DIVISION PLAN

DIVISION OF
CHEMICAL, BIOENGINEERING, ENVIRONMENTAL, AND TRANSPORT SYSTEMS
(CBET)

DIRECTORATE FOR ENGINEERING

NATIONAL SCIENCE FOUNDATION

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CONTENTS

EXECUTIVE SUMMARY

The research areas supported by the NSF Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) are ultimately responsible for understanding and improving many processes in industry, in the environment, in transportation systems, in medicine, and in living organisms.

CBET funds research in many engineering disciplines, including bioengineering, biomedical, aerospace, and chemical, biochemical, civil, environmental, and mechanical engineering. It also partners with the physical, biological and information sciences. This research impacts countless products and services that are ubiquitous throughout society. These services include all modes of transportation, health care, drug delivery, consumer products, safety and security, housing, and leisure and entertainment.

In industrial processes, CBET-sponsored technological areas are largely responsible for increased process rates and improved product quality, such as for plastics used in applications from vehicles to hospitals to grocery bags.

CBET researchers are involved in the recovery and processing of fuels that power automobiles and airplanes and conduct research about emerging power sources such as fuel cells.

The transport of thermal energy from production sources to utilization destinations is an integral part of the CBET research agenda.

CBET researchers have developed advanced diagnostic techniques for medical lab-on-a-chip applications, employing microfluidics for DNA sequencing, blood tests, etc. Other applications for such sensors include biohazard detection to ensure safety and homeland security, and monitoring of a sustained supply of high-quality water for the nation.

In many cases, research sponsored by CBET improves the ability to predict and control chemical, biological and transport phenomena to improve design of devices and to regulate performance. The specialized fields within CBET find uses in fuel cells, sensors, health care, thermoelectric devices, and innovative environmental technologies, among other practical applications.

Healthcare products and biomedical engineering solutions based on fundamental aspects of neuroscience and of electrical and mechanical systems are significant outcomes of CBET activities.

CBET research also improves other processing areas of growing importance, such as powder processing based on a fundamental understanding of particle interactions, and also laser surface interactions, crystal growth processing, combustion synthesis of materials, manufacturing with jets of materials, plasma synthesis, and the development of nano-materials for tailoring the thermal, mechanical, and electrical properties of composite systems. CBET research focuses on fast, accurate, non-intrusive detection and sensing methods for chemical, thermal and biological events and also on process control and prevention strategies.

Another aspect of safety and security is the reduction of US dependence on imported fossil fuels through research in alternative energy technologies such as bio-based fuels and more environmentally benign recovery and use of domestic fossil fuel resources. Processes for efficiently producing, storing and converting hydrogen are also of growing interest to CBET to help in improving national economic security. CBET will continue supporting environmentally relevant technologies and fundamental aspects of energy production and conversion.

Sustainability and pollution prevention strategies, increased use of renewable energy sources and feedstocks, and the concomitant technological challenges are important CBET research topics. New chemicals and products synthesized from biomass, hydrogen production from non-fossil fuel sources, and novel techniques for water purification are examples of environmentally focused research areas.

The basic research done by CBET engineers has contributed to a vast array of solutions beneficial to society, ranging from development of products used every day in hospitals to enabling the 1969 manned landing on the moon. CBET researchers are poised to make even more significant contributions in the future. The diversity of expertise available in the Division positions CBET to lead the integration of physical, mathematical and life sciences with engineering research.

This plan provides the background on the Division, its vision and mission, and the planning process and context. The plan presents detailed justifications for the following recommendations, which are discussed in more detail starting on page 6.

Discovery Goal:

CBET will lead engineering discovery and innovation in chemical, bioengineering, environmental and transport systems through the following objectives:

1. **Fund more investigator-identified and defined awards**: By 2010 CBET will dedicate at least 50 percent of its budget to unconstrained investigator-identified and defined awards in the core disciplines of chemical, biochemical, and biotechnology systems; transport and thermal fluids phenomena; biomedical engineering and engineering healthcare; and environmental engineering and healthcare.

2. **Support research in four thematic areas**:

    a) Energy, Water and Sustainability
    b) Systems, Multi-scale Modeling and Applications of New Techniques in Engineering Research
    c) Nanoscience and Engineering
    d) Integrating Life Sciences with Engineering

CBET will support the Energy, Water, and Sustainability; Systems and Multi-scale Modeling; and Life Sciences in Engineering areas and maintain support in Nanoscale Science and Engineering.

Learning Goal:

CBET will develop and support the best and the brightest researchers, innovators and educators in CBET's fields through the following objectives:

3. **Support new faculty:** CBET will annually fund workshops focusing on new faculty and on the successful recruitment, retention and advancement of minority engineering faculty, graduate students and undergraduates, including African-American, Hispanic, Native American and women engineers. Funding rates for CAREER proposals will increase to 15% with CAREER funding more uniformly distributed across programs.

4. **Promote lifelong learning and professional development for science, technology, engineering and mathematics (STEM) workforce and science at large:** CBET will increase the number of graduate and undergraduate students trained through the funded research by encouraging all proposals to include at least one graduate student and several undergraduate students.

Infrastructure Goal:

CBET will enhance its support of both human and physical research infrastructure through the following objectives:

5. **Encourage interdisciplinary group projects:** CBET will encourage interdisciplinary group projects that provide leverage over individual awards. Group projects will be funded through the existing unsolicited windows in single programs or co-funded by different programs. The goal is to spend 15% of the annual budget on these interdisciplinary awards and to review these proposals in interdisciplinary panels.

6. **Apply cyberinfrastructure to CBET engineering fields:** CBET programs will provide planning grants to enable groups to develop networks of researchers so that CBET PIs are well-placed to succeed in NSF-wide solicitations.

7. **Fund small and intermediate-sized ($50,000–$200,000) instrumentation and equipment requests**: PIs will be encouraged to submit small instrumentation proposals through the regular unsolicited windows so that 5 percent of CBET's annual awards will be for instrumentation. These proposals will be reviewed by panels together with unsolicited proposals.

Stewardship Goal:

CBET will enhance divisional operations, staff development and external relations through the following objectives:

8. **Pursue and implement partnerships and create a sense of CBET community to disseminate research results and outcomes to the general public:** CBET will assign a mentor to all new Program Directors (PD) and will participate fully in the

ENG Directorate PD Training Program. Administrative staff will be encouraged to attend training courses as appropriate. CBET will continue to contribute to and lead inter-agency working groups and to initiate interactions within NSF and the public. CBET will hold brown bag lunches and invited seminars from NSF staffers and visitors to initiate discussion on issues for potential collaborations.

9. **Broaden diverse participation throughout CBET in all its activities:** The Division will maintain representation of women (30%) and minority (5%) program directors and reviewers that is above the average of that for the engineering community; funding rates for women and minorities will be monitored to ensure that they remain at or above average; and panel membership will be monitored to ensure they are similarly diverse.

INTRODUCTION

Background

The Division of Chemical, Bioengineering, Environmental, and Transport Systems (CBET) supports research and education covering core and applied disciplines. These areas include chemical, biochemical, and biotechnology systems; transport and thermal fluids phenomena; biomedical engineering and engineering healthcare; and environmental engineering and sustainability. Essential to ensure continued growth of the fundamental engineering knowledge base, these areas provide the foundation for advances in a wide range of technologies.

The expertise in the Division places it at the forefront of the integration of physical, mathematical and life sciences with engineering research. The Division's research and educational investments contribute significantly to the knowledge infrastructure and development of the workforce for major components of the U.S. economy. These components include the process industries (chemicals, pharmaceuticals, health, forest products, materials, petroleum, food, and textiles), healthcare (including preventative issues and aids to people with disabilities), utilities, transportation industries (land and air-based), electronics systems and communications providers, and producers of consumer products of all kinds.

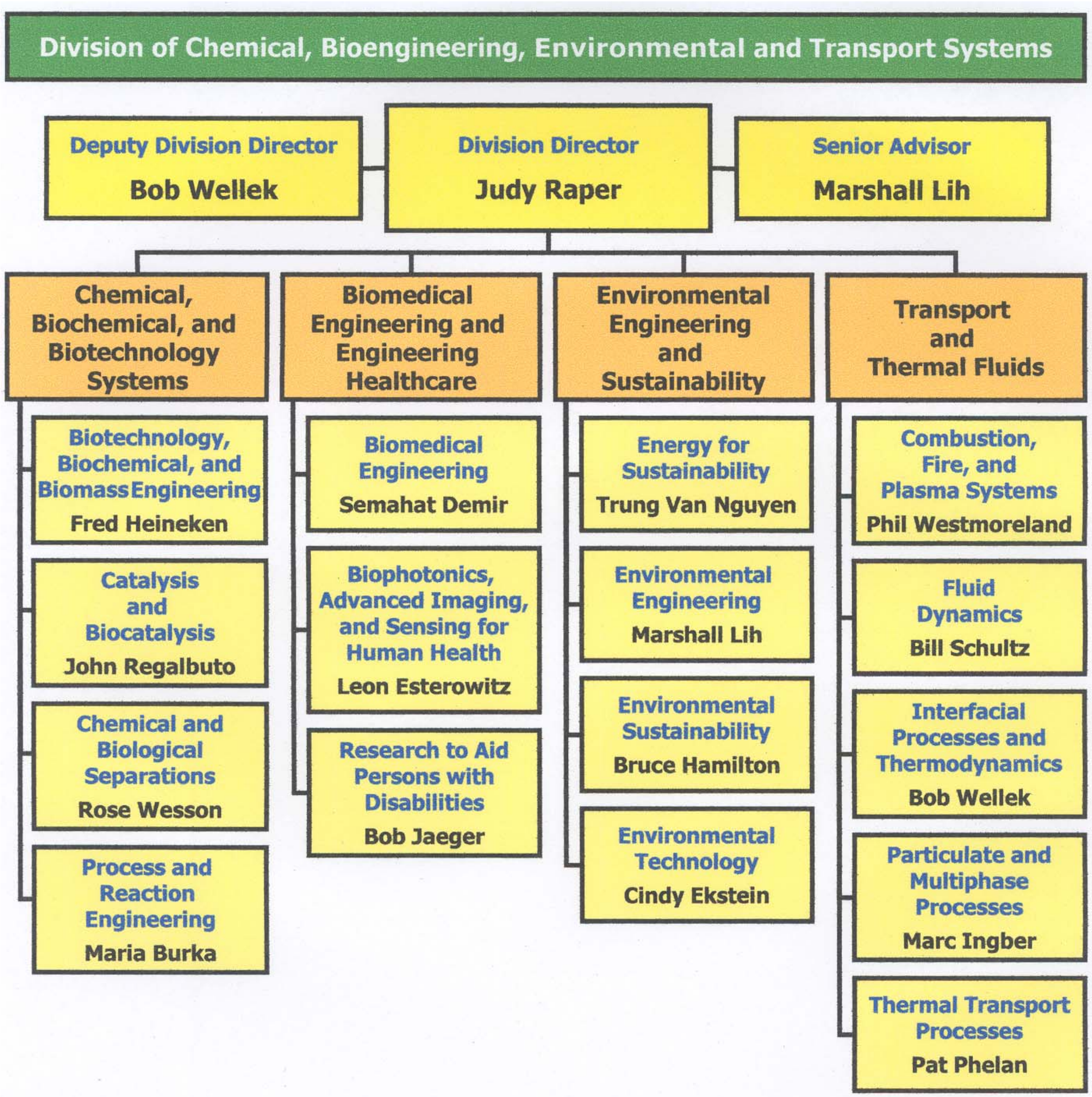
The Engineering (ENG) Directorate was reorganized starting October 1, 2006, to address the ever-changing and dynamic nature of the expanding disciplines encompassed by engineering. CBET is central to new developments in engineering. In the case of bio- and nano-engineering, the Division is an incubator for civil, electrical and mechanical engineering programs as well as other interdisciplinary programs. As with other basic engineering disciplines, chemical engineering, bioengineering, environmental engineering, and transport systems not only have provided the foundation for innovation and creation of new knowledge, but also have remained a cornerstone of engineering discovery and innovation.

Consistent with NSF's long-term vision [NSF ENG Long View], CBET contributes to the two overriding goals in the allocation of its resources:

- To support first-rate research at many points of the frontiers of knowledge, identified and defined by the best researchers, and

- To balance the allocation of resources in strategic research areas in response to scientific and engineering opportunities to meet national goals

The Division's support of the research community is administered through 16 programs within its four clusters. The structure and program directors are noted below. Key disciplinary emphases are:



- **Chemical, Biochemical and Biotechnology Systems** supports fundamental research on processing and manufacture of products of economic importance by effectively utilizing chemical and renewable resources of biological origin. A key tool is bioinformatics originating from genomic and proteomic information.

- **Biomedical Engineering and Engineering Healthcare** supports research related to the development of novel ideas into products that integrate engineering with life science principles. By providing solutions to biomedical problems, these products are examples of how engineering research serves humanity.

- **Environmental Engineering and Sustainability** supports engineering with the goal of reducing adverse effects of solid, liquid, and gaseous discharges into land, fresh and ocean waters, and air that result from human activity. Research in this cluster also considers the long-term availability of these resources and of energy.

- **Transport and Thermal Fluid Processes** supports fundamental research in thermal, mass and momentum transport. This research enables new technological solutions to understanding pressing issues in the environment, manufacturing, health care, energy and other fields.

Expanded statements for each program are contained in Appendix I.

Current planning context

ENG has been involved in strategic thinking processes over the past few years. As a result of the planning, the ENG directorate was reorganized on October 1, 2006, resulting in the establishment of CBET. Since then, CBET has been undergoing a divisional planning process. The process has included:

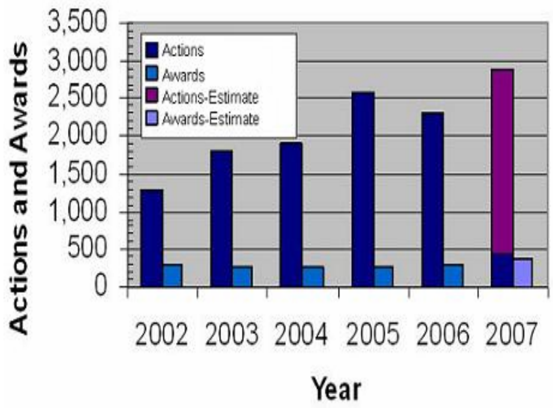
- Divisional meetings and planning, complemented by regular cluster meetings

- An off-site, two-day strategic planning retreat including SWOT (strengths, weaknesses, opportunities and threats) analyses, and preceded and followed by four on-site retreats

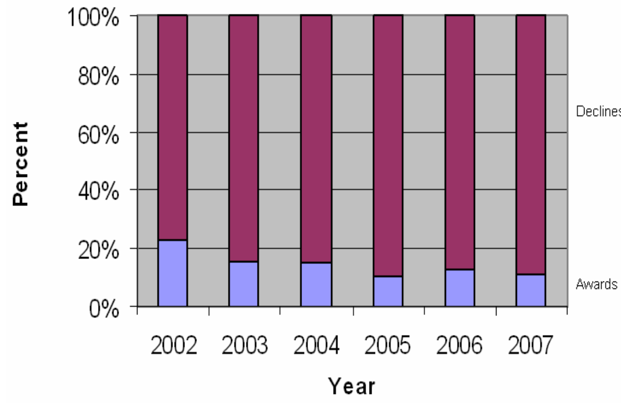
- Input from the external communities through focused workshops (the major workshops supported over the past few years are listed in Appendix II)

- Assessment and input from the recent Chemical and Transport System (CTS) and Bioengineering and Environmental Systems (BES) Committee of Visitors (membership is listed in Appendix III)

The recent trends in proposal and awards activity are presented below and are obtained from the NSF Enterprise Information System (EIS) with FY07 estimates based upon activity through February 2007. It is noteworthy that the new division has resulted in the establishment of two windows (February and September) for unsolicited proposals across all programs in the division. Previously, CTS had two windows while programs in BES had either no window (proposals accepted at any time) or one window.



Number of annual research proposal actions and awards. FY07 values are estimated based upon the actions through February 2007.



Percentage of annual research proposal actions that are awarded and declined. FY07 are the best estimates based upon actions through February 2007.

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Vision and Mission

Vision

The NSF vision expressed in the NSF Strategic Plan [NSF Strategic Plan 06-11] is: Advancing discovery, innovation and education beyond the frontiers of current knowledge, and empowering future generations in science and engineering.

The Engineering Directorate vision is: ENG will be the global leader in advancing the frontiers of fundamental engineering research, stimulating innovation, and substantially strengthening engineering education. [NSF ENG Long View].

Consistent with these vision statements, the **CBET vision** is:

> CBET will be a global leader in identifying and enabling the most innovative research and education at the frontiers of engineering; inspiring the integration of physical, mathematical and life sciences with engineering; and cultivating a vibrant, diverse community in key, emerging and core areas benefiting society.

Mission

As stated in the NSF Strategic Plan 2006–2011, the NSF mission is: To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense.

The ENG Long View states that: ENG seeks to enable the engineering and scientific communities to advance the frontiers of engineering research, innovation and education, in partnership with the engineering community, and in service to society and the nation. It enables this advancement by supporting programs and activities that foster innovation, creativity, and excellence in engineering education, fundamental research, and knowledge application and by promoting the natural synergy among these elements.

The **CBET mission statement** is:

> CBET will promote and support transformative research and education in engineering areas based on the physical, mathematical and life sciences; advance scientific and engineering knowledge; and develop a diverse, globally engaged workforce enhancing the economy of the United States.

SWOT ANALYSIS

The SWOT analysis was carried out at the off-site retreat by the program directors of the Division.

Strengths

- Excellent program staff with strong and diverse intellectual base
- Interaction with competitive industrial sectors and communities
- Good intra/inter-divisional, inter-directorate and interagency interactions
- Fair-handed funding of outstanding research, which includes diverse and new investigators
- PIs who are international leaders in their fields
- Strong fundamental scientific base, including strong and direct interaction with fundamental physical, biological, computer and mathematical sciences
- Record of visionary achievement (Nano initiative, EFRI, etc)

Weaknesses

- Inability to gain good leverage in some NSF programs (e.g., Information Technology Research (ITR)/Computer Science)
- Extremely low success rates
- Communication within NSF and with external communities is not robust
- Little consistency in reviewing broader impacts of funded research
- Variable responsiveness to the engineering community
- Little mentoring of new program directors

Opportunities

- Well placed for the integration of physical, mathematical and life sciences with engineering
- The new programs in energy, sustainability and the WATERS network may attract extra funding from outside NSF.
- New opportunities in cyberinfrastructure, neuroscience and interagency developments
- In a position to be sure that the science funded is connected to applications through technology transfer

Threats

- Low funding rates endanger NSF relevance to PIs and reviewers
- Continual decrease in public perception of engineering
- Slow response time allows other agencies to pick up new areas

GOALS

This plan sets forth goals for the division for the next five years. In this section, CBET goals are presented in the following categories: discovery, learning, research infrastructure, and stewardship. For each stated goal, objectives, brief descriptions, justifications/benefits, and implementation strategies are presented.

Discovery Goal:

CBET will lead engineering discovery and innovation in chemical, bioengineering, environmental and transport systems through the following objectives:

Strategic Objective 1: Fund more investigator-identified and defined awards:

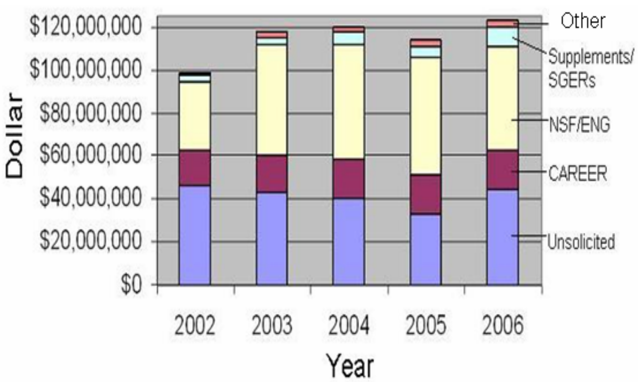
Support for new engineering discovery and innovation ideas from a researcher or a group of researchers has been a foundation of NSF. Unlike mission agencies, the Foundation seeks to fund the best ideas and thus contribute to building the knowledge infrastructure of the nation. The CBET *goal* is to dedicate at least 50% of its annual budget to unconstrained, unsolicited awards that are identified and defined by investigators in the core disciplines of chemical, biochemical and biotechnology systems; transport and thermal fluids phenomena; biomedical engineering and engineering healthcare; and environmental engineering and sustainability. This goal is generally achieved through support of unsolicited proposals that show significant novelty and potential impact.

Many reasons support making this goal a top priority, yet the best presentation of the *justification* is through past examples. Possibilities that came out of investigator-identified and defined research range from wireless communications to treatment of debilitating diseases to the Internet. Common to all these advancements is the continuous support of scientific and engineering knowledge generation and innovation, along with investments in the development of instrumentation concepts. These specific and distributed advances, both small and large, could not be predicted, planned or directed. NSF and CBET must provide similar opportunity for funding investigator-identified and defined awards to future engineers so that the pipeline for discovery of new enabling technologies will continue.

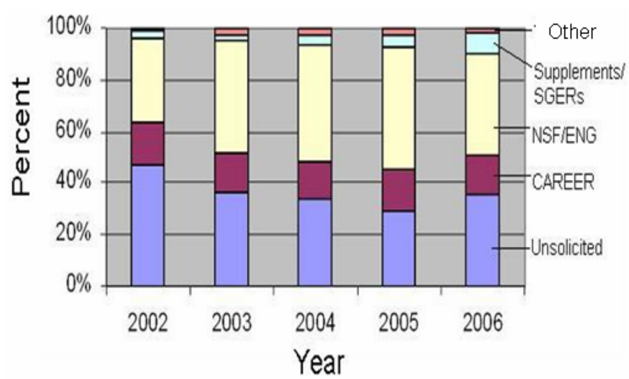
Striking a prudent balance between supporting investigator-initiated research and supporting strategic research is a challenge. Awareness of and the need to address pressing socio-economic issues have over the past two to three decades gradually shifted the balance of funding. It might be argued that today too many investigator-initiated opportunities to generate new, fundamental knowledge are being missed. This change has the potential to create a dearth in investigator-identified and defined awards as researchers become increasingly discouraged, and the long-term impact on discovery and innovation could be devastating. Unfortunately, the precise impact of this trend is not only unknown but also unknowable. Metrics to assess this loss in opportunity do not exist because we cannot measure, before the fact, what society loses from the absence of major scientific advances. NSF must embrace the argument to support unsolicited research with the unwavering belief that discovery and innovation are the bedrock of an advancing society.

Directed programs are generally designed to foster and shepherd progress toward the solution of identified problems (see examples in Thematic Research Areas below). More often than not, elements of the fundamental science and engineering base required are in place and strategically directed advance is the focus. Such emphasis is important, but it cannot proceed at the expense of the development and encouragement of new ideas and the creation of general knowledge.

To provide a basis for divisional *implementation* scenarios, the recent budget trends for ENG and CBET are analyzed. Appendix V contains CBET budgets provided by the Office of the Assistant Director of Engineering, and they are presented below. This information is divided into: NSF and ENG solicitations; Small Grants for Exploratory Research (SGERs) and supplements; stipends; CAREER; and unsolicited. The NSF/ENG solicitations include a large element of STC support. FY07 budgets are only estimates based upon funding projections through February of 2007.



CBET budgets by category. Unsolicited (dollars that are used for investigator-identified and defined awards), NSF priority areas, ENG emphasis areas, supplements, and stipends.



CBET budget percentages by category. Unsolicited (dollars that are used for investigator-identified and defined awards), NSF priority areas, ENG emphasis areas, supplements, and stipends.

Based upon the most recent CBET FY07 budgets, CBET will spend just over one-third of its budget on unsolicited, investigator-identified and defined awards. Dedicating future budget increases to such awards for the next five years will permit CBET to reach the 50% goal, while also addressing other objectives laid out in this plan. With CBET playing a significant role in the American Competitiveness Initiative (ACI), it is hoped that the CBET budget will increase significantly over the next five years. By maintaining funds for targeted activities, the 50% goal is achievable within two years. However it is possible that these activities will increase slightly, particularly to implement some of CBET's other goals, and focus and discipline on the part of CBET and ENG will be required to place investigator-identified and defined awards as a top priority.

Strategic Objective 2: Emphasize four thematic research areas

As noted above, the research emphasis of CBET disciplines has provided the foundation for many of the current research themes in ENG. The CBET impact in the areas of bio-and nano-technology are examples. This process of incubation at the intersections and boundaries of disciplines is a natural extension of the research in the basic engineering disciplines and will continue into the future.

CBET has been actively involved in a strategic planning process and has identified a number of future thematic areas. The *strategic objective* and list of divisional thematic areas has been culled from that initial and much larger list. The result is the generation of three key characteristics a thematic research area must have. They are:

- Demonstrate significant societal need,
- Show strong potential for impact, and
- Be central to CBET's vision and mission.

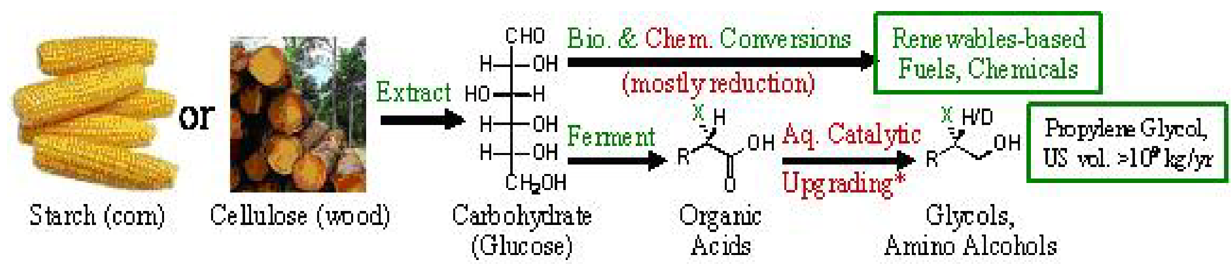
1. ENERGY, WATER AND SUSTAINABILITY (EWS)

The establishment of two new programs, Energy for Sustainability and Environmental Sustainability, demonstrates the Division's commitment to this thematic area. Further, throughout its other programs, CBET will continue its investment in environmentally relevant technologies and fundamental aspects of energy production and conversion. Pollution prevention strategies, increased use of renewable energy sources and feedstocks, and the concomitant technological challenges are important CBET research topics. New chemicals and products synthesized from biomass, hydrogen production from non-fossil fuel sources, and novel techniques for water purification are examples of environmentally focused research areas. Other related environmental and energy-focused CBET interests include studies of river flow and of fluid-sediment interactions over complex coastal topography.

Research leading to products and processes that avoid negative local and global environmental impacts will be a CBET priority. Examples of CBET interest areas are environmentally benign production processes that minimize undesirable side products, new biocatalysts that permit the use of renewable feedstocks, and separation and purification processes that use less energy. CBET also funds work to findand use environmentally sound solvents, cleaner combustion processes, more efficient energy conversion, and reliable process-design methods that reduce or eliminate environmental impact.

More than 1 billion people in the world do not have access to safe drinking water, and it is estimated that 1.8 million people are killed each year by using unclean water. New membranes for purification and cheaper desalination processes can help improve the supply and quality of water. Novel sorbent materials for removing pollutants from wastewater are being investigated, and polymeric hydrogels have been used to remove selected ions from wastewater. Furthermore, CBET is the lead division for the ENG/Geosciences (GEO) WATERS Network initiative, a potential Major Research Equipment and Facilities Construction (MREFC) project aimed at observing, monitoring and finally predicting the nation's water supply integrating complex natural environments with engineered systems.

Energy-focused research is an active CBET area. It includes catalysts and membranes for fuel cells, new structures and compositions for hydrogen storage and production (from biological and organic sources), and materials used in energy production from alternative resources. Renewable energy resources are a focus of the new Energy for Sustainability program. Efficient fuel cells and hydrogen-combustion devices are expected to reduce U.S. dependence on hydrocarbon-based fuels. The hydrogen economy will need an array of new materials for energy production, fuel storage and conversion. CBET is interested in the fundamental aspects of fuel-cell development including, micro-fuel cells as well as large fuel cells for transportation. Environmentally focused strategies for employing hydrogen within existing and new combustion devices are also of interest. The combustion of domestically derived fuels produced within the emerging hydrogen economy infrastructure offers another route for cleaner energy conversion. Combustion strategies such as burning in pure oxygen may facilitate carbon sequestration processes to help reduce global warming.



The most economic path for large scale production of biofuels and chemicals from biomass will consist of a blend of biochemical and thermochemical conversions. Enzymes are needed to break down the starch or cellulose into sugar units (left hand side of figure), while less expensive, more robust inorganic catalysts can be used thereafter (right side of figure). [Miller and Jackson, Michigan State University]

2. Systems and multi-scale approaches using novel engineering methods and techniques (SME)

Many of CBET's research activities require fundamental modeling and simulation and the use of cyber-infrastructure. Adopting a systems and multi-scale approach to these efforts will lead to significant advances in many of the Division's fields. As an example, ENG has established a leadership position across NSF with a solicitation on Quantitative Systems Biology and leads a worldwide World Technology Evaluation Center (WTEC) study on Systems Biology.

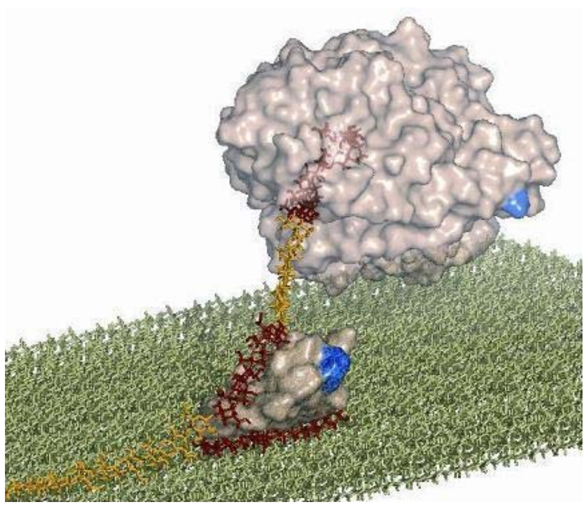
The current emphasis in the Directorate and Division is to reduce the number of specialized solicitations. Therefore, Systems Biology proposals will be funded through the regular unsolicited proposal cycle.

ENG and CBET also lead the $20 million Multi-scale Modeling (MSM) initiative in Biomedical, Biological & Behavioral Sciences involving partners both within NSF - - Civil, Mechanical, and Manufacturing Innovation (CMMI), Mathematical and Physical Sciences (MPS), Computer and

Information Science and Engineering (CISE), and Biological Sciences (BIO) - - and outside NSF (NIH, DOE and NASA).

By using a systems and multi-scale approach, the CBET community of researchers should be better able to understand, predict and optimize the products and processes that benefit society in the areas of the environment, safety and security, medicine, and healthcare. Multi-scale modeling has been applied widely to all programs within the Division and has also been the topic of several NSF-wide and interagency solicitations. This area is also part of the NSF initiative in Cyber-enabled Discovery and Innovation. The aim now is to ensure that multi-scale approaches are also translated to core research programs with increased funding through regular unsolicited awards.

Program directors and review panels will consider the application of a systems and multi-scale approach when considering awards to be made. The goal is to increase funding to these awards by 20% over the next five years.



Hypothetical concerted action by CD (catalytic domain) and CBD (cellulose-binding domain) to detach cellulose chain from cellulose crystal and to cleave cellobiose units from chain reducing end by CD. **Red**: Docked portions of cellulose chains (partly obscured by transluscent CD); **Yellow**: Non-docked portions of cellulose chain; **Green**: Cellulose crystal; **Blue**: Points of attachment of O-glycosylated linker to CD and CBD (linker structure is unavailable). [Reilly, Iowa State University]

3. NANOSCALE SCIENCE AND ENGINEERING (NSE)

CBET has been at the forefront of the National Nanotechnology Initiative since its inception. NSE now plays an important role in the core disciplines of the Division. As a critical focus for CBET, nanotechnology inspires fundamental research and innovation in areas such as materials synthesis and handling, new product development, new manufacturing methodologies, new applications of nano-bio-technology and nano-medicine, homeland security, and energy and environmental sustainability. Support of NSE initiatives allows fundamental research in the synthesis and processing of nanostructured materials with novel physical, chemical, and biological properties. The synthesis of nanoparticles, thin films, and 3-D nanostructures with unique functionality by methods involving nucleation, molecular or particle self-assembly, directed assembly, cell mobility and functionalization, controlled thermal and molecular transport, combustion, or plasma synthesis, is a priority for CBET investments in NSE-related research.

NSE-related research areas in which CBET plans to invest in the next five years are:

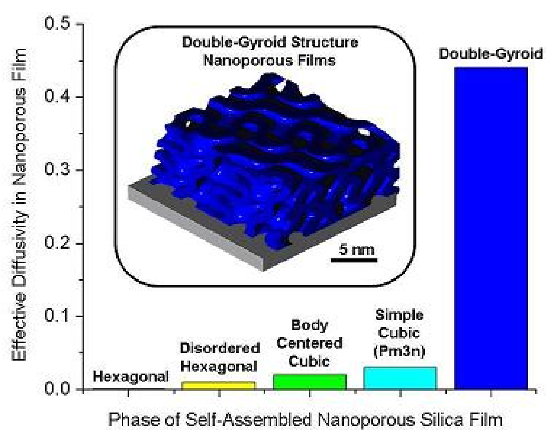
- Synthesis and assembly of active and adaptive nanomaterials and nanostructures that can enable new developments in fields such as nanoelectronics and nanomagnetics, nanomedicine, sensors and actuators, and targeted drug delivery. Techniques for synthesizing nanoscale materials can include liquid-phase routes, aerosol processing, combustion synthesis, biotechnology and tissue engineering, plasma processing, and vapor-phase synthesis.

- Research on interfacial and transport phenomena at the nanoscale and on reaction processes that enable the self- or directed-assembly of nanostructures, and transport and processing of nanomaterials. Research will also focus on developing novel devices and on manufacturing processes and products.

- Development of new experimental techniques and instruments that enable structural, chemical, biomolecular, electronic and morphological characterization of nanoscale materials. Also needed is the development of standards for nansocale metrology (nanometrology).

- Development of novel nanostructured catalysts, enzymes, adsorbents and membranes with high selectivity for chemical and biological processing and separation applications.

- Energy and environmental applications, including the use of nanostructured materials to enable high-flux heat transfer, research on fuel cells and novel thermoelectric devices, the use of nanostructured materials for environmental remediation applications, and studies of health-related issues involving nanomaterials.



Nano-wires and Porous Films: a Key to Advance Development of the Next Generation of High Efficiency Thermal and Solar Energy Conversion Devices. The figure shows the dramatic enhancement of species transport in the double-gyroid phase of highly oriented and ordered nanoporous silica thin films. The boxed inset shows the structure of the double-gyroid film determined by grazing-angle x-ray scattering and high resolution electron microscopy. [Hillhouse, Purdue University].

To accelerate the benefits to society from targeted investments in fundamental research on the above topics, CBET will allocate funds to support research addressing fundamental questions underlying the scale-up of synthesis processes, the development of new instrumentation and nanometrology, research related to chemical sensors and bio-sensors, synthesis of nanomaterials with unique physical, chemical and biological properties, and new approaches for materials processing and characterization at the nanoscale. The results of these research projects will also find applications in fields of science, engineering and medicine.

4. Integration of Life Sciences with Engineering

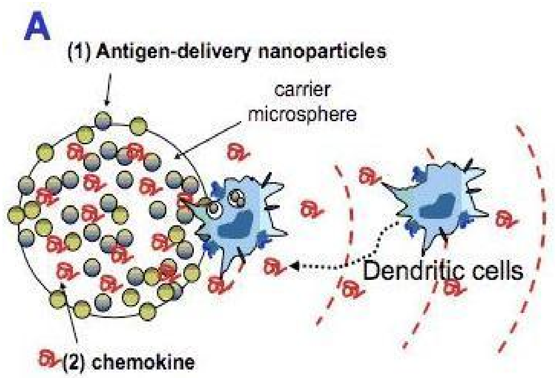
The merging of CTS with BES has given the new division the expertise to lead the integration of life sciences, along with physical and mathematical sciences, into engineering research. The array of program directors with divergent knowledge and experience offers collaborative and synergistic opportunities in many areas.

The Quantitative Systems Biology approach is an example of the application of engineering thinking to problems in the life sciences. Another example is the joint NSF/NIH Solicitation on "Engineering Approaches to Energy Balances in Obesity," for which CBET was the lead NSF division. Other areas where engineering approaches can be of benefit include health care and bioengineering systems, such as molecular biomachines and biomimetic devices, the brain-computer interface, and new biophotonics imaging methods.

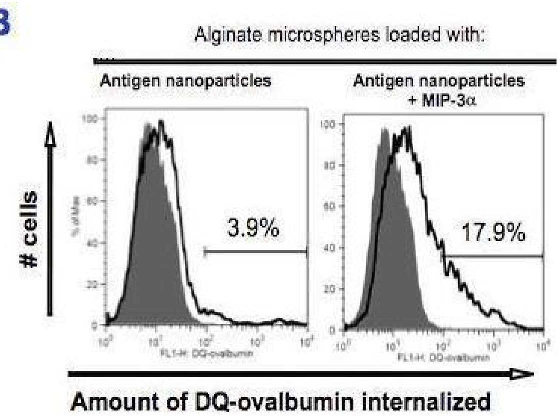
Additionally, program directors from the Division took a leading role in the defining the Cellular and Biomolecular Engineering topic within EFRI. Applications received in the solicitation are expected to apply transformative tools to the following:

- Measurement of the interaction between cells, molecules, non-biological surfaces, membranes and other materials
- Modeling and simulation of cells and the interface of cells with materials (sensors, medical diagnostics, bio-electronics)
- Identification and measurement of mechanisms for interactions between biological and non-biological material (physical-chemical-biological, intra/extra cellular signaling, bio-structures)
- Understanding how to alter genetic structures of cells to deliver new functionality and meet needs via metabolic engineering.

These areas are all important in CBET programs and as interdisciplinary activities between programs. The goal is to fund these areas through core programs after the EFRI support expires.



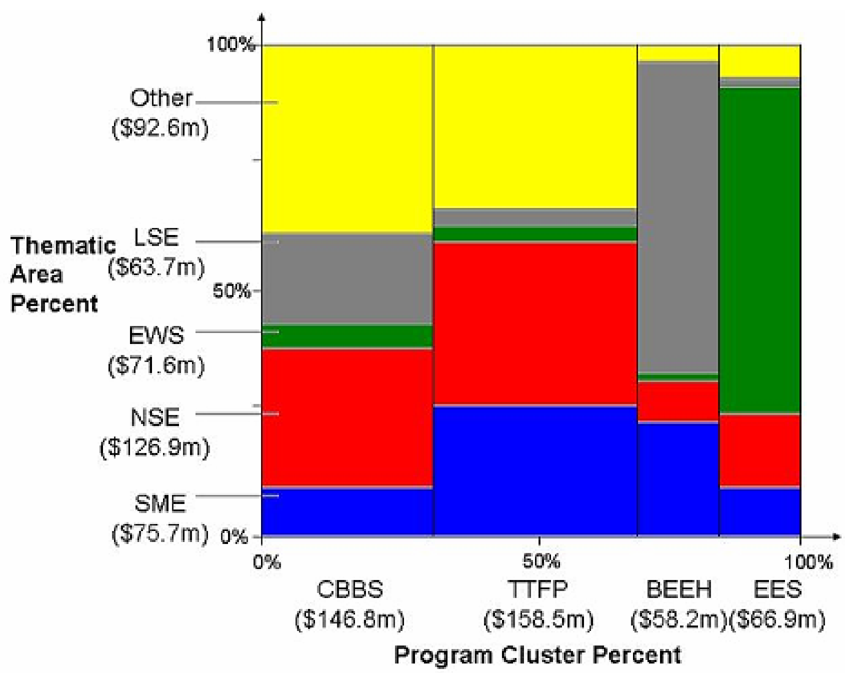
(A) Schematic view of compound delivery microspheres. Carrier microparticles fabricated from calcium-crosslinked alginate are loaded with both protein chemokines and hydrogel nanoparticles. The nanoparticles themselves carry antigen and immunostimulatory factors for dendritic cells (DCs). Chemokine slowly releases from the carrier microsphere and draws dendritic cells to the carrier, where they phagocytose the nanoparticles entrapped in the carrier bead.



(B) Flow cytometry data illustrating how chemoattraction of dendritic cells to microspheres increases the number of cells internalizing large quantities of a fluorescent antigen (DQ-ovalbumin) entrapped in nanoparticles [Jain and Irvine, Massachusetts Institute of Technology]

Implementation of Thematic Research Areas

The four thematic research areas are central to the CBET mission as well as to ENG, NSF and the nation. Distributed across the four CBET program elements are significant ongoing activities in each of the four priority areas:



CBET contributions by program element and research priority areas for the CBET investments as of December 2006. The abscissa is the percent of total dollars within each program element. The ordinate is the percent of expenditures by research priority areas. The dollars are noted in parenthesis for the acronyms – CBBS - Chemical, Biochemical & Biotechnology Systems, TTFP-Transport & Thermal Fluid Phenomena, BEEH-Biomedical Engineering & Engineering Healthcare, ESS-Environmental Engineering and Sustainability, EWS – Energy, Water and Sustainability, SME – Systems and Multi-Scale Modelling, NSE-Nanoscale Science and Engineering, and LSE – Life Sciences in Engineering

The awards portfolio of active CBET investments as of December 2006 yields the above representation of CBET activities (Appendix VII contains the values). The horizontal axis is the percent of the entire CBET awards portfolio based on dollars in each program cluster. The distribution among the award dollars is divided among two large program clusters (Chemical, Biochemical & Biotechnology Systems (CBBS) and Transport & Thermal Fluids Phenomena (TTFP)), and two smaller program clusters (Biomedical Engineering & Engineering Healthcare (BEEH) and Environmental Engineering & Sustainability (EES)). The vertical axis provides the percent of CBET awards within each research thematic area. Almost a third of CBET investments are in nanoscale science and technology through NSE. Fifteen percent of CBET investments are in Energy, Water and Sustainability (EWS), and another 17 % are in systems and multi-scale modeling through SME.

Yet much more needs to be accomplished. For the five-year period of this division plan, the CBET implementation strategy is to increase its percentage of activity in the areas of Life Sciences in Engineering (LSE) and in EWS, while maintaining its current percentage level of activities in SME. Although the fraction of CBET activities in NSE will probably decrease, this decrease will be relative because actual dollar investment will increase. The CBET implementation strategy will be implemented in each thematic area depending on the realization of the top CBET priorities noted above. Thus the funding in NSE will at least remain constant, while the funding in EWS, LSE and SME will increase by 20%.

CBET will continue to emphasize collaborations and partnerships that will lead to an important impact with an emphasis on the four thematic areas.

Learning Goal:

CBET will develop and support the best and the brightest researchers, innovators and educators in CBET's fields through the following objectives:

Strategic Objective 3: Support new faculty

CBET is dedicated to learning through education and faculty development. Building a globally engaged Science, Technology, Engineering and Mathematics (STEM) workforce depends, to a large extent, on the existence of a diverse, well-motivated faculty body.

CBET has taken a leadership role in trying to increase the number of faculty members from underrepresented groups. The CAREER and PECASE programs are highly valued in CBET and CAREER awards are a high priority in all programs. The CBET *goal* is to annually fund workshops focusing on new faculty and on the successful recruitment, retention and advancement of minority engineering faculty, graduate students and undergraduates, including African-American, Hispanic, Native American and women engineers. CBET will continue to support CAREER proposals with a goal of success rates exceeding 15% by 2010.

The budgetary information outlined above clearly demonstrates the Division's commitment to new faculty, with the percentage of Division funds allocated to CAREER awards rising from 17 percent in 2002 to 27 percent in 2006. For FY07 the success rate in the Division for CAREER awards is 13.5%. However, this rate is not constant across the programs, with variation from approximately 10 percent to 30 percent. The Division will work, through the allocation of resources and delineation of program elements, to ensure CAREER success rates are relatively uniform across programs.

Excellent documentation has been provided [ENG Workforce Report] to *justify* the need for this goal. The voluminous data and analyses of this subject show some very disturbing trends. Examples include:

- The percentages of academic engineering positions held by women and minorities are low relative to the overall percentages of women and minorities receiving engineering doctorates (18.3 percent of Ph.D. degrees in engineering are awarded to women and 7.4 percent are awarded to racial and ethnic minorities, yet only 10.6 percent of engineering tenured or tenure-track faculty are women and only 4.7 percent are minorities).

- The percentage of women earning doctorates in engineering is low (18.3 percent) relative to the proportion of women in the general public (51 percent).

- The percentage of all college students majoring in engineering has been declining over the last five years, even though the absolute numbers of college students are starting to increase. Furthermore, the projections that the number of high school students will decrease by 2010 suggest a drastic shortfall of engineering graduates if this trend continues.

- Women and minorities make up more that two-thirds of the U.S. workforce, yet they represent less than one third (19 percent women, 11 percent underrepresented minorities) of engineering graduates at the bachelor's level.

Specific CBET workshops aimed at minority and women faculty have been held every year since 2004 at NSF headquarters in order to facilitate free communication of participants with program directors and relevant NSF staff. CBET will continue to take a lead role in these annual workshops even as they are being expanded to cover the entire ENG Directorate.

CBET proposes to increase its outreach. This outreach is especially aimed at new faculty, particularly new faculty from underrepresented groups. In this respect, CBET will increase its participation in CAREER Workshops for young faculty by partnering with other divisions in hosting these workshops at the annual symposia of the American Society of Mechanical Engineers (ASME) and the American Institute of Chemical Engineers (AIChE). In addition, CBET will continue to support other forms of CAREER proposal counseling, particularly through active participation in the Minority Faculty CAREER Workshops organized by the Quality Education for Minorities (QEM) Network.

Strategic Objective 4: to promote lifelong learning and professional development for science, technology, engineering and management (STEM) workforce and for science at large.

Building the human infrastructure in engineering is a continuing CBET priority. The CBET emphasis in student education is supported by the fact that over three-fifths of CBET annual personnel expenditure in its awards is dedicated to graduate and undergraduate student support. In addition, CBET has a strong history of support of Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) supplements and, more recently, RET Sites. In FY07, CBET is participating in an ENG-wide call for special supplements to assist faculty in recruiting new, minority graduate students. Building the human infrastructure will continue to be a top priority, with the CBET *goal* to place increased emphasis on support for graduate and undergraduate students on all CBET awards.

The history of NSF's impact on graduate education is impressive. In order to maintain the nation's current excellence in graduate education and leadership role in the international arena, NSF, ENG, and CBET must renew their commitment to graduate and undergraduate education through its research grants.

To *implement* this aspect of the goal, CBET will encourage all awards to include support for a minimum of one graduate student and several undergraduate students each year of the grant. The traditional support mechanisms of graduate research assistantships, graduate fellowships, REU, and RET will continue to be utilized. The goal will be implemented via professional society presentations, conference presentations, panel reviews, paper and electronic transmissions, and, perhaps most effectively, through specific award interactions between PIs and PDs.

Design Projects to Develop Recreational Technology for Persons with Disabilities. Image of the Challenged America crew racing the B'Quest (as taken from a helicopter by Geri Conser).

Image of B'Quest crew on dock [May-Newman, San Diego State University]

Infrastructure Goal:

CBET will enhance its support of both human and physical research infrastructure

Strategic Objective 5: Encourage interdisciplinary, group projects

The *goal* is to position CBET researchers to be well placed to succeed in NSF and ENG-wide interdisciplinary solicitations requiring established teams, networks, and facilities. Supporting interdisciplinary research proposals is perceived to be difficult within standard NSF processes. Some of the avowed difficulties with interdisciplinary research include (excerpted from the ENG Strategic Thinking Group draft report):

- Review of interdisciplinary research proposals often requires reviewers and panels representing very broad knowledge bases.
- Panel reviews often tend toward a consensus, but can yield mixed reviews for interdisciplinary research.
- Tight program budgets reduce the flexibility to handle proposals having mixed reviews.

Some mechanisms are currently available to handle interdisciplinary research within NSF. Some solicitations specify the multidisciplinary make-up of the teams and allocate funds directly for multidisciplinary use. Divisions currently support small groups of investigators working on interdisciplinary projects. However, such efforts are relatively small, and tight funding has led to a decline in such activity.

Based on the 2006 CBET awards portfolio, less than 4% of the awards (and less than 8% of the funds) were categorized as substantial, investigator-initiated, interdisciplinary awards. However CBET's PIs come from many disciplines (see Appendix VIII) and hence the opportunity exists to encourage and create interdisciplinary teams. The goal is to reach an investment of 15% of the budget on such investigator-initiated interdisciplinary awards, so that an estimated additional commitment of between $5 million and $7 million annually is needed. These awards will be funded through the existing unsolicited proposal windows in single programs or co-funded by different programs. In order to facilitate co-funded awards, funds will be set aside specifically for these awards, and these proposals will be reviewed in joint panels.

Strategic Objective 6: to apply cyberinfrastructure to CBET engineering fields

Cyberinfrastructure requirements involve both hardware and software to enable major developments throughout CBET programs. In FY06, CBET invested approximately $25 million in activities broadly related to cyberinfrastructure. Many of these investments are related to the development of simulations and models to enable frontier research. However, we still need to build networks and relationships of researchers to best utilize the facilities available and the models developed, and ensure they are validated with reliable and realistic experimental data. The goal is to have CBET PIs succeed in NSF cyber initiatives. In order to implement this goal

CBET programs will provide planning grants to encourage the development of these networks so that that our communities are well-placed to succeed in NSF and ENG-wide solicitations.

Strategic Objective 7: to fund small and intermediate ($50K–$200K) instrumentation and equipment requests.

Research awards in CBET have increasingly become focused on supporting personnel with little left for instrumentation or equipment. Furthermore the availability of funds for major equipment items through the Major Research Instrumentation (MRI) program is limited to large requests (above $200K), leaving a gap in opportunities for researchers to support the small and intermediate requests. In the last two years, no equipment purchases of this type have been funded. The goal is to fund up to 5% of CBET's annual grants for these small instruments. To *implement* this goal, CBET will encourage researchers to seek equipment support through unsolicited proposal submissions.

STEWARDSHIP GOAL: CBET WILL ENHANCE ITS DIVISIONAL OPERATIONS, STAFF DEVELOPMENT AND EXTERNAL RELATIONS

STRATEGIC OBJECTIVE 8: TO PURSUE AND IMPLEMENT PARTNERSHIPS, CREATE A SENSE OF CBET COMMUNITY, AND COMMUNICATE IMPACT TO THE GENERAL PUBLIC

Together with ENG, the CBET goal is to orient and mentor all new CBET staff to enable them to significantly contribute to fulfilling the Division's mission.

NSF has a tradition of a fifty-fifty mix of permanent and temporary program directors. It is in the Foundation's best interest for the program directors to have productive and effective assignments and become integral parts of the Division. *Benefits* of orientation and mentoring programs include effective use of all resources - - time, funds, people - - and increased impact on the research communities. Additional advantages include exposure to external opportunities, assistance with the effective and timely use of NSF systems and support, and crucial advice on balancing all the activities. ENG has developed written guidelines for merit review training [Merit Review Training Manual, Merit Review Committee, Draft Report, 2007]. The Division will be actively engaged in this training process, and it will also continue to pair new program directors and staff with experienced mentors to improve their start-up period. Additionally, administrative staff will be encouraged to take advantage of training opportunities to be challenged and to reach their full potential.

CBET intends to continue to aggressively pursue and implement partnerships with other engineering divisions, directorates and agencies. Through collaborations and partnerships, CBET has built important connections within ENG and NSF as well as with other external agencies and laboratories. Within NSF, CBET has participated through funding, planning and leadership of various collaborations including NSE, ITR, MRI, Grant Opportunities for Academic Liaison with Industry (GOALI), Materials Use: Science, Engineering and Society (MUSES), CAREER, Quantitative Systems Biotechnology (QSB), CRNS, Mechanics and Structures of Materials (MSM), and Sensors and Sensor Networks (Sensors). Equally important are partnerships with external groups including NIH, EPA, DOE, NASA and Sandia National Laboratories. Also, international partnerships are supported throughout the programs within

CBET. Appendix VI lists CBET participation in various organizations where there are important CBET contributions.

Outreach and dissemination to the general public are important aspects of the Division's activities. Dynamic interaction with universities, industry, foundations, non-profits and the other agencies mentioned above provide the opportunity to inform the public about the impact of the research and education supported by CBET programs. To implement this goal, CBET program directors and reviewers will use dissemination as one of the criteria in assessing the broader impacts of proposals, and encourage PIs to use any means available to them to ensure the public is aware of their impacts. Collaborations will be encouraged by holding more in-house technical meetings and seminars. Brown bag lunches with NSF staffers as well as invited guests will be held monthly on topics of interest across the Division.

Strategic Objective 9: broaden diverse participation throughout CBET in all activities

In all activities, CBET wishes to represent the diversity of its community, which include, program directors, reviewers, and PIs. Thus the goal is to have, as program directors, panelists and *ad hoc* reviewers, at least the same proportion of women and underrepresented minorities as exists in the Assistant Professor pools in the CBET disciplines. The complement of full time program directors in the Division is 20. Of these, six (30%) are women and one (5%) is an underrepresented minority. These percentages are higher than the Assistant Professor pool in Engineering (18.5% for women and 3.4% for underrepresented minorities).
The percentage of awards made to women and underrepresented minorities are 16% and 8% respectively. The funding rates are equal to or higher than the average funding rates across NSF (17 percent) for both these groups (19 percent for women and 17 percent for minorities). However, the number of proposals submitted is low for both classes (15 percent for women and 7 percent for minorities), so CBET needs to work to ensure these groups have the confidence and ability to submit proposals.

Data for reviews undertaken by women and underrepresented minorities are not separated. However, for FY06, 28 percent of CBET reviews were made by underrepresented groups (either women or minorities). This percentage is slightly under the percentages in the Assistant Professor ranks but above the tenured or tenure-track faculty available in engineering schools.

In order to meet its goal of increasing these percentages, CBET will monitor panels, proposals and awards and make every effort to ensure diversity is maintained and increased. This diligence will require effort in identification of potential candidates, panelists, and reviewers, and will also require discipline in making strategic decisions when opportunities arise.

Workforce planning

CBET has a complement of 20 full-time program directors including the Division Director. Of these, 10 are career NSF employees and 10 are temporary or rotating positions. It is proposed to maintain the current balance of 50% rotators among the Division's professional positions. Maintaining this balance will require recruitment of two to four program directors every year for the next five years and beyond. Appendix IX shows the recruitment cycle for current and future program directors based on the average rotator term of two years. Based on past experience, the continual recruitment and renewal of rotating program directors has worked very well to bring new ideas to the division and to ensure healthy exchange with academic stakeholders. This rotation not only gives faculty the opportunity to influence program directions but also raises understanding of the Division and its activities in the community.

REFERENCES

The Engineering Workforce: Current State, Issues, and Recommendations, 2005

The Engineer of 2020: Visions of Engineering in the New Century, National Academy of Engineering, 2004

Facilitating Interdisciplinary Research, National Academies Press, 2005

Innovate America: National Innovation Initiative Final Report, Council on Competitiveness, 2005

Making Imagination Real, Advisory Committee, Directorate for Engineering, NSF 04-21, 2004

Making the Case for Engineering; Study and Recommendations, Directorate of Engineering, 2005

Merit Review Training Manual, Merit Review Committee, Draft Report, 2007

National Academy of Engineering, Engineering Research and America's Future: Committee to Assess the Capacity of the U.S. Engineering Research Enterprise, 2005

National Science Foundation, Directorate for Engineering, The Long View, 1993

National Science Foundation Strategic Plan, FY2006-2011

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, NRC/COSEPUP, 2005

APPENDIX I. CBET PROGRAM DESCRIPTIONS

Chemical, Biochemical, and Biotechnology Systems

Process and Reaction Engineering - This program supports fundamental and applied research on:

- Rates and mechanisms of important classes of catalyzed and uncatalyzed chemical reactions as they relate to the design, production, and application of catalysts, chemical processes, and specialized materials;
- Chemical phenomena occurring at or near solid surfaces and interfaces;
- Electrochemical and photochemical processes having engineering significance or commercial potential;
- Design and optimization of complex chemical processes;
- Dynamic modeling and control of process systems and individual process units;
- Reactive processing of polymers, ceramics, and thin films; and
- Interactions between chemical reactions and transport processes in reactive systems, and the use of this information in the design of complex chemical reactors.

Catalysis and Biocatalysis - This program primarily supports fundamental and applied research on:

- Kinetics and mechanisms of important catalyzed chemical reactions as they relate to the production of chemicals, fuels, and specialized materials;
- Characterization of chemical phenomena occurring at or near solid surfaces and interfaces;
- Electrocatalytic processes having engineering significance or commercial potential;
- Sustainability, environmental catalysis, and basic research related to green chemistry or utilization of biorenewable resources;
- Kinetic modeling and theory of heterogeneous, homogeneous catalysis and biocatalysis;
- Fundamental aspects of reactive deposition and processing for thin film materials; and
- Interactions between chemical reactions and transport processes in reactive systems, and the use of this information in the design or control of complex chemical reactors.

Biochemical and Biomass Engineering - This program primarily supports fundamental and applied research on:

- All innovative aspects of biochemical and biomass engineering;
- Areas including bioenergy and bioproducts, basic research aspects of biorefineries, enzyme and protein engineering, bioreactors and fermentation, biosensing, and animal and plant cell culture technology, including vaccine and stem cell culture technology (as within federal government funding restrictions),
- Research driven by engineering principles and including the education of students in engineering areas; and
- Proposals emphasizing enhancement of American Competitiveness Initiative (encouraged).

Biotechnology - This program primarily supports fundamental and applied research on:

- Problems involving processing and manufacturing of products of economic importance by effectively utilizing renewable resources of biological origin and utilizing bioinformatics originating from genomic and proteomic information;
- Emphasizing basic engineering and biological research that advances the fundamental knowledge base that contributes to a better understanding of biomolecular processes (in vivo, in vitro, and/or ex vivo) and eventually to the development of generic enabling technology and practical application;
- Performing quantitative assessments of bioprocesses and their rates at the levels of gene regulation and expression, signal transduction pathways, posttranslational protein processing, enzymes in reaction

systems, metabolic pathways, cells and tissues in cultivation, and biological systems including animal, plant, microbial and insect cells; and

- Studies of fermentation technology, enzyme technology, recombinant DNA technology, cell culture technology, ex vivo and therapeutic stem cell culture technology, metabolic pathway engineering, biosensor development, bioreactor design and bioprocess optimization, bioseparation and purification processes, bioprocess optimization and integration, monitoring and control of bioprocesses, food processing with special focus on the safety of the nation's food supply, tissue engineering, quantitative systems biotechnology, and information technology relevant to biotechnology including bioinformatics, nanobiotechnology and biomimetics.

Chemical and Biological Separations - This program primarily supports fundamental research and education on:

- Membranes, adsorbents, separation processes, crystallization, chromatography, and nanostructured materials;
- Transport processes at the nanoscale including molecular modeling;
- Elements of the hydrogen economy including hydrogen separation processes and fuel-cell membrane materials;
- Water purification, hydrocarbon separations, natural gas purification, and fuel desulfurization; and
- Biological separations including protein and DNA separations.

Transport and Thermal Fluids Phenomena

Thermal Transport Processes - This program primarily supports fundamental research on:

- Gaining a basic understanding at the microscopic and macroscopic levels of thermal phenomena underlying energy conservation, the synthesis and processing of materials, the cooling and heating of equipment and devices, the interaction of industrial processes with the environment, and the thermal phenomena in biological systems and in the propulsion of air and land-based vehicles;
- Researching flow and convective processes with and without phase change, thermal conduction at nano- and molecular scales, radiative transport, and the fundamental characterization of material properties important to these processes; and
- Highlighting projects that deal with problems on the cutting edge of technology, potentially of great societal benefit, while developing human resources in engineering.

Interfacial Processes and Thermodynamics - This program primarily supports novel fundamental research on:

- Supporting engineering science areas related to interfacial phenomena, mass transport phenomena, separation science, and phase equilibrium solution thermodynamics;
- Emphasizing molecular engineering approaches as applied to processing of soft materials, especially thin films and porous media;
- Researching surface-active molecules leading to the direct formation of novel responsive or functional surfaces and materials at the nano-scale, which can be used in new consumer product, and in bio-medical applications;
- Using methods such as molecular simulation and/or experimental observation at multi-scales;
- Developing new theories and simulation approaches defining the thermodynamic, interfacial, and mass transport phenomena properties of fluids and fluid mixtures in biological systems, and defining these properties for other fluids composed of complex molecules;
- Studying pollution prevention at the source and energy storage in the context of the above phenomena;

- Encouraging collaboration with international and industry partners; and
- Investigating, generally, non-reactive systems, but funded research may include reactive systems where interfacial and transport phenomena are dominant.

Particulate and Multiphase Processes - This program primarily supports fundamental and applied research on:

- Mechanisms and phenomena governing single and multiphase fluid flow, particle formation and transport, various multiphase processes, formation of nanostructures, granular materials, and fluid-solid system interaction;
- Improvement of the basic understanding, design, predictability, efficiency, and control of existing systems that involve the dynamics of multiphase fluids and particulates; and
- Uses of multiphase flows and particulates in materials development, manufacturing processes, biotechnology, energy, and the environment.

Fluid Dynamics - This program primarily supports fundamental and applied research on:

- Mechanisms that govern phenomena of fluid flow;
- Newtonian and non-Newtonian fluids, experimental and computational investigations, instrumentation and flow diagnostics, micro- and nano- scale flow phenomena, multi-scale and multi-physics phenomena, biological and biomedical fluid flow, and environmental flows;
- The basic understanding of fluid dynamics, thus enabling the better design, predictability, efficiency and control of systems that involve fluids; and
- Areas such as hydrodynamic stability, turbulence and flow control, rheology, polymers and complex fluids.

Combustion, Fire, and Plasma Systems - This program primarily supports fundamental and applied research on:

- Combustion science including laminar and turbulent flame structure, pollutant formation and mitigation, chemical kinetics, combustion of domestically generated fuels such as bio-fuels and hydrogen, and combustion synthesis of materials;
- Science of fires and fire suppression;
- Plasma processing science, including material synthesis plasmas, atmospheric-pressure plasmas, and plasmas for processing biomaterials;
- Broad-based tools—computational, experimental, or theoretical—that can be applied to a variety of problems in combustion and/or plasmas. Examples are laser diagnostics and molecular modeling;
- Contributions toward a cleaner environment, improved energy and homeland security, better fire safety, and new manufacturing methods; and
- Basic knowledge that can be used by others in development of systems for civil, industrial, or military applications through a non-applied area of study.

Biomedical Engineering and Engineering Healthcare

Research to Aid Persons with Disabilities - This program primarily supports fundamental and applied research on:

- Developing technologies for new and improved devices or software for persons with disabilities;
- Studying the characterization, restoration, and/or substitution of normal functions in humans;

- Emphasizing significant advancement of fundamental engineering knowledge rather than incremental improvements;
- Supporting undergraduate engineering design projects, especially those that provide prototype "custom-designed" devices or software for persons with mental and/or physical disabilities; and
- Developing areas of sample study including novel acoustic wave processing and noise reduction techniques for applications such as hearing aids; developing biocompatible detection technologies that could serve as massively parallel interfaces for communicating with neural tissue such as used in artificial retina; and creating novel technologies for home healthcare, such as new approaches for transdermal drug delivery and home healthcare medication management and telemonitoring.

Biomedical Engineering - This program primarily supports fundamental and applied research on:

- Serving humanity by developing novel ideas integrating engineering and life science principles in solving biomedical problems;
- Focusing on high-impact transforming methods and technologies and including models and tools for understanding and control of biological systems; fundamental improvements in deriving information from cells, tissues, organs, and organ systems; new approaches to the design of structures and materials for eventual medical use; new methods for understanding and controlling living systems, and new methods of reducing health care costs through new technologies;
- Emphasizing the advancement of fundamental engineering knowledge, rather than product development, possibly leading to the development of new technologies or the novel application of existing technologies;
- Encouraging initial evaluation of discovery research in a clinical setting but not supporting clinical trials;
- Projects highlighting a multidisciplinary integration of engineering and the life sciences; and
- Balancing theory, modeling and experiment.

Biophotonics, Advanced Imaging, and Sensing for Human Health - This program primarily supports fundamental and applied research on:

- Generating and harnessing light and other forms of radiant energy in which the quantum unit is the photon, thus harnessing the unparalleled combination of spatial resolution, sensitivity, and spectral specificity of optical techniques to provide new biomedical research tools for visualization, measurement, analysis, and manipulation;
- Furthering biomedical engineering by developing sensing specific at the molecular level, as well as imaging and monitoring systems having high optical sensitivity and resolution for applications in biology and medicine;
- Integrating photonics, molecular biology, and material science to provide low-cost diagnostics;
- Formulating complex biosensors capable of detecting and discriminating among many classes of biomolecules important to biology, medicine, environmental sensing, and homeland defense;
- Advancing optical technology, such as nanoparticle fluorescent quantum-dots, novel waveguiding structures, plasmon surface resonance, nanofluidics, lens microarrays, nanochannel interconnects, and multi-function focal plane detector/emitter arrays; and
- Incorporating optic solutions with surface science, nanotechnology, and microelectronics for a variety of purposes including sensitive, multiplexed, high-throughput characterization of macromolecular properties of cells; imaging molecular interactions that underpin normal physiology; imaging diseases at the molecular and cellular levels; and structural and functional biomedical imaging that can be utilized for medical diagnostics and therapy.

Environmental Engineering and Sustainability

Environmental Engineering - This program primarily supports fundamental and applied research on:

- Understanding the impacts of human activities on the natural environment and developing the scientific basis for solving, mitigating or managing environmental problems caused by human activities;
- Applying engineering principles to understand and reduce adverse effects of solid, liquid, and gaseous discharges into land, inland and coastal waters, and air that result from human activity and that impair the ecological and economic value of those resources;
- Fostering cutting-edge research based on fundamental science and four types of engineering tools: measurement, analysis, synthesis, and design;
- Developing major areas of interest and activity in the program, which include developing innovative biological, chemical, and physical treatment processes to remove and degrade pollutants from water and air; measuring, modeling and predicting the movement and fate of pollutants in the environment; and developing and evaluating techniques to clean up polluted sites such as landfills and contaminated aquifers; to restore the quality of polluted water, air, and land resources; and to rehabilitate degraded ecosystems;
- Developing techniques to minimize or avoid generating pollution, improving the cost-effectiveness of pollution avoidance, developing new principles for pollution avoidance technologies; and
- Improving sensors for environmental conditions and innovative waste reduction and recycling processes.

Environmental Technology - This program primarily supports fundamental and applied research on:

- Developing and testing new technologies across the range of sub-areas and activities in the field of environmental engineering;
- Including new devices and systems for more effective pollutant removal from air and water as well as new technologies that minimize or avoid the pollutant generation inherent in older commercial and domestic processes and activities;
- Advancing and refining sensors and sensor network technologies used to measure a wide variety of physical, chemical, and biological properties of interest in characterizing environmental systems;
- Emphasizing engineering principles underlying pollution avoidance as well as pollution treatment and remediation;
- Improving innovative production processes, waste reduction, recycling, and industrial ecology technologies and techniques to restore polluted land, water, and air resources;
- Current areas of support, such as nanotechnology; environmental, health, and safety implications and applications; environmental cyberinfrastructure; sensor and sensor network technologies; and mitigation of environmental impacts of natural disasters (such as hurricanes);
- Improving material accounting techniques as part of environmental reconstruction efforts following natural disasters;
- Reducing adverse effects of pollutant discharges from human activities; and
- Enhancing the quality and integrity of the natural environment that provides essential ecological services to humans.

Energy for Sustainability - This program primarily supports fundamental and applied research on:

- Supporting fundamental research and education in energy production, conversion, and storage;
- Focusing on energy sources that are environmentally friendly and renewable;
- Reducing greenhouse gases;
- Improving methods for energy production from sustainable sources such as sunlight, wind, biomass, and hydrogen;
- Producing and storing hydrogen for use in direct combustion or in fuel cells and including hydrogen conversion from biomass and from electrolysis, photolysis or thermolysis of water;

- Addressing key challenges in efficiency, durability, power density, and environmental impacts;
- Studying the engineering aspects of fuel-cell design and operation in areas such as water and thermal management and process control;
- Increasing efficiency of wind generators through a fundamental knowledge of the interaction of wind with the blade structure and understanding the fluid flow to optimize blade design; and
- Enhancing photovoltaic devices through new material and fabrication techniques for solar energy conversion.

Environmental for Sustainability - This program primarily supports fundamental and applied research on:

- Promoting sustainable engineered systems supporting human well-being and compatible with sustaining natural (environmental) systems, which provide ecological services vital for human survival;
- Preserving natural capital critical for many areas of human endeavor, including agriculture, industry, and tourism;
- Considering future horizons and incorporating contributions from social sciences and ethics;
- Balancing society's need to provide ecological protection and maintain stable economic conditions;
- Advancing the next generation of water and wastewater treatment decreasing material and energy use, considering new paradigms for delivery of services, and promoting longer life for engineered systems; Advancing engineering methods to promote smart growth strategies; Integrating economic development and protection of natural resources; Regenerating ecological functions of degraded environments; Understanding how large complex environmental systems behave; Developing effective principles for adaptive management of such systems; Improving distribution and collection systems for smart growth strategies and the effects of growth; Innovating areas such as stormwater management, wastewater technology, indoor air quality, recycling and reuse of drinking water, and other green engineering techniques to support sustainable construction projects; Understanding material flows and taking advantage of such understanding to substitute less toxic, longer-lived materials; Emphasizing engineering principles underlying pollution avoidance and remediation of degraded environments; andImproving the cost-effectiveness of pollution prevention and pollution management technologies.

APPENDIX II. RECENT CBET WORKSHOPS

Fourth Eastern Mediterranean Chemical Engineering Conference for Collaborative Research, Dead Sea, Israel, January 9-12, 2006, S. Cramer.

Workshop on Dynamic in situ electron microscopy as a tool to meet the challenges of the nanoworld, Arizona State University, January 3-6, 2006, R. Sharma.

Second International Conference on Transport Phenomena in Micro- and Nanodevices, Barga, Italy, 11-15 June 2006, M. Gad-el-Hak.
http://www.engconfintl.org/pastconf/06atfin1.pdf

International Conference on Aging, Disability and Independence, St. Petersburg, Florida, February 2-4, 2006, W. Mann.

Cities of the Future - Wingspread Workshop: Racine, Wisconsin; July 12-14, 2006, V. Novotny.
http://www.bluewatergreencities.net/default.html

Workshop on Research Frontiers for Combustion in the Hydrogen Economy; Arlington, VA; March 9-10, 2006, N. Glumac.
http://mechse.uiuc.edu/research/glumac/NSFW/Glumac.pdf

Workshop on Cyber-Based Combustion Science, Arlington, Virginia, April 19-20, 2006, A. Trouve.
http://www.nsf-combustion.umd.edu/pdf/NSF-CBCS%20-Report-vf.pdf

Student Travel Support for the 2006 North American Membrane Society Meeting, June 2006, S. Ritchie.

Conference on Thermal Challenges in Next Generation Electronic Systems: THERMES 2007, Sante Fe, New Mexico, January 7-10, 2007, A. Fleischer and S. Garimella.
http://www.engconfintl.org/7ac.html

Workshop for Frontiers in Transport Phenomena Research and Education: Energy Systems, Biological Systems, Security, Information Technology and Nanotechnology, Storrs, CT, Fall of 2006/Spring of 2007, A. Faghri and T. Bergman.

The Fifth International Workshop on Virtual Rehabilitation, New York, New York,
August 29-30, 2006, G. Burdea.
http://www.iwvr.org/2006.html

Partial Support for Graduate Students and Junior Faculty to Attend the 3rd International Workshop on Microplasmas, Greifswald, Germany, May 9-11, 2006, J. Lopez.

Grand Challenges of the Future for Environmental Modeling, Tucson, Arizona in May 2006, M. B. Beck.

U.S.-Poland Workshop on Nanoscience and Nano-Structured Materials, Poznan, Poland, June 26-28, 2006, M. Radosz and K. Gubbins.

Travel Support for Young Researchers to the Second North American Symposium on Chemical Reaction Engineering (NASCRE-2), Houston, TX, February 4-7, 2007, B. Subramaniam and D. Luss.

Summit of Experts in Biomechanics, Washington, D.C., October- November, 2006, R. Kamm, S. Goldstein, and D. Butler.

Nanotechnology Occupational and Environmental Health & Safety Workshop, Cincinnati, Ohio, December 4-8, 2006, A. Genaidy and O. Salem.

Frontiers and Interfaces of Ion Exchange, Antalya, Turkey, June 11-15, 2006, A. Sengupta.

Workshop on Fundamentals of Transport, Pollution and Energy Processes, Durham, New Hampshire, August 20-23, 2006, V. Mathur and W. Ho.

Workshop for Integrating Social Science Research, Washington, DC, Fall 2006, A. Krupnick.

Workshop on Incorporating Sustainability and Business Content into Engineering Education, Washington, D.C., Winter 2006, S. Willoughby, M. Milstein, and E. Kisenwether.

Workshop on Frontiers in Environmental Education, Troy, NY, January 2007, J. Kilduff.

International Workshop on Soot Formation, Italy, May/June 2007, H. Wang.

US-Australia-Singapore Workshop: Sustainable Nano-Manufacturing, Australia, March 2007, B. Moudgil.

Interactive Undergraduate Fluid Dynamics, 2007, C. Rowley.

Workshop on Cyber Infrastructure in Chemical and Biological Systems: Impact and Directions, Arlington, VA, September 25-26, 2006, J. Davis.

International Workshop on Nanoscale Energy Conversion and Information Processing Devices, Nice, France, September 24-26, 2006, A. Shakouri.

Workshop on Complex Interacting Systems for a Sustainable Future, University of Florida, 2007 , T. Anderson.

Workshop on Stem Cell Research Applied to Regenerative Medicine and Tissue Engineering, Arlington, VA, Fall 2006, R. Shelton.

Support of IUTAM Symposium "Recent Advances in Multiphase Flows: Numerical & Experimental", Istanbul, Turkey, 11-14 June 2007, A. Acrivos.

First International Symposium on Sustainable Chemical Product and Process Engineering, Guangzhou, China, 2007, Y. Huang and H. Lou.

Student Travel Support for the 2007 North American Membrane Society Meeting, Orlando, FL, May 2007, I. Escobar.

Workshop on Recovered Materials: Inter-Industry Synergy Workshop, Georgia, October 2006, B. Toktay.

Engineering Approaches to Energy Balance and Obesity Conference, Washington, DC, June 6-7, 2006, J. Hill.

Workshop on Periodic Patterns and Relationships of Well-Defined Nano-Building Blocks, Arlington, VA, 2007, D. Tomalia and A. Jensen.

Brain-Computer Interface Assessment in North America Workshop, Feb 27, 2006.

Brain-Computer Interface Assessment International Workshop, July 21, 2006.

APPENDIX III. CTS COV MEMBERS - 2006

Dr. Ronald J. Adrian
Department of Mechanical Engineering
Arizona State University

Dr. Linda J. Broadbelt
Department of Chemical Engineering
Northwestern University

Dr. Pamela A. Eibeck
Dean of College of Engineering
Department of Engineering
Texas Tech University

Dr. Henry C. Foley (Chair)
Head and Robb Chair
Department of Chemical Engineering
The Pennsylvania State University

Dr. Joseph J. Helble
Department of Chemical Engineering
Dartmouth University

Dr. Sangtae Kim
Department of Chemical Engineering
Purdue University

Dr. Henry A. McGee, Jr.
Founding Dean of Engineering
Department of Chemical and Life Science Engineering
Virginia Commonwealth University

Dr. Lloyd M. Robeson
Principal Research and Associate
Air Products and Chemicals, Inc.

Dr. Levi T. Thompson
Department of Chemical Engineering
University of Michigan

APPENDIX IV. BES COV MEMBERS - 2005

Dr. Gilda Barabino
Department of Chemical Engineering
Northeastern University

Dr. Jacimaria R. Batista
Department of Civil and Environmental Engineering
University of Nevada, Las Vegas

Dr. Christine A. Kelley
Director, Division of Discovery Science and Technology
National Institute of Biomedical Imaging and Bioengineering/National Institutes of Health

Dr. Debra Knopman (Vice-Chair)
Rand Science and Technology
Arlington, VA

Dr. Manfred R. Koller
President and CTO
Cyntellec

Dr Larry McIntyre (Chair)
Institute of Biosciences and Bioengineering
Rice University, Houston

Dr. Hendrik J. Meerman
Senior Scientist
Genencor International, Inc.

Dr. Vincent G. Murphy
Department of Chemical Engineering
Colorado State University

Dr. John T. Novak
Department of Civil and Environmental Engineering
Virginia Polytechnic Institute and State University

APPENDIX V. CBET EXPENDITURES BY CATEGORY

The following data have been provided by the Office of the Assistant Director of Engineering.

	Years				
	2002	2003	2004	2005	2006
A. NSF/ENG Level					
for example:	$31,867,304	$51,245,365	$53,636,964	$54,114,337	$48,028,703
NSE					
BE					
ITR					
Math Priority Area					
Sensors and Sensor Networks					
Science & Technology Center (STC)					
ADVANCE					
Optical Comms & Networks					
UD-Path					
CLEANER					
B. CAREER	$16,322,638	$17,631,048	$17,934,201	$17,728,045	$18,682,924
C. Supplements/SGERs, etc.	$3,337,684	$3,325,432	$5,674,770	$5,990,484	$9,657,195
for example:					
REU Supplements					
RET Supplements					
RET Sites					
SGER					
D. General	$761,813	$774,000	$844,801	$977,005	$843,687
E. Stipends	$0	$1,610,002	$1,638,363	$1,667,801	$1,623,027
F. Unsolicited	$46,240,561	$43,179,063	$40,483,064	$33,532,328	$44,034,464
Total Budget	$98,530,000	$117,764,910	$120,212,163	$114,010,000	$122,870,000

APPENDIX VI. RECENT COLLABORATIONS AND PARTNERSHIPS

ENG Division

- Active Nanostructures and Nanosystems (NSF 06-595)
- Emerging Frontiers in Research and Innovation (NSF 06-595)
- Engineering Research Centers (NSF 07-)
- Materials Use: Science, Engineering and Society (NSF 06-518)

NSF Directorates and Divisions

- Centers of Research Excellence in Science and Technology (NSF 07-526)
- Cyberinfrastructure Training, Education, Advancement, and Mentoring for the 21st Century Workforce (NSF 06-548)
- Environmental Cyberinfrastructure (NSF 06-505)
- Ethics Education in Science and Engineering (NSF 07-541)
- Explosives and Related Threats: Frontiers in Prediction and Detection (NSF 07-528)
- Grant Opportunities for Academic Liaison with Industry, GOALI (NSF 07-522)
- Human and Social Dynamics (NSF 06-604)
- Major Research Instrumentation (NSF 07-510)
- NSF Graduate Teaching Fellows in K-12 Education (NSF 06-556)
- Partnerships for International Research and Education (NSF 06-589)
- Office of International Science and Engineering
- WATERS Network Initiative
- Collaborative Research on Computational Neuroscience (CRCNS)

External Organizations

- Bioengineering Approaches to Energy Balance and Obesity (NSF/NIH)
- Department of Energy Partnership in Basic Plasma Science and Engineering, GEO and MPS
- Interagency Metabolic Engineering Working Group (MEWG)
- Joint Domestic Nuclear Detection Office/ National Science Foundation Academic Research Initiative (NSF 07-545)
- Office of Science and Technology Policy Hydrogen R&D Interagency Task Force – subgroups on Photoelectrochemical Hydrogen Production, Hydrogen Internal Combustion Engines, and Hydrogen Turbines
- Multi-Agency Combustion Research Working Group with Department of Defense, Department of Energy, and National Institute of Standards and Technology
- Multi-Agency Tissue Engineering Science (MATES) Working Group
- National Science and Technology Council Manufacturing Research and Development Interagency Working Group - subgroup on Bioenergy
- Technology for a Sustainable Environment (NSF 03-510)
- Interagency Modeling and Analysis (IMAG)
- Multi-scale Modeling in Biomedical, Biological and Behavioral Systems (MSM)
- Inter-Agency Modeling and Analysis Group
- National Science and Technology Council, Biometrics Subcommittee

APPENDIX VII. CBET PORTFOLIO DATA

CBET Investments by Topic

Active awards as of December 2006

Topic	Tally	% by Tally	Total $	% by $
Air pollution control	17	1.3%	$4,426,274	1.0%
Biomass and bioenergy	2	0.2%	$1,996,695	0.5%
Water treatment and resources	88	6.9%	$49,776,515	11.6%
Remediation	26	2.0%	$9,722,844	2.3%
Sustainability	6	0.5%	$945,489	0.2%
Pollutant formation and mitigation	11	0.9%	$3,610,550	0.8%
Pollutant transport and fate	31	2.4%	$8,496,669	2.0%
Pollution avoidance and control	21	1.6%	$7,878,248	1.8%
Nanobiology and nanotoxicology	9	0.7%	$2,552,782	0.6%
Environmental nanotechnology	18	1.4%	$3,884,274	0.9%
Industrial ecology and material use	4	0.3%	$2,919,914	0.7%
Catalysis	62	4.8%	$21,849,458	5.1%
Chemical process control	23	1.8%	$6,835,003	1.6%
Chemical process design	30	2.3%	$10,730,578	2.5%
Advanced materials processing	5	0.4%	$1,995,652	0.5%
Electrochemistry and processes	14	1.1%	$7,284,377	1.7%
Materials and processes for chemical separations	51	4.0%	$12,148,187	2.8%
Reaction engineering	31	2.4%	$9,886,992	2.3%
Bio-catalysis	7	0.5%	$2,432,520	0.6%
Bioseparations	17	1.3%	$7,221,082	1.7%
Biomechanical engineering	20	1.6%	$5,282,408	1.2%
Biomedical engineering and diagnostics	84	6.6%	$25,522,594	5.9%
Biophotonics and biomedical imaging	38	3.0%	$13,034,586	3.0%
Bioprocess engineering	15	1.2%	$8,356,006	1.9%
Cellular and metabolic engineering	47	3.7%	$18,209,764	4.2%
Molecular engineering	24	1.9%	$7,335,698	1.7%
Protein and enzyme engineering	5	0.4%	$2,526,801	0.6%
Tissue engineering	7	0.5%	$3,048,853	0.7%
Disabled resources and homecare	27	2.1%	$4,236,251	1.0%
Biotransport	31	2.4%	$13,844,257	3.2%
Interfacial and transport phenomena	57	4.5%	$12,967,569	3.0%
Multiphase transition phenomena	13	1.0%	$3,414,690	0.8%
Particle technology	81	6.3%	$19,033,455	4.4%
Flames	21	1.6%	$6,337,397	1.5%
Industrial plasmas	22	1.7%	$7,527,139	1.7%
Thermal phenomenon in manufacturing	38	3.0%	$10,171,223	2.4%
Convection phenomena	22	1.7%	$5,568,480	1.3%
Turbulence, hydrology, and flow	58	4.5%	$15,188,461	3.5%
Rheology and non-Newtonian flows	24	1.9%	$4,732,361	1.1%
Waves, hydraulics and environmental fluids	14	1.1%	$2,517,020	0.6%
Multi-scale modeling	15	1.2%	$6,401,477	1.5%
Sensors and sensing	49	3.8%	$22,009,243	5.1%
Computational framework and informational technology	14	1.1%	$9,638,332	2.2%
Instrumentation	64	5.0%	$24,219,744	5.6%
Other	17	1.3%	$2,737,468	0.6%
CBET Total	1280	100.0%	$430,455,380	100.0%

CBET Investments by Program Cluster

Active awards as of December 2006

Program Cluster	Tally	% by Tally	Total $	% by $
Chemical, Biochemical, and Biotechnology Systems	384	30.00%	$154,786,762	35.96%
Transport and Thermal Fluids Phenomena	496	38.75%	$150,136,093	34.88%
Biomedical Engineering and Engineering Healthcare	205	16.02%	$59,104,406	13.73%
Environmental Engineering and Sustainability	195	15.23%	$66,428,119	15.43%
Total for CBET	1280	100.00%	$430,455,380	100.00%

CBET Investments by Research Thematic Area

Active awards as of December 2006

Research Thematic Area	Tally	% by Tally	Total $	% by $
Energy, Water and Sustainability	169	13.20%	$71,553,536	16.62%
Systems, Multi-scale Modeling and Applications of New Techniques in Engineering Research	221	17.27%	$75,671,275	17.58%
Nanoscience and Engineering	316	24.69%	$126,881,847	29.48%
Life Sciences in Engineering	213	16.64%	$63,732,480	14.81%
Other	361	28.20%	$92,616,242	21.52%
Total for CBET	1280	100.00%	$430,455,380	100.00%

APPENDIX VIII. DISCIPLINARY ORIGIN OF CBET PIS

DISCIPLINE OF PI	PROPOSALS (%)	ACTIVE AWARDS (%)
Aerospace	3	1
Agriculture	2	1
Biological Sciences	1	1
Bio/Biomedical Engineering	9	8
Chemical Engineering	25	38
Chemistry	7	4
Civil Engineering	1	2
Environmental Science and Engineering	4	8
Electrical/Computer Engineering	6	4
Materials Science and Engineering	4	2
Mechanical Engineering	28	21
Medical Sciences	2	2
Physics/Mathematics	6	3
Other	3	4

APPENDIX IX. WORKFORCE PLANNING - AS OF APRIL 2007

Program Director for	Current Term Expires	Has agreed to stay to	Recruiting in
Division Director	January 2008	January 2009	Fall 2008
Chemical, BioChemical and Biotechnology Systems			
1401: Catalysis and Biocatalysis	September 2007	September 2008	Spring 2008
1402: Biochemical & Biomass Engineering	Career Employee		
1403: Process and Reaction Engineering	Career Employee		
1417: Chemical and Biological Separations	Career Employee		
1491: Biotechnology	Career Employee		
Transport and Thermal Fluids Phenomena			
1406: Thermal Transport Processes	September 2007	September 2008	Spring 2008
1407: Combustion, Fire & Plasma Systems	July 2007	July 2008	Spring 2008
1414: Interfacial Processes & Thermodynamics	Career Employee		
1415: Particulate & Multiphase Processes	July 2008	July 2009	Spring 2009
1443: Fluid Dynamics	September 2007	September 2008	Spring 2008
Biomedical Engineering and Engineering Health Care			
5342: Research to Aid Persons with Disabilities	September 2009	September 2011	Spring 2010
5345: Biomedical Engineering	Career Employee		
7236: Biophotonics	Career Employee		
Environmental Engineering and Sustainability			
1440: Environmental Engineering	August 2007	August 2007	Spring 2007
1179: Environmental Technology	Career Employee		
7643: Energy for Sustainability	July 2008	July 2007	Spring 2007
7644: Environmental Sustainability	July 2007	July 2009	Spring 2009
Interdisciplinary Activities	Career Employee		