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Civil infrastructure systems materials research support at the National Science Foundation

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1. Introduction

Civil infrastructure systems (CIS) "facilitate the movement of people and goods, provide adequate safe water for drinking and other uses, provide energy where it is needed, and remove waste, and generally support our economy and quality of life." [1] A variety of researchers, academic institutions, private firms and governmental departments are engaged in research and development focused on strengthening and retrofitting civil infrastructure. "Many of these players have sought to define CIS in a way that brings coherence to the different concerns of the community. The American Society of Civil Engineers' (ASCE) Journal of Infrastructure Systems describes infrastructure as (Fig. 1) including 'complex and interrelated physical, social, ecological, economic, and technological systems.' CIS involves both the physical environment and the social and economic characteristics of communities that are located within that environment." [2] It encompasses many fields including engineering, social sciences, urban planning, weather and natural disasters, and environmental quality.

America's, civil infrastructure is valued at $3.4 trillion based upon an estimate by Andrew Lemer of a per capita CIS value of $12,000. However, even with all the improving technologies and techniques for infrastructure development, the United States infrastructure system is seriously deficient. The ASCEs 2001 report card gave America's infrastructure system a grade of D+ (Fig. 2). The report card states that although local governments have increased spending on the maintenance of schools, 75% of our nation's schools are overcrowded, and outdated. One-third of the roads in America were reported to be "poor and mediocre", and 29% of our nation's bridges have been structurally deficient or functionally obsolete since 1998. Over the past 10 years, air traffic within the US has increased by 37%, while airport capacity has only increased by 1%. The ASCE argues that one-third of the United State's surface waters do not meet water quality standards. Eleven billion dollars are needed to replace facilities associated with the nation's 54,000 drinking water systems. The report goes on to say that our nation's wastewater, dams, solid waste, and hazardous waste systems are all facing enormous needs. In order to resolve this problem and bring America's infrastructure system up to par, a total CIS investment of $1.3 trillion is needed.

2. General National Science Foundation (NSF) research sponsorship

The NSF plays a key role in addressing US CIS research issues (Fig. 3). It sponsors basic research at academic institutions and small businesses in a wide array of disciplines, including engineering, the mathematical and physical sciences, computer science and engineering, and many others. It is an independent federal government agency, reporting to the president, and invests $4.5 billion annually to assist the US in upholding a position of world leadership in science and engineering (S&E) research through the sponsorship of an estimated 20,000 research projects. The organizational structure of NSF comprises seven research directorates and an administration directorate. These include: Engineering (ENG), Biological Sciences (BIO), Education and Human Resources (EHR), Geosciences (GEO), Computer and Information Sciences and Engineering (CISE), Mathematical and Physical Sciences (MPS), and Social, Behavioral, and Economic Sciences (SBE).

NSFs vision (Fig. 4) is "Enabling the Nation's Future Through Discovery, Learning and Innovation." To accomplish that vision, it stresses three strategic goals, comprising:

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[1] Committee for Measuring and Improving Infrastructure Performance et al., 1995.

[2] O'Rourke TD, Uy CO, 2000, p. 2.

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- Definition
  - » *"Complex and interrelated physical, social, ecological, economic, and technological systems that involve both the physical environment and the social and economic characteristics of communities that are located within the environment."*
- Value of the United States' CIS
  - » $ 3.4 trillion

Fig. 1. Civil infrastructure systems (CIS).

- Overall Grade - D+
- 75% of U.S. Schools are Overcrowded and Outdated
- 29% of U.S. Bridges are Structurally Deficient
- 1/3 of U.S. Major Roads are Poor or Mediocre
- 54,000 U.S. Drinking Water Systems Need Replacement-Cost of $11 billion
- Total CIS Upgrade Investment Needs
  - » $1.3 Trillion

Fig. 2. ASCE 2001 CIS report card.

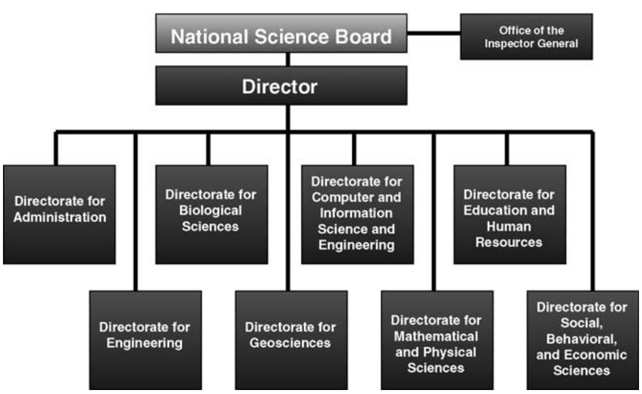

Fig. 3. National science foundation.

- People: diverse, internationally competitive and globally engaged S&E workforce.
- Ideas: discovery across the frontiers of S&E, connected to learning, innovation and service to society.
- Tools: accessible, state-of-the-art, and shared research and education tools.

A leader in science and engineering research, NSF realizes that advances in S&E will shape the economic growth and quality of life in America. It currently focuses on several priority research areas (Fig. 5).

2.1. Information Technology Research (ITR)

NSFs ITR research supports information system infrastructure growth, access, education, and training to advance leading edge capabilities to enable discovering, collecting, representing, transmitting, sharing, and applying information for testing new ideas and creating new tools.

Enabling the Nation's future through discovery, learning, and innovation...

Strategic goals:

People: Diverse, internationally competitive and globally engaged S&E workforce
Ideas: Discovery across the frontiers of S&E, connected to learning, innovation and service to society
Tools: Accessible, state-of-the-art, and shared research and education tools

Fig. 4. The NSF vision.

- *Information Technology Research*
- *Biocomplexity in the Environment*
- *Nanoscale Science and Engineering*
- *21st Century Workforce*
- *Mathematics and Statistics*

Fig. 5. FY 2001 NSF priorities.

2.2. Biocomplexity in the Environment (BE)

NSFs BE research supports a variety of coordinated activities in environmental science, engineering, and education. This is especially important as ways are sought to prevent damage to the natural environment and thereby enhance quality of life while sustaining the environment.

2.3. Nanoscale Science and Engineering (NSE)

NSEs research involves basic research at the nanoscale (one billionth of a meter), or the creation and utilization of materials, devices, and systems through the control of matter on the nanometer scale, that is at the level of atoms, molecules and supramolecular structures.

2.4. 21st century workforce

NSF recognizes its obligation to assist in improving math, science and engineering education, and thereby impact substantially the development and maintenance of the US science and engineering workforce of the future. It does this through special initiatives to encourage the science and education communities to better understand learning in disciplinary contexts, and to act on that understanding by developing improved materials, courses, and curricula. Other initiatives focus on field-specific methods for bridging levels of education and for maintaining lifelong learning capabilities.

2.5. Mathematics and statistics

NSF plays an important role in the support of research in the mathematical sciences, comprising statistics, probability, analysis, geometry, topology, foundations, algebra, number theory, combinatorics, applied mathematics, biomathematics, and computational mathematics. Mathematical science research is essential in the education and training of all Americans, and especially of the nation's total scientific and engineering workforce, and it is of increasing importance to discovery in all fields of science and engineering.

3. NSF civil infrastructure materials research

NSF sponsors materials research through many of its research directorates, and CIS materials research is supported primarily in the ENG and MPS Directorates. This section focuses on that research.

NSFs Directorate of ENG (Fig. 6) serves to promote the progress of engineering in the US. "Its investments in engineering research and education aim to build and strengthen a national capacity for innovation that can lead over time to the creation of new shared wealth and a better quality of life." [3] Its current fiscal year (FY) budget is 430.8 million dollars. The Directorate is organized into six divisions. These include: Bioengineering and Environmental Systems (BES), Civil and Mechanical Systems (CMS), Chemical and Transport Systems (CTS), Design Manufacturing and Industrial Innovation (DMII), Electrical and Communications Systems (ECS), and Engineering Education and Centers (EEC). In addition to its focus on disciplinary research, ENG also stresses research in key priority areas, including information technology, engineering the nano/micro-world, engineering the environment, biotechnology, advanced manufacturing and materials, engineering the service world, and engineering education.

Research sponsorship in ENG (Fig. 7) is primarily through single investigator awards for unsolicited research proposals. These average $80K per year for an average award duration of 2.7 years. Additional investments are made for proposals submitted in response to specific solicitations for NSF and ENG priority areas. These may be for exploratory, small group, or large group proposals. The EEC division sponsors Engineering Research Centers (ERCs), large groups of investigators who research technology areas in a systems approach and in partnership with industry. They are funded at approximately $2.5M annually. EEC also sponsors group research through its Industry University Cooperative Research Centers program, another university–industry partnerships where the primary share of support is provided by industry. The division also is the directorate's primary focal point for engineering education activity. It invests in Engineering Education Coalitions, Research Experiences for Undergraduates, Research Experiences for Teachers, Combined Research and Curriculum Development initiatives and others. The Coalitions investment of $25M annually for the last 10 years has focused on engineering education reform.

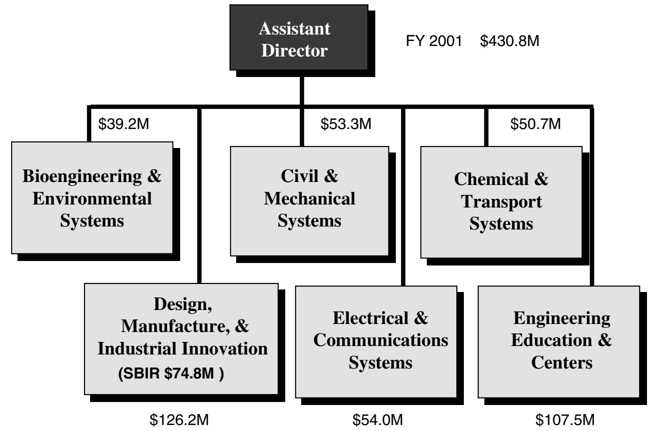

Fig. 6. Directorate for Engineering distribution of FY 2001 funds by division.

- Single Investigator Grants
- Small Group Awards
- Large Group Awards
  - » Engineering Research Centers (ERC)
  - » Industry University Cooperative Research Centers (IUCRC)
- Engineering Education Awards
  - » Engineering Education Coalitions
  - » Research Experience for Undergraduates
  - » Research Experience for Teachers
  - » Combined Research and Curriculum Development Initiative

Fig. 7. Engineering modes of support ($430.84M).

[3] http://www.nsf.gov/home/eng.

4. Division of Civil and Mechanical Systems

4.1. Programmatic activity

Most of the ENG CIS materials research is sponsored by its CMS Division. It provides a fundamental underpinning for the engineering profession in application to mechanical systems and the constructed environment, including infrastructure systems. It comprises five discipline programs (Fig. 8) and the Networked Earthquake Engineering Simulation (NEES) program. The discipline programs are Structural Systems and Engineering (SSE), Solid Mechanics and Materials Engineering (SMME), Infrastructure and Information Systems (IIS), Geotechnical and GeoHazards Systems (GHS), and Dynamic System Modeling Sensing and Control (DSMSC).

The SSE program (Fig. 9) emphasizes new discoveries in the design, construction, repair, rehabilitation, upgrading and maintenance of structural materials and systems. It is largely CIS materials research oriented. It supports research on the application of advanced polymer materials and high performance steel and concrete materials; the durability of construction materials; soil structure interaction; the safety and reliability of bridges and other structures, including applications of condition assessment to structural systems; and indoor environmental conditions. The program also emphasizes understanding the impact of extreme events on the performance of the constructed environment, and on interactions between natural and constructed environments.

The SMME program (Fig. 10) links analytical, computational and experimental solid mechanics and biomechanics with materials and surface engineering to understand, characterize, analyze, design and control the mechanical properties and performance of materials and devices. The program supports research into deformation, fracture, fatigue, friction, wear and corrosion of all types of materials, including composites, nanostructured materials, construction materials, and coatings and surface modification for service under extreme conditions. The program also supports experimental and analytical investigations and simulation modeling of material microstructures and their connections to nano-, meso- and macro-scale structural behavior.

- Structural Systems and Engineering
- Solid Mechanics and Materials Engineering
- Infrastructure and Information Systems
- Geotechnical and GeoHazards Systems
- Dynamic System Modeling Sensing and Control
- Network Earthquake Engineering Simulation (NEES)

Fig. 8. Civil and mechanical systems CIS materials research programs.

- » Advanced Polymer materials and High Performance Steel and Concrete Materials
- » The Durability of Construction Materials
- » Soil Structure Interaction
- » The Safety and Reliability of Bridges and other structures
- » Impact of Extreme Events on Constructed Environments
- » Interaction Between Natural and Constructed Environments

Fig. 9. Structural systems and engineering program.

- Materials
  - » *Deformation*
  - » *Fracture*
  - » *Fatigue*
  - » *Friction*
  - » *Wear*
  - » *Corrosion*
- Experimental and Analytical Investigations
- Simulation Modeling of Material Microstructures, Nanostrcutures

Fig. 10. Solids mechanics and materials engineering program.

The IIS program (Fig. 11) supports research on the development and deployment of advanced information systems and technologies needed to sustain the nation's infrastructure. IIS research impacts on infrastructure system design, construction, maintenance, operation and control. It includes networking technology, internet-based data systems, voice and data communications technologies and geographical information systems-based multimedia global infrastructure information systems. IIS also includes systems and network approaches to infrastructure management and life-cycle engineering, integrated systems behavior and network simulation, hazard preparedness and response, societal and economic impacts, decision theory, intelligent systems and engineering (life-cycle design), and conceptual and theoretical bases of scalable enterprises for civil systems construction and management.

The GHS program (Fig. 12) advances fundamental engineering knowledge for geostructures (foundations, slopes, excavations, soil and rock improvement technologies, and reinforcement systems); geohazards mitigation; constitutive modeling and verification; reme-

- Development and Deployment of Advanced Information Systems and Technologies Need to Sustain the Nation's Infrastructure
- IIS Research Impacts
  - » Infrastructure System Design, Construction, Maintenance, Operation, and Control.
- IIS Includes Networking Technology, Internet-Based Data Systems, Voice and Data Communications Technologies, and Geographical Information Systems(GIS) Based Multimedia Global Infrastructure Systems.
- IIS Includes Systems and Network Approaches to Infrastructure Management and Life Cycle Engineering, Integrated Systems Behavior and Network Simulation, Hazard Preparedness and Response, Societal and Economic Impacts, Decision Theory, Intelligent Systems and Engineering, and Conceptual and Theoretical Bases of Scalable Enterprises for Civil System Construction and Management

Fig. 11. Infrastructure and information systems.

diation and containment of geoenvironmental contamination; transferability of laboratory results to field scale; and nondestructive and in situ evaluation. GHS research increases geotechnical and geohazards knowledge that will mitigate the impacts of natural and technological hazards on both the constructed and the natural environment. GHSs research includes the use of data from laboratory and field experiments to verify design procedures and methodologies, simulation of phenomena, and collection of data from catastrophic events (including rapid-response reconnaissance inspections).

The DSMSC program (Fig. 13) supports research on the fundamental engineering concepts and mathematical theories for modeling, analysis, simulation and control of complex, nonlinear dynamic systems. It also invests in research on information technologies related to smart and autoadaptive CMS. This research advances the knowledge base for the integration of sensors, actuators, controllers, and power sources for autoadaptive applications.

4.2. Institute for Civil Infrastructure Systems (ICIS)

CMS also sponsors ICIS (Fig. 14), "which develops resources and networks to disseminate knowledge for sustaining, renewing, and improving the nation's infrastructure system." [4] Its goal is to incorporate various views and disciplines into infrastructure planning. By bringing together various advocates for CIS development, ICIS addresses the serious problems facing 21st century societies. ICIS implements its mission through a variety of coordinated projects and programs, including: Sustainability and Coordinated Renewal, Community Awareness and Participation, Performance Measurement Assessment, Education and Adaptive learning, and Research Needs Assessment. ICIS supports engagement and collaboration among a variety of disciplines through workshops, conferences, and outreach.

- Geostructures Research (*Foundations, Slopes, Excavation, Soil, and Rock Improvement Technologies,and Reinforcement Systems)*
- GeoHazards Mitigation
- Constitutive Modeling and Verification
- Remediation and Containment of Geoenvironmental Contamination
- Transferability of laboratory results to Field Scale
- Non-Destructive and In Situ Evaluation

Fig. 12. Geotechnical and GeoHazards systems.

- Modeling
- Analysis
- Simulation & control of nonlinear dynamic systems
- New control methods
- Acoustics
- Vibrations
- Kinematics relationships.

Fig. 13. Dynamic system modeling sensing and control (DSMSC).

- Develops Resources and Networks to Disseminate Knowledge for Sustaining, Renewing, and improving the U.S. CIS
- ICIS Projects Programs
  - » Sustainability and Coordinated Renewal
  - » Community Awareness and Participation
  - » Performance Measurement Assessment
  - » Education and Adaptive Learning
  - » Research Needs Assessment

Fig. 14. Institute for civil infrastructure systems (ICIS).

4.3. Network for Earthquake Engineering Simulation

NEES (Figs. 15 and 16) is another CIS entity supported by CMS. This project is funded under the NSF Major Research Equipment program. NEES is designed to enhance the nation's experimental earthquake engineering research capability. The intent is to change the focus from physical testing to seamless integration of testing, analysis and simulation. NSF is investing $81.9 million dollar in NEES which will comprise a number of

[4] http://www.nyu.edu/icis/about/about2.html.

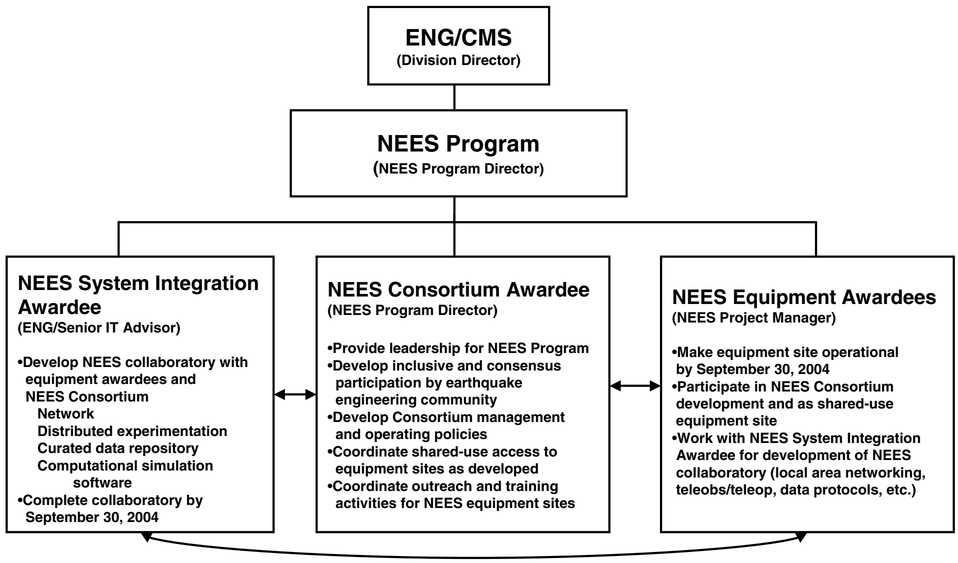

Fig. 15. Network for earthquake engineering simulation, construction period: 2000–2004 (http://www.eng.nsf.gov/nees).

- Equipment Categories
  - Shake tables
  - Centrifuges
  - Tsunami/wave tank
  - Large-scale laboratory experimentation systems
  - Field Installations
- Equipment Proposal Competitions
  - Phase 1 ($45 million) - 11 awards
  - Phase 2 (est. $15 to $20 million)
    - announcement to be issued in Fall, 2001
    - 5 to 10 additional awards expected

Fig. 16. NEES earthquake engineering testing equipment and facilities.

facilities nodes as well as a network to integrate the nodes and provide teleobservation and teleoperation capabilities. NEES has three components including equipment, systems integration, and a consortium to ultimately operate the network.

Currently, 11 equipment awards (Fig. 17) totaling $45 million dollars have been made and include new and upgraded shake tables, large-scale laboratory experimentation systems, a tsunami wave basin, centrifuges, and field experimentation and monitoring installations.

The universities under NEES that received the equipment awards in the phase one competition include:

- Oregon State University—$4.78 million. Upgrading Oregon State's Multidirectional Wave Basin for Remote Tsunami Research.
- Rensselaer Polytechnic Institute, New York—$2.38 million. Upgrading, Development and Integration of Next Generation Earthquake Engineering Experimental Capability at Rensselaer's Geotechnical Centrifuge.
- State University of New York at Buffalo—$6.16 million. Versatile High Performance Shake Tables Facility Towards Real Time Hybrid Seismic Testing.

- Oregon State University- $4.78 million
  - » *Multidirectional Wave Basin for Remote Tsunami Research*
- Rensselaer Polytechnic Institute- $2.38 million
  - » *Upgrading of Rensselaer's Geotechnical Centrifuge*
- State University of New York at Buffalo- $6.16 million
  - » Versatile High Performance Shake Tables Facility
- State University of New York at Buffalo-$4.38
  - » Large Scale High Performance Shake Tables Facility
- University of California at Berkely-4.27 million
  - » Reconfigurable Reaction Wall-Based Earthquake Simulator
- University of California at Davis-$4.61million
  - » Geotechnical Centrifuge Facility
- University of California at Los Angeles- $2.65 million
  - » Field Testing and Monitoring of Structural Performance
- University of Colorado at Boulder-$1.98 million
  - » Test Platform for Seismic Performance Evaluation of Structural
- University of Minnesota-$6.47 millions
  - » System For Multi-Axial Subassemblage
- University of Nevada at Reno-$4.40 million
  - » Biaxial Multiple Shake Table Research Facility
- University of Texas at Austin-$2.94 million
  - » Large Scale Mobile Shakers and Instrumentation

Fig. 17. NEES award recipients.

- State University of New York at Buffalo—$4.38 million. Large-Scale High Performance Testing Facility Towards Real-Time Hybrid Seismic Testing.
- University of California at Berkeley—$4.27 million. Reconfigurable Reaction Wall-Based Earthquake Simulator Facility.
- University of California at Davis—$4.61 million. A NEES Geotechnical Centrifuge Facility.
- University of California Los Angeles—$2.65 million. Field Testing and Monitoring of Structural Performance.
- University of Colorado at Boulder—$1.98 million. Fast Hybrid Test Platform for the Seismic Performance Evaluation of Structural Systems.
- University of Minnesota—$6.47 million. A System for Multiaxial Subassemblage Testing.
- University of Nevada at Reno—$4.40 million. Developing of a Biaxial Multiple Shake Table Research Facility.
- University of Texas at Austin—$2.94 million. Large-scale Mobile Shakers and Associated Instrumentation for Dynamic Field Studies of Geotechnical and Structural Systems.

A phase two equipment competition is expected to invest another $15M to $20M in the fall of this year.

The Systems Integration component of NEES will integrate the NEES facilities and provide the teleoperation and teleobservation capabilities (Fig. 18). The Systems Integration award will be made this summer, and cost $10M. The third component of NEES, the Consortium, will develop the leadership, management and coordination for the NEES collaboratory from 2005 through 2014. It will interact with the research community in developing and managing NEES research operations.

4.4. CIS partnerships

The ENG Directorate partners with many other federal agencies and professional societies to address the needs of CIS materials research. Three of these partnerships are described in the sequel (Fig. 19).

The National Earthquake Hazards Reduction Program (NEHRP) partners with NSF in the research of CIS materials. NEHRP also engages in earthquake research, mitigation, and education activities. The research is implemented by four federal agencies, including the NSF, the Federal Emergency Management Agency (FEMA), the US Geological Survey of the Department of the Interior (USGS), and the National Institute of Standards and Technology (NIST). FEMA is responsible for applying the results of research and technology improvement at the state and government levels to reduce loss. They also support activities on loss reduction. USGS produces products for earthquake loss reduction, timely and accurate earthquake notification, and it supplies research on the occurrence and effect of earthquakes. NIST performs studies to develop codes, practices, and standards. Their present research focuses on allowing buildings and lifelines to survive earthquakes.

As a partner in the NEHRP program, NSF is responsible for performing studies in the earthquake sciences, engineering, and the social sciences. Because an integrated body of information is required to develop effective solutions for earthquake problems, NSF

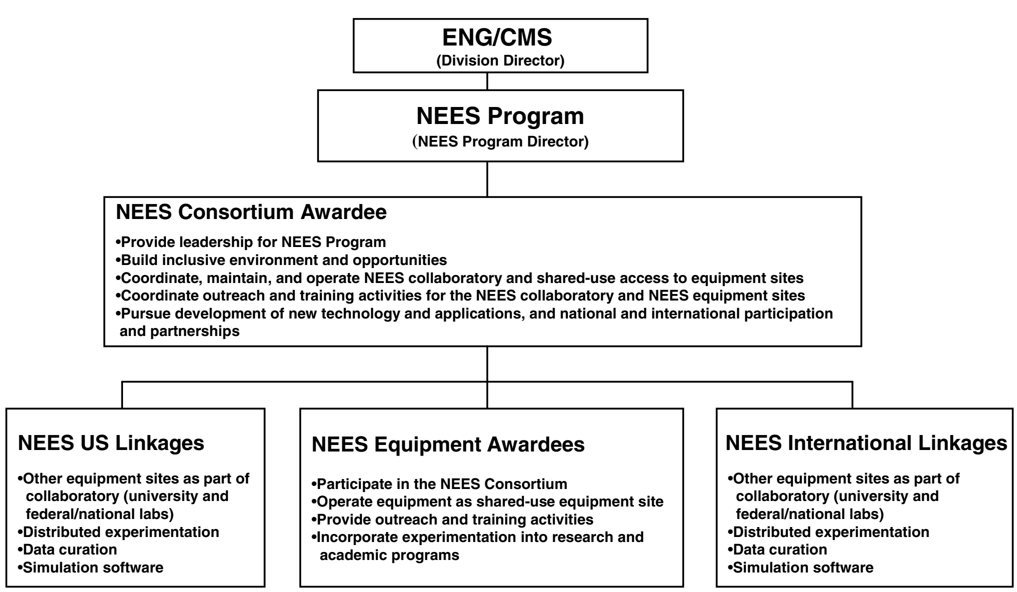

Fig. 18. Network for earthquake engineering simulation.

- The National Earthquake Hazards Reduction Program (NSF, FEMA, USGS, NIST)
  - » Engages in Earthquake Research, Mitigation, and Educational Activities
- The Civil Engineering Research Foundation/ NSF Partnership
  - » Develops Programs that Increase the Collaboration Between Industry and Academic Research
- U.S. Japan Cooperative Research in Urban Earthquake Disaster Mitigation
  - » Performance Based Design and Engineering, Integrated Social Sciences and Related Research, Advanced Steel Structures, Geotechnical Engineering Systems, and Advanced Technologies

Fig. 19. CIS partnerships.

supports cross-disciplinary research. Earthquake research and educational activities are primarily funded through the GEO Directorate, the SBE Directorate, and the ENG Directorate.

The Civil Engineering Research Foundation (CERF) works with NSF to develop programs that increase the collaboration between industry and academic research. CERF develops, coordinates, and facilitates solutions to complex challenges facing the design, construction, and environmental industries. By recognizing the needs of civil engineering research, CERF strives to provide better solutions to the management of bridges, highways, hazardous waste, and water quality.

In collaboration with Japan, the NSF launched a five-year "US Japan Cooperative Research in Urban Earthquake Disaster Mitigation" beginning in 1998. Active through FY 2002, funding was established at up to $1.5 million dollars per year. The cooperative research program comprises five thrusts including Performance Based Design and Engineering, Integrated Social Sciences and Related Research, Advanced Steel Structures, Geotechnical Engineering Systems, and Advanced Technologies. This initiative has further developed a mutual trust and cooperation between researchers in Japan and in the United States. Strengthening established ties, this partnership has forged new and valuable connections.

5. Division of Engineering Education and Centers (EEC)

The EEC division manages ENGs portfolio of 25 ERCs, three of which (Fig. 20) focus on earthquake engineering. They are the Pacific Earthquake Engineering Research (PEER) Center, the Mid-America Earthquake (MAE) Center, and the Multidisciplinary Center for Earthquake Engineering Research (MCEER).

PEERs mission is to develop, validate, and disseminate performance-based seismic design technologies for buildings and infrastructure to meet the diverse economic and safety needs of owners and society. Its vision is to transform earthquake engineering assessment and

- Earthquake Engineering Research Centers
  - » Pacific Earthquake Engineering Research (PEER)
  - » Mid-America Earthquake Center (MAE)
  - » Multidisciplinary Center for Earthquake Engineering Research (MCEER)

Fig. 20. Division of engineering education centers (EEC).

design from a traditional approach where performance expectations are not directly addressed to a performance-based approach in which they are.

MAE comprises seven core institutions, and its center projects address: (a) research, (b) implementation of research results, (c) education and or (d) outreach. Projects are multidisciplinary and coordinated to serve three focus areas: essential facilities, transportation networks and hazards evaluation. A program coordinator for each of these three programs is responsible for the planning and execution of research and implementation projects. Education Program projects extend earthquake engineering knowledge and awareness to students from K-12 through graduate school. MAE networks the laboratories and other research facilities of its core institutions and has cooperative agreements with federal agencies for use of its facilities.

MCEER develops and applies knowledge and advanced technologies to reduce earthquake losses. Headquartered at the University at Buffalo, the Center was established in1986 by the NSF. MCEER unites leading researchers from numerous disciplines and institutions throughout the United States to integrate knowledge, expertise, and interdisciplinary perspective with state-of-the-art experimental and computational facilities in the fields of earthquake engineering and socioeconomic studies. The result is a systematic "engineered" program of basic and applied research that produces solutions and strategies to reduce the structural and socioeconomic impacts of earthquakes. MCEER is sponsored by the NSF, New York State and the Federal Highway Administration.

6. Division of Materials Research

The Division of Materials Research (DMR) (Fig. 21) resides in the MPS Directorate. Its budget is $190 million and is invested in basic materials research in the nation's colleges and universities. Most academic materials research departments were established over a quarter century ago and address materials issues ranging from the quantum realm to engineering. Materials re-

- Budget- $190 million
- Materials Disciplines(*Physics, chemistry, ceramics, metallurgy,and engineering)*
- Materials Research Society
- Regional Material Research Societies
- Division Programs (*Condensed Matter Physics, Solid State Chemistry, Polymers, Metals, Ceramics, Electronic Materials, Material Theory, Materials Research Science and Engineering Centers, and National Facilities and Instrumentation)*
- Science and Technology Center on Cementitious Materials at Northwestern University

Fig. 21. Division of materials research (DMR) modes of support.

search draws on a variety of disciplines, including physics, chemistry, ceramics, metallurgy, and engineering. The Materials Research Society (MRS) was established in 1973 and provides a forum for exchange of research information among the various materials subdisciplines. In recent years, DMR has sought to broaden the shape of MRS to an international status through a number of regional workshops, and through subsequent agreements with those regions to provide opportunities for them to enhance their materials research profiles and also to provide opportunities for research collaboration between these regions and US researchers.

The DMR division comprises nine programs, including Condensed Matter Physics, Solid State Chemistry, Polymers, Metals, Ceramics, Electronic Materials, Materials Theory, Materials Research Science and Engineering Centers, and National Facilities and Instrumentation. Its activity addresses NSFs primary strategic themes in People, Ideas and Tools through a variety of support modalities, including single and multiinvestigator awards, multidisciplinary centers, and user facilities. It supports 2000 faculty members, and 3000 students (graduate as well as undergraduate) and postdoctoral investigators. Tools comprise synchrotron radiation, neutron scattering facilities, nanofabrication and high magnetic fields facilities. Ideas emanating from this effort have extended the frontiers of our materials understanding. DMR is a key player in the recent multiagency initiative on nanoscience and engineering.

7. Summary

NSFs investment in CIS materials research is substantial and broad based throughout the ENG and MPS Directorates (Fig. 22). A precise accounting of the size of the investment is not available, but it probably is between 20 and 40 million dollars annually. Annual expenditures for centers engaged in related activity is six million dollars. And the NEES infrastructure will consume nearly 90 million dollars on completion. NEES

- NSF Infrastructure Broad Based
- Support Level $20-40 million Annually (excluding NEES)
- Nanotechnology Initiative
- International Partnerships

Fig. 22. Summary.

operations will focus to some extent on CIS materials issues, and this focus will enhance the current CIS materials research portfolio.

Furthermore, new and emerging NSF thrusts will only add to this substantial portfolio. For example, the federal government has developed a new research priority on nanotechnology. Government wide investment in the National Nanotechnology Initiative (NNI) is slightly less than a half billion dollars in the current FY. NSFs part of the initiative is the Nano Science and Engineering program. The expectation is that basic research in nanotechnology will ultimately deliver on a promise to revolutionize the materials world. Such a revolution will certainly have an impact on CIS materials.

To assist in realizing this promise, ENG and MPS are evolving a new concept called the National Experiment and Testing (NEXT) facility. The intent is to fill the gap between basic nanotechnology research and the development of commercially available products which use nanotechnology. NEXT will comprise approximately eight functional nodes each of which focuses on a specific area of nanotechnology (nanoimprint, nanobio systems, etc.). These nodes will be integrated into a network, which will develop the technology to provide precompetitive nanotechnology capability to the industrial sector.

Clearly, the NSF is a major US player in CIS materials research. Its primary constituency is American researchers. However, several international partnerships are currently in place, primarily with Japan. The Foundation, in agreement with its three strategic goals on People, Ideas and Tools continuously looks for ways to expand its CIS research activity both in the US and abroad. The 2000 Workshop in Pretoria and its follow-up meeting in Nairobi in August and this week's symposium in San Diego will go a long way to initiating and sustaining CIS materials research collaboration between American and African researchers. MRS agreements in several regions around the world provide excellent strategies to insure greater collaborations between the US and other countries on CIS materials research. Other strategies should be developed and are welcome as the US enhances its overall global research cooperation in CIS materials research.