Engineering at NSF: Directions and Opportunities

A Presentation for the University of Arizona
April 2, 2009

Michael M. Reischman
Deputy Assistant Director
Directorate for Engineering

Staff Offices

- Office of Management and Budget
- Science Advisor, Office of Science and Technology Policy
- Other Boards and Councils

Major Departments

- Homeland Security
- Agriculture
- Commerce
- Defense
- Energy
- Health and Human Services
- Interior
- Transportation

Independent Agencies

- National Science Foundation (NSF)
- National Aeronautic and Space Administration
- Environmental Protection Agency
- Nuclear Regulatory Commission
- Smithsonian Institution
- Other Agencies

NSF's Origin, Mission, and Goals

- Independent agency established in 1950 by NSF Act:

  "To Promote Progress of Science," and "Advance National Health, Prosperity, and Welfare," and "Secure the National Defense"
- Support basic research and education across science and engineering
- Uses grant mechanism
- Maintains low overhead and extensive automation
- Discipline-based structure with cross-disciplinary mechanisms
- Uses "rotators" or IPAs
- Works with the National Science Board

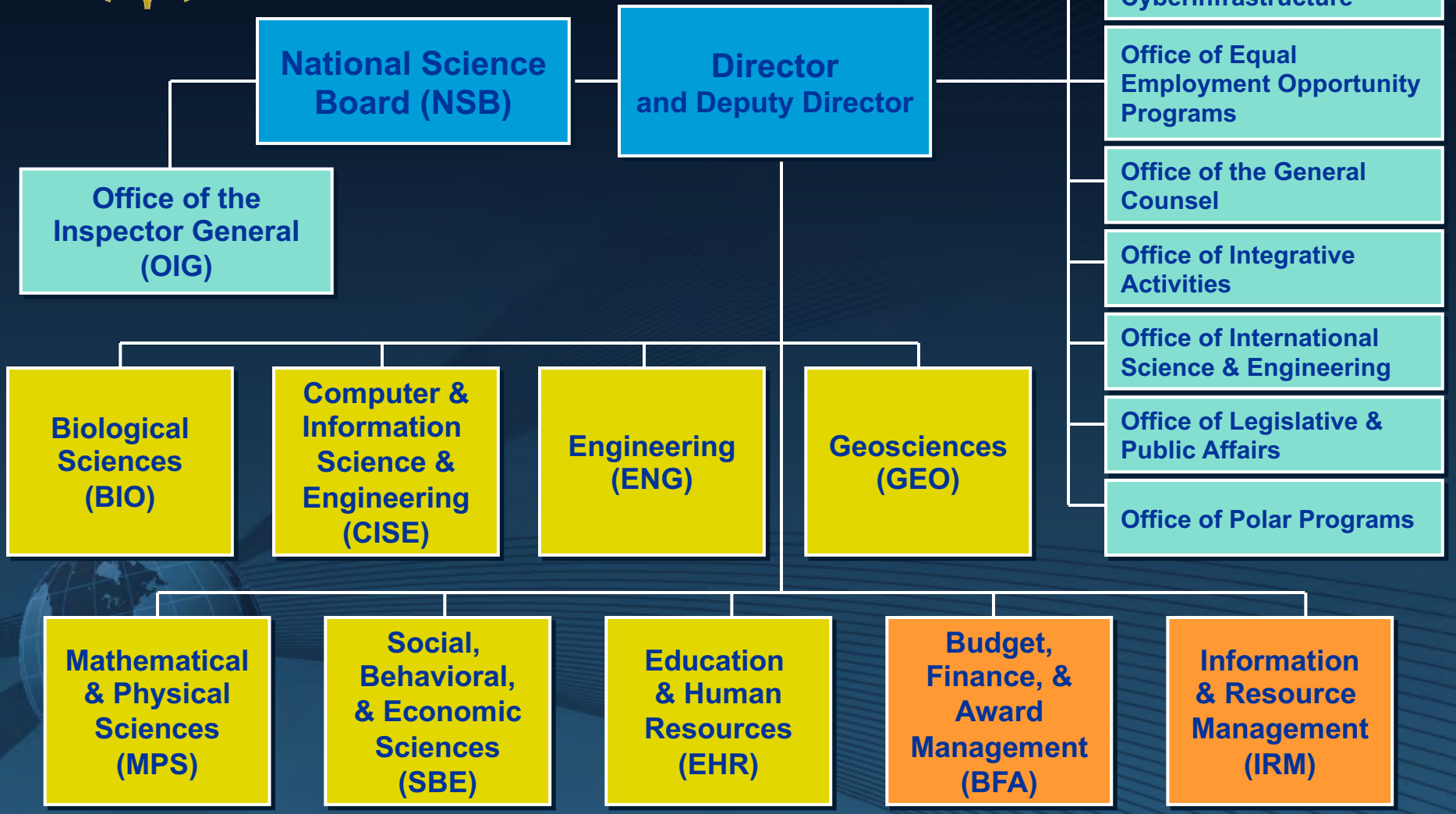
NSF by the Numbers

$6.13 B	FY 2008 Appropriations received
$6.49 B	FY 2009 Current Plan
4%	NSF's share of total annual federal spending for R&D
44%	NSF's share of federal funding for non-medical basic research at academic institutions
1,900	Colleges, universities, and other institutions receiving NSF funding in FY 2008
11,162	Competitive awards funded in FY 2008
44,000	Students supported by NSF Graduate Research Fellowships since 1952
44,400	Proposals evaluated in FY 2008 through a competitive merit review process
197,000	People NSF supports directly (researchers, postdoctoral fellows, trainees, teachers, and students)
248,000	Proposal reviews conducted in FY 2008
1,300	Approximate number of full-time NSF personnel
150	Approximate number of NSF "rotators" (IPAs)

NSF's Vision

Advancing discovery, innovation, and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering

National Science Foundation



OSTP/OMB 2008 Research Priorities*

- Homeland Security
  - Prevention, Detection, & Remediation of NCB Threats
  - Medical Countermeasures and Biosurveillance Networks
- Energy Security
  - Diversified Energy Sources and Renewables
- Advanced Networking and High-End Computing
  - Supercomputing & Cyberinfrastructure
- National Nanotechnology Institute
- Environment
  - Global Climate Change Science and Technology
  - Global Supply of Fresh Water
- Understanding Complex Biological Systems

*See www.ostp.gov/html/M-06-17.pdf

NAE Grand Challenges

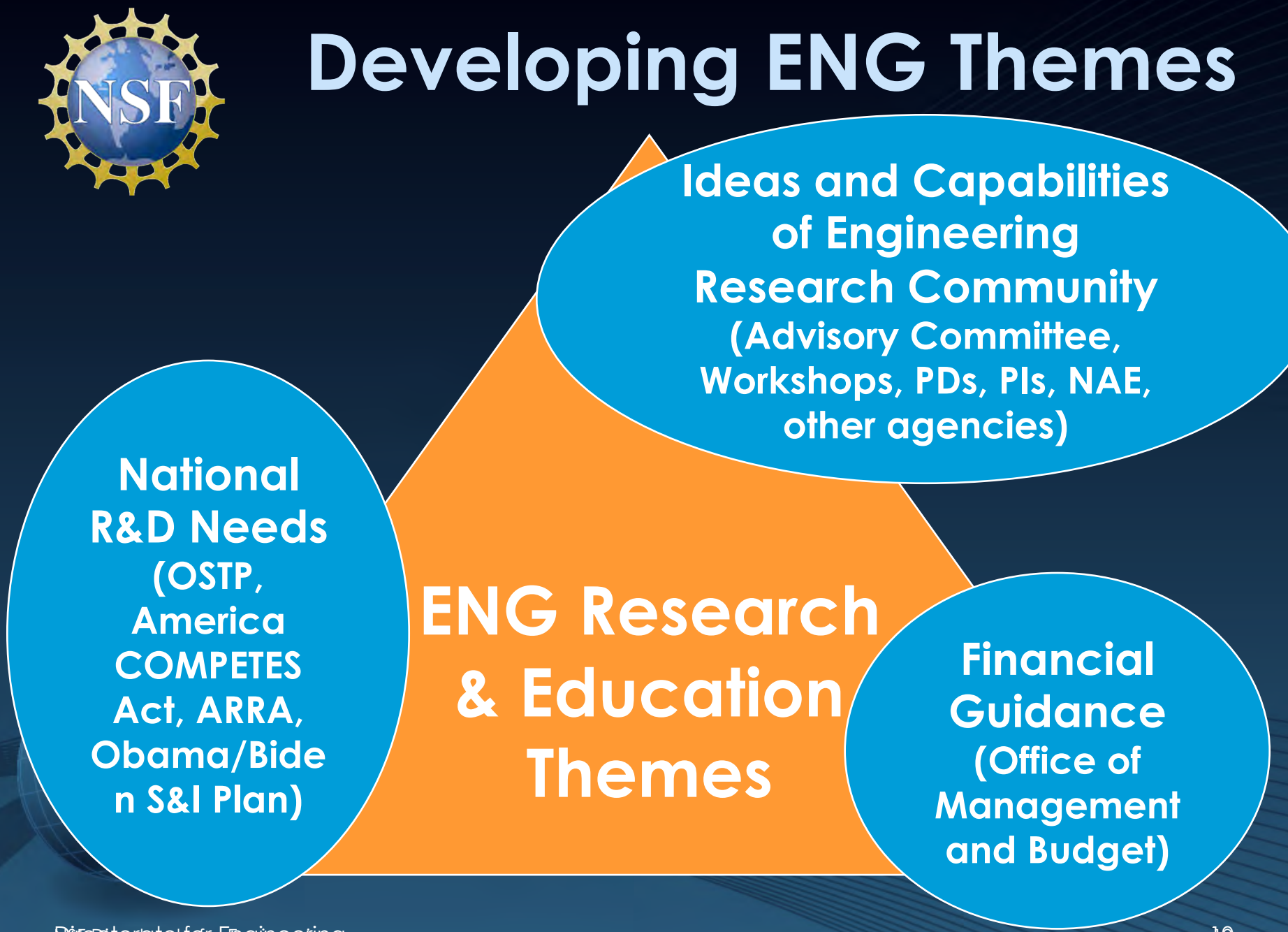
- Make solar energy economical
- Provide energy from fusion
- Develop carbon sequestration methods
- Manage the nitrogen cycle
- Provide access to clean water
- Restore and improve urban infrastructure
- Advance health informatics
- Engineer better medicines
- Reverse-engineer the brain
- Prevent nuclear terror
- Secure cyberspace
- Enhance virtual reality
- Advance personalized learning
- Engineer the tools of scientific discovery

NSF Research and Related Activities

	FY 2008 Actual	FY 2009 Request	Amount Change	Percent Change
Biological Sciences	$611.49	$675.06	$63.57	10.4%
Computer & Information Science & Engineering	534.07	638.76	104.69	19.6%
Engineering (includes SBIR/STTR)	636.32	759.33	123.01	19.3%
Geosciences	752.01	848.67	96.66	12.9%
Mathematical & Physical Sciences	1,166.30	1,402.67	236.37	20.3%
Social, Behavioral & Economic Sciences	214.94	233.48	18.54	8.6%
Office of Cyberinfrastructure	185.17	220.08	34.91	18.9%
Office of International Science and Engineering	41.3	47.44	6.14	14.9%
U.S. Polar Research Programs	442.22	490.97	48.75	11.0%
Integrative Activities	236.17	276	39.83	16.9%
Arctic Research Commission	1.47	1.53	0.06	4.1%
Total, R&RA	$4,821.46	$5,593.99	$772.53	16.0%

Totals may not add due to rounding.

Developing ENG Themes



ENG Mission and Vision

- Mission: To enable the engineering and scientific communities to ***advance the frontiers*** of engineering ***research, innovation and education***, in service to society and the nation.

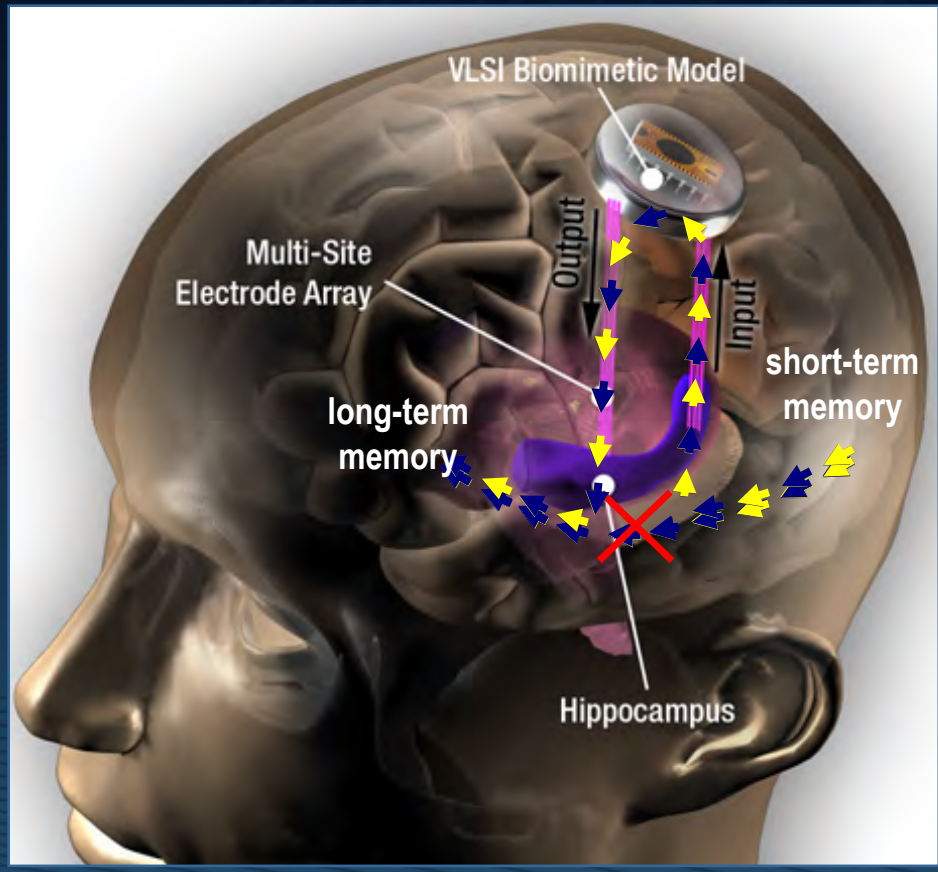
- Vision: ENG will be the ***global leader*** in advancing the frontiers of fundamental engineering research, stimulating innovation, and substantially strengthening engineering education.

ENG Research and Education Themes

- Cognitive engineering: Intersection of engineering and cognitive sciences
- Competitive manufacturing and service enterprises
- Complexity in natural and engineered systems
- Energy, water, and the environment
- Systems nanotechnology

Cognitive Engineering

- ENG invests in improving understanding of the brain and nervous system to enable the engineering of novel systems and machines
- Examples include:
  - Devices that augment the senses
  - Intelligent machines that analyze and adapt



A neural prosthesis restores cognitive function lost due to damage or degenerative disease.

Credit: Biomimetic MicroElectronic Systems ERC, University of Southern California

Competitive Manufacturing and Service Enterprises

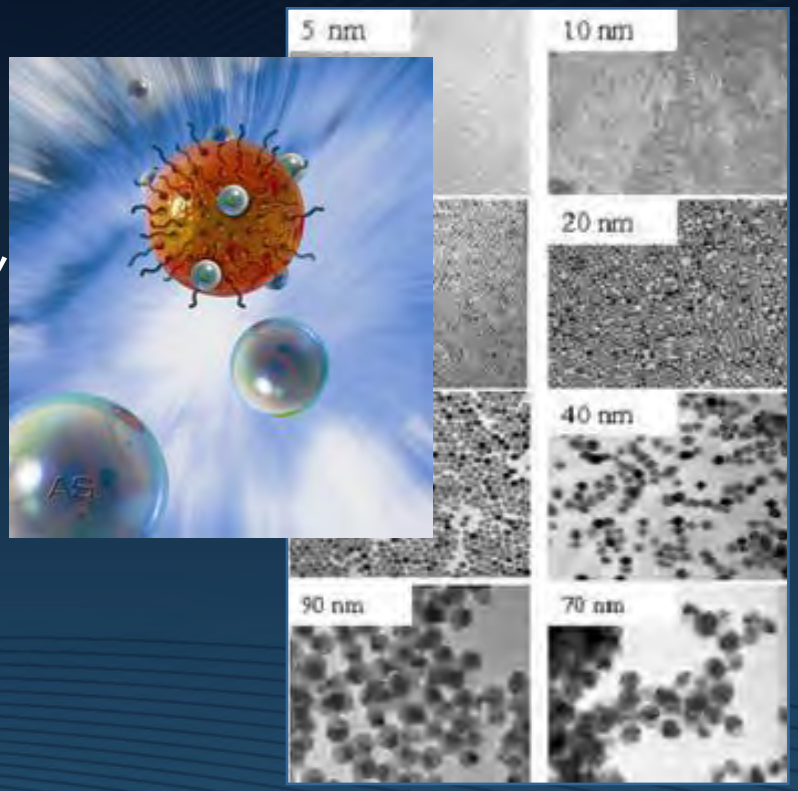
- ENG enables research to catalyze and optimize multi-scale manufacturing and service delivery
- Examples include:
  - Achieving perfect atomic- and molecular-scale manufacturing
  - Understanding & optimizing decision-making in service industries

The time needed for vaccine design, production, and administration must all be balanced.

Credit: James Gathany, courtesy of CDC.

Competitive Manufacturing and Service Enterprises

- Commercial-scale production of affordable, high-quality, multi-use nanomaterials
  - Nanocrystals for separations and pollution control
  - Nanotubes for medical therapies and chemical and biological sensors



Various sizes of high quality Fe_3O_4 nanocrystals and Fe_3O_4 beads.

Credits (L to R): Rice University Center for Biological and Environmental Nanotechnology (CBEN); Nanomaterials & Nanofabrication Laboratories.

Complexity in Engineered and Natural Systems

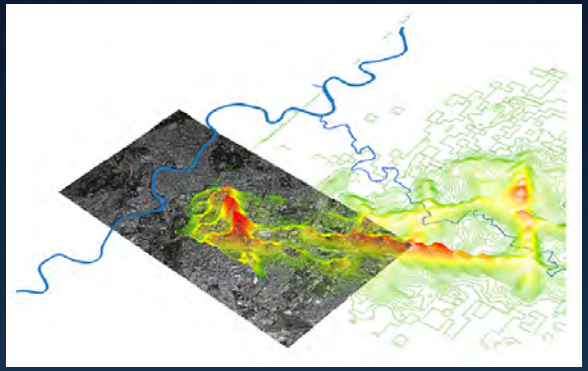
- ENG research addresses unifying principles that enable modeling, prediction, and control of emergent behavior in complex systems
- Engineering seeks
  - Predictable behavior
  - Optimization
  - Consistency of operation

Complex robotic systems can self-assemble, self-organize, and exhibit emergent behavior. These structures will self-assemble at disaster sites.

Credit: Daniela Rus, MIT.

Complexity in Engineered and Natural Systems

- Addresses unifying principles that enable ***modeling, prediction, and control*** of emergent behavior in complex systems
- Examples include:
  - Improving structural performance during disasters through advanced materials
  - Advancing quantum information processing



Combining maps (gray square) and density of cell-phone usage (shown as red and yellow 3-D peaks) can yield information about how a complex system responds to unplanned events. *Dahleh, 0735956* .

Energy, Water, and the Environment

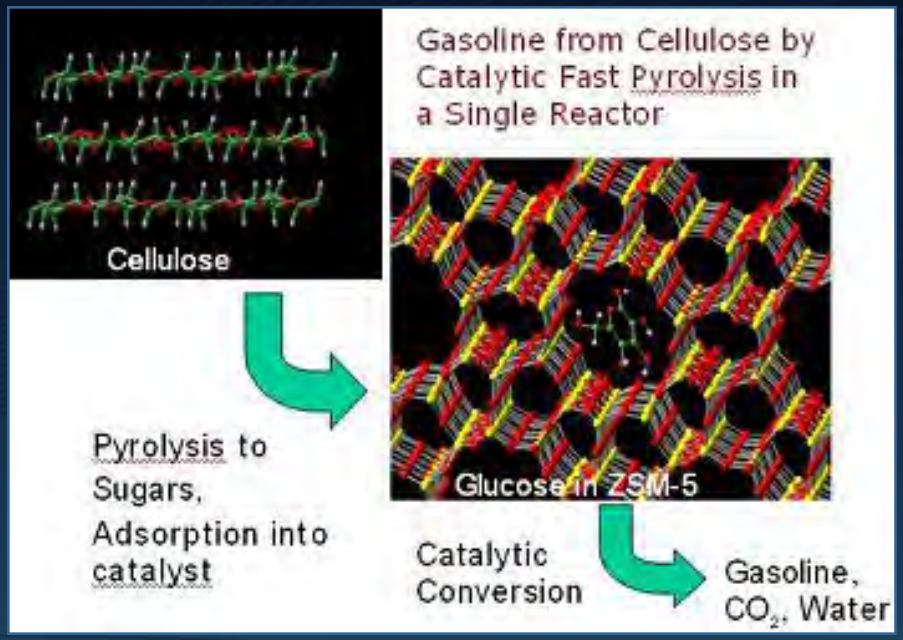
- ENG supports breakthroughs essential to the provision of energy and water in an environmentally sustainable and secure manner.
- Examples include:
  - Developing quantitative understanding of energy–environment interactions
  - Researching materials and systems to increase use of alternative energy sources

Dr. Efraín O'Neill-Carrillo describes solar energy and power quality to a group of Hispanic high school students. His CAREER project contributes to the research and workforce development needed to move towards a more sustainable energy future.

Credit: University of Puerto Rico

Energy, Water, and the Environment

- Biofuels
  - Catalysis
  - Synthetic biology

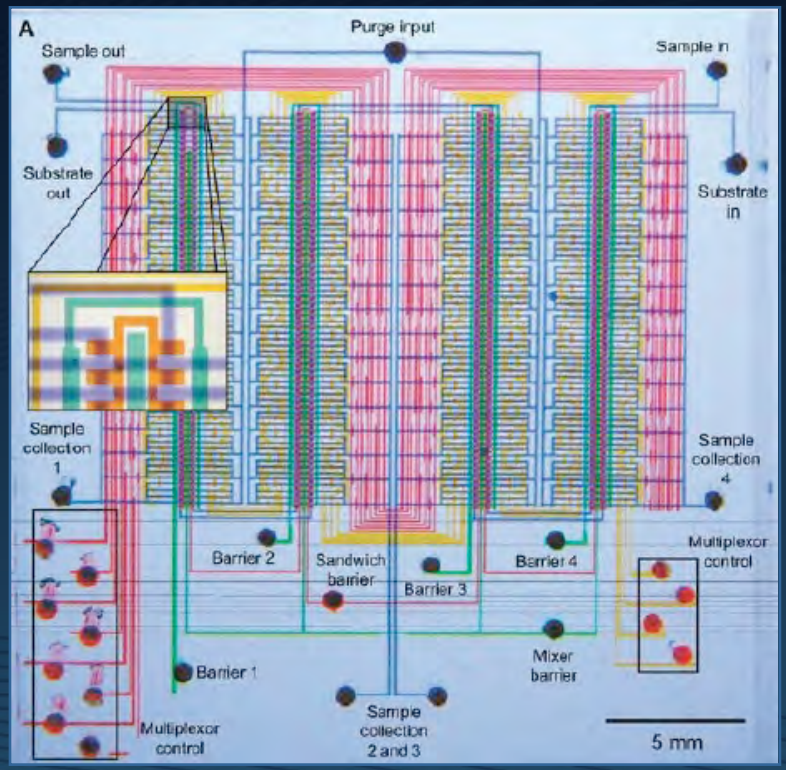


In one reactor, cellulose is broken up into sugar fragments which interact with a catalyst to become aromatic compounds used for gasoline.

Credits (L to R): DOE; George Huber, University of Massachusetts-Amherst.

Systems Nanotechnology

- ENG supports research to develop active and complex nanosystems and integrate them into:
  - Biology and medicine
  - Computing
  - Communications
  - Energy
- Examples include:
  - Nanomechanical systems for control and sensing
  - Smart tools for medical diagnosis and treatment



Integrated circuits that are smaller and faster are possible with microfluidics systems built from or incorporating nanocomponents. *Ferreira, 0328162.*

ENG Divisions

Dollars in Millions

Assistant Director
Dr. Thomas Peterson
Deputy Assistant Director
Dr. Michael Reischman

$759.33

- Emerging Frontiers in Research and Innovation (EFRI) — $29.00
- Senior Advisor for Nanotechnology
- Program Director for Diversity & Outreach

- Engineering Education and Centers (EEC) — $119.85
- Chemical, Bioengineering, Environmental, and Transport Systems (CBET) — $173.34
- Civil, Mechanical, and Manufacturing Innovation (CMMI) — $201.88
- Electrical, Communications, and Cyber Systems (ECCS) — $94.36
- Industrial Innovation and Partnerships (IIP) — $140.90

Chemical, Bioengineering, Environmental, and Transport Systems (CBET)

Deputy Division Director
Bob Wellek

Division Director
John McGrath

Senior Advisor
Marshall Lih

Chemical, Biochemical, and Biotechnology Systems

- **Catalysis and Biocatalysis**
  John Regalbuto
- **Chemical and Biological Separations**
  Rose Wesson
- **Process and Reaction Engineering**
  Maria Burka
- **Biotechnology, Biochemical, and Biomass Engineering**
  Fred Heineken

Biomedical Engineering and Engineering Healthcare

- **Bioengineering, Interdisciplinary, and Centers**
  Aleksandr Simonian
- **Biomedical Engineering**
  Semahat Demir
- **Biophotonics, Advanced Imaging, and Sensing for Human Health**
  Leon Esterowitz
- **Research to Aid Persons with Disabilities**
  Ted Conway

Environmental Engineering and Sustainability

- **Energy for Sustainability**
  Trung Van Nguyen
- **Environmental Engineering**
  Clark Liu
- **Environmental Implications of Emerging Technologies**
  Paul Bishop
- **Environmental Sustainability**
  Bruce Hamilton
- **Environmental Technology**
  Cynthia Ekstein

Transport and Thermal Fluids

- **Thermal Transport Processes**
  Theodore Bergman
- **Interfacial Processes and Thermodynamics**
  Bob Wellek
- **Particulate and Multiphase Processes**
  Marc Ingber
- **Fluid Dynamics**
  Bill Schultz
- **Combustion, Fire, and Plasma Systems**
  Phil Westmoreland

CBET Areas of Interest

- Post-genomic engineering, metabolic engineering, and tissue engineering
- Biomedical photonics and sensing, medical technology innovation, environmental and personal assistive technology for persons with disabilities
- Complex environmental systems, especially with respect to understanding the fate and transport of surface and groundwater pollutants; novel processes for waste treatment; industrial ecology; and technologies for avoiding pollution
- The development and integration of new principles and knowledge underpinning use-inspired products and services based on chemical, fluid-thermal and biological transformations of energy and matter
- Nanoscale science and engineering, safety and security, environmentally-friendly and energy-focused processes and products, and smart manufacturing and processing
- Fundamental aspects of fluid, thermal and mass transport processes, and research to support the development of renewable energy sources

Civil, Mechanical, and Manufacturing Innovation (CMMI)

Division Director
Bruce Kramer *
Deputy Director
George Hazelrigg

* Acting

Interdisciplinary and Cross-Divisional Activities
Bruce Kramer

Advanced Manufacturing
- **Manufacturing and Construction Machines and Equipment** — George Hazelrigg
- **Manufacturing Enterprise Systems** — Cerry Klein
- **Material Processing and Manufacturing** — Jocelyn Harrison
- **Nano Manufacturing** — Shaochen Chen

Mechanics and Engineering Materials
- **Geomechanics and Geotechnical Systems** — Richard Fragaszy
- **Materials and Surface Engineering** — Clark Cooper
- **Mechanics of Materials** — Ken Chong
- **Nano/Bio Mechanics** — Demitris Kouris
- **Structural Materials and Mechanics** — Lawrence Bank

Resilient and Sustainable Infrastructures
- **Civil Infrastructure Systems** — Dennis Wenger *
- **NEES** — Joy Pauschke
- **Geotechnical Engineering** — Richard Fragaszy
- **Hazard Mitigation and Structural Engineering** — M.P. Singh
- **Infrastructure Mgmt. and Extreme Events** — Dennis Wenger

Systems Engineering and Design
- **Control Systems** — Suhada Jayasuriya
- **Dynamical Systems** — Eduardo Misawa
- **Engineering Design and Innovation** — Christina Bloebaum
- **Operations Research** — Robert Smith
- **Sensors and Sensing Systems** — Shih Chi Liu
- **Service Enterprise Systems** — Cerry Klein

CMMI Areas of Interest

- Supports fundamental research in design, manufacturing, and industrial engineering
- Seeks to advance economic competitiveness and benefit society
- Emphasizes environmentally-benign manufacturing and a sustainable industrial economy

CMMI Areas of Interest

- Two submission windows each year: Oct. 1 and Feb. 15.
- Supported areas include:
  - Dynamics and control, mechanics and materials, nano- and bio-mechanics, sensing for civil and mechanical systems, simulation–based engineering science
  - Management of risks induced by earthquakes and other natural and technological hazards, critical infrastructure protection
  - Infrastructure development and management, geotechnology, structures

Electrical, Communications, and Cyber Systems (ECCS)

Senior Engineering Advisor
Lawrence Goldberg

Acting Division Director
Lawrence Goldberg

Electronics, Photonics, and Device Technologies

Optoelectronics; Nano-photonics; Ultrafast/Extreme Ultra-Violet Technologies
Eric Johnson

Micro/Nanoelectronics; NEMS/MEMS; Bioelectronics; Sensors
Vacant

Molecular, Spin, Organic, and Flexible Electronics; Micro/Nanomagnetics; Power Electronics
Pradeep Fulay

Microwave Photonics; Millimeter, Sub-millimeter, and Terahertz Frequency Devices and Components
Usha Varshney

Integrative, Hybrid, and Complex Systems

Optical, Wireless, and Hybrid Communications Systems; Inter and Intra-chip Communications; Mixed Signals
Andreas Weisshaar

Micro and Nano Systems; Systems-on-a-chip; Diagnostic and Implantable Systems
Yogesh Gianchandani

Cyber-Physical Systems; Next-Generation Cyber Systems; Signal Processing
Scott Midkiff

Power, Controls, and Adaptive Networks

Embedded, Distributed and Adaptive Control; Sensing and Imaging Networks; Systems Theory; Telerobotics
Radhakishan Baheti

Power and Energy Systems and Networks and their Inter-dependencies; Power Drives; Renewable/Alternative Energy Sources
Dagmar Niebur

Adaptive Dynamic Programming; Quantum and Molecular Modeling and Simulations; Neuromorphic Engineering
Paul Werbos

ECCS Areas of Interest

Electronics, Photonics, and Device Technologies EPDT

- ✓Bioelectronics
- ✓Electromagnetics
- ✓Flexible Electronics
- ✓MEMS/NEMS
- ✓Micro/Nanoelectronics
- ✓Micro/Nanomagnetics
- ✓Microwave Photonics
- ✓Molecular Electronics
- ✓Nanophotonics
- ✓Optoelectronics
- ✓Power Electronics
- ✓Sensors and Actuators
- ✓Spin Electronics

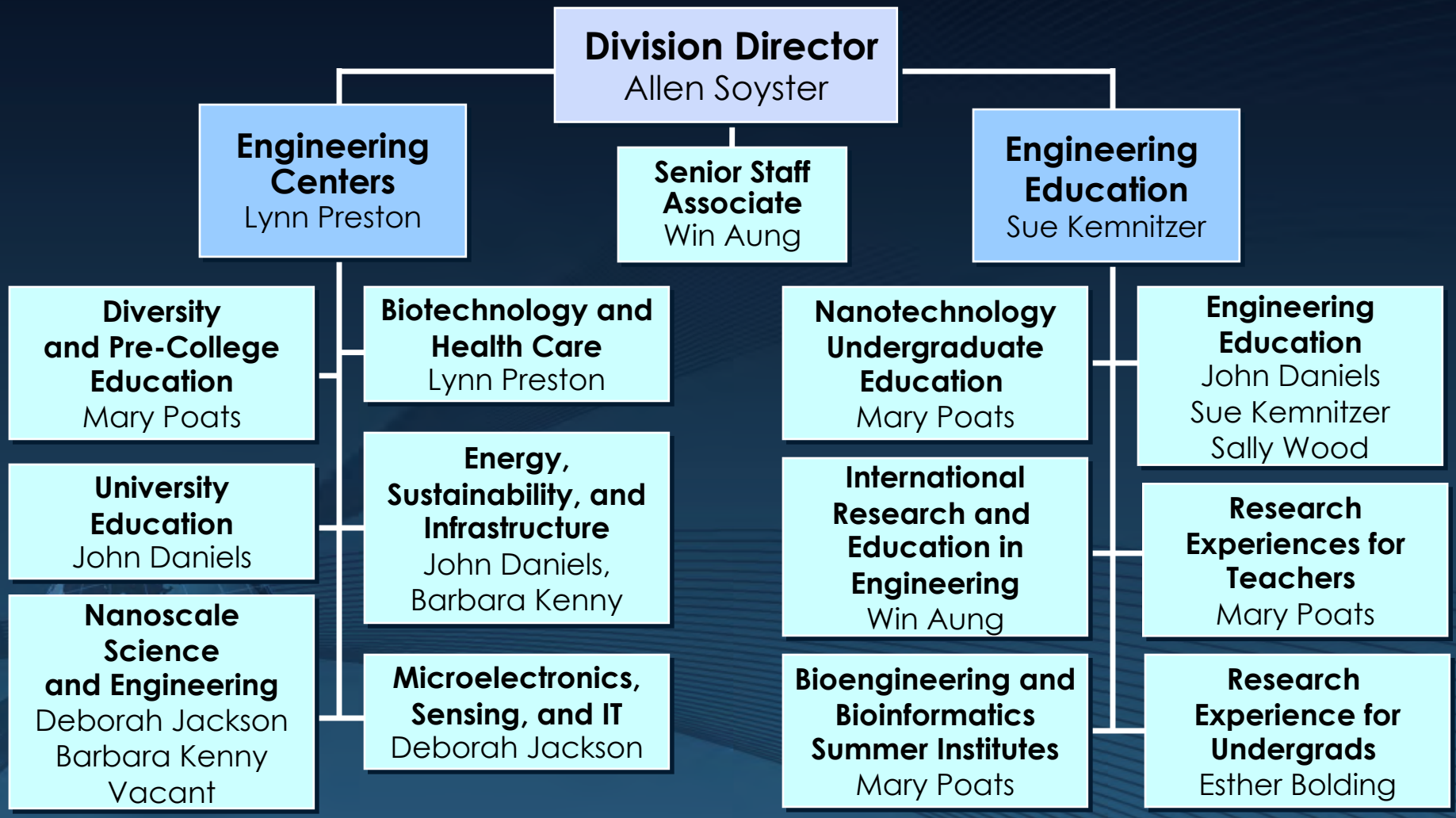
Integrative, Hybrid, and Complex Systems IHCS

- ✓Nanosystems/Microsystems/ Macrosystems
- ✓Cyber Systems and Signal Processing
- ✓Nano and Microsystems
  - ✓System-on-a-chip
  - ✓System-in-a-package
- ✓RF and Optical Wireless and Hybrid Communications Systems
  - ✓Inter- and Intra-chip Communications
  - ✓Mixed Signals

Power, Controls, and Adaptive Networks PCAN

- ✓ Adaptive Dynamic Programming
- ✓ Alternate Energy Sources
- ✓ Embedded, Distributed and Adaptive Control
- ✓ Neuromorphic Engineering
- ✓ Power and Energy Systems and Networks
- ✓ Quantum and Molecular Modeling and Simulation of Devices and Systems
- ✓ Sensing and Imaging Networks
- ✓ Telerobotics

Engineering Education and Centers (EEC)



EEC Areas of Interest

- Centers that collaborate with industry to promote innovative research and education
- Centers that promote partnerships with small business and international researchers
- Focused efforts that integrate research into new advances in undergraduate and PhD engineering education, and partner with K-12 pipeline innovators

Engineering Centers

- Supports centers that collaborate with industry to promote innovative research and education
- Engineering Research Centers
  - 15 in operation, including 5 new for 2008
    - Funding for 10 years
  - 2-year process from solicitation to funding
  - New solicitation released in March 2009
- Nanoscale Science and Engineering Centers
  - 6 of 10 are engineering
  - 2007 solicitation established 2 Centers for the Environmental Implications of Nanotechnology

Engineering Education Research

- Addresses educational goals of the engineering community
- Supports focused efforts that integrate research into advances in undergraduate and PhD engineering education, and partner with K–12 pipeline innovators
- Curriculum and Infrastructure

Industrial Innovation and Partnerships (IIP)

AAAS Fellow
James Brown

Division Director
Kesh Narayanan

Academic Partnerships
Donald Senich

- **Grant Opportunities for Academic Liaison with Industry**
  Donald Senich
- **Industry/University Cooperative Research Centers**
  Rathindra DasGupta
  Glenn Larsen
- **Partnerships for Innovation**
  Sara Nerlove

- **Advanced Electronics**
- **Advanced Manufacturing**
- **Advanced Materials**
- **Biotechnology**
- **Civil Infrastructure Systems**
- **Energy and the Environment**
- **Fabrication and Processing Technology**
- **Health and Safety**
- **Information and Communications**
- **Quality, Reliability and Maintenance**
- **System Design and Simulation**

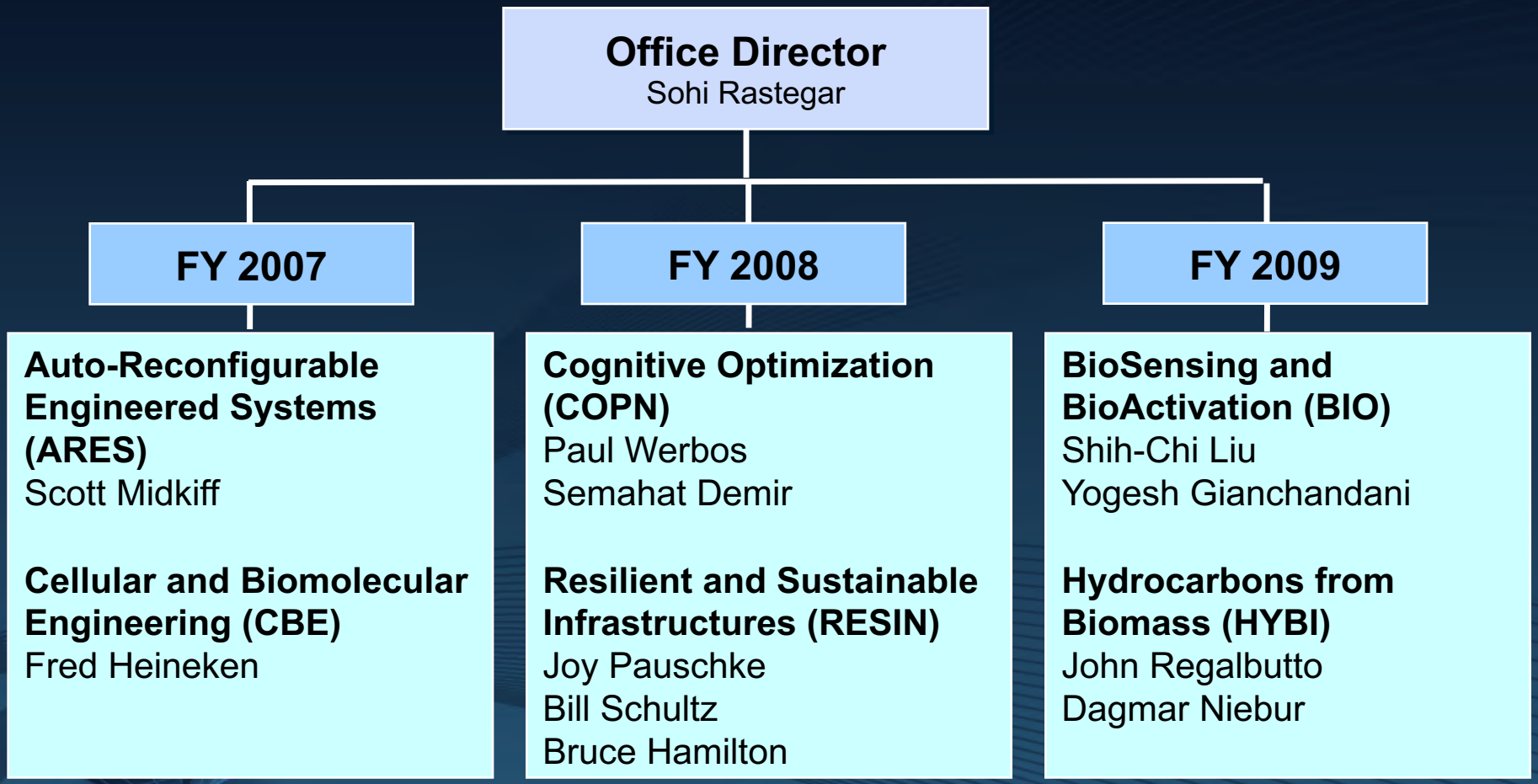
Small Business Partnerships
Joe Hennessey

- **Advanced Materials and Manufacturing**
  Cheryl Albus, Vacant
- **Biotechnology and Chemical Technology**
  Gregory Baxter, Cynthia Znati, Vacant
- **Electronics**
  Juan Figueroa, William Haines, Murali Nair
- **Information Technology**
  Errol Arkilic, Ian Bennett
- **Special Topics**
  James Rudd, George Vermont

Industrial Innovation and Partnerships (IIP)

- Current programs supporting academic-industry partnerships
  - Small Business Innovation Research (SBIR)
  - Small Business Technology Transfer Research (STTR)
  - Industry/University Cooperative Research Centers (I/UCRC)
  - Partnerships for Innovation (PFI)
  - Grant Opportunities for Academic Liaison with Industry (GOALI)
- IIP supports a wide spectrum of Technology Areas
  - Advanced Materials
  - Manufacturing
  - Civil Infrastructure Systems
  - Chemical-Based Technologies
  - Energy and Environment
  - Biotechnology
  - Electronics
  - Information-based Technologies

Emerging Frontiers in Research and Innovation



Emerging Frontiers in Research and Innovation (EFRI)

- EFRI will support higher risk, higher payoff opportunities leading to:
  - new research areas for NSF, ENG, and other agencies
  - new industries/capabilities resulting in a leadership position
  - significant progress on advancing a "grand challenge"
- Successful topics would likely require:
  - small- to medium-sized interdisciplinary teams
  - the necessary time to demonstrate substantial progress and evidence for follow-on funding through other established mechanisms
- The current investment for EFRI totals $25 million for 4-year awards at $500k per year.
- Sohi Rastegar, Office Director

EFRI Criteria

- **TRANSFORMATIVE-** Does the proposed topic represent an opportunity for a significant leap or paradigm shift in a research area, or have the potential to create a new research area?
- **NATIONAL NEED/GRAND CHALLENGE**- Is there potential for making significant progress on a current national need or grand challenge?
- **BEYOND ONE DIVISION-** Is the financial and research scope beyond the capabilities of one division?
- **COMMUNITY RESPONSE-** Is the community able to organize and effectively respond (but not in very large numbers; i.e., it is an "emerging" area)?
- **ENG LEADERSHIP**- Are partnerships proposed, and if so, does NSF/ENG have a lead role?

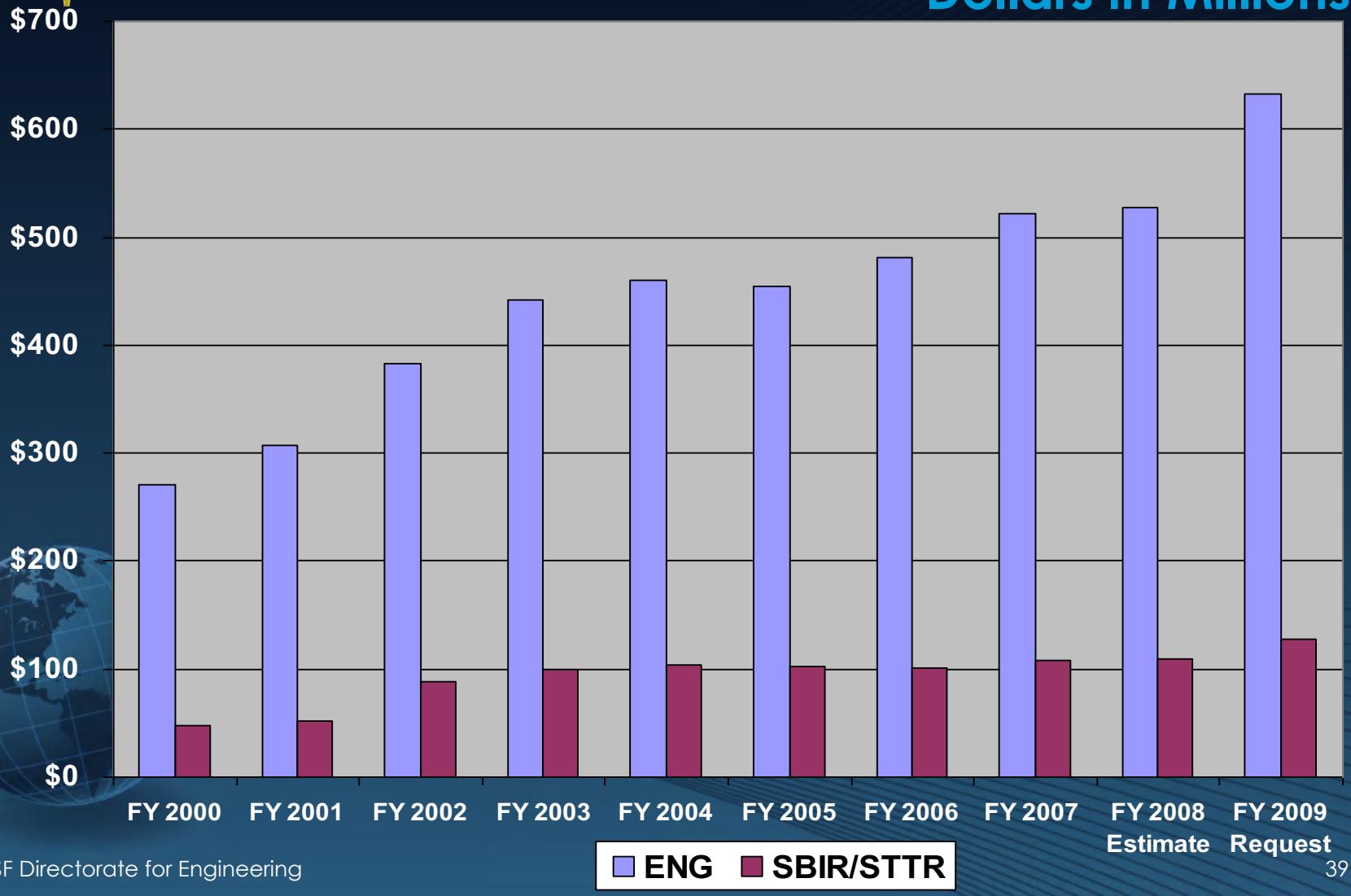
Economic Stimulus Package: American Recovery and Reinvestment Act (ARRA)

- NSF Support $3B
- To be Spent primarily in FY 2009
- Primary Focus: Improving Success Rate *(currently about 16% in ENG)*
- Emphasis on CAREER Awards
- No new solicitations* or Supplements
- Additional Accountability and Reporting

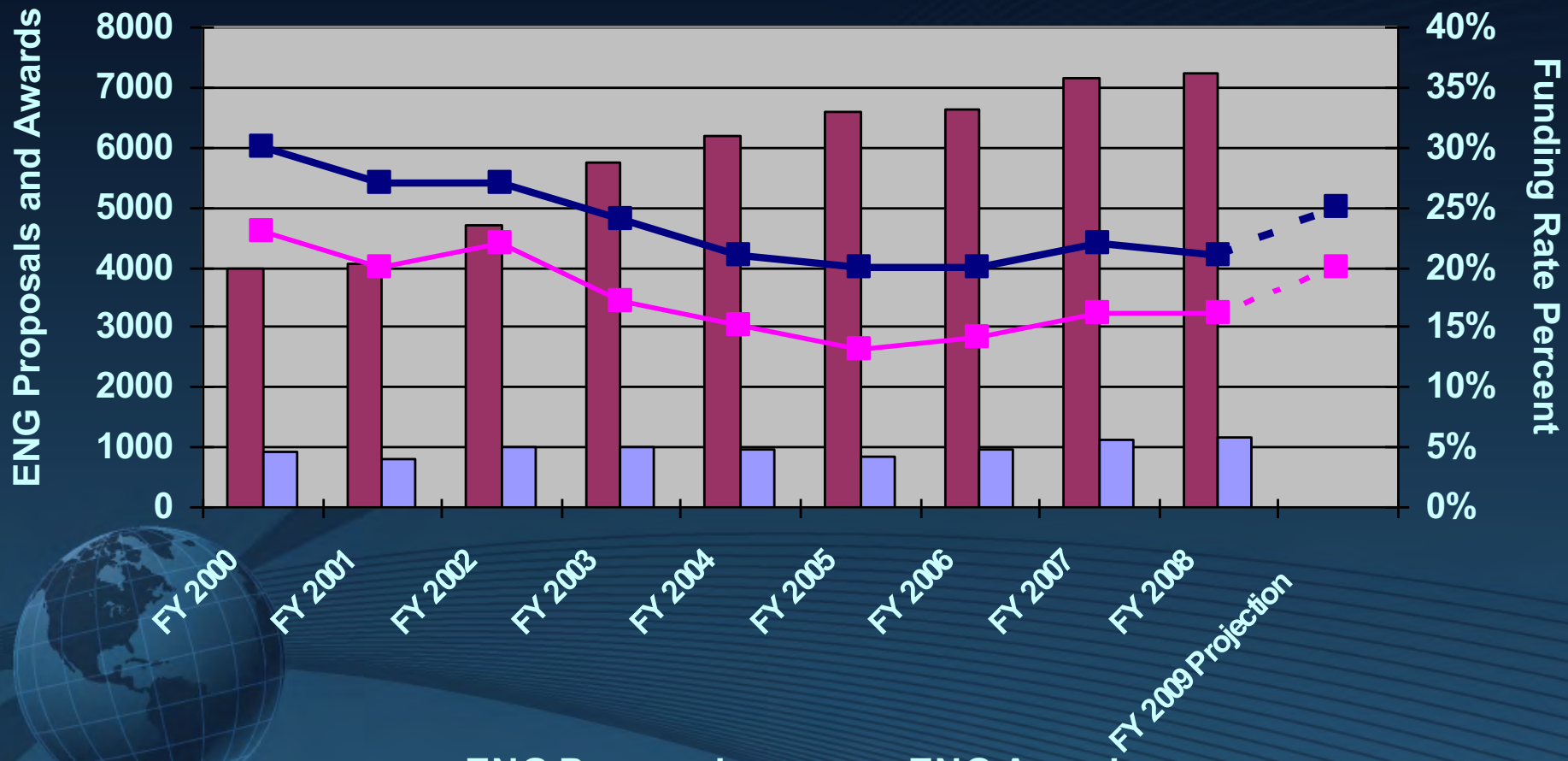
**Exceptions are ARI, MRI and PSM*

ENG and SBIR/STTR Budget History

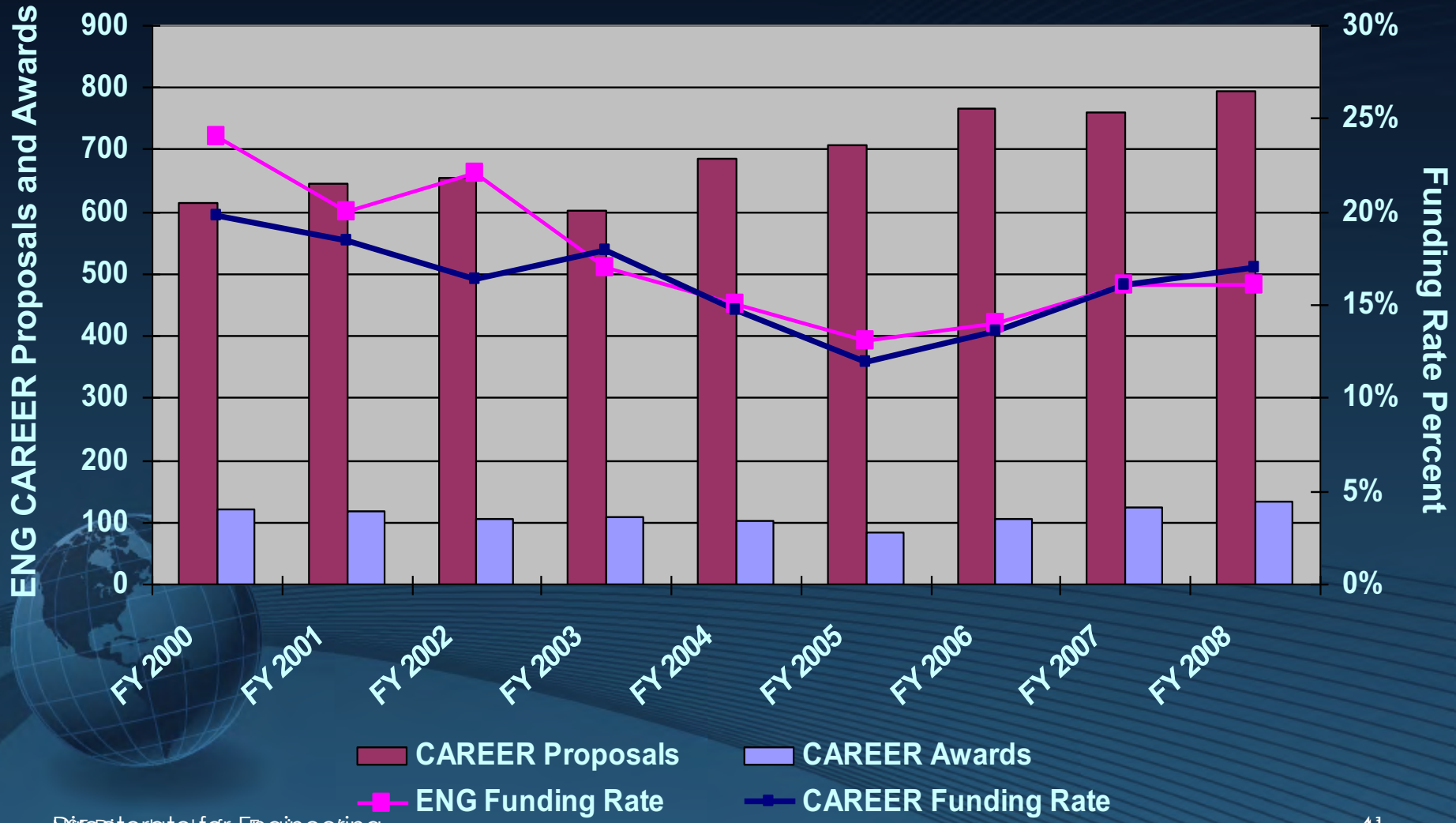
Dollars in Millions



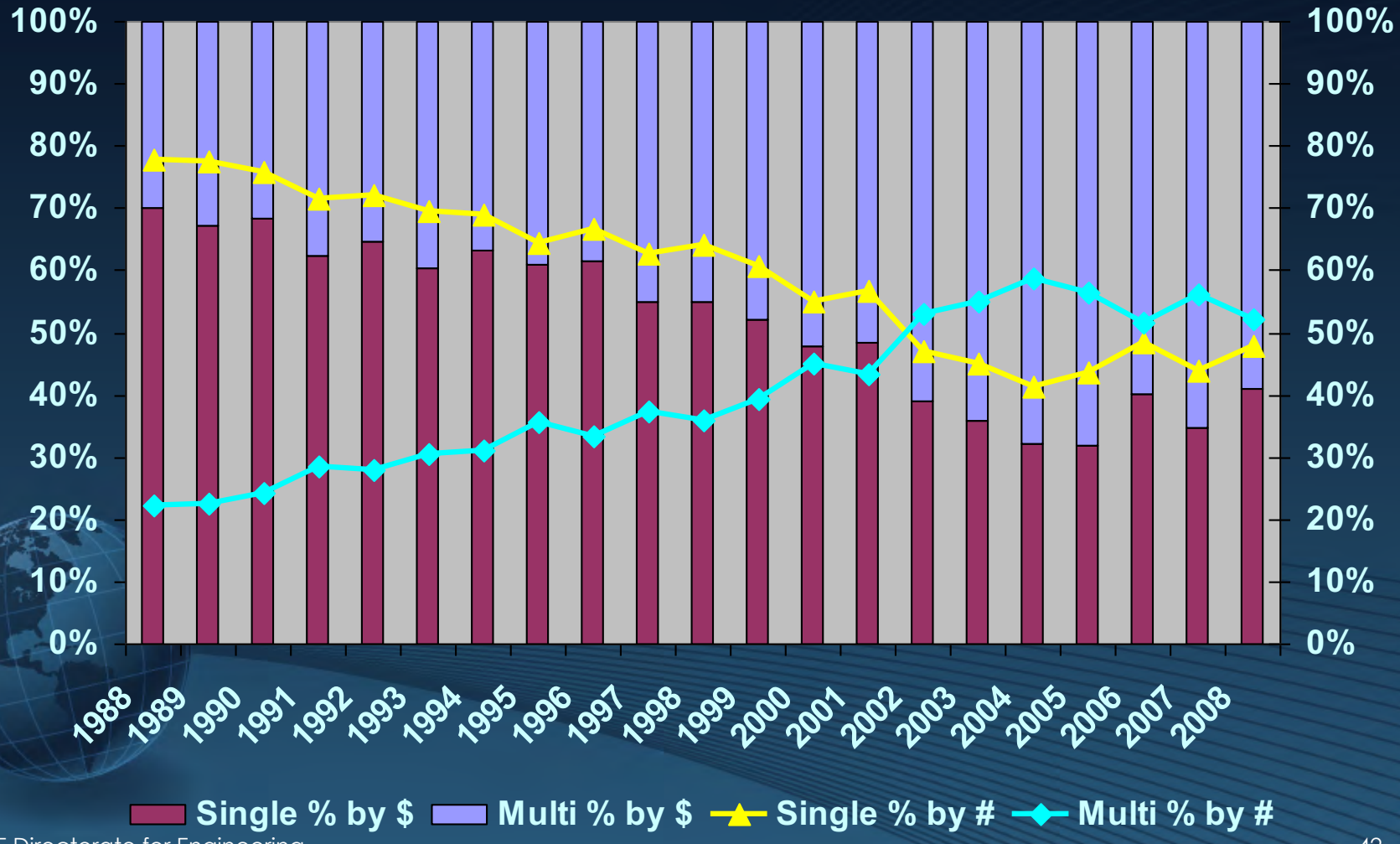
ENG and NSF Research Grant Proposals and Awards



ENG and NSF CAREER Proposals and Awards

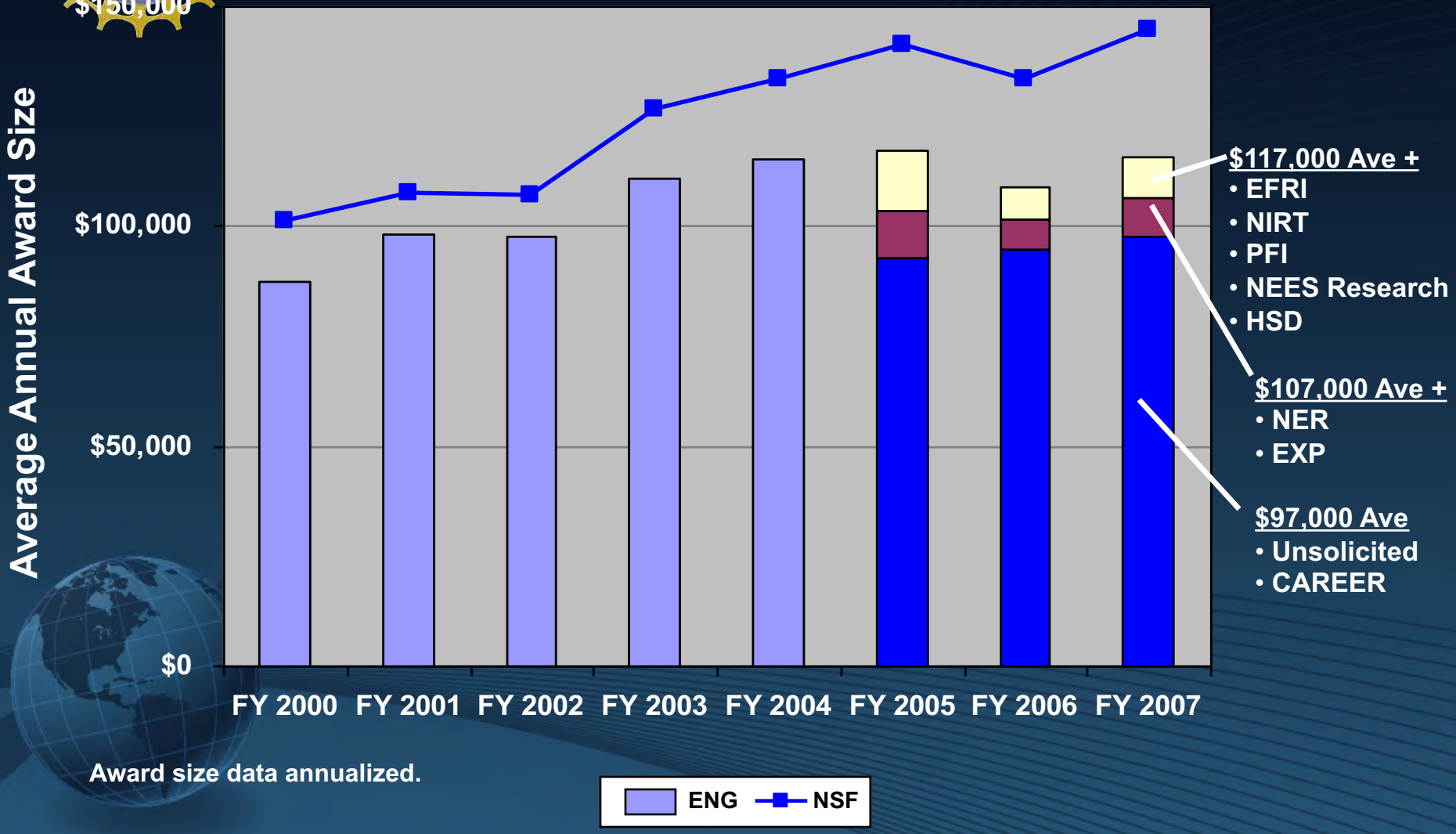


Single vs. Multiple Investigator ENG Awards



Annual Award Size

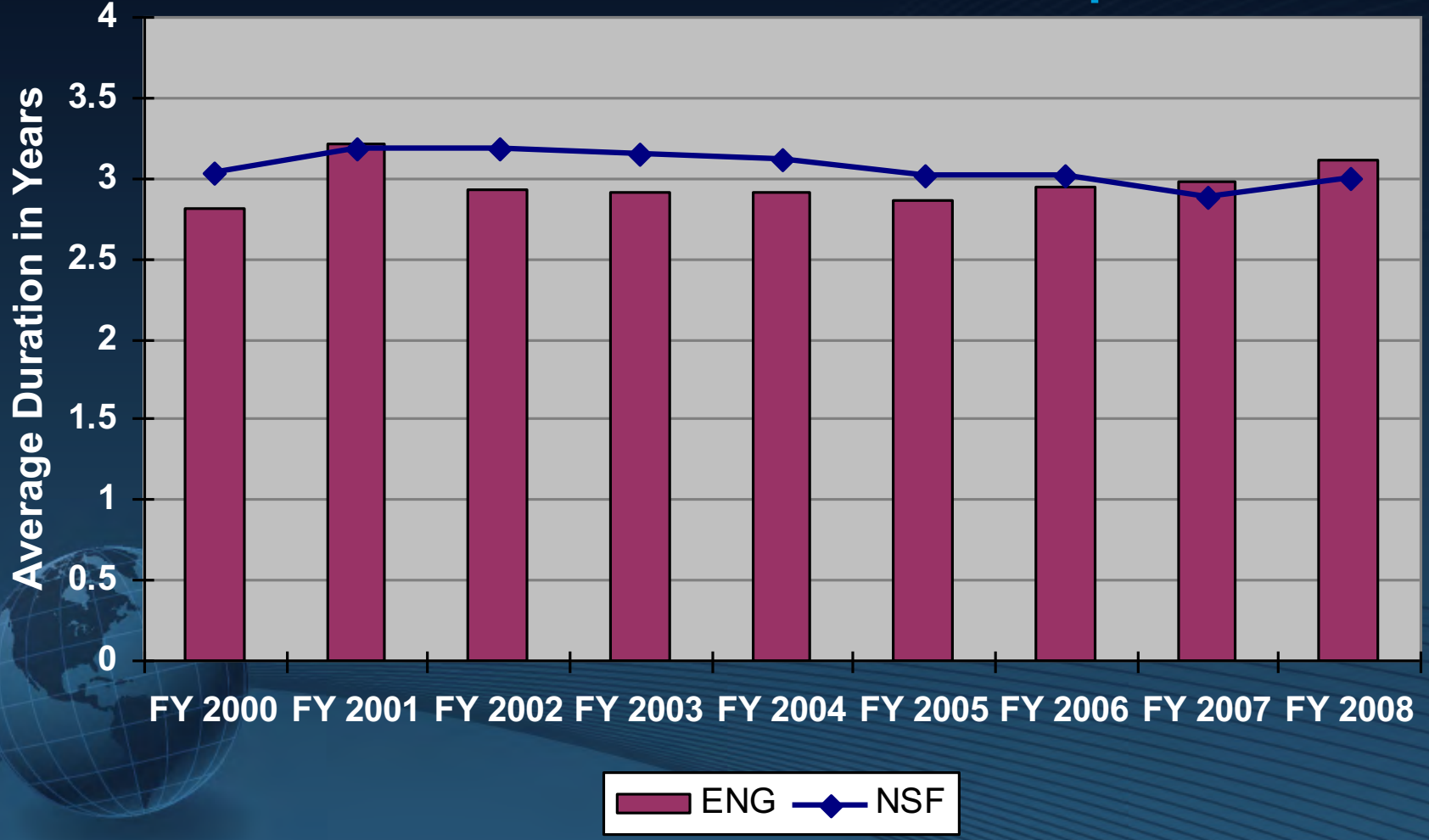
Averages for ENG Research Grants



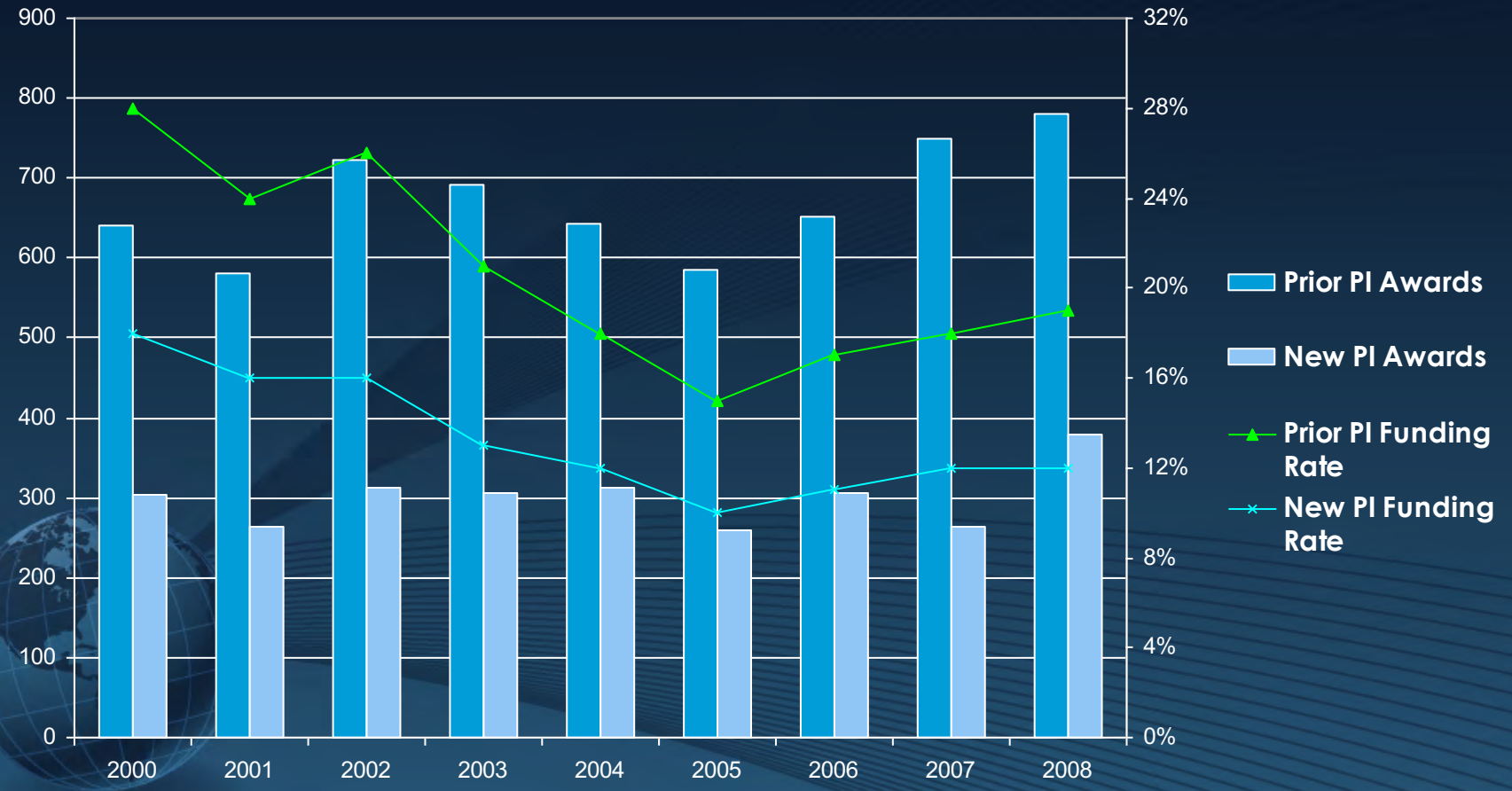
Award size data annualized.

Average Award Duration in Years

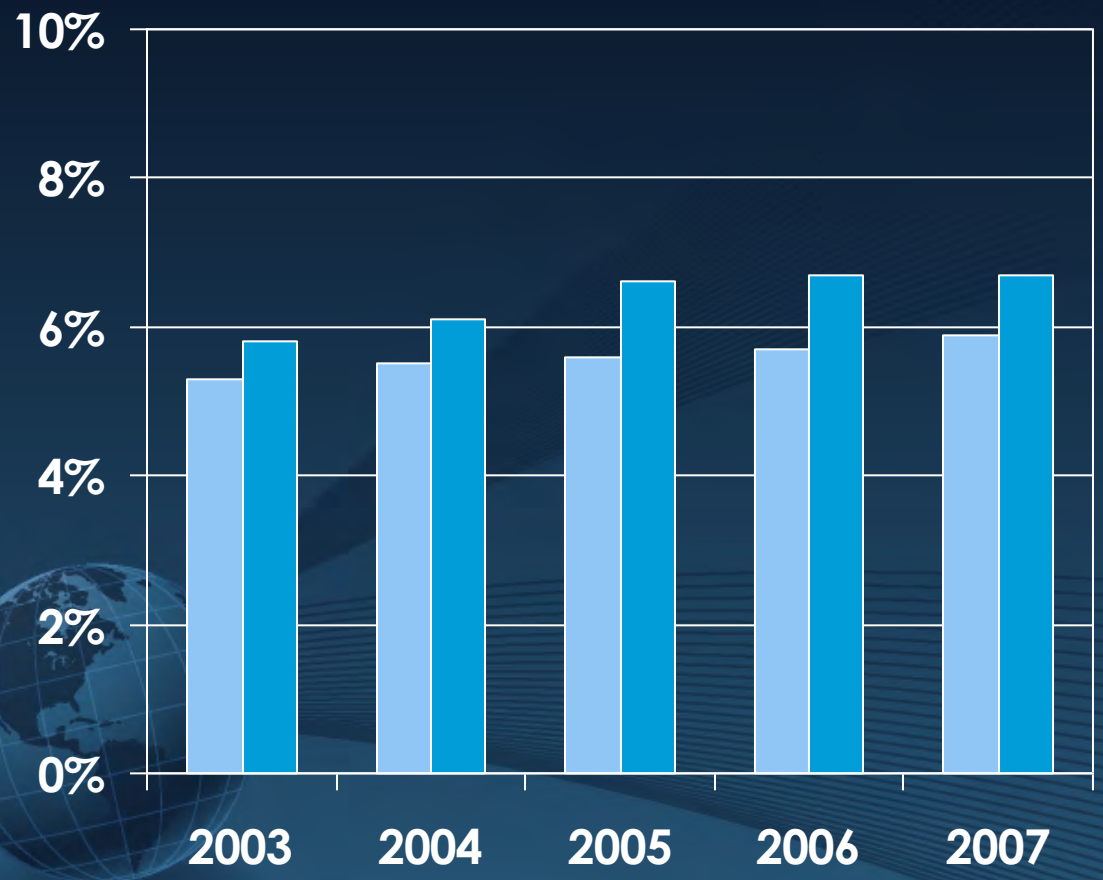
ENG Research Grants in Comparison to NSF



ENG Success Rates for Prior and New PIs



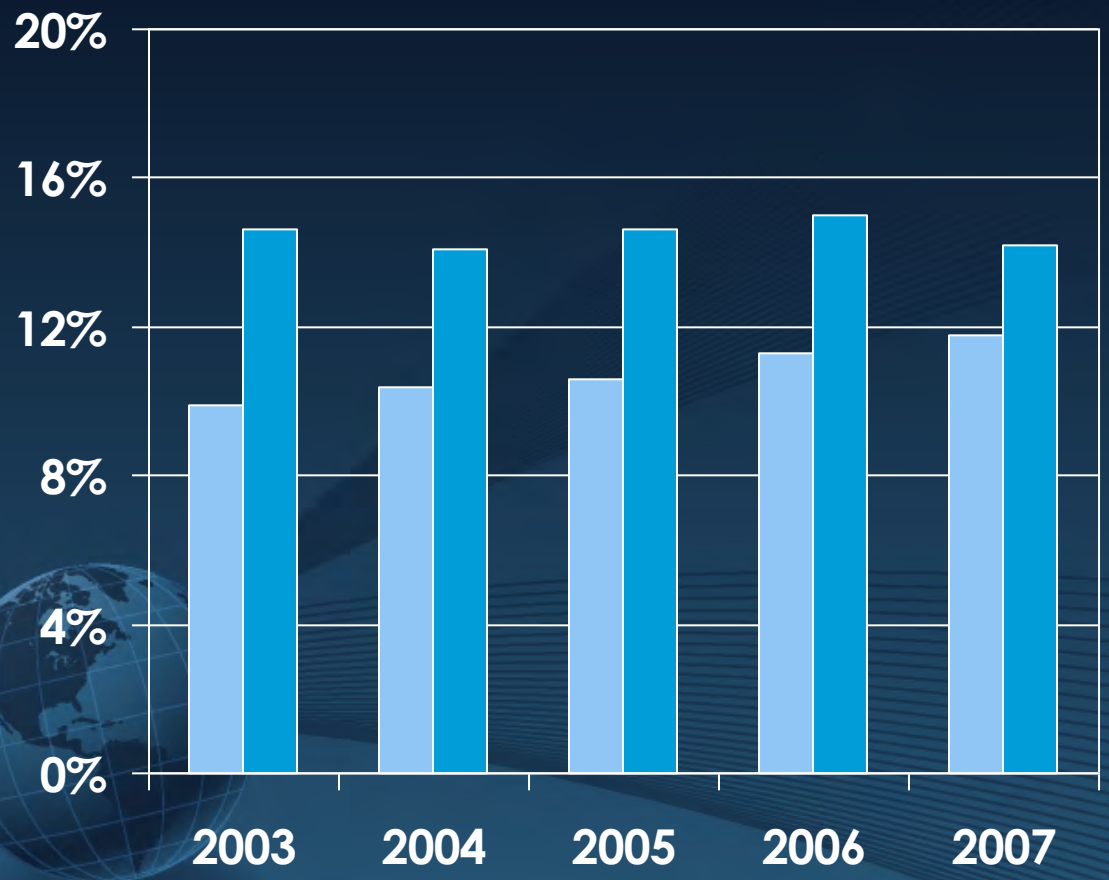
Proposal Submissions to ENG by Under-Represented Minorities



- Under-Represented Minority Faculty Nationwide*
- Proposal Submissions to ENG by Under-Represented Minorities

* Source: ASEE, 2007, *Engineering By the Numbers*

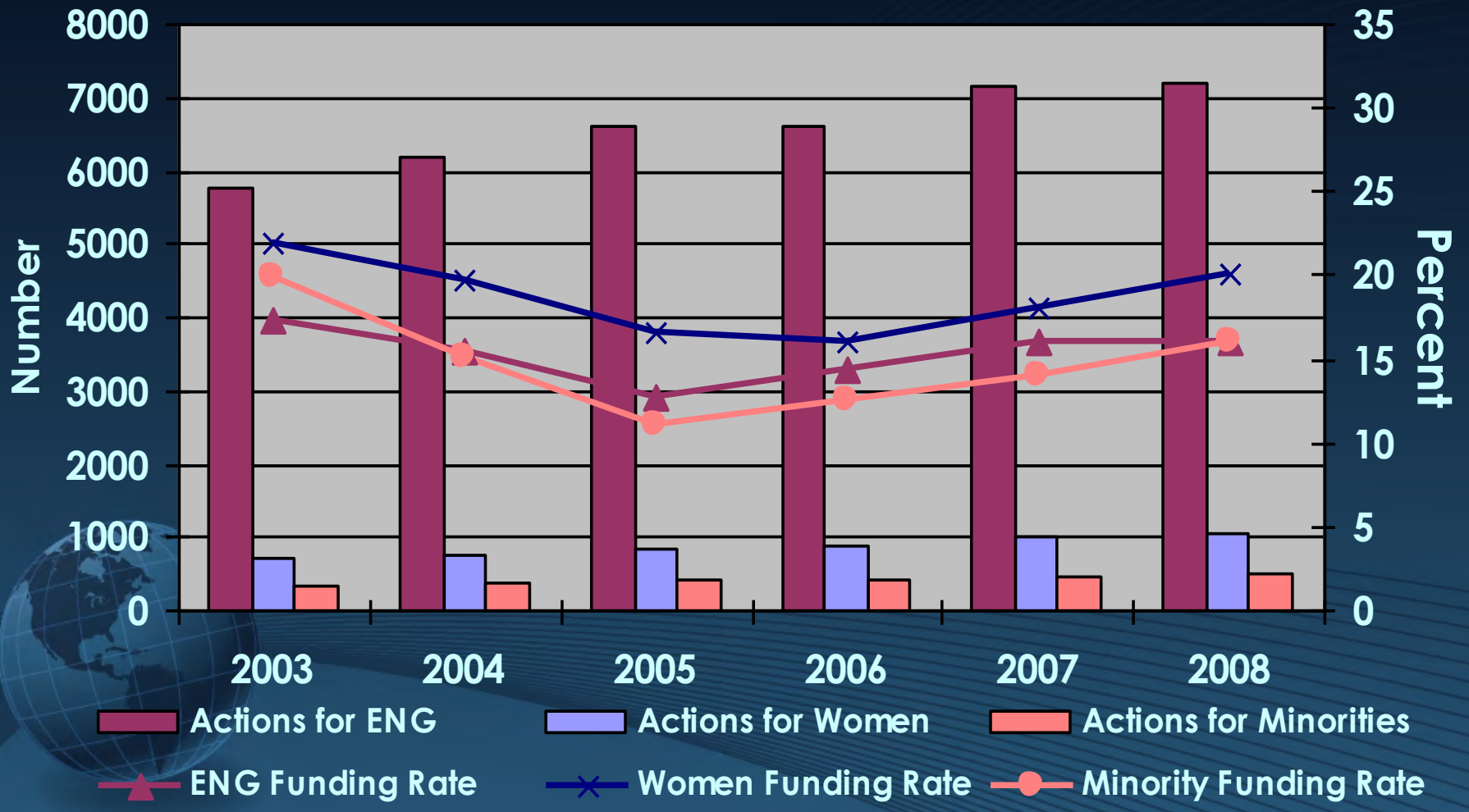
Proposal Submissions to ENG by Women



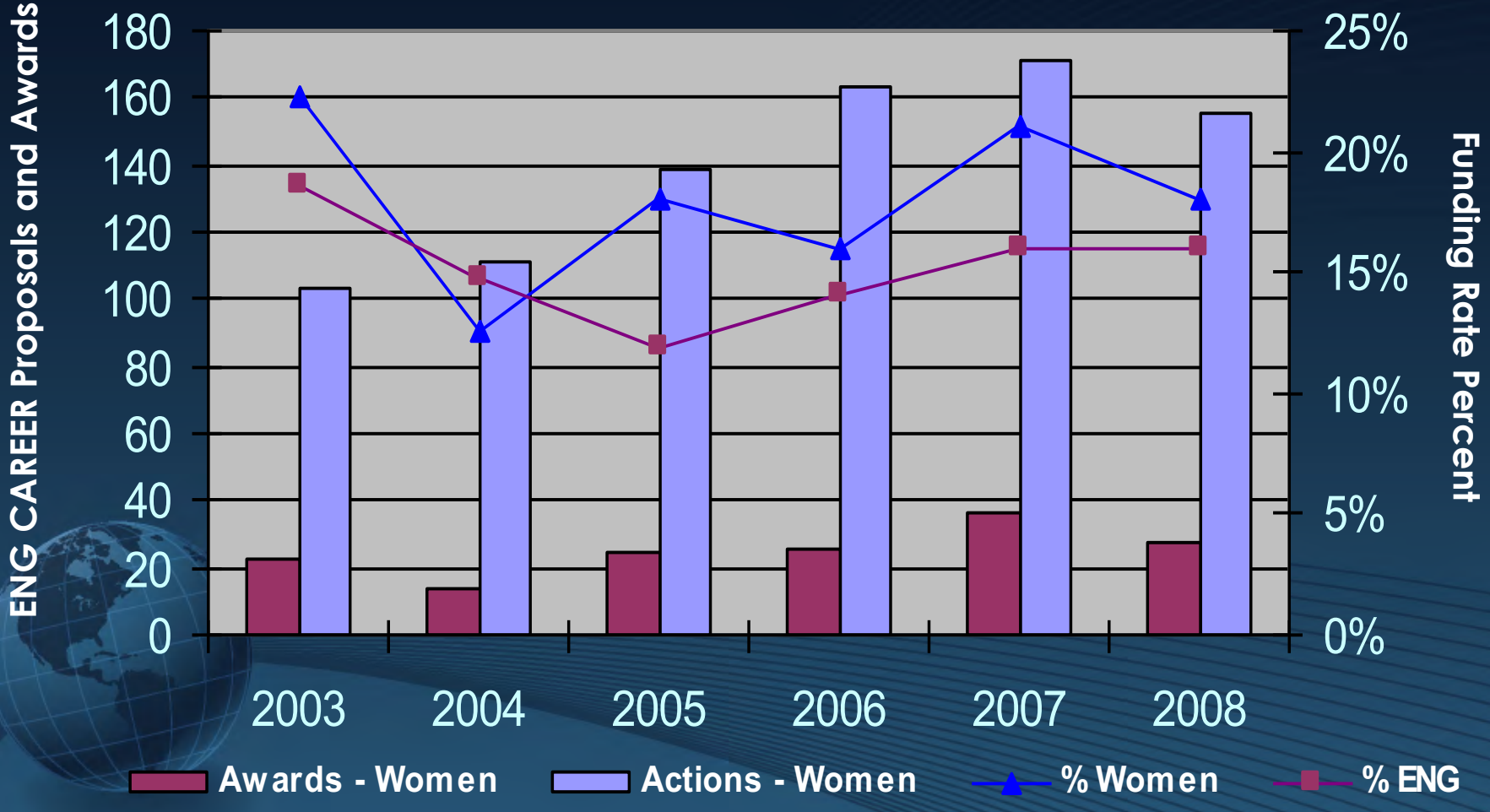
- Women Faculty Nationwide*
- Proposal Submissions to ENG by Women

* Source: ASEE, 2007, *Engineering By the Numbers*

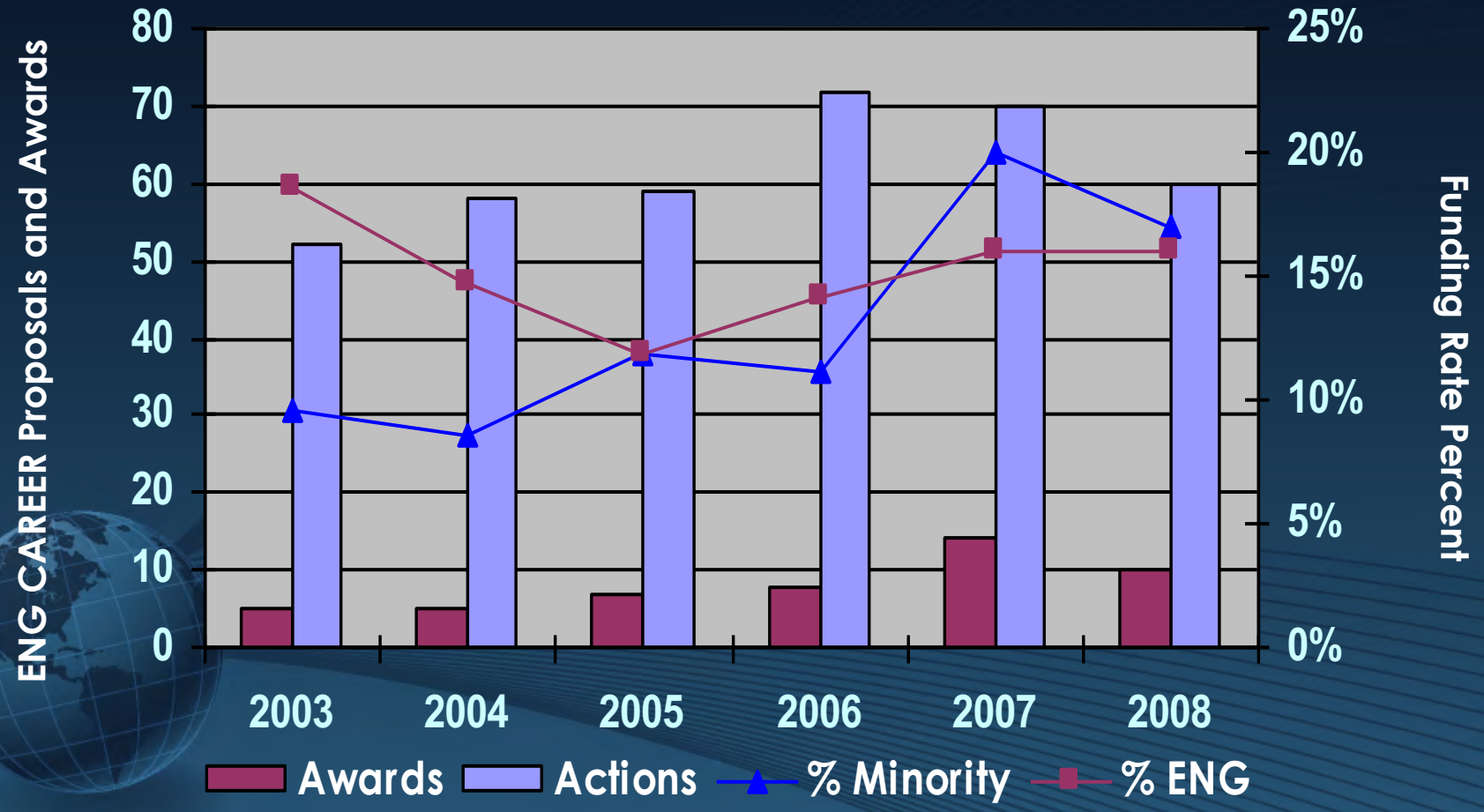
Research Proposal Funding Rates for All ENG, Women, and Minorities



CAREER Funding Rates for Women and All ENG



CAREER Funding Rates for Under-Represented Minorities and All ENG



Resources

- Directorate for Engineering:
  - http://www.nsf.gov/eng
- Funding Opportunities:
  - http://www.nsf.gov/funding/
- E-mail
  - xxxxxxxx@nsf.gov
- Phone
  - 703.292.XXXX

Free Advice for Success…

or "I'm from the government and I'm here to help"

- It all starts with Dialog, a White Paper and a Short Bio
- Get involved in NSF Reviews: Panel or Mail
- Don't be afraid of Teams
- Spread Your Research Wings
- Deliver on Your Promises
- "No" is not Forever…Seek Feedback
- "….don't ever give up"