# DIVISION OF CHEMICAL AND TRANSPORT SYSTEMS
# DIRECTORATE FOR ENGINEERING
# NATIONAL SCIENCE FOUNDATION

## STRATEGIC PLAN

MAY 31, 2005

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# EXECUTIVE SUMMARY

Chemical and transport phenomena, the research areas supported by the NSF Division of Chemical and Transport Systems (CTS), are ultimately responsible for many processes in industry, in the environment, in transportation systems, and in living organisms. CTS funds research in many engineering disciplines including: aerospace, chemical, civil, environmental, and mechanical engineering, as well as partnering with the physical, biological and information sciences. This research impacts countless products and services that are ubiquitous throughout society. These include all modes of transportation, health care, consumer products, safety and security, housing, and leisure and entertainment. In industrial processes, CTS sponsored technological areas are largely responsible for the rates at which many processes proceed, and for the quality of the resulting product. An excellent example is development of materials and manufacturing processes, such as plastics that are used by nearly everyone in applications from vehicles to hospitals to grocery bags. CTS researchers are involved in the recovery and processing of fuels that power automobiles and airplanes as well as emerging power sources for the future such as fuel cells. The transport of thermal energy from production sources to utilization destinations is an integral part of the CTS research agenda. CTS researchers have developed advanced diagnostic techniques that are utilized on medical lab-on-a-chip applications, which employ microfluidics for DNA sequencing, blood tests, etc. Other applications for such sensors include biohazard detection to ensure safety and security of the homeland.

In many cases, research sponsored by CTS has as its ultimate goal improvement of the ability to predict and control chemical and transport phenomena, in order to improve the ability to design devices and to regulate performance. The specific fields of catalysis, high heat flux heat transfer, the use of microreactors, micro-fluidics, interfacial phenomena, plasma, bulk materials processing, the use of adsorption media for selective chemical and biochemical separations and selective membranes find uses in fuel cells, sensors, health care, thermoelectric devices, and innovative environmental technologies, among other practical applications. Other CTS processing areas of growing importance are powder processing based on a fundamental understanding of particles interactions, 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. CTS research focuses on fast, accurate, non-intrusive detection and sensing methods for chemical, thermal and biological events and process control and prevention strategies. Another aspect of safety and security is the reduction of US dependence on imported fossil fuels through research in alternate energy technologies such as bio-based fuels and more environmentally benign recovery and use of domestic fossil fuels resources. Processes for efficiently producing, storing and converting hydrogen are also of growing interest to CTS to help develop improved national economic security. CTS will continue supporting environmentally relevant technologies and fundamental aspects of energy production and conversion. Pollution prevention strategies, increased utilization of renewable energy sources and feedstocks, and the concomitant technological challenges are important CTS 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. In short, CTS researchers have contributed to a vast range of engineering solutions beneficial to society ranging from development of products used in hospitals everyday to enabling the moon landing, and are poised to make even more significant contributions in the future.

This draft strategic 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:

### IDEAS GOAL - CTS WILL LEAD ENGINEERING DISCOVERY AND INNOVATION IN CHEMICAL AND TRANSPORT SYSTEMS THROUGH INCREASED SUPPORT FOR RESEARCH IDENTIFIED AND DEFINED BY INVESTIGATORS.

The CTS goal is to dedicate at least 50% of its annual budget to investigator-identified and -defined awards in the core disciplines of chemical reaction processes, interfacial phenomena and separations, fluid dynamics and particle processes, and thermal systems.

**PEOPLE GOAL - CTS WILL DEVELOP A DIVERSE GROUP OF LEADERS WITHIN THE CHEMICAL AND TRANSPORT SYSTEMS COMMUNITY THROUGH FACULTY DEVELOPMENT AND STUDENT EDUCATION**

The CTS goal is to annually fund workshops focusing 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, and to continue to support an appropriate level of CAREER proposals.

**INTERDISCIPLINARY RESEARCH GOAL - CTS WILL ENHANCE ITS SUPPORT OF INTERDISCIPLINARY RESEARCH THROUGH THE CREATION OF A CTS INTERDISCIPLINARY RESEARCH PROGRAM, INCLUDING AN ADDITIONAL PROGRAM DIRECTOR AND NEW FUNDS**

The goal is to develop a separate CTS program to support interdisciplinary research through a direct allocation of new funds and the addition of a new program director. This program is intended to encourage and support interdisciplinary research outside focused solicitations and centers.

**PRIORITY RESEARCH AREAS GOAL - CTS WILL ENHANCE ITS IMPACT IN THE FOLLOWING RESEARCH AREAS: NANOSCALE SCIENCE AND ENGINEERING, SAFETY AND SECURITY, SMART MANUFACTURING AND PROCESSING, ENVIRONMENTALLY-FRIENDLY AND ENERGY-FOCUSED PROCESSES AND PRODUCTS**

Through collaborations, partnerships and expanded funding, CTS will continue to emphasize these priority areas.

**ORGANIZATIONAL EXCELLENCE GOAL – CTS WILL ENHANCE ITS DIVISIONAL OPERATIONS AND STAFF DEVELOPMENT**

The CTS goal is to use all the currently available NSF electronic systems (FastLane, eJacket, eCorrespondence, etc.) to process proposals, correspond with PIs, and manage divisional funds. Together with ENG, CTS will develop orientation and mentoring programs for all new CTS staff.

# INTRODUCTION

## BACKGROUND

The Division of Chemical and Transport Systems (CTS) supports research and education in the core disciplines of chemical reaction processes, fluid and particle processes, interfacial phenomena and separations, and thermal systems. These areas are essential to ensure continued growth of the fundamental engineering knowledge base, which is the foundation for advances in a wide range of technologies. These research and educational investments contribute significantly to the knowledge infrastructure and development of the workforce for major components of the U.S. economy. These include the process industries (chemicals, pharmaceuticals, health, forest products, materials, petroleum, food, and textiles), utilities, transportation industries (land and air-based), electronics systems and communications providers, and producers of consumer products of all kinds.

Engineering chemistry and energy appeared as one of the earliest components of NSF and has played an important role in various organizational structures of NSF until this day. In the late ‘50s, NSF engineering started as a program within the Division of Mathematical, Physical and Engineering Sciences. After maturing into a division, the program structure of engineering emerged in the early ‘60s with five programs. The programs were:

- Engineering Chemistry,
- Engineering Energetics,
- Engineering Materials,
- Engineering Mechanics, and
- Engineering Systems.

This structure existed throughout the ‘60s. The division of engineering appears in the early ‘70s with three sections:

- Engineering Chemistry and Energetics
- Mechanics, and
- Electrical Sciences and Analysis.

Additional programs were added to these sections, and a Mechanical Sciences and Engineering Section and a Civil and Environmental Engineering Section replaced the Mechanics Section in the late ’70s. When the Directorate of Engineering (ENG) was formed in the early ‘80s (after first residing in the Directorate of Engineering and Applied Science), one of the three Divisions was the Division of Chemical and Process Engineering. The areas of thermal and fluid transport were in the Division of Mechanical Engineering and Applied Mechanics until ENG was reorganized in the late ‘80s. (It is interesting to note that the Office of Interdisciplinary Research appeared within ENG in the early ‘80s.) Various reorganizations added divisions in the ‘80’s and ‘90’s including those dealing with cross-disciplinary research, design, manufacturing and computer-integrated engineering, emerging and critical engineering systems, infrastructure development, centers, bioengineering, environment, and various combinations of these areas. The last major reorganization formed divisions that were somewhat cross-disciplinary, rather than mirroring the disciplines in academia. The chemical and transport programs have been within the Division for Chemical and Transport Systems (CTS) since the ‘80’s.

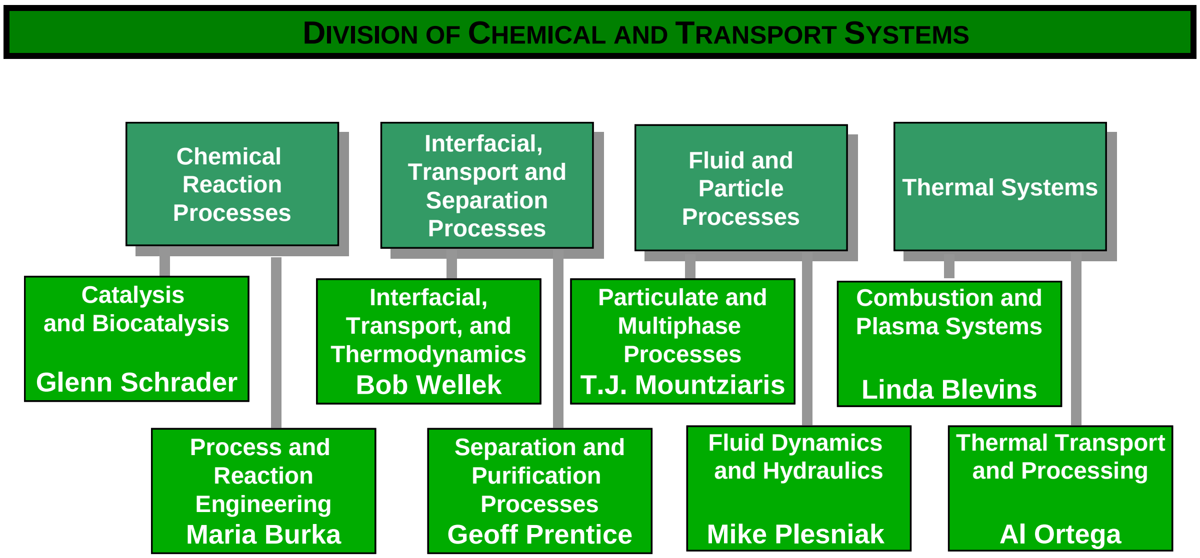
These reorganizations of ENG address the ever-changing and dynamic nature of and the expanding disciplines encompassed by engineering. The first major disciplinary changes from the original programs added the electrical and then computational elements to ENG. Then bio-, environment-, info- and nano-technology contributions were incorporated. Throughout all these additions and changes, CTS has been central to these developments and, in the case of bio- and nano-, an incubator for other disciplinary and interdisciplinary programs. As with other basic engineering disciplines, chemical engineering and transport systems provide both the foundation for innovation and creation of new knowledge and have remained a cornerstone of engineering discovery and innovation.

Consistent with NSF's long-term vision [NSF ENG Long View], CTS 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 four program elements with two subprograms within the four major elements. The structure program directors are noted below, and key disciplinary emphases are:




- Chemical Reaction Processes – supports fundamental and applied research on engineering processes as they relate to the design, production, and use of catalysts, the design and control of chemical processes, the synthesis of fine and specialty chemicals including polymers, biorenewables and specialized materials.

- Fluid and Particle Processes – supports fundamental research in the basic mechanisms and phenomena governing the motion of fluids, particle formation and transport, and multiphase systems that contribute to improving basic understanding, design, predictability, efficiency, and control of systems as well as for innovative uses in materials development, manufacturing, biotechnology, and the environment.

- Interfacial, Transport and Separation Processes – supports research related to interfacial phenomena, mass transport phenomena, separation science, and phase equilibrium thermodynamics directed towards the chemical and material processing, as well as bioprocess and environmentally benign engineering.

- Thermal Systems – supports the basic understanding of thermal and thermochemical phenomena, through theoretical, computational, and experimental investigations, underlying the production of energy, the synthesis and processing of materials, the interaction of industrial processes with the environment, the propulsion processes in air and land-based transportation systems, and the thermal phenomena in biological systems.

Expanded statements for each program are contained in Appendix I.

## CURRENT PLANNING CONTEXT

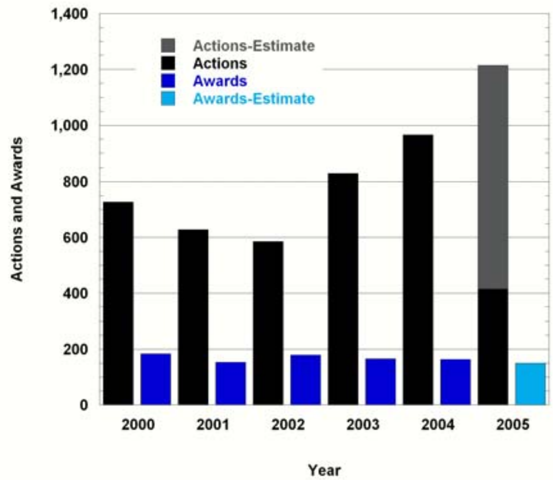
ENG has been involved in strategic thinking processes over the past year. Committees have been formed across ENG. The ENG process is organized around the following task groups with the noted charges:

- Strategic Thinking Group – to foster strategic thinking and coordinate long range planning within the Directorate for Engineering
- Making the Case for Engineering – to strategize how the Directorate for Engineering can better define and communicate its role in enabling the Nation's future through research, education and innovation
- Awards Impact and Assessment – responsible for recommending how ENG should determine the impact of its investments in research, education and innovation
- Awards and Solicitations – responsible for providing information and making recommendations on the processing and approval of ENG awards and proposal generating documents, such as program announcements and solicitations
- Organization and Structure – to provide advice to the Assistant Director for ENG on possible organizational structures to better achieve the goals of the Directorate
- Engineering Workforce – to identify important trends in the engineering workforce and education systems, especially regarding diversity and globalization

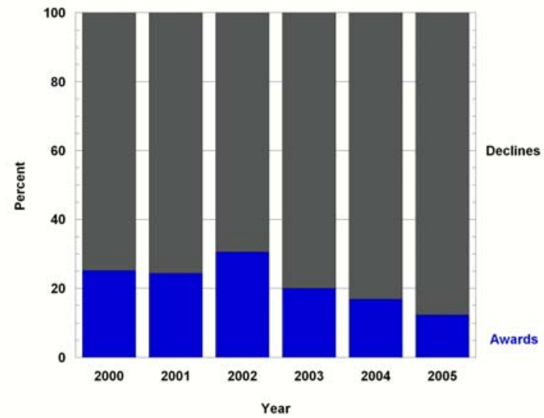
Simultaneously, CTS has been undergoing a divisional planning process. The process has included:

- Divisional meetings and planning
- Traditional strengths, weaknesses, opportunities and threats analyses
- 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 CTS 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 FY05 estimates based upon activity through February 2005. It is important to note that CTS is the last division in ENG to establish submission windows for its investigator-identified and defined (unsolicited) proposals in FY05 (previously CTS accepted unsolicited proposals throughout the year). This move was necessary to handle the ever-increasing number of proposals while providing efficient decisions to the community. Thus, the increasing actions and reduced awards for FY05 are the best, yet probably conservative, estimates available. Unfortunately, these projections yield the lowest success rate in the history of CTS.




Number of annual research proposal actions and awards. FY05 values are estimated based upon the actions through February 2005. (Note that CTS initiated proposal windows for the first time in FY05.)




Percentage of annual research proposal actions that are awarded and declined. FY05 are the best estimates based upon actions through February 2005.

This draft strategic plan will continuously be refined over the next months to ensure that the CTS plan is consistent with the overall ENG planning process.

# VISION AND MISSION

## VISION

The NSF vision expressed in the NSF Strategic Plan [NSF Strategic Plan 03-08] is: Enabling the nation's future through discovery, learning and innovation. The Engineering Directorate vision in the '90s was stated as: In partnership with society, engineering creates, integrates and applies new knowledge across ever-changing disciplines to create shared wealth, protect and restore the environment, and improve the quality of life [NSF ENG Long View].

The Strategic Thinking Group has revisited the ENG vision, and incorporated many of the above concepts. The current working version is: ENG is the global leader in advancing the frontiers of fundamental engineering research, stimulating innovation, and enhancing engineering education, in partnership with the engineering community, and in service to society and the nation.

Consistent with these vision statements, the CTS vision is:

> **TO CREATE ENHANCED SOCIETAL VALUE THROUGH CHEMICAL, FLUID-THERMAL AND BIOLOGICAL ENGINEERING DISCOVERY, INNOVATION AND EDUCATION.**

## MISSION

As stated in the NSF Strategic Plan 2003-2008, the NSF mission is: To promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes. The ENG Long View states that: ENG seek to strengthen the capability of engineering – its knowledge bases and systems, its institutions, and its human and physical resources – to contribute to the Nation's prosperity, security and welfare. It does this 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 between these elements.

The CTS mission statement is:

> **TO DEVELOP AND INTEGRATE NEW PRINCIPLES AND KNOWLEDGE UNDERPINNING USE-INSPIRED PRODUCTS AND SERVICES BASED ON CHEMICAL, FLUID-THERMAL AND BIOLOGICAL TRANSFORMATIONS OF ENERGY AND MATTER.**

# CTS GOALS

This strategic planning document sets forth goals for the division for the next five years. In this section, CTS goals are presented in the following categories – ideas, people, interdisciplinary research, priority research areas and organizational excellence. For each stated *goal*, brief descriptions, *justifications/benefits*, and *implementation* strategies are presented.

## IDEAS GOAL - CTS WILL LEAD ENGINEERING DISCOVERY AND INNOVATION IN CHEMICAL AND TRANSPORT SYSTEMS THROUGH INCREASED SUPPORT FOR RESEARCH IDENTIFIED AND DEFINED BY INVESTIGATORS.

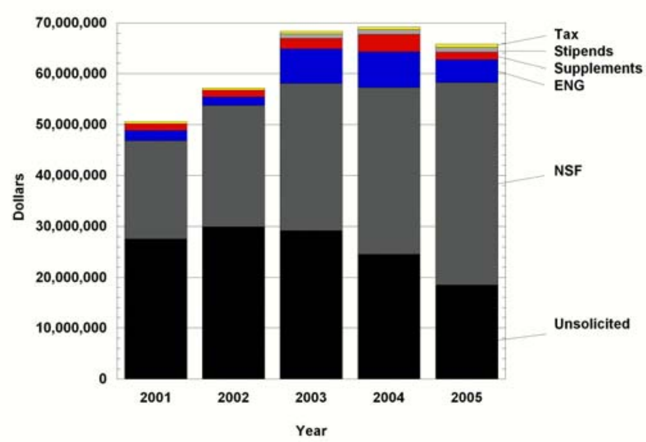
Support for new engineering discovery and innovation ideas from a researcher or a group of researchers has been the foundation of NSF. Unlike mission agencies, the Foundation seeks to fund the best ideas and thus contribute to building the knowledge infrastructure of the nation. The CTS *goal* is to dedicate at least 50% of its annual budget to investigator–identified and –defined (unsolicited) awards in the core disciplines of chemical reaction processes, interfacial phenomena and separations, fluid dynamics and particle processes, and thermal systems. This is generally achieved through support of unsolicited proposals that show significant novelty and potential impact.

There are many reasons for this top priority goal, yet the best presentation of the *justification* is through past examples. There are numerous possibilities ranging from wireless communication to the internet, yet a particularly important and current example is found in the recent Nobel prize awardees. Magnetic Resonance Imaging (MRI) development contains all the essential elements to demonstrate the importance of investigator–identified and –defined awards on engineering innovation – new ideas, development of general knowledge, and investments in physical infrastructure. (Human infrastructure is also essential as noted below in People.) The understanding of magnetic resonance on the atomic scale long preceded its practical use in MRI machines [NAE draft report]. Continual investments and advancements in many areas – some directly connected (atomic and subatomic phenomena), some associated (instrumentation), and some more remote (computers) – were absolutely necessary to provide the means to the end. Common to all these advancements are the continuous support of general knowledge generation and innovation as well as 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 CTS must provide this opportunity to fund investigator–identified and –defined awards for future engineers so that examples like MRI will occur and the pipeline for discovery of new enabling technologies will continue.

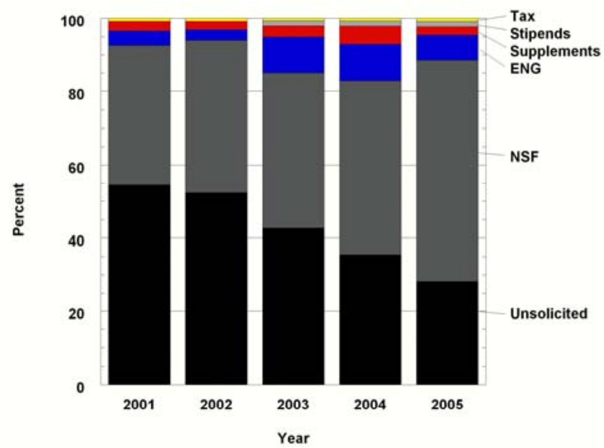
Striking a prudent balance between supporting investigator-initiated research and strategic research is a challenge. Awareness of and the need to address pressing socio-economic issues has over the past two to three decades gradually shifted the balance to the point where today it might be argued that too many investigator-initiated opportunities to generate new fundamental knowledge are being missed. This 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 is not only unknown but unknowable - metrics to assess this loss in opportunity do not exist since there is no way to measure the loss to society of the absence of, for example, MRI before the fact. NSF must embrace the argument 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 Priority 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. This is not to diminish the importance of such emphasis 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 *implementation* scenarios, the recent budget trends for ENG and CTS are analyzed. Appendix IV contains CTS budgets provided by the Office of the Assistant Director of Engineering and they are presented below. This information is divided into NSF priority areas, ENG emphasis areas, supplements, taxes, stipends and unsolicited. The NSF priority areas include CAREER support and, for CTS, it also includes a large element of STC support. FY05 budgets are only estimates based upon funding projections through February of 2005. Note that for the entire ENG directorate, the NSF priority areas and ENG emphasis areas have increased from 48% of its budget in FY01 to 54% in FY04.

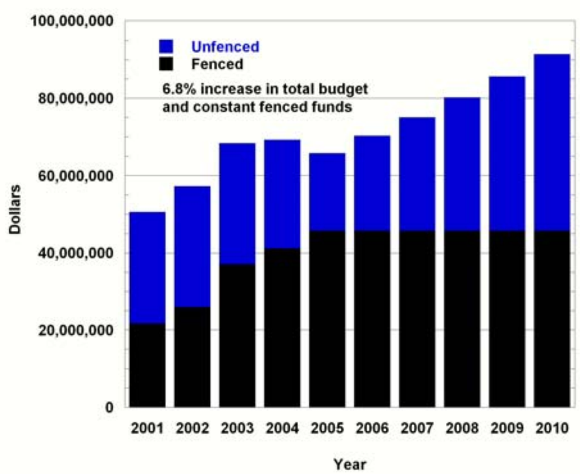



CTS budgets by category – Unsolicited (dollars that are used for investigator-identified and -defined awards), NSF priority areas, ENG emphasis areas, supplements, taxes, and stipends. FY05 are estimates based upon activities through February 2005.

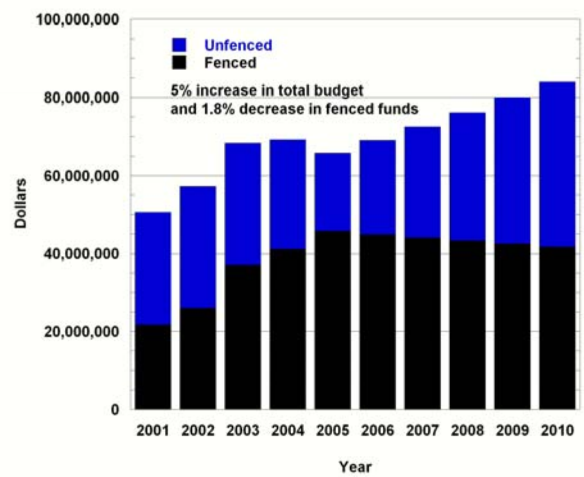



CTS budget percentages by category. FY05 are estimates based upon activities through February 2005.

Based upon the most recent CTS FY05 budgets, CTS will spend less than one-third and closer to one-fourth of its budget on investigator–identified and –defined awards. Dedicating future budget increases to investigator–identified and –defined awards for the next five years will permit CTS to reach the 50% goal, yet there a number of tactics to reach this goal. Two scenarios are considered – a constant fenced funds model with a 6.8% annual increase in total budgets and a 5% increase in total budget with reductions in fenced funds. Both scenarios shown below meet the goal of 50% of CTS funds dedicated to investigator–identified and –defined awards with a final CTS budget between \$84 m and \$91 m in 2010.




CTS constant-fenced budget projection scenario to dedicate at least 50% of its annual budget to investigator-initiated awards by 2010. This scenario assumes constant fenced funds with a 6.8% annual increase in total budgets.




CTS 5%-increase budget projection scenario to dedicate at least 50% of its annual budget to investigator-initiated awards by 2010. This scenario assumes a 5% increase in total budget with reductions in fenced funds.

Either of these models will require focus and discipline on the part of CTS and ENG to place investigator–identified and –defined awards as a top priority. As noted above from the NSF Long View, this is not only a responsibility of the NSF, it is NSF's obligation.

## PEOPLE GOAL - CTS WILL DEVELOP A DIVERSE GROUP OF LEADERS WITHIN THE CHEMICAL AND TRANSPORT SYSTEMS COMMUNITY THROUGH FACULTY DEVELOPMENT AND STUDENT EDUCATION

CTS is dedicated to faculty development and increasing the number of faculty members from underrepresented groups, and CTS has taken a leadership role in meeting this objective. The CAREER and PECASE programs are highly valued in CTS and CAREER awards are a high priority in all programs. The CTS *goal* is to annually fund workshops focusing 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, and to continue to support an appropriate level of CAREER proposals.

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

- Women and minorities working in academic engineering positions in a low percentages relative to the overall percentages receiving engineering doctorates degrees
- The percentage of women earning doctorates in engineering is low (17%) relative to the proportion of women in the general public (51%)
- The percentage of all college students majoring in engineering has been decreasing since 1991
- Women and minorities make up more that two-thirds of the US workforce, yet they represent only 23% of engineering graduates at the bachelor's level.

Specific CTS workshops in 2001 and 2004 to address this goal were very successful and attest to the potential positive impact on these groups, yet the workshops are irregular in their offerings. The specific *implementation* strategy is to hold a minimum of one CTS sponsored workshop per year targeted to minority faculty as a group and to women faculty members as a group. These workshops will be held at NSF headquarters in order to facilitate the free communication of participants with program officers and relevant NSF staff. The community can expect and plan to participate in these events that will ensure connectivity and enhance its potential impact.

CTS proposes to increase its outreach especially to new faculty, and in particular to new, underrepresented faculty. In this respect, CTS 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 ASME and the AIChE. In addition, CTS will continue to support other forms of CAREER proposal counseling, in particular through active participation in the Minority Faculty CAREER Workshops organized by the Quality Education for Minorities (QEM) Network.

Building the human infrastructure in engineering is a continuing CTS priority. The CTS emphasis in student education is supported by the fact that over three-fifths of CTS annual personnel expenditures in its awards are dedicated to graduate and undergraduate student support. In addition, CTS has a strong history of support of REU and RET supplements and, more recently, RET Sites. Building the human infrastructure will continue to be a top priority, with the CTS *goal* to place increased emphasis on support for graduate and undergraduate students on all CTS awards.

The history of NSF's impact on graduate education is impressive. The nation's current excellence in graduate education and leadership role in the international arena can be attributed to NSF's support the latter half of the 20$^{th}$ century. While some have suggested that there has been a recent decline in US graduate education in engineering, this collaborative model of faculty and student research education is still the standard.  To minimize future deterioration in this area, NSF, ENG and CTS must renew their commitment to graduate and undergraduate student education through its research grants.

To *implement* this aspect of this goal, CTS will encourage all awards to include support for a minimum of one graduate student and undergraduate students each year of the grant.  The traditional support mechanisms of graduate research assistantships, graduate fellowships, Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET) will continue to be utilized.  The implementation of this goal will be via professional society presentations, conference presentations, panel reviews, paper and electronic transmissions, and probably the most effective, through specific award interactions between PIs and PDs.

### INTERDISCIPLINARY RESEARCH GOAL - CTS WILL ENHANCE ITS SUPPORT OF INTERDISCIPLINARY RESEARCH THROUGH THE CREATION OF A CTS INTERDISCIPLINARY RESEARCH PROGRAM, INCLUDING AN ADDITIONAL PROGRAM DIRECTOR AND NEW FUNDS

The *goal* is develop a program to enhance interdisciplinary research through a direct allocation of new funds.  To simply encourage funding of interdisciplinary research by suggesting that it would be “good” to fund such projects is insufficient.  As recommended by the CTS COV and discussed in the National Academies report entitled Facilitating Interdisciplinary Research, the objective proposed here is to increase interdisciplinary research through an allocation of additional funds.

Supporting interdisciplinary research proposals is perceived to be difficult within standard NSF processes. Some of the avowed difficulties with interdisciplinary research include (excepted from the ENG Strategic Thinking Group draft report):

- Review of interdisciplinary research proposals often require reviewers and panels with a very broad knowledge base
- Panel reviews often tend towards a consensus and often yield mixed reviews for interdisciplinary research
- Tight program budgets reduce the flexibility to handle mixed-reviewed proposals

There are currently some mechanisms available to handle interdisciplinary research within NSF.  Some solicitations specify the multidisciplinary make-up of the teams and allocate funds directly for this use. Divisions currently support small groups of investigators working on interdisciplinary projects.  However, such efforts are relatively small, and there is not presently an effective mechanism to support and encourage interdisciplinary proposals outside of focused solicitations and centers.

To *implement* this goal, CTS proposes to add a program director and additional funds to solely support interdisciplinary research.  This program will include entirely separate funds to encourage interdisciplinary proposals.  To initiate this effort, three-year proposals not to exceed a total of $1m will be sought.  At least three PIs and co-PIs, all with funded time committed in the budget, will be required.  Other participants may be listed in the project summary and on the budget pages.  Principal investigators will be encouraged to form synergistic collaborations with industry, government laboratories, and scientists and engineers at foreign organizations where appropriate, yet no funds will be provided to those organizations.

Based upon the 2002 CTS awards portfolio, less than 4% of the awards (and less than 10% of the funds) were categorized as substantial, investigator-initiated, interdisciplinary awards.  If the goal is to reach an investment of 25% of the budget on such investigator-initiated interdisciplinary awards, an estimated additional commitment of between $7m and $10m annually is needed.

## PRIORITY RESEARCH AREAS

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

CTS has been actively involved in a strategic planning process and has identified a number of future priority areas. The following *goal* and list of divisional priority areas has been culled from that initial and much larger list and was generated with three overriding characteristics in mind:

- there has to be a significant societal need,
- there has to be significant potential for impact, and
- the topic area has to be central to CTS's vision and mission.

### PRIORITY RESEARCH AREAS GOAL - CTS WILL ENHANCE ITS IMPACT IN THE FOLLOWING RESEARCH AREAS: NANOSCALE SCIENCE AND ENGINEERING, SAFETY AND SECURITY, SMART MANUFACTURING AND PROCESSING, ENVIRONMENTALLY-FRIENDLY AND ENERGY-FOCUSED PROCESSES AND PRODUCTS

#### NANOSCALE SCIENCE AND ENGINEERING (NSE)

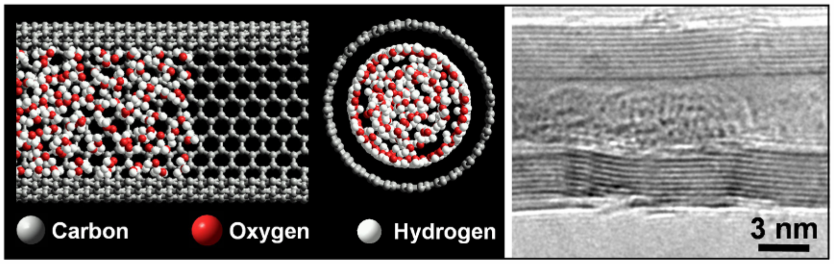
As a critical focus for CTS, nanotechnology inspires fundamental research and innovation in areas such as materials synthesis and handling, new product development, new manufacturing methodologies, new applications of nano-bio-technology and nano-medicine, homeland security, energy and environmental 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 3D nanostructures with unique functionality by methods involving nucleation, molecular or particle self-assembly, directed assembly, controlled thermal and molecular transport, combustion or plasma synthesis, is a priority for CTS investments in NSE-related research.

NSE-related research areas in which CTS 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. Nanoscale materials synthesis techniques can include liquid-phase routes, aerosol processing, combustion synthesis, plasma processing, and vapor-phase synthesis.
- Research on interfacial and transport phenomena at the nanoscale and reaction processes that enable the self- or directed-assembly of nanostructures, transport and processing of nanomaterials, development of novel devices, as well as new manufacturing processes and products.
- Development of new experimental techniques and instruments that enable structural, chemical, electronic and morphological characterization of nanoscale materials and the necessary development of standards for nansocale metrology (nanometrology).
- Development of novel nanostructured catalysts, adsorbents and membranes with high selectivity for chemical 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.

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




Carbon nanotubes are extremely nano-scale hollow tubes fabricated by assembly of carbon atoms into tube-like structures. Such small tubes can be used to transport a liquid, just as a large pipe can convey liquid water or natural gas, from place to place. This study of fluid flow at such small scales is termed "nanofluidics." Left and middle images: HyperChem simulation of water molecules in a (15, 15) carbon nanotube. Right image: TEM observation of water in a carbon nanotube with an inner diameter of 4 nm. (Gogotsi, Bradley, Megaradis, and Bau; Drexel University, University of Illinois, Chicago, University of Pennsylvania ).

## SAFETY AND SECURITY (SS)

CTS activities in safety and security, including physical and cyber infrastructure, are directed at assisting the development of improved, long-range homeland security technologies as well as addressing industrial safety and security issues. Safety involves a systems approach integrating detection, analysis, validation and decision making into a proactive prevention process. CTS research focuses on fast, accurate, non-intrusive detection and sensing methods for chemical, thermal and biological events and process control and prevention strategies**.** Another aspect of safety and security is the reduction of US dependence on imported fossil fuels through research in alternate energy technologies such as bio-based fuels and more environmentally benign recovery and use of domestic fossil fuels resources. Processes for efficiently producing, storing and converting hydrogen are also of growing interest to CTS to help develop improved national economic security. The prevention of industrial accidents, to insure that there are no repeats of incidents like the chemical spills in Bhopal, India are also of priority to CTS.

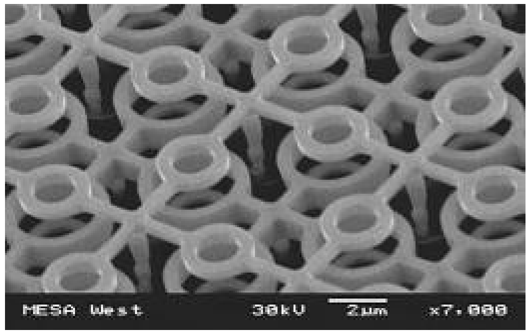
Some specific priority topics for additional future support include:

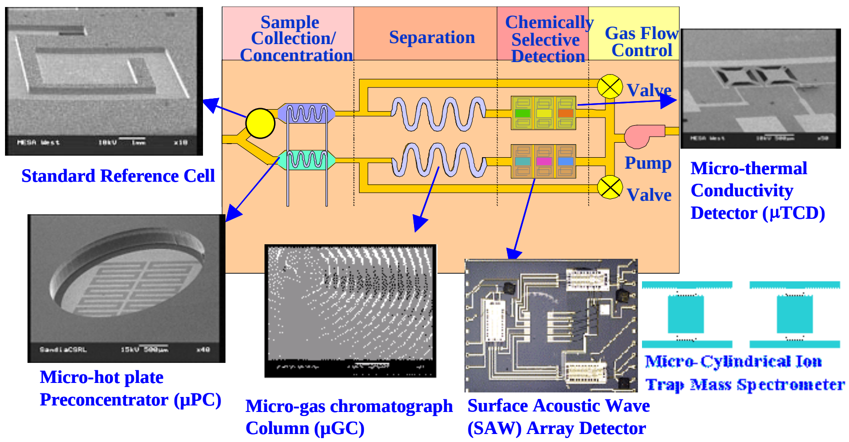
- Flow and mixing of cohesive powders is a CTS research topic of great interest to the pharmaceutical, chemical and petrochemical industry, and also has application in natural phenomena such as landslides and avalanches.

- Understanding the physics and chemistry of fire spread will enable better fire safety in the face of terrorist attacks or other unplanned fires.

- A fundamental understanding of the underlying mechanisms will enable process design and optimization of industrial processes and prediction and mitigation of related natural hazards.

- Chemical process design for enhanced plant security is an important aspect of homeland security since the potential for severe environmental and economic consequences is substantial.



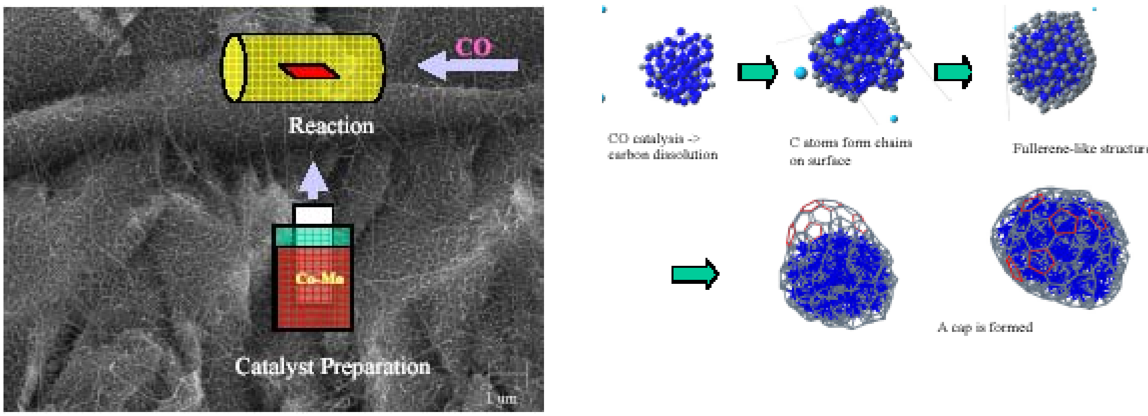




With application in the area of chemical and biological sensing, a novel micro cylindrical ion trap array (µChemLab™) has been developed, fabricated and tested. Top image: A three-dimensional SEM image of a cylindrical ion trap array fabricated by micro-fabrication techniques is shown above. Bottom image: Schematic of the ion trap. (Chang, UCLA)

## SMART MANUFACTURING AND PROCESSING (SMP)

Manufacturing of specialty products, such as pharmaceuticals, health-related diagnostics, and high-value additives, involve the integration of materials design, synthesis, characterization and processing steps. Both theoretical and experimental strategies, such as combinatorial methods and lab-on-the-chip techniques, contribute to this integration. Molecular design and synthesis, self-assembly and directed assembly of gaseous, liquid and solid materials at the nano-scale, micro-fluidics and nano-fluidics constitute some of the frontier research activities that CTS will pursue. Molecular design and process control based on molecular to enterprise-wide considerations is an important activity. Other CTS processing areas of growing importance are powder processing based on a fundamental understanding of particles interactions, 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. A promising new approach explored in CTS is high throughput manufacturing of nano-porous films via flow-induced micelle alignment and other liquid-liquid micro-fluidics systems. Another promising approach funded by CTS is the enhancement of thermoelectric properties or polymer composite materials by addition of nano-particles.

Smart manufacture of new materials will increasingly rely on the theoretical modeling of material-property relationships as well as on the simulation of the comprehensive synthesis procedure. Advanced techniques that utilize *ab initio* calculations for both deterministic and stochastic approaches can now provide key insights into reactivity and kinetic performance. In leading edge research, the design of new functionality can now be largely explored independently of experimentation. Theoretical modeling when coupled with other approaches such as combinatorial synthesis provides an extraordinary opportunity to enable highly efficient and creative designs for manufacturing processes.



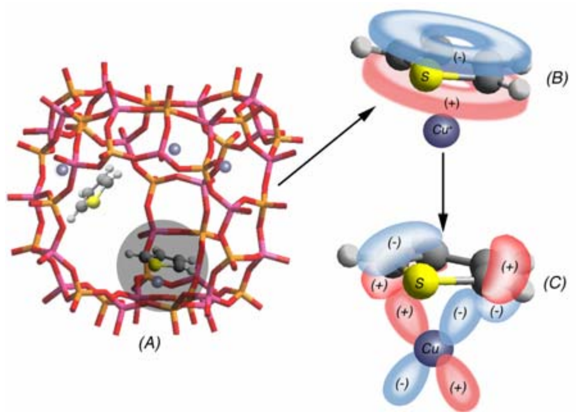

Smart manufacturing of materials is enabled by a molecular dynamic simulation of the reactive force fields that predicts the material properties and the synthesis pathway. Growth of single walled carbon nanotubes (shown extending over a surface) can be controlled to conform to specific technological requirements (size and chirality) by using precisely defined nanoscale catalytic particles. (Balbuena and Resasco, Texas A&M University and University of Oklahoma)

## ENVIRONMENTALLY-FRIENDLY AND ENERGY-FOCUSED PROCESSES AND PRODUCTS (EE)

CTS will continue its investment in environmentally relevant technologies and fundamental aspects of energy production and conversion. Pollution prevention strategies, increased utilization of renewable energy sources and feedstocks, and the concomitant technological challenges are important CTS 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 CTS interests include fluid-sediment interactions over complex coastal topography and river flow. The analysis and design methodology may revolutionize the shape and energy efficiency of aircraft of the future**.**

Research leading to products and processes that avoid negative local and global environmental impact will be a CTS priority. Examples of CTS 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, as well as environmentally sound solvents, cleaner combustion processes, more efficient energy conversion and reliable process-design methods that reduce or eliminate environmental impact. More than one billion people 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.

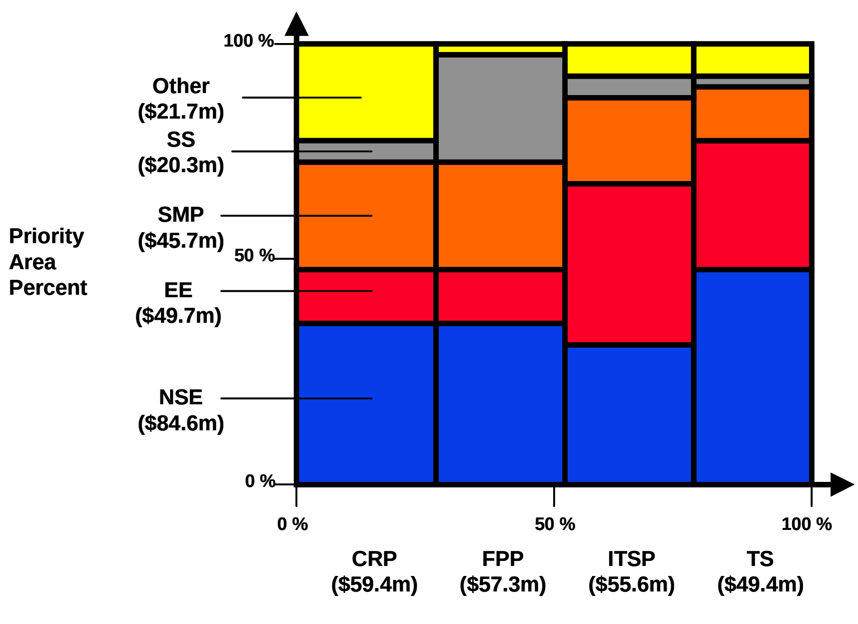
Energy-focused research is an active CTS area, and it includes catalysts and membranes for fuel cells, new structures and compositions for hydrogen storage, and materials used in energy production from alternative resources. Efficient fuel cells and hydrogen-combustion devices are expected to reduce US dependence on hydrocarbon-based fuels. The hydrogen economy will need an array of new materials for energy production, fuel storage and conversion. CTS is interested in the fundamental aspects of fuel cell development including micro-fuel cells as well as large ones for transportation uses. 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.




Selective adsorption of sulfur from fuels: (A) zeolite cage for trapping sulfur, (B,C) details of copper's role in maintaining the special electronic structure for sulfur trapping. Removal of contaminants will reduce the air pollution resulting from burning sulfur- and nitrogen-containing compounds. It may also solve the critical problem involved in using liquid fuels as the power source for future hydrogen fuel cells, which are degraded by sulfur contamination. (Yang, University of Michigan)

## PRIORITY RESEARCH AREA IMPLEMENTATION

The four priority areas are central to the CTS mission as well as to ENG, NSF and the nation. Distributed across its four program elements, CTS has significant ongoing activities in each of the four priority areas.




CTS contributions by program element and research priority areas for the CTS investments as of December 2004. 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 – CRP-Chemical Reaction Processes, FPP-Fluid and Particle Processes, ITSP-Interfacial, Transport and Separations Processes, TS-Thermal Systems, NSE-Nanoscale Science and Engineering, EE-Environmentally-Friendly and Energy-Focused Processes and Products, SMP-Smart Manufacturing and Processing, and SS-Safety and Security.

The awards portfolio of active CTS investments as of December 2004 yields the above representation of CTS activities (Appendix VI contains the values). The horizontal axis is the percent of the entire CTS awards portfolio based upon dollars in each program element. The distribution among the award dollars is almost equally divided among the four program elements – Chemical Reaction Processes (CRP), Fluid and Particle Processes (FPP), Interfacial, Transport and Separations Processes (ITSP) and Thermal Systems (TS). The vertical axis provides the percent of CTS awards within each research priority area. Over a third of CTS investments are in the Nanoscale Science and Technology area. Over one-fifth of CTS investments are in Environmentally-Friendly and Energy-Focused Processes and Products, and another over one-fifth are in Smart Manufacturing and Processing.

Yet much more needs to be accomplished. For the five-year period of this strategic plan, the CTS *implementation* strategy is to increase its percentage of activity in the areas of Safety and Security while maintaining its current percentage level of activities in Smart Manufacturing and Processing and Environmentally-Friendly and Energy-Focused Processes and Products. Although the fraction of CTS activities in NSE will probably decrease, this relative decrease will represent an increase in actual dollar investment. The degree to which this plan will be implemented in each priority area will depend upon the realization of the top CTS priorities noted in the section above.

Through collaborations and partnerships, CTS has built important connections within ENG and NSF as well as with other external agencies and laboratories. Within NSF, CTS has participated through funding, planning and leadership of various collaborations including NSE, ITR, MRI, GOALI, BE, CAREER, Sensors and TSE. Equally important are partnerships external groups including DOE and Sandia National Laboratories. Also, international partnerships are supported throughout the programs within CTS. Appendix V lists CTS participation in various organizations where there are important CTS contributions.

CTS will continue to emphasize collaborations and partnerships that will lead to an important impact with an emphasis on our four priority areas.

## ORGANIZATIONAL EXCELLENCE

## ORGANIZATIONAL EXCELLENCE GOALS – CTS WILL ENHANCE ITS DIVISIONAL OPERATIONS AND STAFF DEVELOPMENT

### EDIVISION

The CTS *goal* is to use all the currently available NSF electronic systems (FastLane, eJacket, eCorrespondence, etc.) to process proposals, correspond with PIs, and manage divisional funds.

The *justification* is clear. CTS needs to mirror the communities it serves. The Foundation and Division interact with researchers electronically, yet internal CTS processes are paper-dominated. NSF IT systems exist for these purposes.

The *implementation* strategy to meet this goal was initiated in January of 2005. All proposals received this year will be automatically electronically data captured. Additional investments in training are required for all personnel within CTS. These steps will provide opportunities to better employ program assistants for alternate divisional activities.

### ORIENTATION AND MENTORING

Together with ENG, the CTS *goal* is to develop orientation and mentoring programs for all new CTS staff.

NSF has a tradition of a fifty-fifty mix of permanent program directors and rotators. 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.

The *implementation* strategy includes multiple steps. Initially, a list of essentials for program directors has been developed (see Appendix VII). Background material currently available will be collected. Orientation and mentoring documents will be developed. New program directors are already being paired with more experienced program director mentors within the division. More comprehensive training for support staff will also be initiated. Concerted effort at all levels will be expended to implement this goal.

## REFERENCES

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

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

National Science Foundation Strategic Plan, FY2003-2008

# APPENDIX I. CTS PROGRAM DESCRIPTIONS

## Chemical Reaction Processes

### 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 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.

### Process and Reaction processes

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 of engineering significance or with 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.

## Fluid and Particle Processes

### Fluid Dynamics and Hydraulics

The Fluid Dynamics and Hydraulics Program supports fundamental research concerning the mechanisms that govern fluid flow phenomena. Topics of interest include 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. Proposed research should contribute to the basic understanding of fluid dynamics, thus enabling the better design, predictability, efficiency and control of systems that involve fluids.

Main research areas funded by the program include:

- Hydrodynamic Stability, Turbulence and Flow Control
- Rheology, Polymers and Complex Fluids
- Micro-, Nano- and Bio- Fluid Dynamics
- Waves, Hydraulics, and Environmental Fluid Mechanics

### Particulate and Multiphase Processes

This program 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. Research proposals are sought that contribute to improving to the basic understanding, design, predictability, efficiency, and control of existing systems that involve the dynamics of multiphase fluids and particulates, as well as innovative uses of multiphase flows and particulates in materials development, manufacturing processes, biotechnology, energy and the environment.

## Interfacial, Transport and Separation Processes

### Interfacial, Transport, and Thermodynamics

The Interfacial, Transport, and Thermodynamics Program (ITTP) supports research in engineering science areas related to interfacial phenomena, mass transport phenomena, separation science, and phase equilibrium solution thermodynamics. Recently, emphasis is placed on molecular engineering approaches as applied to processing of soft materials, especially thin films and porous media. Often surface-active molecules direct the formation of novel responsive or functional surfaces at the nano-scale, which can be used in new consumer products. Methods such as molecular simulation are sometimes used, in addition to experimental observation. New theories and simulation approaches determining the thermodynamic, interfacial, and mass transport phenomena properties of fluids and fluid mixtures in biological and other fluids with complex molecules are supported. Proposals dealing with pollution prevention at the source and energy storage in the context of the above phenomena are also entertained. International collaboration and industrial is encouraged. Generally, non-reactive systems are studied.

### Separation and Purification Processes

The Separation and Purification Processes program supports fundamental research on membranes, adsorbents, transport processes, separation processes, crystallization, chromatography, and nanostructured materials. Theoretical work is focused on modeling of transport processes at the molecular level. Results of the fundamental work are applied to areas such as water purification, hydrocarbon separations, natural gas purification, protein separations, fuel-cell electrolytes, and fuel desulfurization. Current areas of emphasis are biological separations, membranes for the hydrogen economy, nanostructured materials for separations, and pollution prevention and remediation.

## Thermal Systems

### Combustion and Plasma Systems

The Combustion and Plasma Systems Program concentrates on research in fundamental engineering science in support of systems applications of combustion and plasmas. The program provides support for combustion research that contributes to a cleaner environment, improved energy and homeland security, better fire safety, and new manufacturing methods. Research into the fundamental properties of plasmas of particular interest to industries is emphasized. Ongoing program interests are in laminar and turbulent flame structure, combustion pollutant formation and mitigation, chemical kinetics, laser diagnostic development, and industrial processing plasmas. Emerging areas include combustion of domestically generated fuels such as bio-fuels and hydrogen, fundamentals of fire, nano-material synthesis and processing, microcombustion, combustion strategies for carbon management, atmospheric pressure plasmas, and plasmas for processing bio-materials. This program is not an applied research program, but provides basic knowledge that can be used by others in development of systems for civil, industrial, or military applications. Broad-based tools--computational, experimental, or theoretical--that can be applied to a variety of problems in combustion and/or plasmas are major products of this endeavor.

## Thermal Transport and Thermal Processing

The Thermal Transport and Thermal Processing Program supports research aimed at gaining a basic understanding at the microscopic and macroscopic levels of thermal phenomena underlying the production of energy, the propulsion of air and land-based vehicles, the synthesis and processing of materials, the cooling and heating in equipment and devices, the interaction of industrial processes with the environment, and the thermal phenomena in biological systems. Basic research in 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 are especially relevant to this program. Higher priority will be given to those projects that deal with problems on the cutting edge of technology while developing human resources in engineering.

# APPENDIX II. RECENT CTS WORKSHOPS

Improving Undergraduate Fluid Mechanics, University of Michigan, 2000, W. Schultz

Thermal Plasma Characterization, 2002, J. Heberlein, https://www.fastlane.nsf.gov/pdfs/d10/565000/2891449.pdf

Workshop on Nanoscale Science and Engineering: Common Challenges and Integrative Opportunities Across Areas of Research, Programming and Industry, Indianapolis, IN, November 3-8, 2002, P. van Tassel.

Emerging Issues in Nanoaerosal Science and Technology, 2003, S. K. Friedlander and D. Y. H. Pui, http://dalton.hosted.ats.ucla.edu/nanoaerosol_workshop/

Future Directions in Catalysis: Structures that Function at the Nanoscale, 2003, M.E. Davis and D. Tilley, http://cheme.caltech.edu/nsfcatworkshop/

Future Directions for Hydrogen Energy Research and Education, 2003, J. Romm

New Faculty Workshops, 2003 - Maine, 2003 - San Francisco AIChE Meeting, 2004 - Florida, 2004 - Austin AIChE Meeting, Tim Anderson and Geoff Prentice

Structures that Function at the Nanoscale, 2003, M.E. Davis and D. Tilley, http://cheme.caltech.edu/nsfcatworkshop/

Workshop on Future Directions in Catalysis, 2003, M. Davis

BioMedical Transport Processes Workshop Bethesda, Maryland, May 6-7, 2004, Ken Diller and Geert Schmid-Schonbein, https://www.psava.com/CTS2004/intro.asp.

Catalysis of Biorenewables Conversion, 2004, D. Miller and J. Jackson http://www.egr.msu.edu/apps/nsfworkshop/

Control and System Integration of Micro- and Nano-Scale Systems, 2004, B. Shapiro, http://www.isr.umd.edu/CMN-NSFwkshp/

Development of Minority Faculty in Engineering, 2004, R. Ofoli, http://www.egr.msu.edu/apps/nsf-dmfe04/

Lean Combustion Technology II: Promise and Practice An International Conference, 2004, D. Dunn-Rankin, https://www.fastlane.nsf.gov/pdfs/d10/764000/WRPT3174627.pdf

Membranes: Materials and Processes, 2004, G. G. Lipscomb
NSF Workshop for the Development of Minority Faculty in Engineering, October 12-19, 2004, Arlington, VA

Theodore Y.-T. Wu Symposium on Engineering Mechanics, Vancouver, Canada, June 20-25, 2004.

Transport Phenomena in Micro- and Nanodevices, Honolulu Hawaii, October 17-21, 2004, M. Gad-el-Hak.

Transport Phenomena in Micro and Nanodevices, 2004, Y. Lu

Fourth International Symposium on Turbulence and Shear Flow Phenomena, Williamsburg, VA on June 27-29, 2005

International Bio-Nano-Information (BNI) Fusion Conference, Marina del Rey, CA , July 20-22, 2005, C-M Ho.

Separations Research Needs for the 21st Century, 2005, R. D. Noble

# APPENDIX III. CTS COV MEMBERS, 2003

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

Dr. Juan J. DePablo
Department of Chemical Engineering
University of Wisconsin, Madison

Dr. John K. Eaton
Department of Mechanical Engineering
Stanford University

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

Dr. Brian G. Higgins
Department of Chemical Engineering & Materials Science
University of California, Davis

Dr. John R. Howell
Department of Mechanical Engineering
University of Texas, Austin

Dr. Vijay T. John
Department of Chemical Engineering
Tulane University

Dr. Lawrence A. Kennedy
Department of Mechanical & Industrial Engineering
University of Illinois, Chicago

Dr. Babatunde A. Ogunnaike
Department of Chemical Engineering
University of Delaware

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

Dr. Timothy W. Tong (Chair)
Dean, School of Engineering & Applied Science
George Washington University

# APPENDIX IV. CTS EXPENDITURES BY CATEGORY

The following data have been provided by the Office of the Assistant Director of Engineering. The FY05 values are estimates based upon activity up to February 2005.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Years** | | **2001** | **2002** | **2003** | **2004** | **2005 EST** |
| | | | | | | |
| **A. NSF Level** | | **$19,314,783** | **$23,804,088** | **$28,915,916** | **$32,799,179** | **$39,700,000** |
| for example, | | | | | | |
| NSE | | | | | | |
| BE | | | | | | |
| ITR | | | | | | |
| Math Priority Area | | | | | | |
| CAREER | | | | | | |
| Science & Technology Center (STC) | | | | | | |
| ADVANCE | | | | | | |
| | | | | | | |
| **B.ENG Special Emphasis** | | **$1,983,984** | **$1,686,149** | **$6,768,876** | **$6,968,192** | **$4,500,000** |
| for example, | | | | | | |
| Sensors and Sensor Networks | | | | | | |
| TSE | | | | | | |
| Optical Comms & Networks | | | | | | |
| UD-Path | | | | | | |
| NSF-Sandia | | | | | | |
| CLEANER | | | | | | |
| | | | | | | |
| **C. Supplements/SGERS, etc.** | | **$1,331,948** | **$1,318,065** | **$2,084,201** | **$3,462,305** | **$1,500,000** |
| for example, | | | | | | |
| REU Supplements | | | | | | |
| RET Supplements | | | | | | |
| RET Sites | | | | | | |
| SGER | | | | | | |
| | | | | | | |
| **D. General Tax** | | **$423,269** | **$444,412** | **$449,212** | **$485,440** | **$563,785** |
| | | | | | | |
| **E.Stipends Tax** | | **$0** | **$0** | **$934,408** | **$958,353** | **$958,353** |
| | | | | | | |
| **F. Unsolicited** | | **$27,556,016** | **$29,957,286** | **$29,177,387** | **$24,535,149** | **$18,567,862** |
| | | | | | | |
| | **Total Budget** | **$50,610,000** | **$57,210,000** | **$68,330,000** | **$69,208,618** | **$65,790,000** |

# APPENDIX V. RECENT COLLABORATIONS AND PARTNERSHIPS

### ENG Division

- Sensors and Sensor Networks (NSF 05-526)
- WTEC Micro Manufacturing Workshop and Study, DMII
- Optical Communications and Networks, ECS
- CLEANER (NSF 05-548)

### NSF Directorates and Divisions

- Grant Opportunities for Academic Liaison with Industry, GOALI (NSF 98-142)
- Major Research Instrumentation (NSF 05-013)
- Information Technology Research for National Priorities (NSF 04-012)
- Office of International Science and Engineering

### External Organizations

- Interagency Opportunities in Multi-Scale Modeling in Biomedical, Biological, and Behavioral Systems (NSF 04-607)
- Department of Energy Partnership in Basic Plasma Science and Engineering, GEO and MPS
- 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
- National Science and Technology Council Manufacturing Research and Development Interagency Working Group - subgroup on Manufacturing for the Hydrogen Economy
- Technology for a Sustainable Environment (NSF 03-510)
- Engineering Sciences for Modeling, Decision-Making and Emerging Technologies (NSF 03-505) (joint with Sandia National Laboratories)

# APPENDIX VI. CTS PORTFOLIO DATA

## CTS Investments by Topic

Active awards as of December 2004

| Code | Tally | | Total $ | % by $ |
|---|---|---|---|---|
| Catalysis | 48 | $ | 17,057,810 | 8% |
| Advanced materials processing | 18 | $ | 9,388,242 | 4% |
| Electrochemical processing and electrochemistry | 7 | $ | 1,834,507 | 1% |
| Reaction engineering | 34 | $ | 10,365,823 | 5% |
| Biorenewable catalysis for the sustainable production of fuels and chemicals | 5 | $ | 1,076,803 | 0% |
| Chemical process control | 19 | $ | 6,064,589 | 3% |
| Chemical process design | 28 | $ | 8,792,744 | 4% |
| Reactive polymer processing | 14 | $ | 4,001,287 | 2% |
| Interfacial phenomena for novel functional and other advanced materials | 49 | $ | 14,044,139 | 6% |
| Mass transport of chemicals and bio-materials in materials processing | 12 | $ | 2,560,567 | 1% |
| Phase equilibrium and solution thermodynamics for chemical processing | 23 | $ | 4,215,878 | 2% |
| Novel non-reactive molecular processes | 28 | $ | 20,692,570 | 9% |
| Novel material for chemical separations | 24 | $ | 7,400,035 | 3% |
| Separation processes | 23 | $ | 5,115,395 | 2% |
| Molecular engineering of chemical, biochemical and materials systems | 13 | $ | 4,121,184 | 2% |
| Multiphase flow phenomena and transport in microstructured fluids | 20 | $ | 4,832,595 | 2% |
| Particle technology (nanoparticles, granular flows) | 25 | $ | 3,952,171 | 2% |
| Multiphase transport phenomena in biological and environmental systems | 3 | $ | 155,000 | 0% |
| Turbulence, hydrodynamic stability, and flow control | 34 | $ | 7,741,574 | 3% |
| Rheology and non-newtonian fluid mechanics | 22 | $ | 4,672,879 | 2% |
| Waves, hydraulics and environmental fluid mechanics | 18 | $ | 4,291,386 | 2% |
| Micro-/nano- and bio-fluid mechanics | 17 | $ | 5,305,953 | 2% |
| Flame structure and dynamics | 28 | $ | 8,346,853 | 4% |
| Structure and dynamics of industrial plasmas | 14 | $ | 3,047,930 | 1% |
| Combustion pollutant formation and mitigation | 20 | $ | 6,039,993 | 3% |
| Combustion- and plasma-based manufacturing and synthesis | 7 | $ | 2,393,903 | 1% |
| Micro-/nano-scale transport phenomena | 28 | $ | 15,020,154 | 7% |
| Multi-phase and interfacial phenomena | 34 | $ | 10,594,538 | 5% |
| Convection in complex flows | 13 | $ | 4,040,112 | 2% |
| Manufacturing and material processing | 23 | $ | 6,073,612 | 3% |
| Instrumentation and diagnostics | 48 | $ | 14,343,445 | 6% |
| Other | 21 | $ | 4,363,888 | 2% |
| Total for CTS | 720 | $ | 221,947,559 | 100% |

## CTS Investments by Program Element

Active awards as of December 2004

| Program Element | Tally | % by Tally | Total $ | % by $ |
|---|---|---|---|---|
| **Chemical Reaction Processes** | 176 | 24.44% | $59,689,708 | 26.89% |
| **Interfacial Phenomena and Separations** | 160 | 22.22% | $55,566,129 | 25.04% |
| **Fluid Dynamics and Particle Processes** | 226 | 31.39% | $57,311,357 | 25.82% |
| **Thermal Systems** | 158 | 21.94% | $49,380,365 | 22.25% |
| **Total for CTS** | 720 | 100.00% | $221,947,559 | 100.00% |

## CTS Investments by Research Priority Area

Active awards as of December 2004

| Research Priority Area | Tally | % by Tally | Total $ | % by $ |
|---|---|---|---|---|
| **Nanocale Sceince and Technology** | 226 | 31.39% | $84,633,720 | 38.13% |
| **Safety and Security** | 76 | 10.56% | $20,311,264 | 9.15% |
| **Smart Manuafaturing and Processing** | 190 | 26.39% | $45,663,716 | 20.57% |
| **Environmentally-Friendly and Energy-Focused Processes and Products** | 140 | 19.44% | $49,673,002 | 22.38% |
| **Other** | 88 | 12.22% | $21,665,857 | 9.76% |
| **Total for CTS** | 720 | 100.00% | $221,947,559 | 100.00% |

# APPENDIX VII. ORIENTATION AND MENTORING

## ORIENTATION PROGRAM ELEMENTS

- **Introductions**
  - AD, DD, PD
  - Support staff
- **NSF Program and Division Management**
  - Proposal processing
    - review – mail, panel
    - analysis
    - recommendations
    - decisions
  - Multidisciplinary activities
  - Publications
    - Personnel Manual
    - Proposal and Awards Manual
  - Budgets, mortgages, and fenced funds
  - Conflicts of Interest
  - Reconsiderations and other special cases
  - Risk, diversity, nuggets, EPSCOR, GOALI, REU, RET, RUI, supplements, extensions, standard and continuing grants
  - Coding
  - Solicitations and “Dear Colleague letters”
  - Committee of Visitors Evaluation Process and Reports
  - Program and staff hiring
- **NSF Organization**
  - Program Management seminar
  - HR activities
  - Office of Legislative and Public Affairs (OLPA)
- **NSF Systems**
  - FastLane
  - eJacket and eCorrespondence
  - Proposal, PI, Panel and Reviewer System (PARS)
  - Electronic Panel System (EPS)
  - Electronic Review Process (ERP)
  - Program Information Management System (PIMS)
  - Awards Database
  - Winstation
  - FedTravel
- **NSF Facilities**
  - Division, Directorate and Foundation offices
  - Library
  - International
  - Finances
  - Personnel
  - Banking
  - Fitness
- **Other**
  - Travel
  - Government charge card
  - Independent Research/Development Proposal
  - Personnel Security Investigation form
  - Fair Credit Reporting Act form

- Executive Branch Personnel Pubic Financial Disclosure Report
- Reimbursements
- Government Performance Results Act (GPRA)

## MENTORING ACTIVITIES

- Assess new program directors' interest and needs for mentoring advice
- Explain the values, culture, norms, workings and operations of the division, directorate and foundation
- Assist with proposal and award process documentation, and all record keeping
- Counsel on the effective use of program funds
- Counsel on the effective use of support staff
- Provide guidance on effective interactions with proposers and PIs
- Assist and counsel on all aspects of reviewer selection
- Introduce the new program directors to others, particularly those outside the division
- Help establish connections with other divisions
- Provide guidance on balancing all program director activities
- Provide informal feedback on performance

Several points of interest and concern are being considered as the CTS mentoring formalism is being developed. First, the mentoring arrangement should have a fixed duration (a clear beginning and end - for example, one year). Confidentiality should be agreed upon by the mentor and mentee. It should be easy to switch mentors or mentees, and both parties should know this ahead of time. ·In lieu of mentoring pairs, CTS might consider the "networking mentoring" model; in this arrangement, groups that contain a couple of experienced and a couple of new program directors or support staff members would be formed. This has a higher probability of success than that of one-on-one matching. CTS may consider the selection of a mentor from outside of the division. This way, the mentor would not be competing for funds or participating in the performance evaluation of the mentee. It might facilitate more open and confidential conversations. CTS is sensitive to the fact that women and members of underrepresented groups may prefer mentors from their own groups. It may be possible to create an in-division mentor (more guarded relationship) and an out-of-division mentor (same under-represented group and more open). There should be a program evaluation at the end of the fixed duration mentoring assignment.