# National Science Foundation
Role in the
National Earthquake Hazards Reduction Program

Presentation
to the
NEHRP Advisory Committee on Earthquake Hazard Reduction
May 10, 2007

Joy M. Pauschke, Ph.D., P.E.

Program Director

Directorate for Engineering

jpauschk@nsf.gov

Eva Zanzerkia, Ph.D.

Program Director

Directorate for Geosciences

ezanzerk@nsf.gov

national earthquake hazards reduction program
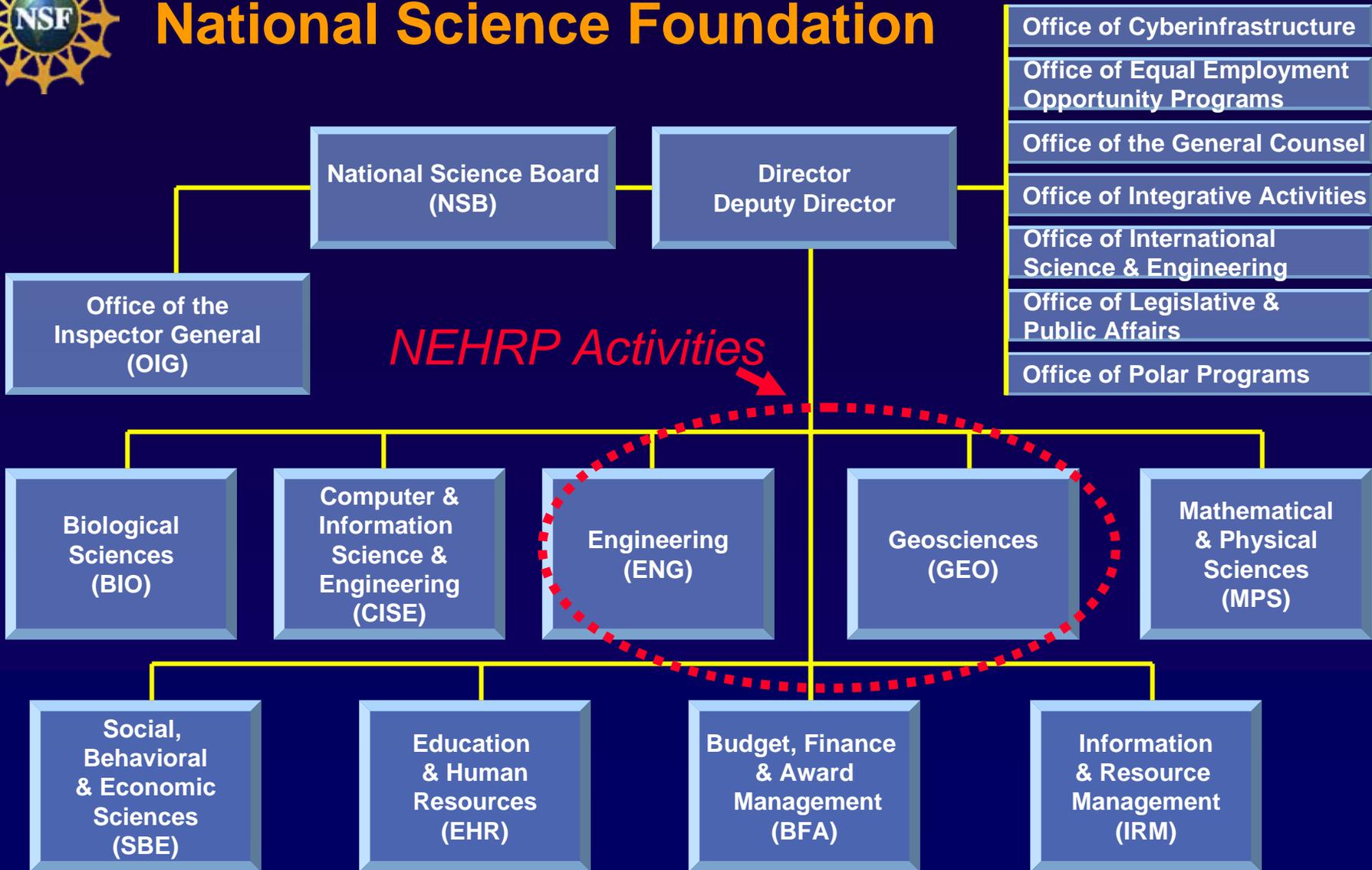
NEHRP Activities funded by NSF

- Directorate for Geosciences
  - Incorporated Research Institutions for Seismology
  - Southern California Earthquake Center
  - Fundamental Research on Earthquakes
  - EarthScope (Related non-NEHRP activity)
- Directorate for Engineering
  - Earthquake Engineering Research Centers
  - Learning from Earthquakes Program
  - National Hazards Research Center
  - Unsolicited Fundamental Research on Earthquake Engineering and Social Science and Public Policy Aspects of Disasters
 - George E. Brown, Jr. Network for Earthquake Engineering Simulation

# Incorporated Research Institutions for Seismology (IRIS)

- NSF-funded university research consortium that explores the Earth's interior through collection and distribution of seismographic data
  - PASSCAL - seismic sensors, data acquisition, telemetry and power systems for earth science research
  - DMS - 8 nodes that coordinate data flow from GSN, PASSCAL & other sources
  - E&O – enables access to and use of seismological data and research for educational purposes
- Partners with USGS to operate GSN
- NSF provides approximately 30% of GSN support through an award to IRIS
- http://www.iris.edu

104 MEMBER INSTITUTIONS

9 Members
Board of Directors
President

Program Coordination Committee
Director of Operations

Planning Committee
Director of Planning

GSN	PASSCAL	DMS	E&O
Standing Committee	*Standing Committee*	*Standing Committee*	*Standing Committee*
IRIS/IDA	**PASSCAL Instrument Center**	**Data Management Center**	**IRIS Staff Universities**
UCSD			
IRIS/USGS			
Albuquerque, NM	*Socorro, NM*	*Seattle, WA*	
Program Manager	Program Manager	Program Manager	Program Manager

DATA COLLECTION — **DATA DISTRIBUTION**

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**national earthquake hazards reduction program**

Examples of IRIS Activities
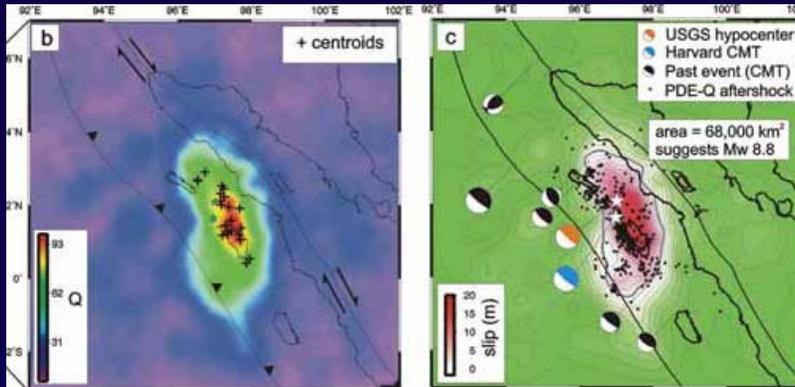
K. Walker, M. Ishii, P. Shearer and P. Earle (USGS) Rapid Imaging of Large Earthquake Rupture Zones with P-waves: Application to the 28 March 2005 Sumatra Mw 8.7 Earthquake suggests bilateral rupture
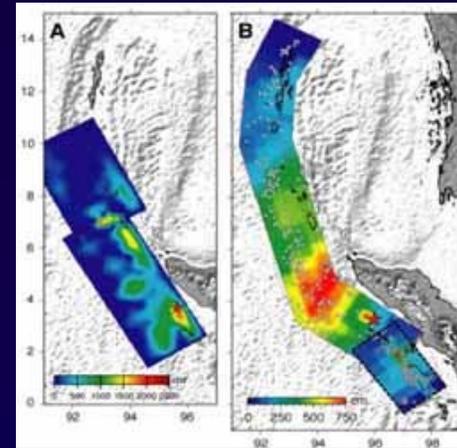
C. J. Ammon, C. Ji, H. K. Thio, D. Robinson, S. Ni, V. Hjorleifsdottir, H. Kanamori, T. Lay, S. Das, D. Helmberger, G. Ichinose, J. Polet and D. Wald, Rupture process of the 2004 Sumatra-Andaman earthquake
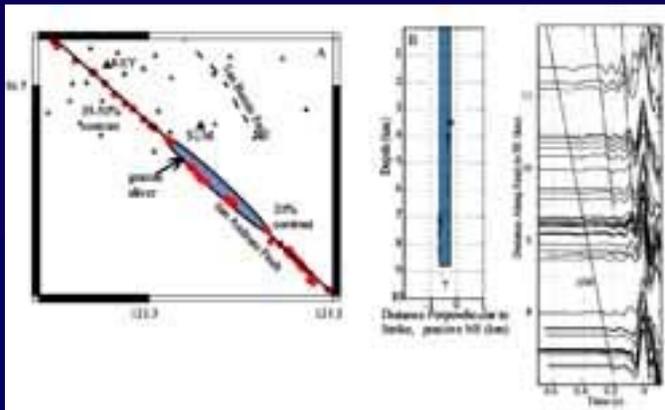
J. McGuire and Y. Ben-Zion, Imaging the Fine Structure of the San Andreas Fault at seismogenic depths using an archived PASSCAL dataset
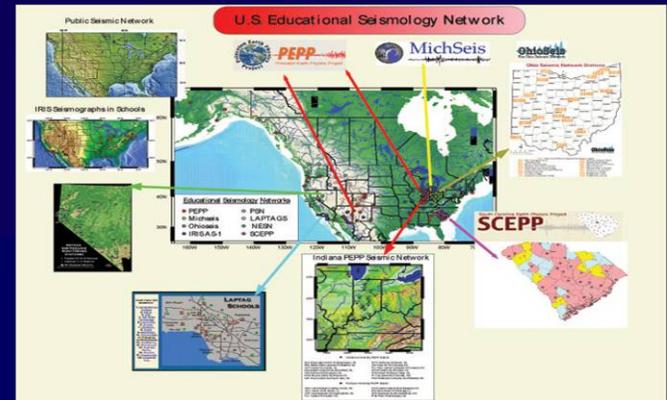
M. W. Hamburger, G. L. Pavlis, L. W. Braile, T. Owens, J. Lahr (USGS), The U.S. Educational Seismology Network: promoting the use of seismographs and seismic data for science education

national earthquake hazards reduction program
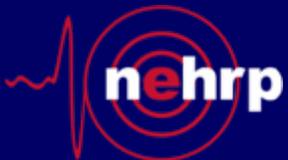
Southern California Earthquake Center

(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- "Collaboratory" co-funded by NSF and USGS
  - Tripartite mission:
    - Gather data on earthquakes in Southern California
    - Integrate information into a comprehensive, physics-based understanding of earthquake phenomena
    - Communicate to the community at large knowledge for reducing earthquake risk
  - 2005-2006: Community Fault, Velocity, and Block Models developed
  - Renewed for 5 years starting February 2007 (SCEC III)

- Community Modeling Environment
  - Cyberinfrastructure collaboration between SCEC member institutions and the San Diego Supercomputer Center, Information Science Institute, and CMU
  - Physics-based PSHA for better estimates of strong ground motion and earthquake forecasts
  - http://epicenter.usc.edu/cmeportal/index.html
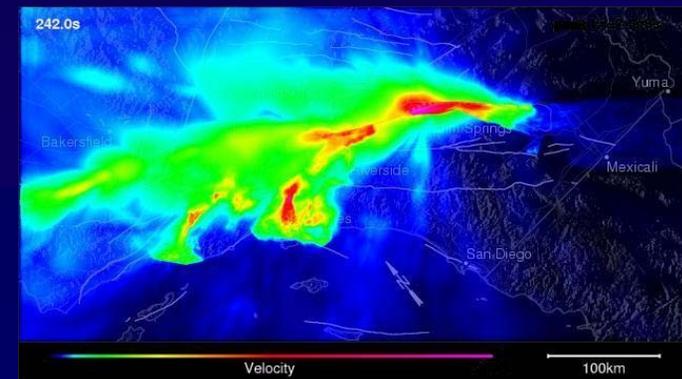
TeraShake simulations of M7.7 earthquake on southern SAF
(Image: Kim Olsen (SDSU), Geoffrey Ely (UCSD))

Fundamental Research on Earthquakes

(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- GEO/EAR programs fund fundamental earthquake-related science through general program solicitations
  - Geophysics, Tectonics, Continental Dynamics, Instrumentation and Facilities
- Individual research projects
  - Southern San Andreas Fault deformation from satellite data, Fialko (awarded 2004)
  - Fault zone modeling to understand earthquake dynamics, Rice (awarded 2005)
- Fundamental research is conducted and facilitated by centers such as SCEC, IRIS, UNAVCO, CIG, GEON and others.

Landsat satellite image of the Salton Sea, Coachella Valley and the San Andreas Fault in California (Fialko, UCSD)
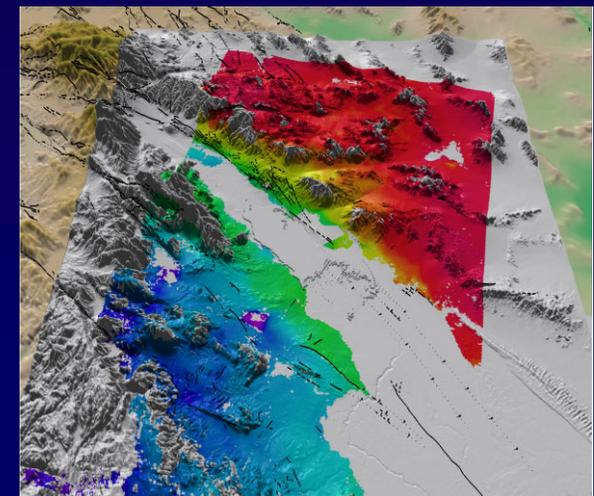
Satellite radar images are used to infer slippage on the Southern San Andreas Fault system (Fialko, UCSD)

Related Non-NEHRP Activities

earthscope

- **A multipurpose array of instruments and observatories to advance understanding of the structure, evolution and dynamics of the North American continent**
  - ➤ **San Andreas Fault Observatory at Depth (SAFOD)**
  - ➤ **Plate Boundary Observatory - geodetic component**
  - ➤ **USARRAY- short-term, intermediate-term and permanent seismograph installation**
- **Installation conducted in partnership with USGS**

- 3.1 km San Andreas Fault borehole
- 852 permanent GPS stations
- 103 borehole strainmeters
- 5 laser strainmeters
- 39 Permanent seismic stations

- 400 transportable seismic stations occupying 2000 sites
- 27 magneto-telluric systems
- 100 campaign GPS stations
- 2400 campaign seismic stations

Related Non-NEHRP Activities

earthscope

EarthScope has already:

- Captured eruptive sequences at Mt. St. Helens and Augustine
- Captured ETS events in Cascadia (seismic, GPS, and strainmeter)
- Drilled across San Andreas Fault
- Begun determining Earth structure from "noise"

Legend:
- ★ Drilling into the San Andreas Fault
- ● GPS Stations
- ◆ Borehole Strainmeters
- ◆ Long-baseline Laser Strainmeters
- △ Transportable Seismic Stations
- ▲ Permanent Seismic Stations
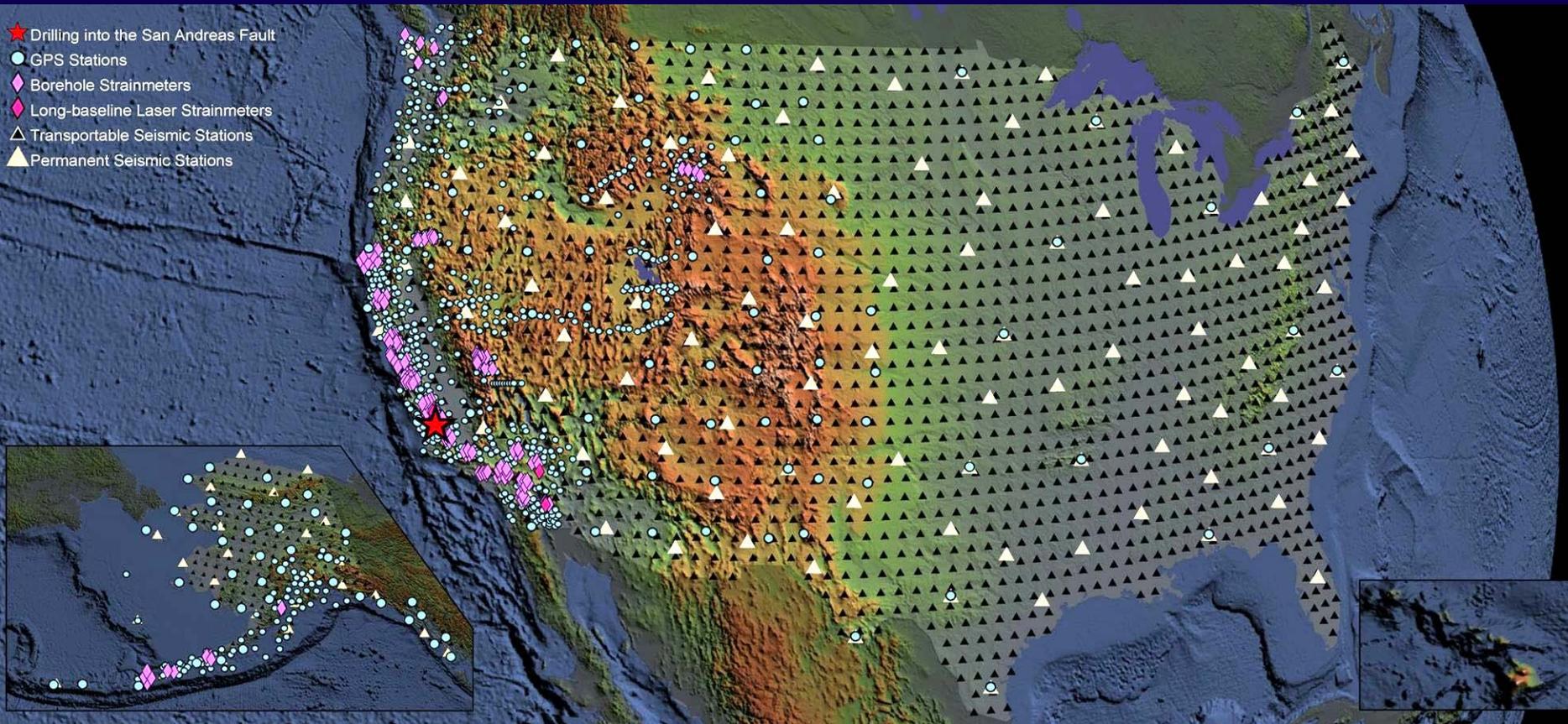
NSF Earthquake Engineering Research Centers (FY 1998 – FY 2007)

(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- Mid-America Earthquake (MAE) Center
  - Lead: University of Illinois, Urbana-Champaign
  - Focus: Earthquakes and their effects in Mid-America
  - http://mae.ce.uiuc.edu
- MCEER – Earthquake Engineering to Extreme Events
  - Lead: SUNY Buffalo
  - Focus: Critical infrastructure, hospitals, response & recovery
  - http://mceer.buffalo.edu
- Pacific Earthquake Engineering Research (PEER) Center
  - Lead: University of California, Berkeley
  - Focus: Performance-based earthquake engineering
 - http://peer.berkeley.edu

# MAE Center Selected Research Accomplishments

- Traffic Flow Models for Impact Assessment

- NMSZ source models and attenuation
  Experimental (deep hole explosions) attenuation

- DEEPSOIL: State-of-the-Art Site Response Analysis

- Uniform Reliability Fragility Relationships
  (85% of US bridges and 90% of US buildings)

- Hazard-Independent Social-Economic Impact Models

- MAEviz: Web-based open-source modular risk assessment
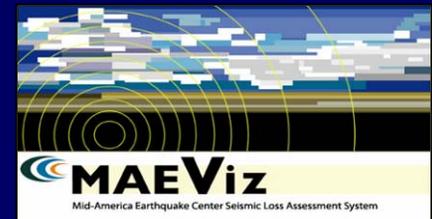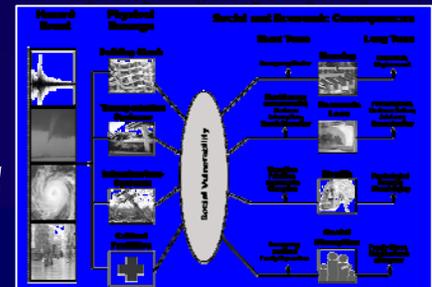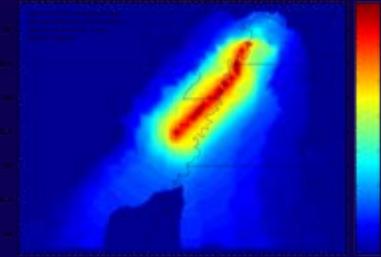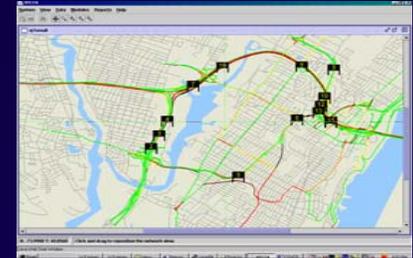
(Graphics courtesy of A. Elnashai,
University of Illinois, Urbana-Champaign)

MCEER Selected Research Accomplishments
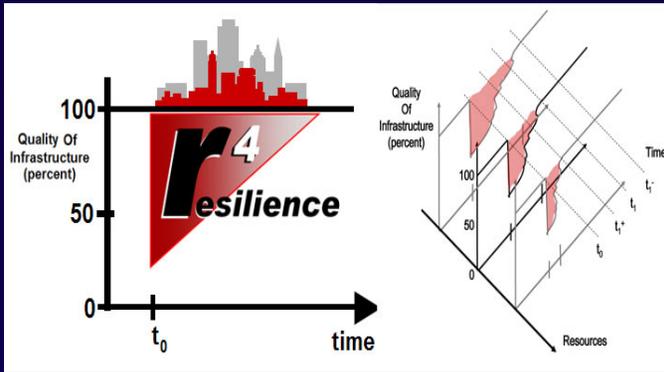
Community seismic resilience (4R's):
- Robustness
- Redundancy
- Rapidity
- Resourcefulness
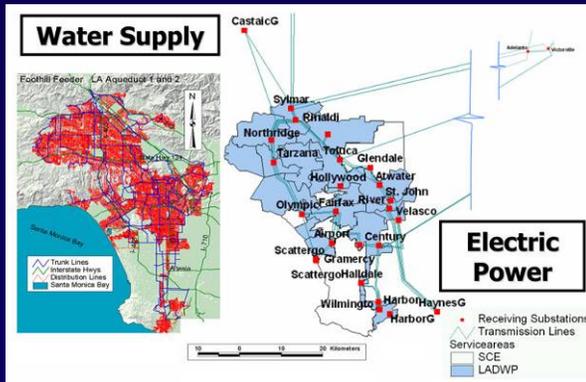
Lifeline facilities

LADWP Decision Support System – interactions between electric power and water distribution systems and heavily damaged network modeling

(Graphics courtesy of M. Bruneau, SUNY Buffalo)
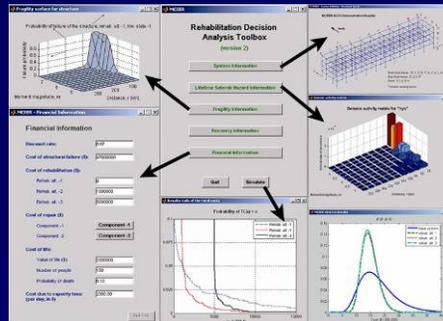
Acute care facilities
- Base isolation
- Passive Dampers
- Decision-Support Tools
- Nonstructural systems

MCEER Selected Research Accomplishments

r⁴

Impacts on Rapidity: Multi-tiered Damage Assessment Methodology using Remote Sensing

TIER 1. Regional
Change detection using moderate-resolution imagery provides a "quick look" regional damage assessment

TIER 2. Neighborhood
Detailed analysis of high-resolution imagery determines the level of damage within affected communities

TIER 3. Per-building
Results support the prioritization and coordination of field-based activities – e.g. response and recovery, and field reconnaissance

Disaster →

(Graphics courtesy of M. Bruneau, SUNY Buffalo)

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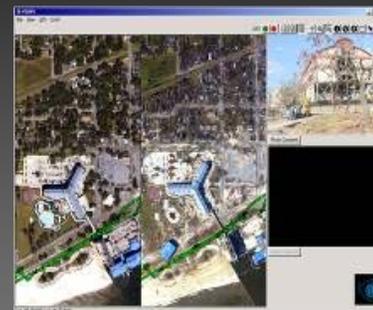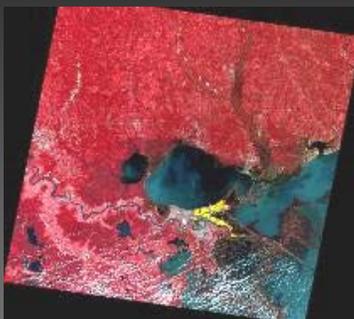
PEER Selected Research Accomplishments
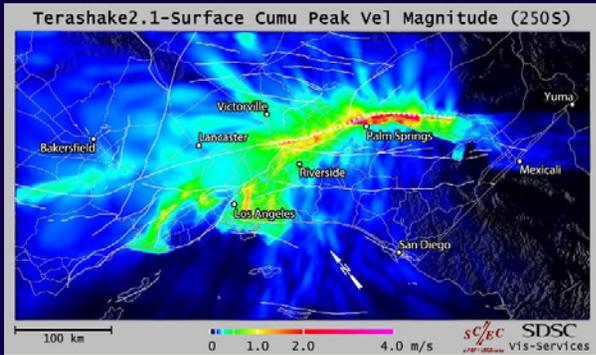
Collaborative research with SCEC and earth sciences for ground motion characterization
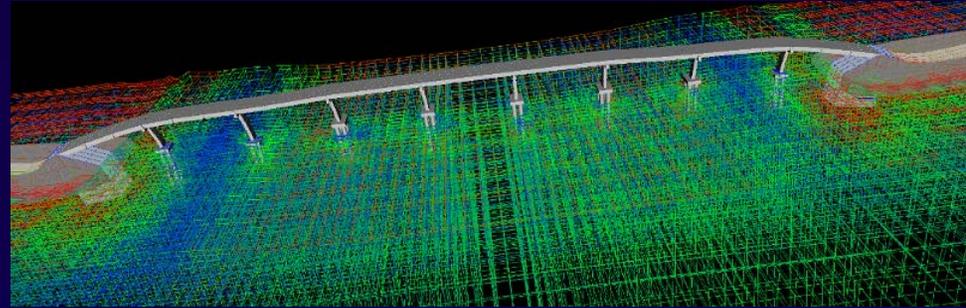
Advanced simulation and visualization for PBEE

Products include
- Loss estimation methodologies for structures
- Open System for Earthquake Engineering Simulation (OpenSees)
- Structural performance database for reinforced concrete columns
- BiSpec - Linear and nonlinear spectra of earthquake records
- Next Generation Attenuation
- PEER strong motion database

(Graphics courtesy of J. Moehle, University of California, Berkeley)

- Lifelines, Nonstructural Systems, and Loss Modeling
  - ➢ Transportation systems – REDARS and MAEviz
  - ➢ Electric power systems
- Social Science, Economics, Public Policy & Urban Planning
  - ➢ *Natural Hazards Review*, "Deciding What's Safe," May 2004
  - ➢ FEMA-funded "Promoting Seismic Safety - Guidance for Advocates"

Promoting Seismic Safety
Guidance for Advocates

Tri-Center Collaborations
Selected Education Accomplishments

- Tri-Center REU Program
- Tri-Center Student Leadership Council
- Tri-Center Student Field Missions
  - 2006 New Zealand
  - 2005 Greece
  - 2004 Japan
  - 2003 Italy
  - 2002 Taiwan
- Tri-Center Student Seminars
- Tri-Center Teaching Modules

Photos from
http://mceer.buffalo.edu

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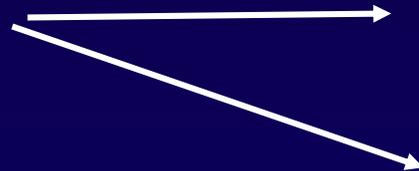
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Learning from Earthquakes Program
Earthquake Engineering Research Institute
(Recent NSF Awards CMMI-0131895 & 0650182)
(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- Purpose: Post-earthquake field investigations
- Since 1973, over 180 investigations
- USGS Circular 1242 – NEHRP Post-Earthquake Investigations
- Recent Reconnaissance Reports
  - Sumatra, Indonesia – 26 December 2004
  - Niigata, Japan – 23 October 2004
  - Bam, Southeastern Iran – 26 December 2003
  - San Simeon, CA, USA – 22 December 2003
  - M 6.8 Northern Algeria - 21 May 2003
- More information: http://www.eeri.org/lfe.html

Natural Hazards Center
University of Colorado, Boulder

(NSF Award CMMI-0408499)
(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- Purpose: To advance and communicate knowledge on hazard mitigation and disaster preparedness, response, and recovery
- Co-funding: NSF, USGS, FEMA, and other federal agencies
- Publications include
  - *Natural Hazards Observer (bimonthly)*
  - *Disaster Research (biweekly e-newsletter)*
  - *Natural Hazards Review Journal (joint w/ASCE)*
- Quick response program and reports (post-disaster studies)
- Annual Workshop: July 8-11, 2007
- More information: http://www.colorado.edu/hazards/

Fundamental Research
ENG/CMMI Unsolicited Proposals
Examples of Recent Awards
(NEHRP Program Activity: Understanding Earthquakes and Their Effects)

- Structural Systems and Hazard Mitigation of Structures
  - Sensitivity analysis of concrete gravity dams subjected to non-uniform seismic excitations
  - Performance-based seismic design of concentrically braced steel frame members
- GeoEnvironmental Engineering and GeoHazards Mitigation
  - Liquefaction resistance of aged soils
  - PBEE using paleoseismic techniques
  - Landslide generated tsunamis
- Infrastructure Management and Hazard Response
  - Investment planning for regional natural disaster mitigation
  - Measuring cross-community disaster preparedness and resiliency: theoretical and practical application development

Shared Use Infrastructure

George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

(NEHRP Program Activities: Understanding Earthquakes and Their Effects and NEHRP Facilities)

**National Science Foundation
Directorate for Engineering
Division of Civil, Mechanical, and Manufacturing Innovation**

Funding Partnerships

NEES Maintenance and Operations

NEES Research (NEESR)

NEES Consortium, Inc. Davis, CA

Research Participation Agreement

Research Awards
- *Grand Challenge*
- *Small Group*
- *Individual Investigator*
- *Payload*
- *Simulation Development*

Facility Partnerships

Project Partnerships

15 Equipment Sites

Cyberinfrastructure

Education, Outreach & Training

Coordination
- *NEESinc Data Sharing and Archiving Policies and Guidelines*
- *NEES Facilities User Guide*
- *Education, Outreach, and Training Plans (Strategic, Execution, Diversity)*

Japan's Earth-Defense (E-Defense) Shake Table
National Research Institute for Earth Science and Disaster Prevention (NIED)

Hyogo Earthquake Engineering Research Center
Miki, Hyogo Prefecture, Japan (Kobe, Japan)
http://www.bosai.go.jp/hyogo/ehyogo/

Full-scale earthquake simulation test on reinforced concrete building structure using E-Defense on January 2006. The test was part of five-year national research project - DaiDaiToku. The specimen was a 6-story wall-frame structure, 2 by 3 bays. NSF has agreement w/MEXT and NEESinc has agreement w/NIED for joint utilization of NEES and E-Defense facilities.

NEES Activities Map
https://central.nees.org/activities/

UCSD NEES Outdoor Shake Table
7-Story Test Structure – Industry-Funded Consortium

Platen 12.20 m x 7.6 m
Max stroke 1.5 m
Max velocity 1.8 m/sec
Laminar soil box
Two adjacent soil pits

7-story reinforced concrete building test at UCSD NEES
outdoor shake table showed that a structural wall with half the
amount of reinforcing steel required by most building codes,
but with more optimal layout, can better resist seismic loads.
(Test funded by industry consortium)
(Photo courtesy of Jose Restrepo, UCSD)

NSF NEESR Project CMMI-0529903 "NEESWood" (Lead: Colorado State University)

Dual 6DOF
Shake Tables at
SUNY Buffalo
NEES Site

Full-scale test of a residential structure
November 2006

Photo courtesy of the NEESwood project web site:
http://www.engr.colostate.edu/NEESWood/

NEESR GC: Seismic Risk Mitigation of Ports
Lead: Georgia Tech

(NSF Awards CMMI-0530478 & NEES Operations CMMI-0402490)

Seaports are a critical national asset in this era of global trade, which is projected to grow at annual rates exceeding 6%

World Container Volume
Source: United Nations (2005)

Seattle
Tacoma
Oakland
Los Angeles
Long Beach
Houston
New York
Norfolk
Charleston
Savannah
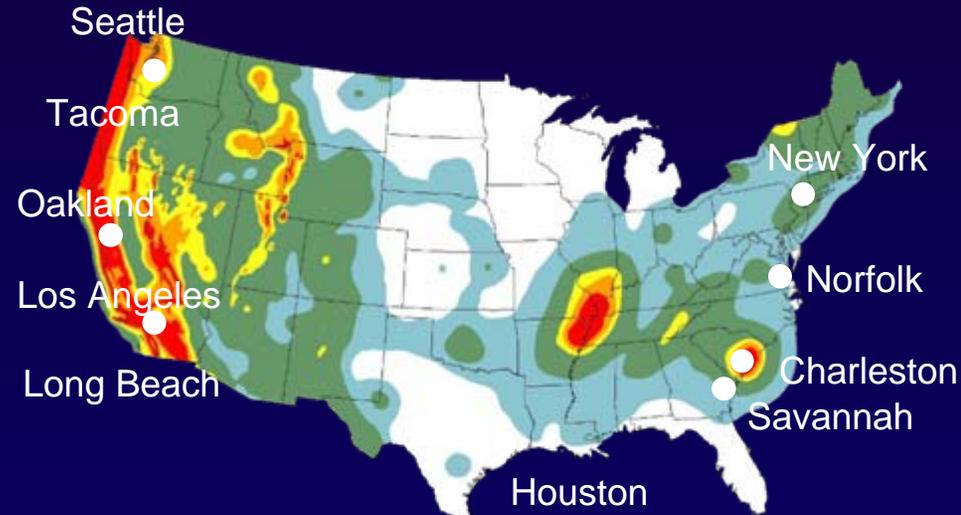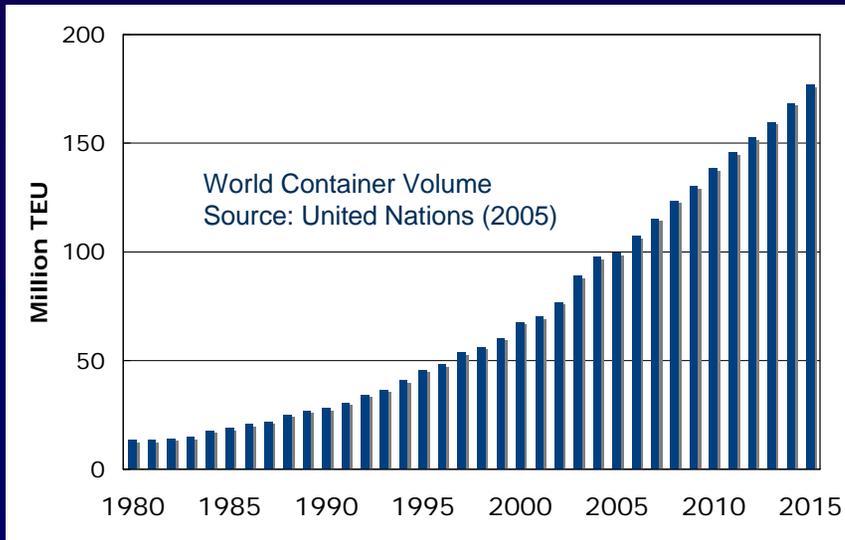
Earthquakes pose a threat to many large U.S. ports with potentially devastating consequences

(Graphics provided by G. Rix, Georgia Tech)

NEESR GC: Seismic Risk Mitigation of Ports

Goal: Design, retrofit, and remediation strategies using experimental and numerical simulations to mitigate damage to vulnerable port infrastructure

Container crane response
(NEES@Buffalo)

Wharf response
(NEES@UIUC)
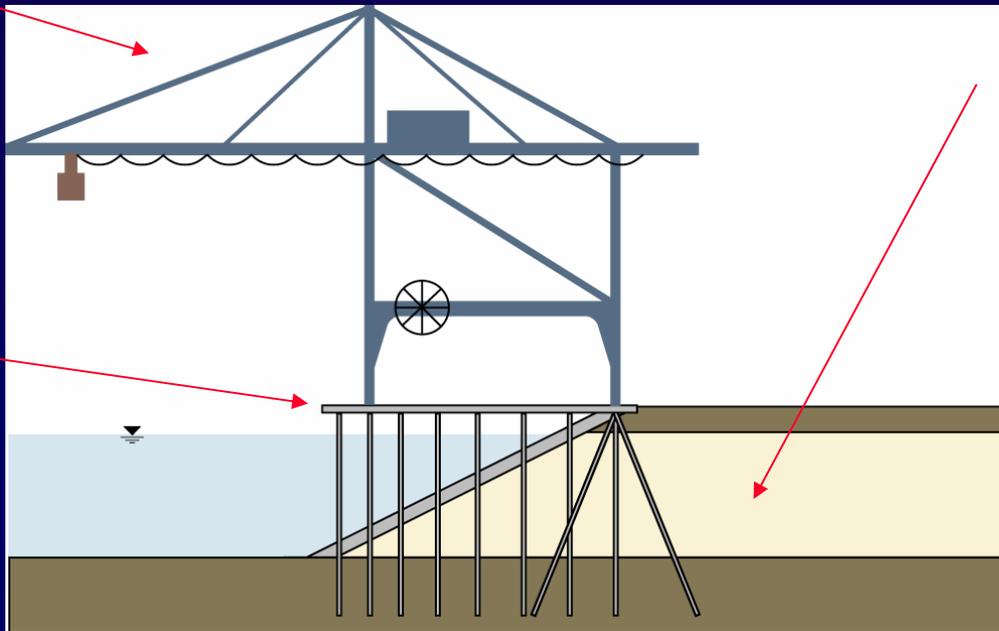
Liquefiable fill soils:
(NEES@UTexas)

(NEES@UCDavis)

national **earthquake** hazards reduction program
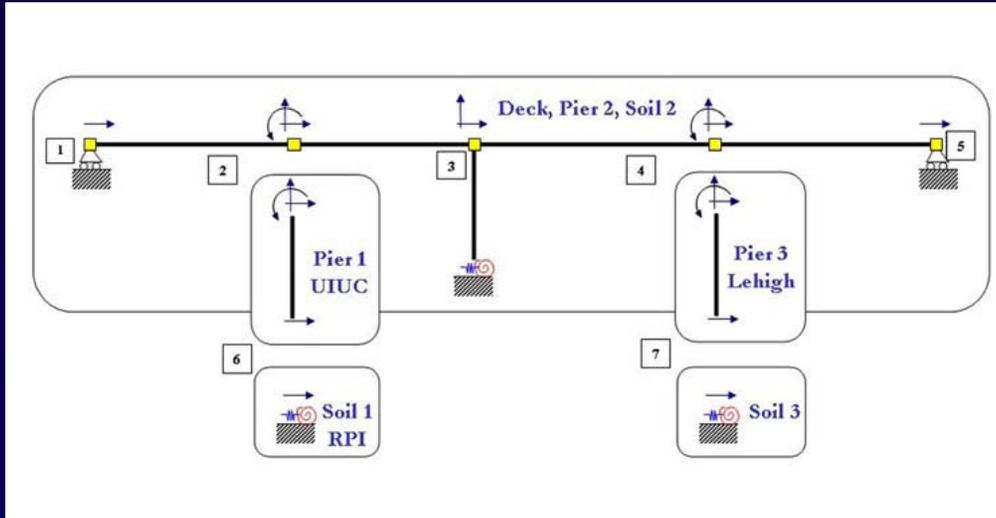
Substructuring
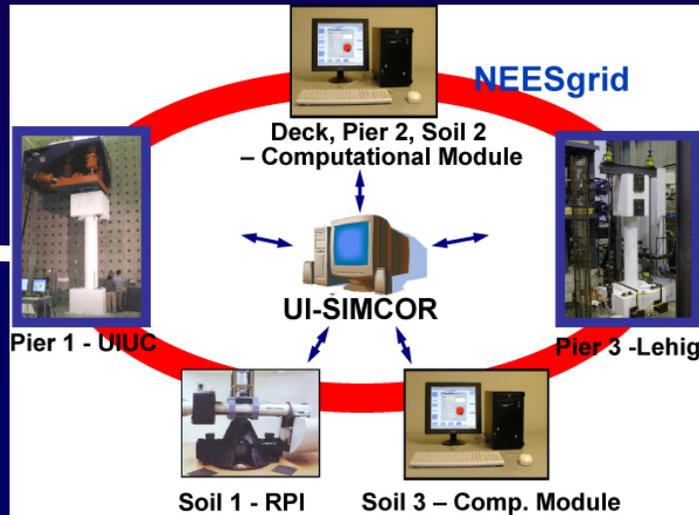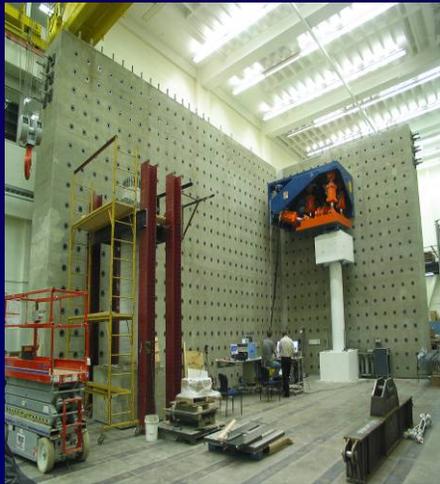
Distributed Hybrid Simulation Test

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NEES Education – Instructional Shake Tables
Lead: Washington University
(NSF Award DUE-0618605)

"Deployment and Integration of Instructional Shake Tables Using the NEES Cyberinfrastructure"
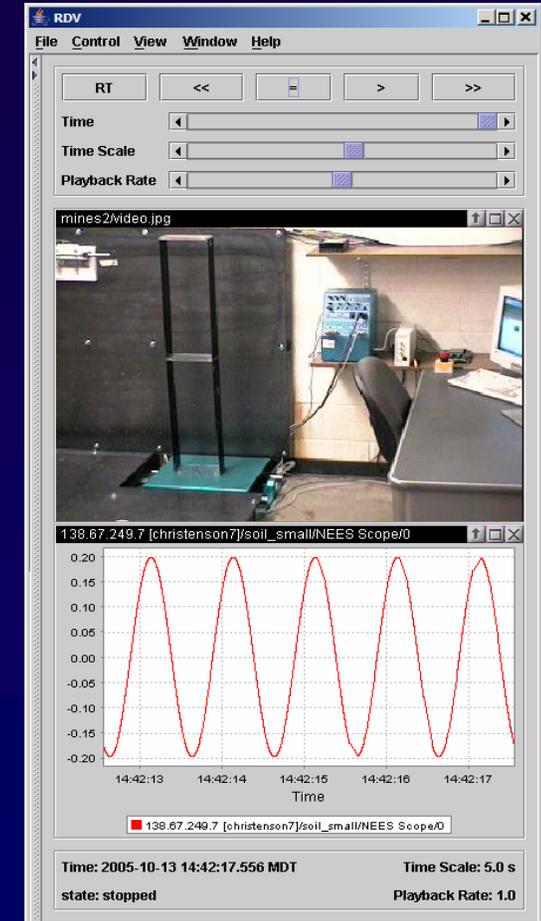
(Photos courtesy of Xiuyu Gao, Washington University)

national earthquake hazards reduction program

# NEES REU Program
NEES Consortium, Inc.
(NSF Award CMMI-0552992)

Research Experience for Undergraduates
NEESreu Program
Summer 2006

NEES NSF

Applicants Sought for Research Experiences for Undergraduates Program
This is not your typical Science and Engineering REU...

Are you ready for a dynamic new experience this summer? Are you interested in changing the world around you? Do earthquakes and tsunamis excite you? Spend the summer studying these things and more while joining cohorts around the country. Experiences may include participating at the NEESit site in San Diego, California. All students will join their cohorts at the NEES Annual Meeting in Washington, D.C., and at the Young Researchers Symposium in Bend, Oregon at the Sunriver Resort. Other REU students from the three big earthquake centers: MAE, MCEER, and PEER will join you in Bend, Oregon.

2006 NEES REU Program
Junior and Senior level undergraduate students are invited to explore new directions in earthquake studies through this National Science Foundation sponsored REU program. Students from universities and four-year colleges will spend ten weeks in the summer conducting individual research projects at various node sites that contribute to ongoing research programs.

Coordination with EERC's

Diversity Strategies with Partners

Utilize IT Collaboration Infrastructure

First Group
2006

(Photos courtesy of NEES Consortium, Inc.)

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NSF Directorate for Engineering

EFRI - Annual Solicitation w/Two New Topics Each Year

(EFRI)
Emerging Frontiers in Research and Innovation

(OAD)
Assistant Director
Deputy Assistant Director

Senior Advisor Nanotechnology

Engineering Education and Centers (EEC)

Civil, Mechanical, and Manufacturing Innovation (CMMI)

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

Electrical, Communications and Cyber Systems (ECCS)

Industrial Innovation and Partnerships (IIP)

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FY 2008 EFRI Solicitation Topic (Available ~July 2007) Resilient and Sustainable Infrastructures (RESIN) - Preliminary ideas below)

Research to design, renew, expand, monitor, and control <u>critical interdependent infrastructures</u> to be both resilient and sustainable.

- <u>Infrastructures</u>: Such as energy, water, wastewater, communications, transportation, public health networks, etc.

- <u>Interdependencies</u>: Such as physical, natural resource, cyber, information, geographic, human, and social connections.

- <u>Resiliency</u>: Ability to recover from shorter term events.

- <u>Sustainability</u>: Long-term reliability through renewable energy and materials and reduced impact on natural systems.