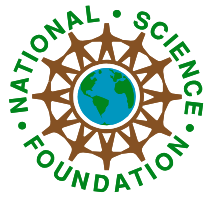
# STRATEGIC PLAN

# ELECTRICAL AND COMMUNICATIONS SYSTEMS DIVISION




**June 1, 2005**

National Science Foundation
4201 Wilson Boulevard, Arlington
Virginia 22230

# Summary

The Division of Electrical and Communications Systems (ECS) addresses fundamental research issues underlying component and device technologies, computation, controls and networking principles at the nano, micro and macro scales, and supports the integration and networking of complex systems for a variety of application domains in sensing, imaging, telecommunications, information networks, disaster mitigation, homeland security, robotics, power systems, environment, transportation, aerospace, healthcare, manufacturing and other systems-related areas. ECS envisions a research community that will address major technological challenges in devices and systems due to the convergence of micro/nano/info/bio-electronics, controls, communications, networks and computation.

ECS has a goal to integrate education into its research programs to ensure a diverse workforce in the 21st Century that will continue innovative advances for the rapid development of emerging technologies as drivers of the global economy. This goal is encouraged and strengthened by the Engineer of 2020 report of the National Academy of Engineering that foresees a "bewildering array of new technologies" confronting an engineering profession that must be educated in research, development and design, as well as possessing the attributes of strong analytical skills, creativity, ingenuity, professionalism and leadership.

The strategic development of ECS programs in research and education supports NSF themes and ENG priorities in nanotechnology, biocomplexity in the environment, cyberinfrastructure, human and social dynamics, sensors and sensor networks, information technology, mathematical sciences and the workforce for the 21st Century. ECS strengthens its programs through linkages to other areas of engineering, science, industry and government.

ECS has identified key technology areas consistent with the goals of the Engineering Directorate. The anticipated changing emphasis within ECS in emerging technologies will require a delicate balance between the continuity of currently funded technical areas and growth of emerging areas. This reshaping of ECS research will result in greater funding in communications systems technologies, as well as hybrid and complex systems engineering for various application domains.

The reorganization of the ECS Division has involved program restructuring, reassignment of Program Directors and renaming of the Integrative Systems program consistent with the research priorities of the Engineering Directorate, and will increase the overall productivity and efficiency of the Division.

In order to broaden participation of women and underrepresented minorities in advanced academic and professional careers, ECS in collaboration with BES has initiated a Graduate Research Supplement pilot program for Ph.D. students majoring in electrical engineering, or biomedical/biochemical/environmental engineering, in on-going research programs funded by ECS or BES.

ECS is addressing declining trends in funding rates due to increased proposal activity and availability of funds, and is taking steps to redress the imbalance between funds committed for NSF and ENG priority areas and ECS program funds for FY 2005.

**STRATEGIC PLAN**

**ELECTRICAL AND COMMUNICATIONS SYSTEMS DIVISION**

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## I. MISSION, VISION, GOALS and STRATEGIES

The mission, vision, goals and strategies of the Electrical and Communications Systems (ECS) Division are as follows:

### Mission

The ECS mission is to:

- Address fundamental research issues underlying component and device technologies, computation, controls and networking principles at the nano, micro and macro scales.
- Support the integration and networking of complex systems for a variety of application-specific domains.
- Ensure education of a diverse workforce prepared to continue the rapid development of emerging technologies as drivers of the global economy.

### Vision

ECS envisions a research community that will address major technological challenges in devices and systems due to the convergence of micro/nano/info/bio-electronics, controls, networks, computation and communications, and that will prepare a future workforce to meet the emerging technological challenges of the 21st Century.

### Goals and Strategies

ECS Mission and Vision are realized through a broad set of goals and strategies. ECS invests in people, ideas and tool, and in the pursuit of organizational excellence consistent with the goals of the Directorate for Engineering (ENG) and of the National Science Foundation. ECS goals are achieved through a set of strategies that include investments in innovative, high-risk, high-payoff ideas at the forefront of technologies; partnerships within NSF and with other federal agencies; outreach to universities, industries, nonprofit organizations and professional societies; enhancement of diversity within staff, researchers and reviewers; professional development of ECS staff; and that improve organizational excellence through e-jacket processing.

ECS also has a goal to integrate education into its research programs to ensure a diverse workforce in the 21st Century that will continue innovative advances for the rapid development of emerging technologies. This goal is encouraged and strengthened by the Engineer of 2020 report of the National Academy of Engineering (NAE) that foresees a “bewildering array of new technologies” confronting an engineering profession that must be educated in research, development and design, as well as possessing the attributes of strong analytical skills, creativity, ingenuity, professionalism and leadership.

The strategic development of ECS programs in research and education supports NSF themes and ENG priorities in nanotechnology, biocomplexity in the environment, human and social dynamics, sensors and sensor networks, information technology, mathematical sciences and the workforce for the 21st Century critical to the future of the Nation. ECS strengthens its programs through linkages to other areas of engineering, science, industry and government.

## II. ECS PROGRAM STRUCTURE

The ECS Division is organized into three programs that focus on research and education issues in device and component technologies, computational technologies and systems engineering:

(1) Electronics, Photonics and Device Technologies (EPDT)
(2) Controls, Networks and Computational Intelligence (CNCI)
(3) Integrative, Hybrid and Complex Systems (IHCS)

The technologies within each program are listed in Figure 1

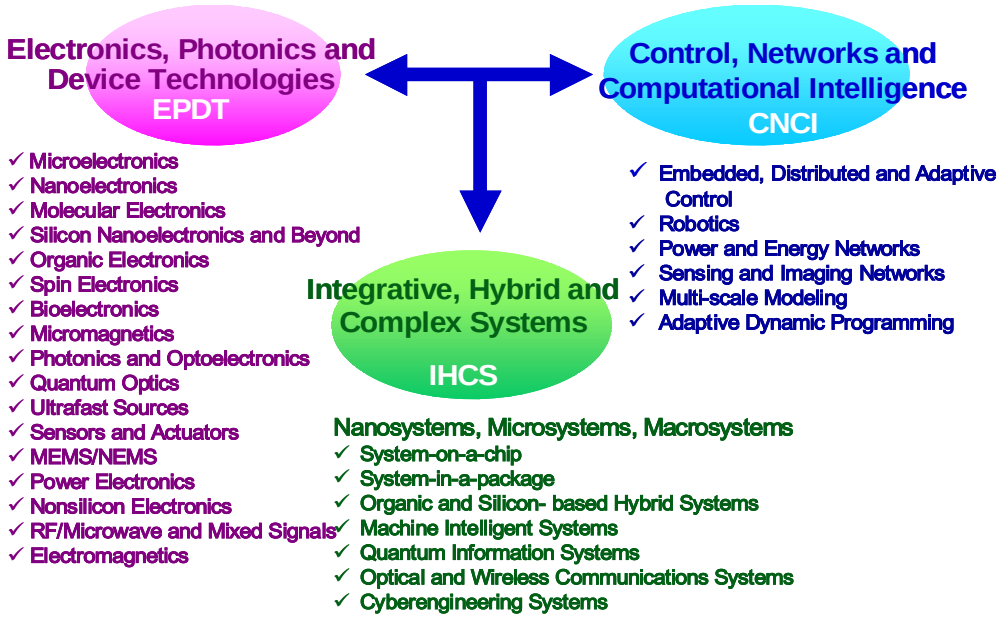



**Figure 1. ECS Programs**

**EPDT:** The EPDT program seeks to improve fundamental understanding of devices and components based on the principles of electronics, photonics, magnetics, electro-optics, electromagnetics, electromechanics and related physical phenomena. The program will invest in advancing the frontiers of spin electronics, molecular electronics, bioelectronics, nonsilicon electronics, organic electronics, photonics, optoelectronics, MEMS/NEMS, power electronics, and microwave and mixed signals, among others. EPDT will continue to support revolutionary electromagnetic materials and device solutions, RF integrated circuits, and reconfigurable antennas needed for telecommunications, telemedicine and other wireless applications. EPDT will enable discovery and innovation through new approaches to electronics, beyond the scaling limits of complementary metal oxide semiconductor (CMOS) by supporting research in Silicon Nanoelectronics and Beyond (SNB).

**CNCI**: The CNCI program supports design and analysis of hardware/software network architectures that includes control, communications and computation for domain-specific applications. CNCI will further invest in embedded, distributed and adaptive control, sensing and imaging networks, adaptive dynamic programming, multi-scale modeling, pattern recognition and intelligent agents to develop brain-like, networked architectures performing real-

time learning and self–organizing, and autonomous robotic control. CNCI also continues a strong emphasis on critical infrastructure aspects of electric power systems and grids, including integration of renewable and distributed energy systems into large power networks, and understanding of associated regulatory and economic structures.

**IHCS**: The IHCS program supports innovative research in areas that integrate physical devices with computational and communications networks in the design, development and implementation of new nano/micro/macro hybrid and complex systems with engineering solutions for diverse, domain-specific applications. The program supports fundamental research and technological challenges at all levels of systems integration. The program is intended to spur visionary systems-oriented activities in collaborative research and education environments. ECS has developed a new strategy in order to make an impact on the IHCS Program of the Division by identifying new systems integration thematic areas at the leading edge of science, engineering, technology and education to be the focus of the program. Some examples include system-on-a-chip, system-in-a-package, cyber systems, wireless and optical communications systems, quantum information systems, machine intelligent systems, and organic/silicon-based hybrid systems, among other complex dynamical systems. IHCS continually offers new challenges in interdisciplinary and multidisciplinary research and education.

## III. PROGRAM MANAGEMENT

ECS is staffed with eight Program Directors, a Senior Engineering Advisor and a support staff of eight. The ECS team includes:

***Program Staff***

- Usha Varshney (Acting Division Director, NSF Career Staff)
- Lawrence Goldberg (Senior Engineering Advisor, NSF Career Staff)
- Radhakisan Baheti, (Program Director, NSF Career Staff)
- Filbert Bartoli, (Program Director, NSF Career Staff)
- Rajinder Khosla, (Program Director, NSF Career Staff)
- Vittal Rao, (Program Director, IPA University of Missouri)
- Kevin Tomsovic, (Program Director, IPA Washington State University)
- Paul Werbos, (Program Director, NSF Career Staff)
- James Mink, (Expert, North Carolina State University)
- Kawthar Zaki, (Expert, University of Maryland)
- Leda Lunardi, (IPA, North Carolina State University)

***Support Staff***

- Gwendolyn Owens, Administrative Manager
- Delores Plater, Center Manager
- Tyffani Smith, Senior Program Assistant
- Jocelyn Sellers, Program Technology Specialist
- Angelo Horton, Senior Program Assistant
- Melyni McGriff- Williams, Acting Secretary of Division Director
- Cynthia Jackson, Senior Program Assistant (Detailed)
- Cassandra Queen, Senior Program Assistant (Detailed)
- Vacant, Program Assistant
- Vacant, Stay-in School Student

## IV. SUPPORTING PHILOSOPHY

ECS will continue to formulate Divisional Strategies consistent with NSF goals with an eye toward the aspirations of NAE as recounted in the "Engineer of 2020" and "Assessing the Capacity of the U. S. Engineering Research Enterprise" reports, the "Innovative America" National Innovation Initiative report of the Council on Competitiveness and the NSF Strategic Plan FY 2003-2008. Within the scope of interdisciplinary and multidisciplinary technical themes, the ECS Division places special emphasis on the identification of high-risk and high-payoff ideas in science and engineering through Small Grants for Exploratory Research (SGER) that are a very effective mechanism for this purpose. Program Directors are encouraged to seek these opportunities, and Division Director's funds are made available as an incentive for these awards. Group discussions of candidate SGER awards are particularly fruitful in identifying promising technical areas and high-payoff investments. ECS strongly encourages cooperative activities among academia, industry and national laboratories, as well as the use of shared facilities and international collaborations with special emphasis on industrial partnerships following Grant Opportunities for Academic Liaison with Industry (GOALI) guidelines.

The promotion of a diverse and talented workforce for the 21st Century will remain an important goal of ECS programs. ECS will emphasize funding of activities that integrate education and research. Special emphasis will continue to be placed on the CAREER program and the ADVANCE program. ECS will strengthen and enhance the REU and RET programs by encouraging and providing supplemental grants, and will remain committed to developing new and innovative programs, including summer programs that assist students and teachers in K-12 with knowledge, education and training. ECS will continue the funding of workshops to advance the frontiers of technology, and curriculum development programs in key technical areas. Further, ECS will encourage participation of women and underrepresented groups in its research and education programs.

## V. COLLABORATIVE ACTIVITIES WITH OTHER ENG DIVISIONS, NSF DIRECTORATES AND FEDERAL AGENCIES

Collaborative activities include Foundation-wide Centers, Workshops, Initiatives and WTEC Studies as follows:

### (a) Centers

ECS provides lead-management oversight for the following Centers:

- ERC: Computer Integrated Surgical Systems Technology at The Johns Hopkins University, Dr. Rajinder Khosla
- ERC: Extreme Ultraviolet Engineering Research Center at Colorado State University, Dr. Filbert Bartoli
- STC: Nanobiotechnology at Cornell University, Dr. Lawrence Goldberg
- NSEC: Center for Nanomechanical Systems at the University of California-Berkeley, Dr. Rajinder Khosla
- SLC: Center of Excellence for Learning in Education, Science and Technology at Boston University, Dr. Vittal Rao

ECS also provides financial support for Industry-University Cooperative Research Centers as well as technical support for

- ERC: Center for Power Electronic Systems at Virginia Polytechnic Institute and State University, Dr. Usha Varshney
- ERC: Collaborative Adaptive Sensing of the Atmosphere at University of Massachusetts-Amherst, Dr. James Mink

National Nanotechnology Infrastructure Network (NNIN) is an integrated partnership of 13 user facilities that serves the needs of the nanoscale research community. It provides users across the Nation with access to leading-edge tools, state-of-the-art instrumentation, and capabilities for characterization, design, fabrication, synthesis, simulation and integration to enable their individual research projects. NNIN was established by ENG in partnership with other NSF Research and Education Directorates (BIO, CISE, EHR, GEO, MPS, and SBE) in FY 2004, as shown in Figure 2. Dr. Lawrence Goldberg has the lead-management oversight responsibility for NNIN.

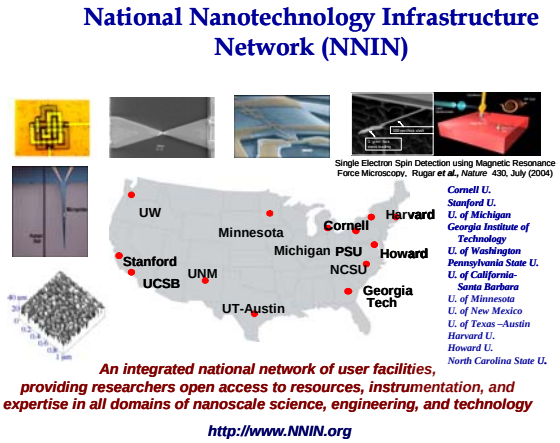



Figure 2. National Nanotechnology Infrastructure Network

### (b) Workshops

ECS supports research and education workshops in collaboration with other Divisions and Directorates at NSF and with other Federal agencies to strategize future funding investments and to develop initiatives at the forefront of visionary technologies. Some typical workshops supported during FY 2003 - 2005 are as follows:

- "Impact on Electrical Engineering Education of the Changing Global Environment due to Convergence of Technologies," organized by the Electrical and Computer Engineering Department Heads Association (ECEDHA) and the International Engineering Consortium (IEC), August 2005 (In-Planning)
- US-Japan Young Scientist Exchange program, 2005
- Research Opportunities in Cyberengineering/Cyberinfrastructure, 2004
- Self-Assembly and Self-Organization, with OAD, 2004
- NSF Tri-National Workshop - Advances in Micro and Nano Technologies for Sensing Applications, 2003
- Ultra-High Capacity Optical Communications and Networking, with CISE, 2003
- Technological Challenges for Flexible, Light-weight, Low-cost Organic Electronics, Photonics and Magnetics, with ONR, AFOSR and DARPA, 2003
- US-Japan Workshop on Tools and Metrology in Nanotechnology, 2003
- Workshop on Nanoengineering Education, 2003
- Second NSF Workshop for High School Teachers of Mathematics and Science, 2003
- Second Workshop for High School Students of Mathematics and Science, 2003
- ECS Workshop on Wireless Networked Sensor Systems, 2003
- Restructured Power System Reliability and Security, 2003

### (c) Initiatives

ECS has an established record of collaboration with other Divisions and Directorates at NSF and with other Federal agencies in developing initiatives in cutting-edge technology areas. As of December 2004, several active ECS awards have been made under the following initiatives:

- Photonic Technology Access program (PTAP), with DARPA
- Integrated Sensing, Computation and Networked Systems for Decision & Action (NSF 02-039)
- Spin Electronics for the 21st Century (NSF 02-036), with ENG/CMS, ENG/DMII ENG/CTS, ENG/BES and ONR
- Collaborative Research in Computational Neuroscience - CRCNS (NSF 02-018), with CISE, BIO, SBE, MPS and NIH
- Joint Investigation of Enabling Technologies for Space Solar Power (NSF 02-098), with ENG/BES, ENG/DMII, CISE/DIIS, EPRI and NASA
- Partnership in Electric Power Network Efficiency and Security I and II (NSF 02-041 and NSF 02-188), with ENG/BES, SBE/INT, EHR/DUE and ONR
- Ultra-High Capacity Optical Communications and Networking I (NSF 01-065), with ENG/BES, CISE and DARPA, and II (NSF 03-537), with ENG/CTS, ENG/DMII, MPS/DMS and DARPA
- Silicon Nanoelectronics and Challenges to Current CMOS Technology (NSF 03-043), with SRC
- Technological Challenges in Organic Electronics, Photonics and Magnetics (NSF 04-554), with ENG/CMS, ENG/CTS, ENG/BES, ENG/DMII, DARPA and AFOSR
- Sensors and Sensor Networks I, II and III (NSF 03-512, NSF 04-522, NSF 05-526), with other ENG Divisions, OPP and GEO
- Nanoscale Science and Engineering, NSF-wide Yearly Solicitation, Centers, Interdisciplinary Teams, Exploratory Research, Undergraduate Education

### (d) World Technology Evaluation Center (WTEC) Studies

ECS monitors scientific progress internationally through World Technology Evaluation Center (WTEC) studies, in collaboration with NSF Divisions and Directorates and other Federal Agencies. The goal of the studies is to measure U.S. Global R&D competitiveness to assist ECS in strategizing future investments. Recently, a study has been concluded in Spin Electronics, and there is an ongoing study in Robotics.

- Spin Electronics conducted in Japan and Europe, supported by NSF, DARPA, DoD, ONR and NIST
- International Assessment of Robotics R&D conducted in East Asia and Europe, supported by NSF (ENG, CISE, OISE) and NASA

## VI. REORGANIZATION OF ECS DIVISION

The ECS Division has undergone a top-down evaluation through a retreat and weekly staff meetings, to include vision and strategy, program analysis and alignment, budgetary considerations, personnel workload distribution, and interdivisional, interdirectorate and interagency programs and activities. This section deals with renaming of the IS program, the rationale for reassignment of Program Directors and anticipated outcomes.

### (a) Renaming of the Integrative Systems (IS) Program to Integrative, Hybrid and Complex Systems (IHCS)

ECS has renamed the Integrative Systems (IS) program to Integrative, Hybrid and Complex Systems (IHCS). The new name of the program provides better definition of the technological challenges supported by the program at all levels of systems integration with engineering solutions for domain-specific applications, and highlights the need for interdisciplinary and multidisciplinary novel systems approaches in research and education. Further, IHCS is consistent with the research priorities of the Engineering Directorate and is a better match with the other two EPDT and CNCI program names within ECS.

### (b) Rationale for Reassignment of Program Directors

The ECS Division is organized into three programs, (1) Electronics, Photonics and Device Technologies (EPDT), (2) Controls, Networks and Computational Intelligence (CNCI), and (3). Integrative, Hybrid and Complex Systems (IHCS). In reality in the past, the Division has operated with two major programs, EPDT and CNCI, and the former IS program was used passively. Each of the two programs, EPDT and CNCI, was managed by four Program Directors. The IS program was a secondary responsibility for all eight Program Directors, and Program Director assignments to Integrative Systems were somewhat nebulous. Analysis of the FY 2004 Awards Portfolio indicated about forty-nine percent of ECS investments were in the EPDT program, twenty-eight percent in the CNCI program, and less than three percent in the Integrative Systems program. However, due to demand for interdisciplinary and multidisciplinary approaches to new research areas with the convergence of micro/nano/info/bio/cogno technologies, and an increasing emphasis on integrative and complex systems engineering research in the 21st Century, it became critical that the IS program in the ECS Division have its own identity, with primary responsibility directly assigned to specific Program Directors rather than as a secondary responsibility of all eight Program Directors.

Consequently, it was reasonable and feasible to effect changes in the organizational structure, shown in Figure 3, to elevate the Integrative Systems program to have greater visibility within ECS. Therefore, it was appropriate that Program Directors be reassigned such that each of the two programs EPDT and CNCI, is managed by three Program Directors and IHCS be managed by two Program Directors as shown in Figure 4. This will ensure that the IHCS program will have the same visibility as the EPDT and CNCI programs. The reassignment will also create more balanced workloads among the Program Directors.

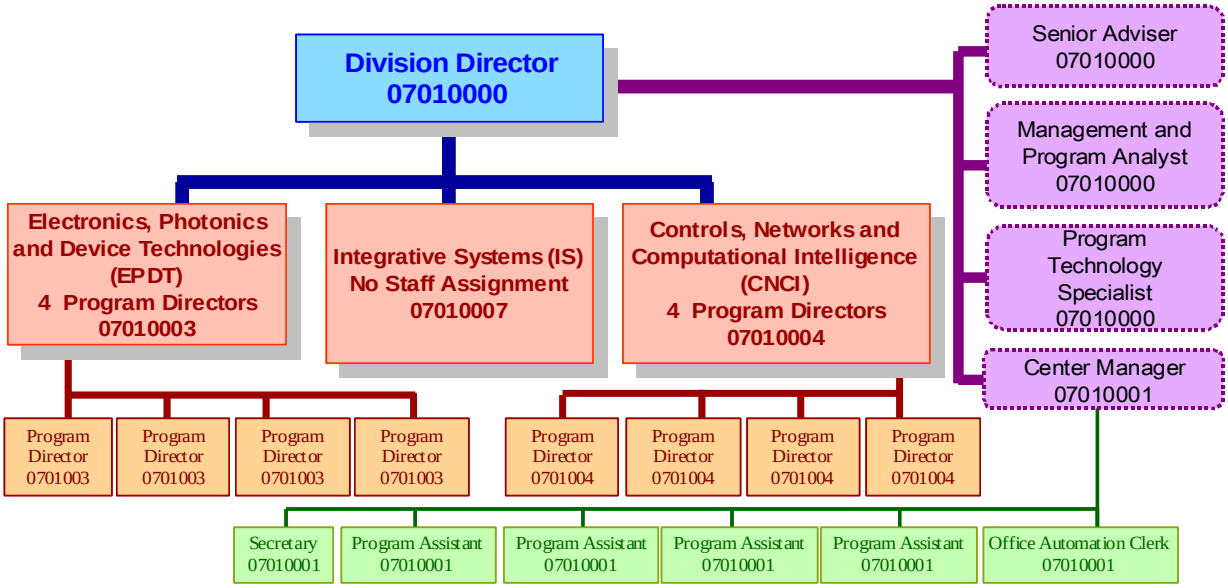
One of the two positions in IHCS will focus on the area of Communication Systems technologies, while the other will address in Micro- and Nanosystems. The Program Director in charge of Communications Systems will be responsible for both wireless and optical communications systems. Similarly, the Program Director in charge of Micro and Nanosystems will also support Cyber Systems and related areas. Two Program Director positions for IHCS have been drawn from the EPDT and CNCI programs.

The reorganization has not affected the workload of the Program Support Staff. The Division continues to operate under the current support structure. There were no displacements of the support staff from their current assignments. In addition, the ECS Administrative Officer and the ECS Center Manager concurred with this assessment.

### (c) Anticipated Outcomes

As a result of the proposed program restructuring and Program Director reassignments, it is anticipated that the following benefits will accrue to the Division:

- Elevation of the IHCS program will provide a greater emphasis on systems engineering research and education within ECS.
- Emerging areas in integrated systems research will be well defined for the external community.
- ECS will have a balanced portfolio consisting of three active research programs.
- The new Communications Systems position in the IHCS program will better define the communications technologies in the Electrical and Communications Systems Division.
- The establishment of a Communications Systems position in IHCS will balance the workload of EPDT Program Directors.
- Reorganization will balance the overall workload among Program Directors in ECS.
- The increased emphasis on IHCS will bring the ECS Division more in line with the research priorities of the Engineering Directorate.
- The proposed reorganization strategy will increase both productivity and efficiency of the ECS Division.




# Program Directors

**Dr. Usha Varshney, Acting Division Director**

**Dr. Lawrence Goldberg, Senior Engineering Advisor**

**National Nanofabrication Infrastructure Network**

## Electronics, Photonics and Device Technologies (EPDT)

**Dr. Filbert Bartoli**
Optoelectronics; Photonics; Ultrafast Technologies; EUV; Nanophotonics

**Dr. Rajinder Khosla**
Micro/Nanoelectronics; NEMS/MEMS Sensors; Bioelectronics

**Dr. James Mink**
Micro/Nanoelectronics; Molecular Electronics; Spin Electronics; Organic Electronics; Power Electronics; Micromagnetics

**Vacant**
Optical and Wireless Communications; Mixed Signals Technologies

## Controls, Networks and Computational Intelligence (CNCI)

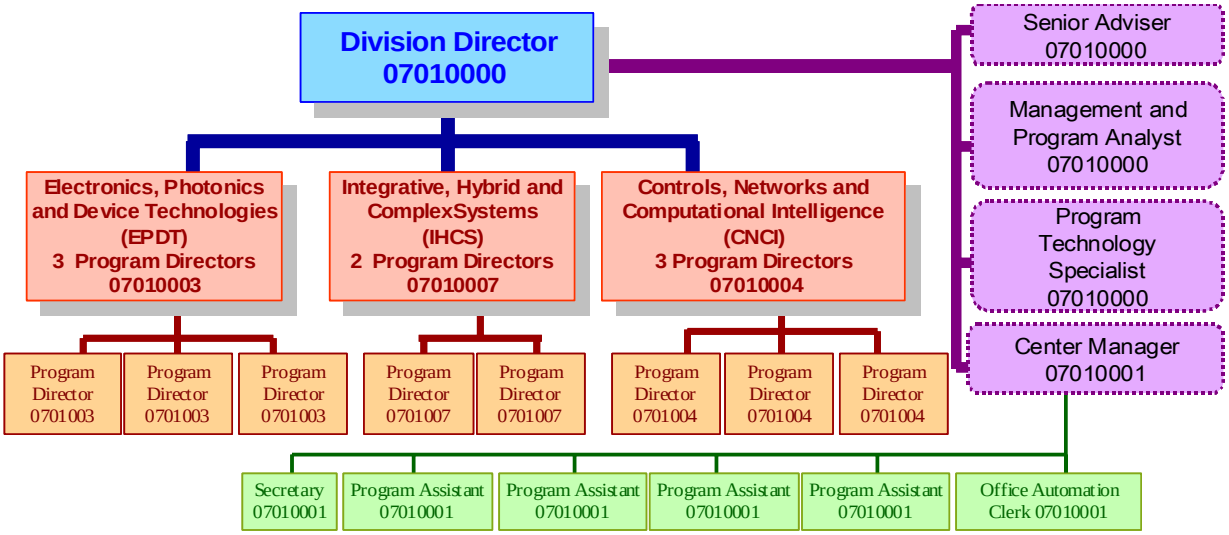
**Dr. Radhakisan Baheti**
Embedded Control, Control Theory and Internet, Biomedical Systems; Robotics

**Dr. Vittal Rao**
Integrated Sensor Networks; Autonomic Communications and Networks; Computational Video and Imaging Networks; Cyberinfrastructure and Cybersecurity

**Dr. Kevin Tomsovic**
Power and Energy Networks; Distributed Networks; Economics of Power Grids; Security and Reliability of Critical Infrastructures

**Dr. Paul Werbos**
Neural Network; Learning and Self-organizing Computations; Biologically Inspired Computation

**Figure 3. ECS Organization Structure.**




# Program Directors

## Dr. Usha Varshney, Acting Division Director

## Dr. Lawrence Goldberg, Senior Engineering Advisor

**National Nanofabrication Infrastructure Network**

### Electronics, Photonics and Device Technologies (EPDT)

**Dr. Filbert Bartoli**
Optoelectronics; Photonics; Ultrafast Technologies; EUV; Nanophotonics

**Dr. Rajinder Khosla**
Micro/ Nanoelectronics ; NEMS/MEMS Sensors; Bioelectronics

**Dr. James Mink**
Micro/ Nanoelectronics ; Molecular Electronics; Spin Electronics; Organic Electronics; Power Electronics; Micromagnetics

### Controls, Networks and Computational Intelligence (CNCI)

**Dr. Radhakisan Baheti**
Embedded, Distributed, and Adaptive Control; Robotics; Sensor Networks

**Dr. Kevin Tomsovic**
Power and Energy Networks; Renewable and Alternative Energy Sources; Economics of Power Grids; Security and Reliability of Critical Infrastructures

**Dr. Paul Werbos**
Neural Network; Learning and Self-organizing Computations; Adaptive Dynamic Programming

### Integrative, Hybrid and Complex Systems (IHCS)

**Dr. Vittal Rao**
Integrative Nano and Micro Systems; Complex Dynamical Systems; Machine Intelligent Systems; and Cyber Systems

**Dr. Leda Lunardi**
Optical and Wireless Communications Systems; Mixed Signals Technologies

**Figure 4. ECS Reorganization Structure**

## VII ECS INVESTMENTS IN FUTURE TECHNOLOGIES

ECS future investments that will have a significant technological impact in meeting ENG and NSF objectives will include the following technology areas: (a) Integrative and Complex Systems; (b) Communications and Networks Systems; (c) Nanoelectronics, Nanophotonics and Nanomagnetics; (d) Cyberengineering and Cyber Systems; (e) Critical Infrastructure Technologies and Systems; (f) Flexible Electronics; and (g) other focused areas.

### (a) Integrative and Complex Systems

Research opportunities for ECS include integrative and complex engineered systems that are ubiquitous and reconfigurable, and that interact with the environment. The goal is to improve performance, reduce downtime and provide new functionality by integrating advances in sensing, computation, communications, control, learning and cognitive sciences. Networks of information-gathering devices are viewed as critical in meeting a broad range of societal challenges in the 21st Century, including those associated with global warming, healthcare, transportation, manufacturing productivity, environmental quality, hazards mitigation and homeland security. In medicine, complex systems will combine sensors, actuators, micropower circuits, embedded computing and wireless interfaces to realize implantable systems for drug delivery on demand, image-guided microsurgical tools, wearable health monitors and low-cost diagnostic devices. Integrative and complex systems will facilitate widely distributed precision measurement of air quality for a cleaner environment and homeland security; smart adaptive manufacturing systems; smart power grids that are reliable, efficient and sustainable; and low power associated with data acquisition, storage, embedded computing, and wireless transmission of information. The realization of integrative and complex systems offers challenges at many levels. ECS envisions complex systems that seamlessly integrate physical devices with networks and computational intelligence in ways that optimize the resulting system performance. Integrative and complex systems will explore research breakthroughs needed to facilitate a broad array of engineering systems.

### (b) Communications and Network Systems

ECS will support research in optical and wireless communications networks to enable continued bandwidth growth and to provide for national needs in a globally connected society. This permits extending access to high-speed communications to users in the home, classroom and workplace, while at the same time laying the foundations for communications networks that interface with massively distributed networks of sensors and embedded intelligent appliances and systems. In order to sustain the demand for bandwidth growth, fundamental advances in components and systems are required to lower component costs, reduce power consumption, and to enable affordable applications. Eliminating the broadband access bottleneck (first-mile/last-mile solution) will require seamless integration of optical and wireless network technologies. Research will address decision-making challenges in dynamic, uncertain and stochastic network environments, arising from communications network constraints and from uncertainty in physical processes and measurements. The mathematical foundations for managing uncertainty in distributed networks and optimizing the optical-wireless interface will be investigated. Broadband optical and wireless communications provide opportunities for collaboration and partnering within NSF and with other Federal agencies.

### (c) Nanoelectronics, Nanophotonics and Nanomagnetics

Research will explore fundamental understanding of materials, processes, devices, design and architecture challenges faced by the semiconductor industry at, and beyond, the time horizons of the International Technology Roadmap for Semiconductors. Further research will determine ultimate limits to scaling of features and alternative physical principles and technologies for

devices employed in sensing, storage, communication and computation, including revolutionary biological, molecular, magnetic and photonic devices and systems. To enable discovery and innovation of new approaches in electronics, beyond the limits of CMOS technology, NSF (ENG, MPS, CISE) has embarked, under ECS leadership, on collaborative efforts with the semiconductor industry and Semiconductor Research Corporation (SRC) on the theme of Silicon Nanoelectronics and Beyond (SNB).

### (d) Cyberengineering and Cyber Systems

Cyberengineering seeks to focus on design, integration and implementation of multi-scale and multi-level complex systems. Research activities in Cyberengineering will integrate physical devices with distributed sensing and actuation, communications, storage and computation for control of complex systems and networks. Cyberengineering will enable visualizing, analyzing and reconfiguring of complex systems to develop reliable and agile infrastructures for domain-specific applications

Examples of Cyber systems include: integrated hybrid optical and electronic systems for high-speed computation and communications; multi-scale dynamic system integration for real-time monitoring and control of engineered complex and hybrid systems; blackout-free electric power grid with integrated power, communication and self-organizing networks; ambient intelligent systems' networks for homes, hospitals and malls of the future; networked intelligent surveillance systems for security of critical infrastructures; computer-integrated telemedicine and robotic surgical systems; and globally interactive environments for engineering education.

Cyberinfrastructure will require partnerships with all ENG divisions, so that ECS will join with other ENG divisions to support Cyber research to enable visualizing, analyzing and reconfiguring complex systems for developing reliable and agile infrastructures. A balanced program of Cyberengineering within ENG will include an aggressive program to advance enabling Cybertechnologies, as well as focused application-specific systems research appropriate to each engineering discipline. While ECS will address application-specific problems, such as the power grid, communications and information technology networks, its strength will be in advancing enabling technologies for Cyberinfrastructures. Other ENG divisions will have a greater focus on application-specific systems research supported by their disciplinary programs. As with all interdisciplinary research, it is critical that the strength of contributing disciplines be maintained. Accordingly, ECS will play a major role in promoting enabling Cybertechnologies. ECS will provide greater visibility to engineering involvement in Cyberengineering technologies that form the basis of Cyberinfrastructure. ECS will also collaborate with other ENG divisions and the NSF Directorates to establish further research directions.

### (e) Flexible Electronics

Polymeric electronics, integrated to intrinsic and hybridized systems, represent a highly promising interdisciplinary area of technology that will provide greatly increased functionality and potential to meet future challenges of scalability, flexibility, low power consumption, light weight and reduced cost. Continued advances in organic-based systems are critically important in sustaining the Nation's economic growth, particularly in the areas of telecommunications, information technology, wearable microprocessors, memories, solid-state lighting, alternate power generation sources and healthcare engineering. Research advances in enabling engineering technologies, including theoretical and experimental aspects of charge transport properties and device physics, processing techniques, interface engineering, device design, circuits and packaging, metrology and diagnostic tools, architectures and systems engineering promise breakthroughs that can have a pervasive impact on technological developments.

### (f) Critical Infrastructure Technologies and Systems

ECS core competencies lie at the center of research in protecting and upgrading the Nation's critical infrastructure, including technologies that support electric power, telecommunications, Internet and general commerce. Advances in control and computational intelligence for recognizing and responding to threats are at the foundation of truly robust and secure systems. Recent thrusts in sensors and sensor networks are vital to recognizing possible failures of physical infrastructures and for providing inputs required for more efficient management. Improved adaptation and efficiency of the electric power grid will be central to the ability to accelerate the deployment of renewable energy, distributed power generation, intelligent appliances and hybrid automobiles. Improved power electronics and other key components of the electric economy offer other crucial opportunities for ECS technologies. ECS will seek collaborations with other NSF Divisions and Directorates, as well as with other Federal agencies.

### (g) Other Focus Areas

ECS has continuing interest in investing in quantum engineering, diagnostic and implantable devices, hydrogen economy, adaptive dynamic programming, and neuro-dynamic control and learning for complexity. The anticipated changing emphasis within the ECS Award Portfolio will require a delicate balance between the continuity of currently funded technical areas and growth of emerging technologies. This reshaping of the ECS Award Portfolio will result in greater funding in communications systems technologies, as well as nano-, micro-, macro- hybrid and complex systems engineering with engineering solutions for various application domains.

## VIII. RECENT DIVISIONAL ACTIVITIES

Recently, the ECS Division was involved in preparation for the ECS Committee of Visitors meeting and on workshop on Integrative Complex Systems. A third activity has been a submission of a Graduate Research Supplement for Women and Underrepresented Minority Ph.D students. These activities are discussed in the following subsections. The section also describes the statistical analysis of ECS investments.

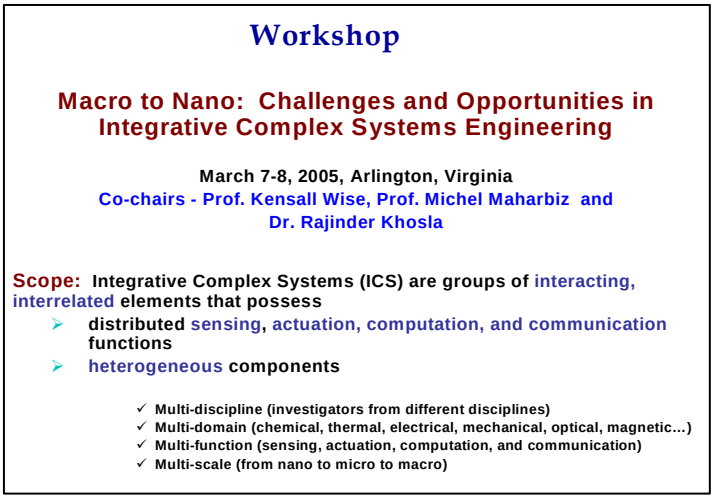
### (a) Committee of Visitors Meeting

The ECS Committee of Visitors (CoV) meeting took place on March 18-20, 2005. ECS participated in the 2005 CoV meeting, following a several-month preparatory run-up to the meeting. The CoV was chaired by Prof. Gary May from Georgia Institute of Technology, with Prof. Robert Trew from North Carolina State University as Vice-chair. Thirteen other CoV members included representation from university (12), industry (2) and government (1) as listed in Appendix (a). The CoV also displayed diversity and geographical representation. The CoV Meeting Agenda is shown in Appendix (b).

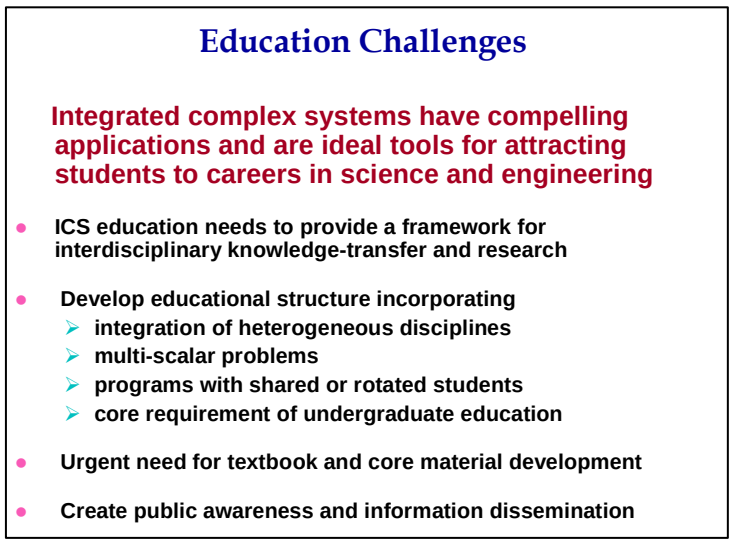
By way of summary, the charge to the CoV was given by Dr. John Brighton, Assistant Director for Engineering, a comprehensive overview was given by Dr. Usha Varshney, Acting Division Director, and Program Directors and the Senior Engineering Advisor made presentations in their respective programs.

### (b) Workshops

The workshop on "Macro to Nano: Challenges and Opportunities in Integrative Complex Systems Engineering", held on March 7-8, 2005, in Arlington, Virginia, was chaired by Prof. Kensall Wise from the University of Michigan, Prof. Michel Maharbiz from the University of Michigan, and Dr. Rajinder Khosla from the National Science Foundation. The workshop was attended by fifty external participants and fifteen NSF Personnel. The goal of the workshop was to identify thematic areas within the IHCS program in ECS. The preliminary findings of the workshop are outlined below. The final report from the workshop will provide considerable information to ECS in support of its strategy to enhance the visibility and elevate the level of IHCS within the Division, consistent with the research priorities of the Directorate for Engineering.







### (c) Graduate Research Supplements

According to the 2003 ASEE report on engineering faculty, there are 9.9% women, 2.0% African American, and 3.2% Hispanic tenured/tenure-track teaching faculty members, with little variation from 2001 to 2003. In a recent NSF study, it was found that among engineering faculty only 13.7% of Assistant Professors were women. This figure dropped to 6.3% at the Associate Professor level and to an even lower 1.4% at the Full Professor level. Comparable percentages for African-American faculty are 2.9%, 2.8% and 1.5%, while percentages for Hispanic faculty members are 4.6%, 4.0% and 2.2%. The percentages of tenured/tenure track teaching faculty in electrical engineering are 8.0% women, 2.6% African American, and 4.7% Hispanic. Similarly, the percentages for environmental engineering are 14.7% women, 4.9% African American, and 2.9% Hispanic and for biomedical engineering are 16.6% women, 1.5% African American, and 1.8% Hispanic. With such exceedingly low levels of women and minority faculty, ECS and BES recognize that women and underrepresented minorities represent a significant untapped technical resource for the Nation.

In order to broaden participation of women and underrepresented minorities in advanced academic and professional careers, ECS in collaboration with BES has initiated a Graduate Research Supplement (GRS) pilot program for Ph.D. students majoring in electrical engineering, or biomedical/biochemical/environmental engineering, in on-going research programs funded by ECS or BES. It is anticipated that GRS will help in the development of intellectual synergy between faculty and students, will provide faculty with the opportunity to involve additional graduate students in on-going research programs, will lead to greater retention of students in the targeted populations, and will foster a learning and career advancement environment that supports students from underrepresented groups.

The supplement was posted on the ECS or BES websites on May 10, 2005.

http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf05586

### (d) Statistical Analysis of the ECS Divisional Investments

In strategizing future activities of the Division, it is informative to evaluate the status and trends of ECS programs in the recent past. Several examples are given in Figures 5-8, for ECS performance relative to the ENG Directorate and NSF as the whole. Figure 5 shows the Career proposal-funding rate decreasing from 31% in FY 2001 to 12% in FY 2005, due to increased proposal activity and availability of funds. A similar decreasing trend is evident for ENG and NSF. Figure 6 shows a decline in funding rates from 34% in FY 1999 to 14% in FY 2004. ECS expects a funding rate of 12% for FY 2005 based on preliminary data. Similar trends are observed in both ENG and NSF. Figure 7 shows that the average grant size in ECS is consistently lower than the average grant size in ENG and NSF. ECS had an increase in budget by 15% from FY 2002 to FY 2004. However, this increase was in NSF and ENG priority areas as compared to ECS core program funds, as shown in Figure 8. Despite a budget decrease of 3.9% in FY 2005, ECS has made substantial progress in redressing the budget imbalance that existed between committed and discretionary funds, and hopes to realize further improvement in FY 2006.

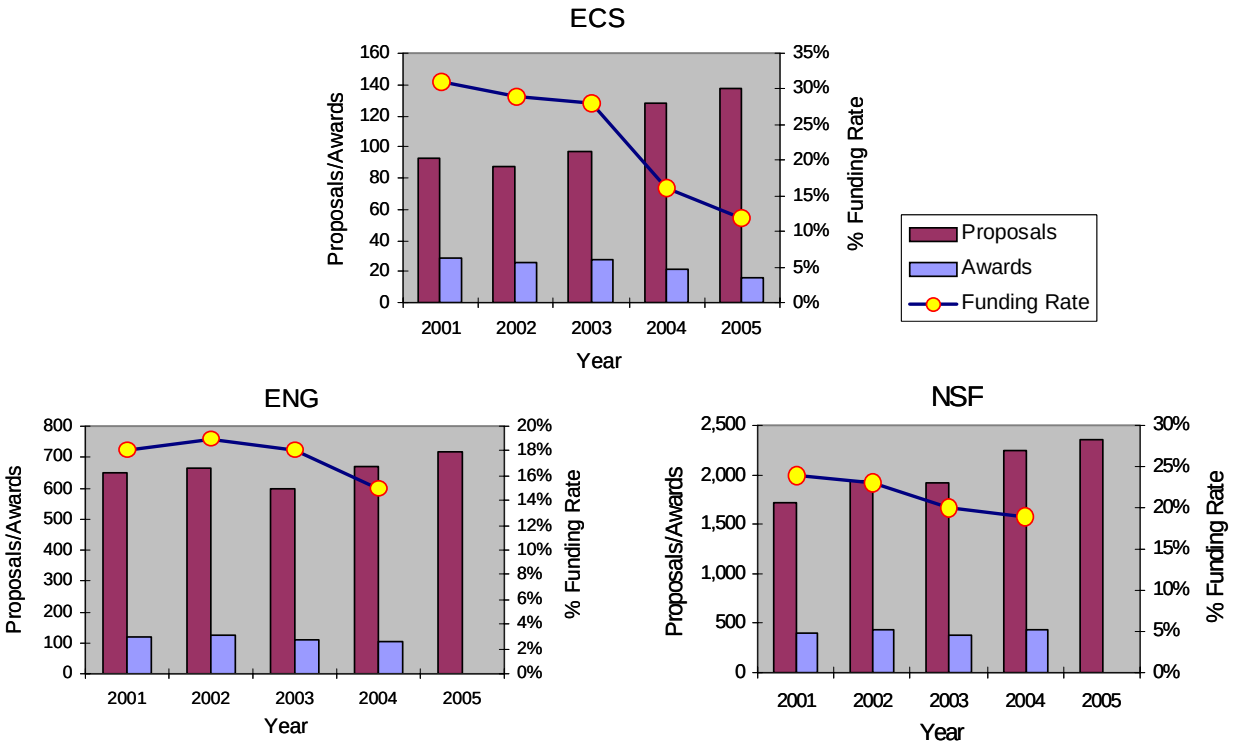



Figure 5. CAREER Awards Summary

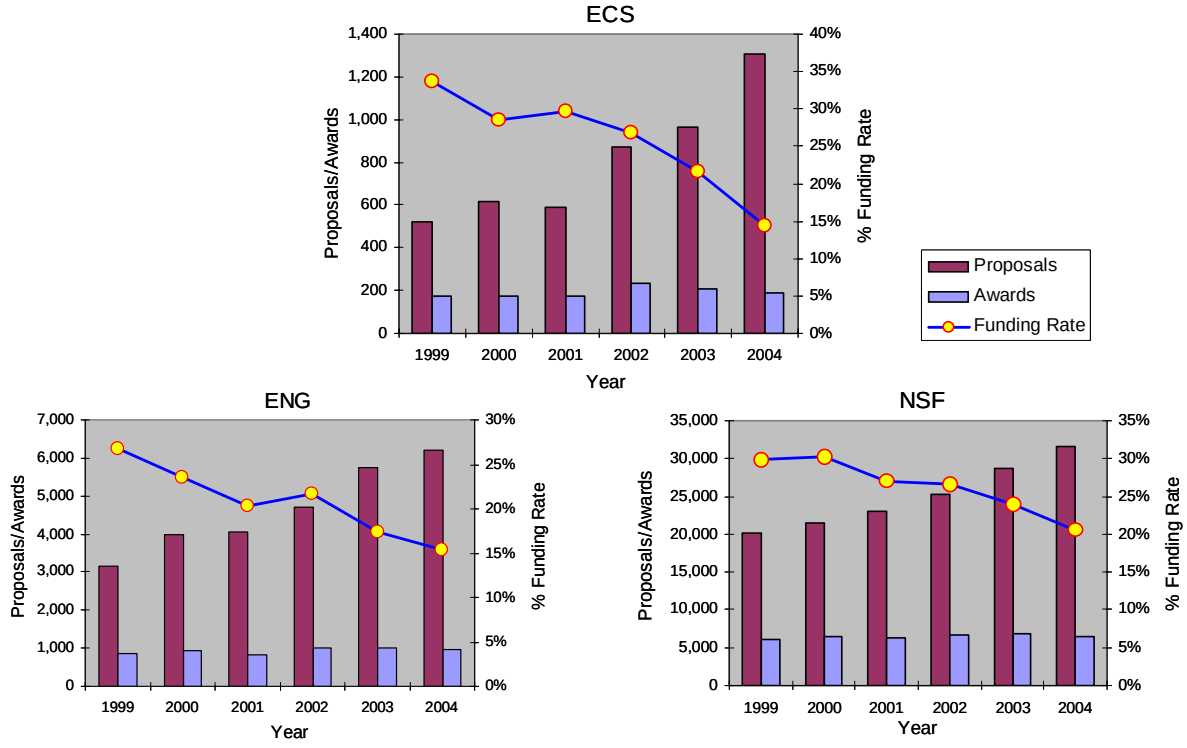



Figure 6. Funding Rates for Research Grants for FY 1999 to 2004

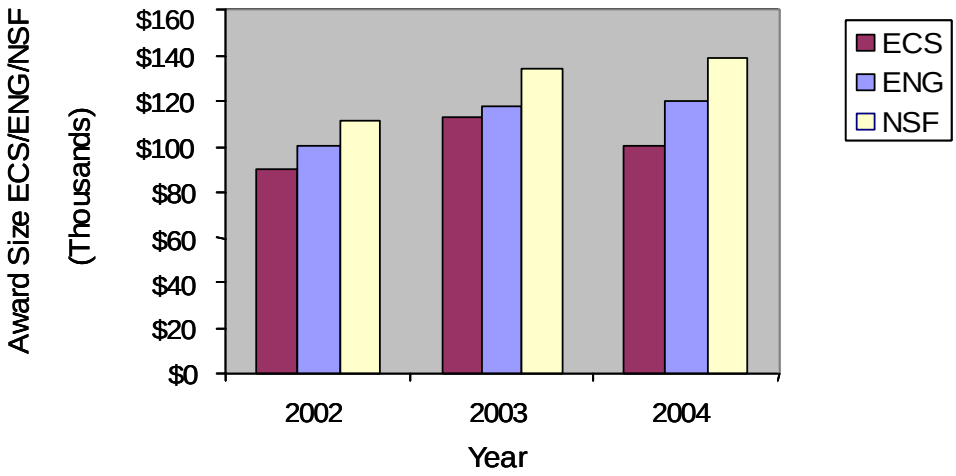



Figure 7. ECS Awards Size for FY 2002 to 2004

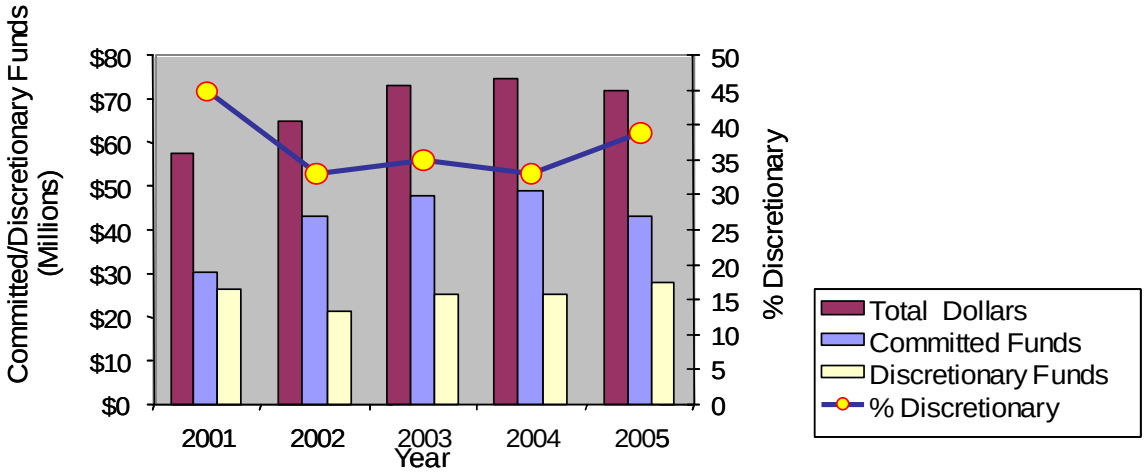



Figure 8. ECS Budget Profile for FY 2001-2005

## IX. ACKNOWLEDGEMENTS

The Acting Division Director wishes to thank the ECS Program Directors and Support Staff for participating in the development of the ECS Strategic Plan.

## X. REFERENCES

(a) "*The Engineer of 2020: Visions of Engineering in the New Century*", National Academy of Engineering, The National Academies Press, September 2004.

(b) "*Assessing the Capacity of the U.S. Engineering Research Enterprise*", Draft Report, National Academy of Engineering, The National Academies Press, January 2005.

(c) "*Innovative America: National Innovation Initiative Report*", Council on Competitiveness", December 2004.

(d) *NSF Strategic Plan FY 2003-2008*.

**APPENDICES**
**APPENDIX (a): List of CoV Members**

## *National Science Foundation*
## *Committee of Visitors (CoV) for FY 2002-2004*
## *Division of Electrical and Communications Systems*

***March 16-18, 2005***
**Room 555, Stafford II**

### *ECS CoV Members*

1. **Bergman, Keren**
   **Columbia University**
2. **Boyd, Stephen**
   **Stanford University**
3. **Cohn, Robert**
   **University of Louisville**
4. **Gabella, Patricia**
   **Sematech, Texas**
5. **Hagness, Susan**
   **University of Wisconsin-Madison**
6. **Hall, Katherine**
   **Wide Net Technologies**
7. **Heydt, Gerald**
   **Arizona State University**
8. **Indeck, Ronald**
   **Washington University, MO**
9. **Long, Stuart**
   **University of Houston**
10. **May, Gary (Chair)**
    **Georgia Institute of Technology**
11. **Meyyappan, Meyya**
    **NASA Ames Research Center**
12. **Principe, Jose**
    **University of Florida**
13. **Tranter, William**
    **Virginia Polytechnic Institute and State University, Virginia**
14. **Trew, Robert (Vice-Chair)**
    **North Carolina State University**
15. **White, Marvin**
    **Lehigh University**

**APPENDIX (b): CoV Agenda**

# *National Science Foundation*
# *Committee of Visitors (CoV) for FY 2002-2004*
# *Division of Electrical and Communications Systems*

***March 16-18, 2005***
**Room 555, Stafford II**

## Agenda

## *Wednesday, March 16, 2005*

| | |
|---|---|
| **8:30 AM** | **Welcome, Introduction of CoV Members**<br>**Dr. Usha Varshney, Acting Division Director** |
| **8:45 AM** | **Charge to CoV**<br>**Dr. John Brighton, Assistant Director for Engineering** |
| **9:00 AM** | **Overview of the Electrical and Communications Systems Division**<br>**Dr. Usha Varshney** |
| **9:45 AM** | **The Government Performance and Results Act (GPRA) and Conflict-of-Interest (COI) Briefing**<br>**Ms. Joanne Culbertson, GPRA**<br>**Dr. Lawrence Goldberg, ECS Conflicts Officer** |
| **10:00 AM** | ***Break*** |
| **10:15 AM** | **Presentations by Program Directors of Electronics, Photonics and Device Technologies (EPDT) Program**<br>**Dr. Rajinder Khosla**<br>**Dr. Filbert Bartoli** |
| **11:00 AM** | **Presentations by Program Directors of Controls, Networks and Computational Intelligence (CNCI) Program**<br>**Dr. Kishan Baheti**<br>**Dr. Paul Werbos**<br>**Dr. Vittal Rao**<br>**Dr. Kevin Tomsovic** |
| **12:00 Noon** | **National Nanotechnology Infrastructure Network (NNIN)**<br>**Dr. Lawrence Goldberg, Senior Engineering Advisor** |
| **12:15 PM** | ***Lunch*** |
| **1:30 PM** | **COI Declarations, CoV Report Plan and CoV Team Assignments**<br>**Dr. Gary May, CoV Chairperson** |

## *Wednesday, March 16, 2005 ECS CoV (Continued)*

| | |
|---|---|
| **2:-00 PM** | **How to Read Jackets (Ms. Gwendolyn Owens)**<br>**EPDT – Room 545**<br>**CNCI – Room 595**<br>**Integrative Systems (IS) combined with EPDT and CNCI** |
| **2:30 PM** | **Review of Jackets – Section A of CoV Report** |

| | |
|---|---|
| | **EPDT – Room 545**<br>**CNCI – Room 595**<br>**Integrative Systems (IS) combined with EPDT and CNCI** |
| **3:45 PM** | ***Break*** |
| **4:00 PM** | **Review of Jackets – Section B - People**<br>**EPDT – Room 545**<br>**CNCI – Room 595**<br>**Integrative Systems (IS) combined with EPDT and CNCI** |
| **6:00 PM** | ***Adjourn for Group Dinner***<br>***Matsutake*** **(4121 Wilson Blvd., Next to NSF Stafford II)** |

## *Thursday, March 17, 2005*

| | |
|---|---|
| **8:00 AM** | ***Refreshments*** |
| **8:30 AM** | **Review of Jackets – Section B – Ideas**<br>**EPDT – Room 545**<br>**CNCI – Room 595**<br>**Integrative Systems combined with EPDT & CNCI** |
| **10:15 AM** | ***Break*** |
| **10:30 AM** | **Review of Jackets – Section B – Tools**<br>**ECS Division – Room 555** |
| **11:15 AM** | **Review of Jackets – Section B – Outcome Goals**<br>**ECS Division – Room 555** |
| **12:00 PM** | ***Lunch*** |
| **1:00 PM** | **Committee Discussion on Draft CoV Report** |
| **3:30 PM** | ***Break*** |
| **3:45 PM** | **Completion and Agreement on CoV Report** |
| **5:00 PM** | **ECS Future Technology Emphasis (CoV Members)** |
| **6:00 PM** | ***Adjourn*** |

**Friday, March 18, 2005**
**Room 555, Stafford II**

| | |
|---|---|
| **8:00 AM** | ***Refreshments*** |
| **8:30 AM** | **Presentation of CoV findings to the ECS Division Director and Program Directors** |
| **9:45 AM** | ***Break*** |
| **10:00 AM** | **Prepare CoV Report for Presentation to ENG Assistant Director** |
| **11:00 AM** | **Meeting of CoV with Dr. John Brighton, AD/ENG, and Dr. Michael Reischman, DAD/ENG** |
| **11:30 AM** | ***Adjourn*** |