirect on-site interface to some of NIST's most significant OA sponsors.

The Office of Microelectronic Programs has leveraged its $12M budget to provide tremendous impact for the microelectronics industry by reaching across NIST to fund the right experts to address this industry's complex challenges. OMP also provided over $200K of support to the AML Nanofabrication Facility (NF), and expects to grow this support in the coming years. The EEEL Semiconductor Electronics Division provided further support to the AML NF through its leadership in organizing and equipping the new facility.

EEEL technical staff support a variety of cross-OU collaborative research efforts. EEEL participated in half of the finalist proposals for 2005 Competence funding, and are partners in 4 of the 7 eventually funded. This builds on EEEL's strong record of successful Competence and other multi-OU collaborations. EEEL is currently collaborating with PL on the development of a chip-scale atomic clock, leads a multidisciplinary team developing magnetic sensors, contributes to an MSEL-led organic electronics effort, was a key contributor in the MEL-led nanoforce Competence effort, and is continuing to collaborate with MSEL on a new nanowire Competence effort even after funding was severely curtailed. EEEL and PL are collaborating on the development of high frequency combs with applications to the optoelectronics industry and new atomic clocks, and EEEL is applying novel single photon detectors to benefit single photon generation research in both PL and EEEL. EEEL continues to provide a dedicated team to establish the electronic kilogram to advance the mass standard for NIST, and has delivered the world's best x-ray microcalorimeter to CSTL. Other prominent examples of cross-OU research efforts include SM^3 (EEEL/CSTL/PL/ITL Competence), Molecular Electronics (EEEL/CSTL competence), GaN material characterization (EEEL/MSEL/CSTL program), Johnson Noise Thermometry (EEEL/CSTL Competence), and electronic data exchange (EEEL/MEL/ITL).

Evaluation of Quality, Relevance, and Performance

EEEL assesses quality, relevance and performance through a variety of mechanisms, some of which are highlighted below:

Industry Scorecards

International SEMATECH (ISMT). ISMT is a global consortium, with members from Asia, Europe, and the U.S., dedicated to cooperative work on semiconductor manufacturing technology, and thus provides a robust interface for NIST to its microelectronics customer base. The OMP, which receives direction and support from ISMT, has formally surveyed this consortium via a "scorecard" every 6-12 months for the past four years. ISMT members are asked to rate OMP projects on a scale from 1 (low) to 5 (high) in the following categories: Familiarity, Quality, Value to Your Organization, Output Use, Output Value, Output Accessibility, and Correlation with the International Roadmap for Semiconductors. They are also asked to provide general comments, and specifically to suggest Opportunities for Greater Impact.

The scorecard was last updated in August 2004, and the quality of most projects was rated Good to Excellent. The scorecard provided very valuable, project-specific feedback, which is used to manage the current portfolio and direct future investments. Comments have highlighted areas where impact is high, such as in Extreme Ultraviolet Lithography, or promising, such as with Time Synchronization and Device Characterization. Comments have also shown areas where impact is being diluted due to industry shifts or slow commercialization of results, such as in Chemical Analysis. Additionally, the scorecard helps to raise the visibility of OMP work to a broader audience.

National Electronics Manufacturing Initiative (NEMI). The NEMI consortium brings together electronics manufacturers and their major suppliers to roadmap industry needs, identify gaps, and initiate projects to address key issues. A subset of OMP efforts are relevant to the NEMI constituency, and thus OMP has surveyed NEMI members to assess quality and relevance twice in the last three years. Similar to the ISMT Scorecard, participants are asked to rate OMP projects on a scale from 1 (low) to 5 (high) in the following categories: Familiarity, Quality, and Value, and to suggest Opportunities for Greater Impact. The latest survey was conducted over the summer of 2004, and shows that respondents:

- see considerable value in the NIST programs surveyed;
- believe the quality of the work to be good to excellent;
- were generally unaware of the NIST efforts prior to the scorecard.

OMP is now planning ways to increase the visibility of their technical portfolio through this Consortium.

NEMI Survey of OMP Projects

	Average Response
Familiarity	1.23
Quality	4.25
Value	3.54

Respondents: 3 companies, 1 consortia member

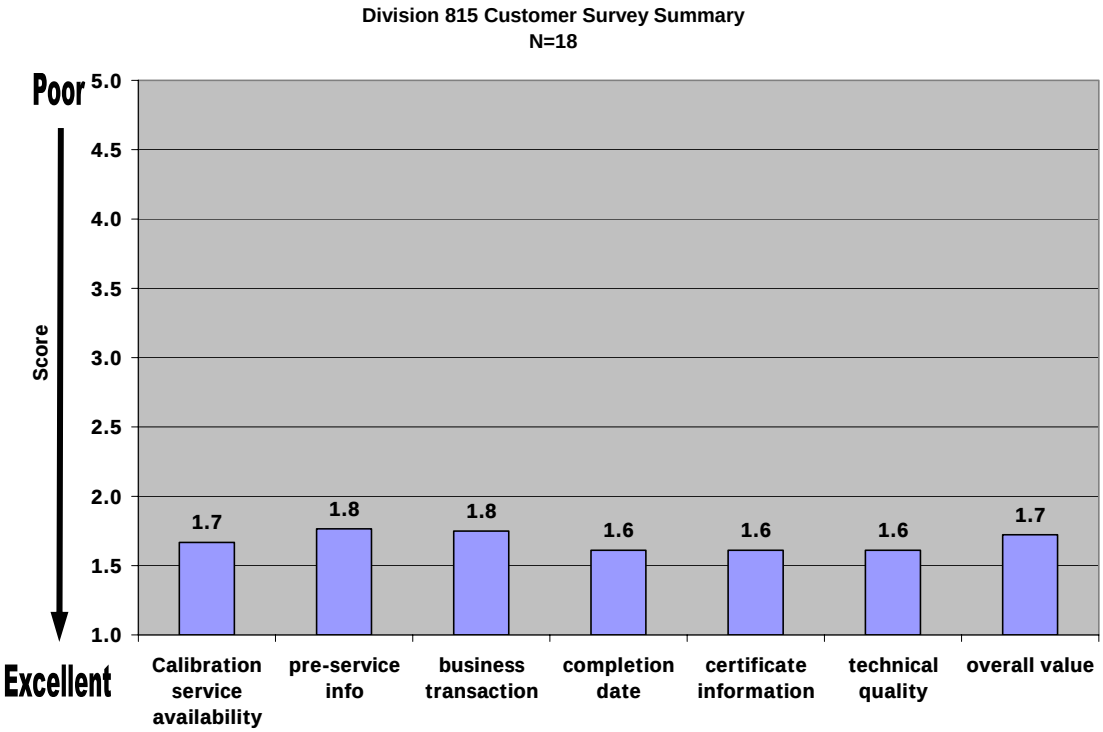
Customer Feedback and Evaluation Forms

EEEL gains a significant amount of direction and feedback from the NIST Customer Satisfaction Report Cards returned by calibration customers. Although the response rate is low (e.g., 11% for EEEL Optoelectronics services, and even lower for the Quantum Electrical Metrology Division), the fact that satisfied customers take the time to provide positive feedback provides a good indication of general customer satisfaction. Sixteen of the seventeen customers reporting on services delivered by the Optoelectronics Division rated the "overall value" as "very good" or "excellent". Further scorecard information for this Division is shown in Customer Survey figure below.

Several customers used this mechanism to complain about the cost of measurement services in 2004. While there is no indication that cost has deterred demand for optoelectronics services, it may be impacting demand for fundamental electrical measurements. One respondent emphasized that although service was "unusually fast", that "cost is the main drawback (in) using NIST."

In response to the market need for lower cost services, all EEEL Divisions are focused on increasing the efficiency of their operations. In addition, the Optoelectronics Division is investigating offering a 5% fee reduction for repeat calibrations based on their lower internal costs and to encourage return customers.

Customer feedback is also solicited via feedback forms at EEEL Short Courses. Following the 2004 Laser Measurements Short Course, the average instructor evaluation score was "Very Good", and scores in general ranged from "Good" to "Excellent". These evaluations, coupled with the fact that attendance at that course increased 90%, provide a good indication of participant satisfaction.



ISSC Scorecard responses for Division 815 Calibration Services. Seventeen responses were received through Aug. 4, 2004 from approximately 150 folders (11 % response rate).

Direct Communications

All EEEL Divisions and Offices prioritize direct communication with customers and sponsors, via teleconferences targeting primary collaborators, and via face to face meetings either using on-site visits or at conferences. This direct interaction provides valuable and specific feedback to EEEL projects. While most of the feedback has been positive, it has also highlighted areas of concern. One such concern is the continued relevance and preeminence of NIST in a number of calibration areas. In the area of on-wafer measurements, for example, NIST is losing its reputation as “first and best” due in part to the inability to invest sufficient resources to keep up with demand for services that accommodate higher frequencies, newer geometries and specialized substrates. Customers have indicated that they will have to find workable timely and possibly suboptimal solutions if NIST cannot respond to their changing needs.

Unsolicited Feedback

EEEL customers are vocal supporters of NIST, and engaged advocates for their industry’s needs. The Semiconductor Industry Association is one of many such customer/advocates that make their needs known through formal and informal channels.

In their recent letter dated September 20, 2004 to Hratch Semerjian from Daryl Hatano, the SIA's Vice President of Public Policy, they show their support of NIST, the importance of metrology for their industry needs, and appeal to NIST to maintain a strong micro- and nano-electronics program:

> *Dear Acting Director Semerjian,*
>
> *"I am writing to urge NIST to increase its research in the micro- and nano-electronics fields in FY 2005 and to increase its proposed budget in these areas in FY 2006. NIST metrology research is critical to the industry's continued technological progress and contribution to our nation's economic prosperity."*
>
> *"…we would encourage you to increase NIST semiconductor spending as much as possible, and to propose a budget for FY 2006 that would allow a doubling of NIST semiconductor spending over a reasonable period. This would allow NIST to achieve the funding level at NIST that was envisioned when the NIST Office of Microelectronics was established in 1994."*

Critical Issues

Progress on Issues Raised in Previous Operational Plans

While many of the issues raised in 2002 and 2003 Plans continue to be of concern, significant progress has been made towards resolving the following issues that were raised in previous plans:

Base Funding for OLES

OLES has been provided $3M in new STRS in the Congressional budget, which enhances operations by providing consistent, reliable funding to support a small dedicated staff at NIST.

Succession Planning

It is of interest to note that the majority of Division Chiefs and Office Directors will be eligible to retire in the next few years. Succession plans have been put in place and successors are being appropriately trained and mentored. EEEL management meets twice a year to discuss personnel issues, including specific succession plans for key management and technical positions.

Managing the AML Nanofabrication Facility

EEEL stepped up to provide leadership for AML NF plans and management. The facility will be directed by EEEL's Semiconductor Electronics Division. In the past year, this team has developed a vision for the facility, instituted a NIST-wide advisory committee, achieved buy-in from NIST management to support fixed operating costs, procured ~$7M of equipment, handled the details associated with the fit-up of the facility for this equipment, developed a 30 page user manual, and safety protocols. The facility is scheduled to begin operations in the spring of 2005.

Deteriorating Facilities in Boulder

While deficiencies in the facilities in Boulder, such as leaky roofs and poor environmental control, continue to impede research and services, the funding approved for the Central Utility Plant represents an important and necessary first step towards maintaining and enhancing the Boulder site's infrastructure.

Current Issues

Continuing Budget Pressures Forcing Redefinition of EEEL

Continued budget uncertainties and limitations are eroding the ability for EEEL to maintain pre-eminence in its work. FY05 is expected to be particularly challenging, with a very low spending ceilings throughout the continuing resolution and nearly no carry-over funding to provide a cushion. Budget constraints are delaying new hires, and the Laboratory is at risk of losing some excellent and diverse post-doctoral students due to the inability to make new offers.

There are several areas in which NIST is at risk of becoming outdated or losing its world-class status due to lack of funds. Support for the electric power industry is severely under-resourced, and there are several calibration services that require substantial new investment to keep up with customer needs. The current scope of the Electromagnetics Division cannot be maintained as is with its current budget. While other agency funding might help fill in the gaps, it also creates a trade-off between sponsor and agency objectives, and is difficult to obtain in those calibration areas core to the NIST mission.

Changing OA Sponsor Relationships

Shrinking federal budgets have created greater competition for the OA funds still available. Reprioritization of sponsor objectives has also left EEEL vulnerable to losing funds. EEEL is refocusing on other agencies which better fit the EEEL mission and resources.

While it is clear that OA support is essential, it is less clear what level constitutes an optimal percentage. How dependent can the Laboratory be on OA sponsors and still stay focused on the NIST core mission? Even the attempt to raise funds diverts valuable resources from mission-oriented work.

Attracting and Maintaining World-Class Staff

Not only is it difficult to make timely hires, but it is also difficult to provide the appropriate rewards and incentives to maintain excellent staff members. Many areas in EEEL are only 1 or 2 experts “deep”, whom the Laboratory can ill afford to lose.

Loss of Core Metrology Programs

Several core research and metrology functions are at risk. For example, EEEL has shut down calibration services in dc and impulse high voltage, and will soon be beginning the process of shutting down calibration services for high current transformers. These services are being transferred. EEEL has also begun planning the termination of some calibration services in radio-frequency technology, which will impact a wide customer base.

It should be noted that flat STRS and OA budgets have left several measurement services positions unfilled. Staff changes in the Quantum Electrical Metrology Division are representative of the entire Lab. Since 1999, the Division lost 8 measurement services staff members, while bringing in only 1 new technician. The Division has filled the most critical gaps by transferring existing staff from other projects, detracting from growth in those other areas.

Similar fiscal strains are impacting EEEL core metrology research programs. For example, reductions in funding from various sources (base STRS, competence, and OA funding) have left the Quantum Voltage Project with nearly a half million dollar deficit for FY2005. The Quantum Electrical Metrology Division will need

to either reduce the Project by half, threatening world leadership in this area, or terminate other efforts to redirect funds.

Outdated Research Facilities in Radio-Frequency Technology

The Electromagnetics Division facilities are becoming inadequate for the next generation of EMI, EMC, wireless and radar measurements for industry. EEEL strongly supports an initiative for the construction of the new world class "RF EM-Field Metrology Laboratory Facility" (REML). This would cost approximately $30M and would fund a new large high bay facility with a basic set of metrology-focused electromagnetic (EM) test chambers to address a wide range of topics, including EM compatibility of electronic products, bioeffects of EM fields, international standards effecting commerce, and basic research related to measurement and characterization of EM field quantities.

Summary

EEEL has a strong, creative technical program, complemented by two offices that serve as engines for collaboration across NIST. The Laboratory is realizing the benefits of its recent reorganization, and is continuing to seek opportunities to re-invent itself in the attempt to best address its customers' needs. EEEL will be making tough choices in the coming year about where to invest its limited resources to maintain world leadership, and in what areas it can afford to be second-best or absent.

Appendix: EEEL New Starts (Detail)

Division	Project or Task Started	Year	SFA*	OA/STRS	$ Cost
812	Bioelectronics (task)	2004	B	OA	300,000
818	Biomagnetics	2004	B	OA	100,000
812	Bioelectronics (task)	2004	B	STRS	300,000
818	Microfluidics	2004	B	STRS	200,000
818	Biomagnetics	2004	B	STRS	100,000
SUBTOTAL 2004 BIOSYSTEMS & HEALTH					**1000000**
				STRS	*600000*
				OA	*400000*
815	Body armor meas (OLES)	2004	HS	OA	200,000
SUBTOTAL 2004 HOMELAND SECURITY					**200000**
				STRS	*0*
				OA	*200000*
817	CCC scaling to 100 MOhm	2004	M	STRS	125,000
817	Modernization of voltage dissemination	2004	M	STRS	200,000
817	Silicon SET pump development	2004	M	STRS	100,000
817	Application of SET technologies to molecular electronics	2004	M	STRS	100,000
817	Frequency dependent capacitor calibrations	2004	M	STRS/Reimb	50,000
SUBTOTAL 2004 CORE METROLOGY					**575000**
				STRS	*575000*
				OA	*0*
815	Nanostructured detectors	2004	N	STRS	75,000
817	RF-SET electron counting electrometer	2004	N	STRS	200,000
818	Nanoprobing	2004	N	STRS	150,000
SUBTOTAL 2004 NANOTECHNOLOGY					**425000**
				STRS	*425000*
				OA	*0*

Division	Project or Task Started	Year	SFA*	OA/STRS	$ Cost
818	Radiated Noise Standard	2004	Other (envir.)	OA	200,000
818	Radiated Noise Standard	2004	Other (envir.)	STRS	200,000
SUBTOTAL 2004 OTHER (ENVIRONMENTAL)					**400000**
				STRS	*200000*
				OA	*200000*
815	OCT metrology	2005	B	STRS	300,000
SUBTOTAL 2005 BIOSYSTEMS & HEALTH					**300000**
				STRS	*300000*
				OA	*0*
815	Laser measurements for biochem sensing	2005	HS	STRS	150,000
817	Gamma ray detector for non-proliferation	2005	HS	STRS	200,000
817	Walkthrough Metal Detectors	2005	OLES	OA	350,000
817	Concealed Weapons	2005	DARPA	OA	400,000
SUBTOTAL 2005 HOMELAND SECURITY					**0**
				STRS	*350,000*
				OA	*750,000*
812	Anticipated new OA	2005	IT	OA	100000
812	Factory time synchronization standards development for e-Manufacturing	2005	IT	STRS	50,000
812	E-Diagnostics - technology to remotely monitor, maintain, diagnose/repair tools via the Internet.	2005	IT	STRS	50,000
812	XML Performance Metrics	2005	IT	STRS	
812	PDX 2.0 with IPC/NEMI	2005	IT	STRS	

Division	Project or Task Started	Year	SFA*	OA/STRS	$ Cost
SUBTOTAL 2005 IT/KNOWLEDGE MANAGEMENT					**200,000**
				STRS	*100,000*
				OA	*100000*
815	AlGaN composition standards	2005	M	STRS	30,000
817	Transfer CCC measurement system technology to DoE	2005	M	STRS	150,000
815	Waveform metrology	2005	M	STRS	320,000
SUBTOTAL 2005 CORE METROLOGY					**500000**
				STRS	*500000*
				OA	*0*
812	More Mol-E and Silicon Nanowires	2005	N	OA	130,000
812	Interconnects-narrow line 'size' effects (task)	2005	N	OA	228,000
812	Electrical and Physical Metrology for Metal Gate/High-k	2005	N	OA	175,000
812	More Mol-E and Silicon Nanowires	2005	N	STRS	500,000
815	Photonic crystals	2005	N	STRS	100,000
815	Indistinguishable photon source	2005	N	STRS	85,000
815	Nanowire lasers	2005	N	STRS	500,000
812	Interconnects-narrow line 'size' effects (task)	2005	N	STRS	200,000
812	MEMS Materials Characterization (task)	2005	N	STRS	240,000
812	Organic Electronics	2005	N	STRS	225,000
812	Electrical and Physical Metrology for Metal Gate/High-k	2005	N	STRS	1,000,000

Division	Project or Task Started	Year	SFA*	OA/STRS	$ Cost
817	SET Silicon Nanotransistor	2005	N	STRS	100,000
815	Mode locked quantum dot lasers	2005	N	STRS	115,000
817	RF SET current	2005	N	STRS	115,000
SUBTOTAL 2005 NANOTECHNOLOGY					**3713000**
				STRS	*3180000*
				OA	*533000*
TBD	Anticipated new OA	2006	HS	OA	600,000
SUBTOTAL 2006 HOMELAND SECURITY					**600,000**
				STRS	
				OA	*600,000*
812	Anticipated new OA	2006	IT	OA	300000
SUBTOTAL 2006 IT/KNOWLEDGE MANAGEMENT					**300000**
				STRS	
				OA	*300000*

Appendix: EEEL Stops (Detail)

Division	Project or Task Stopped	Year	SFA*	OA/STRS	$ Cost Savings
818	30 MHz Attenuation	2004	HS	STRS/Reim	100,000
SUBTOTAL 2004 HOMELAND SECURITY					**100000**
812	Electronic Dictionary Mapping Experiment	2004	IT	STRS	
812	Web Portal	2004	IT	STRS	
812	2004 Roadmapping effort for SEMATECH	2004	IT	STRS	
SUBTOTAL 2004 IT/KNOWLEDGE MANAGEMENT					**0**
815	Relative intensity noise	2004	M	STRS	275,000
815	UV materials characterization	2004	M	STRS	300,000
815	Photodetector modeling	2004	M	STRS	300,000
815	PDL metrology	2004	M	STRS	275,000
817	Current transformer research	2004	M	STRS	150,000
817	Quantum Hall device fabrication and characterization	2004	M	STRS	250,000
817	Cryogenic thermal transfer standard	2004	M	STRS	50,000
817	AC high voltage measurements	2004	M	STRS/Reim	50,000
817	Completion of FPOCS software development for use in fast pulse calibrations by the U.S. military. (CCG)	2004	M	OA	75,000
817	Develop of new detection system for AF IVD calibration facility (CCG)	2004	M	OA	75,000

Division	Project or Task Stopped	Year	SFA*	OA/STRS	$ Cost Savings
SUBTOTAL 2004 CORE METROLOGY					**1800000**
				STRS	*1650000*
				OA	*150000*
812	Test Structures-Linewidth	2004	N	STRS	817,000
SUBTOTAL 2004 NANOTECHNOLOGY					**817000**
812	Time-stamping needs of Semiconductor Industry	2005	IT	STRS	100,000
SUBTOTAL 2005 IT/KNOWLEDGE MANAGEMENT					**100000**
815	PMD & CD metrology development	2005	M	STRS	400,000
815	Wavelength Calibration SRM development	2005	M	STRS	100,000
815	Native oxide measurements	2005	M	STRS	80,000
817	Current transformer calibrations	2005	M	STRS	75,000
817	Transition to AML calibration labs	2005	M	STRS	150,000
817	High resistance standard development	2005	M	STRS	150,000
818	RF Voltage	2005	M	STRS	100,000
818	Impedance calibrations	2005	M	STRS/Reim	150,000
817	Jitter and Propagation Delay	2005	M	STRS	100,000
SUBTOTAL 2005 CORE METROLOGY					**1205000**
817	Quantum dot single photon generation	2005	N	STRS	100,000
812	Dopant profiling by SCM	2005	N	STRS	500,000
812	High-k Ellipsometry	2005	N	STRS	600,000
812	SiO2 Reliability	2005	N	STRS	400,000
SUBTOTAL 2005 NANOTECHNOLOGY					**1600000**

Division	Project or Task Stopped	Year	SFA*	OA/STRS	$ Cost Savings
812	SoC (without OA funding)	2006	HS	STRS	440,000
SUBTOTAL 2006 HOMELAND SECURITY					**440,000**
815	157 nm excimer	2006	M	STRS	150,000
815	Phosphine purity measurements	2006	M	STRS	80,000
818	Scattering Parameters	2006	M	STRS	250,000
SUBTOTAL 2006 CORE METROLOGY					**480000**