Update on the Role of the National Science Foundation in the National Earthquake Hazards Reduction Program (NEHRP)

Presentation to the NEHRP
Advisory Committee for Earthquake Hazards Reduction (ACEHR)
November 23, 2009

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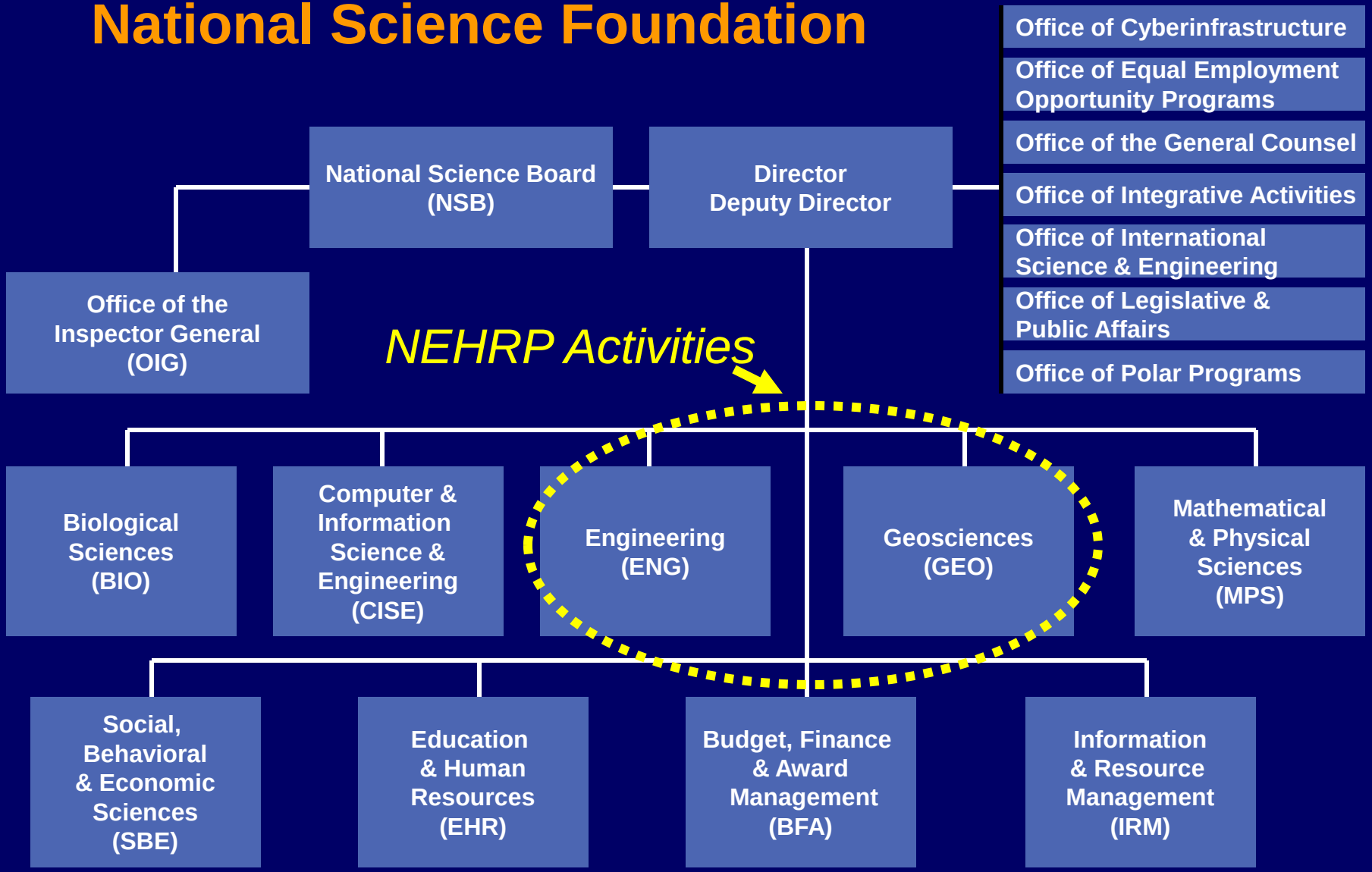
Arlington, VA

National Science Foundation



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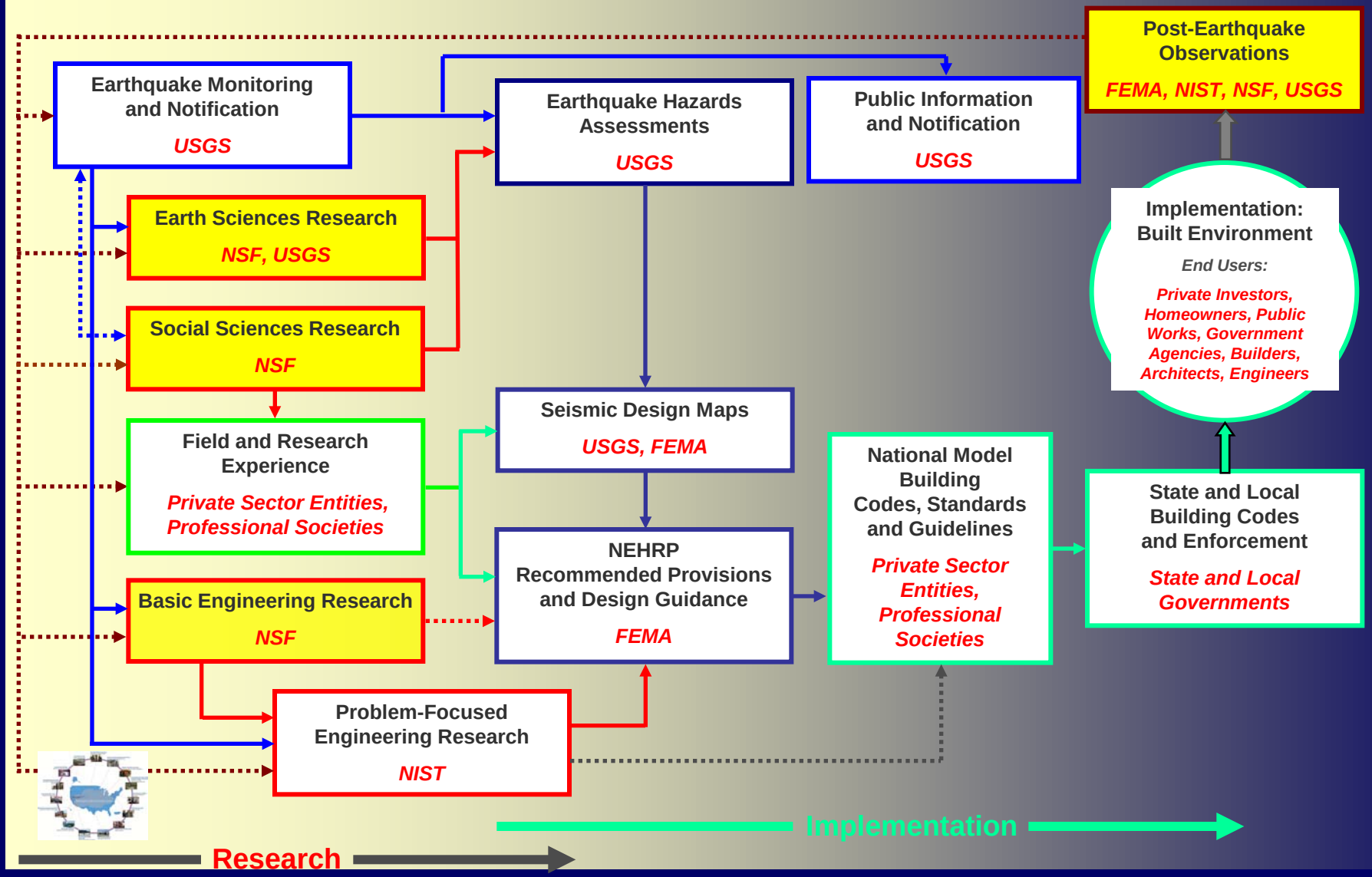
national earthquake hazards reduction program



NEHRP Impact on the Built Environment

NEHRP Activities Supported by NSF

- **Directorate for Geosciences**
  - Incorporated Research Institutions for Seismology (IRIS)
  - Southern California Earthquake Center (SCEC)
  - Fundamental Research on Earthquakes
  - EarthScope (Related non-NEHRP activity)
- **Directorate for Engineering**
  - George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Operations and Research
  - Fundamental Research (Unsolicited Proposal Programs)
    - Hazard Mitigation and Structural Engineering
    - Geotechnical Engineering
    - Infrastructure Management and Extreme Response
  - Post-earthquake reconnaissance
  - National Hazards Center

American Recovery and Reinvestment Act of 2009 NEHRP Awards

- NSF did not have a separate ARRA solicitation for earthquake research; ARRA funds supported additional awards

- Awards
  - ENG
    - 23 research awards for $9.6 million total
  - GEO
    - 20 research awards for $4.8 million total
    - SCEC: $800,000
    - GSN: $5 million
    - NEHRP-Related activity: $10 million

NEHRP (NSF) Success Stories *Seismic Waves*

http://www.nehrp.gov/plans/index.htm#success

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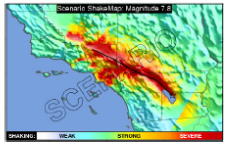
How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Drilling Toward a New Level of Preparedness

The Great Southern California ShakeOut

Drills and response exercises are vital components of earthquake preparedness. Drills teach behavior that helps people protect themselves once the ground starts shaking, and in response exercises, trained personnel practice what to do when the shaking stops.

Preparedness can be heightened when it is understood that preparation is the responsibility not just of trained responders but of everyone in earthquake-prone regions, and that it involves not only learning what to do when earthquakes strike, but also doing things before they strike to mitigate their effects on people and property. Depending on how they are designed and executed, drills and exercises can help cultivate such understanding.



Simplified ShakeMap of the ShakeOut scenario earthquake, designed by USGS for the news media. Colors denote intensity of shaking across southern California. Courtesy of USGS.

Grounded in Science

The Great Southern California ShakeOut was an unprecedented combination of events held in and around the week of November 12–18, 2008, in Los Angeles and other communities across the eight counties of southern California. The objective was to conduct drills, exercises, and associated events in a coordinated, innovative, and science-based manner so that collectively, they would begin to transform the public's understanding of preparedness.

Organizers utilized cutting-edge expertise from the physical and social sciences in designing the "ShakeOut." First, a multidisciplinary team of more than 300 experts drawn from government, academia, and industry developed the ShakeOut Earthquake Scenario, the most comprehensive earthquake scenario ever created. Issued in May 2008, the ShakeOut scenario revealed how a very large, but plausible, earthquake would impact southern California, describing in detail what would happen if the southernmost 200 miles of the San Andreas Fault were to rupture at 10 a.m. on November 13, 2008, producing a magnitude 7.8 earthquake. The size, scope, plausibility, and credibility of the effects described made the scenario a rich and compelling resource for preparedness planning.[1]

Social scientists evaluated how this information could be used to help shake people out of an all-too-common attitude toward preparedness characterized by "it won't happen to me" passivity. ShakeOut organizers then planned a group of events that reflected the scientists' recommended principles for motivating behavioral change.

Innovative Pieces of a Motivational Puzzle

The ShakeOut events, which provided a framework for applying these principles, included a southern California–wide earthquake drill, state and local response and recovery exercises, an international earthquake conference, a public preparedness rally, and several novel follow-on activities. The Earthquake Country Alliance organized these events using managerial and technical support provided by the U.S. Geological Survey (USGS), which had earlier led development of the ShakeOut scenario, and the Southern California Earthquake Center, a joint National Science Foundation–USGS multi-institution collaboration. The Alliance came together as a southern California–wide, public-private partnership of individuals and organizations representing government, the business community, disaster responders, academics, and media representatives. The partnership launched www.shakeout.org, an online clearinghouse of ShakeOut information for organizers, participants, the news media, and the public.

The signature event of the ShakeOut was the earthquake drill, held as the scenario earthquake "struck" southern California at 10 a.m. on November 13. With more than 5 million participants, the drill lived up to its billing as the

[1] The ShakeOut Earthquake Scenario is described more fully in "A Hypothetical Disaster Comes to Life," the June 2008 issue of *SeismicWaves*.

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How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Safely Spreading the Benefits of Precast Construction

The Diaphragm Seismic Design Methodology Project

Should scientific research advance knowledge, commercial activity, or the public good? These objectives are sometimes viewed as competitors in a zero-sum game or as rivals for increasingly scarce societal resources. The Diaphragm Seismic Design Methodology (DSDM) Project is serving all of these objectives, however, and that is just one of several attributes that make this a remarkable research effort.

A Convergence of Interests

Precast concrete structures, particularly parking garages, were among the types of buildings found to be vulnerable when a powerful earthquake struck Northridge, CA, in 1994. This event heightened concerns about the safety of

Integrated and Comprehensive

The DSDM project, which got under way in 2004 and will be completed in 2011, has successfully integrated research activities in comprehensive and challenging ways. This is reflected in the number of organizations and individuals involved, the scope of the objectives pursued, the range of diaphragm behaviors examined, and the mix of design approaches and research methods employed in the project.

The consortium formed to carry out the project includes engineering research teams located at the University of Arizona, at Pennsylvania's Lehigh University, and at the University of California, San Diego (UCSD). A panel of

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The researchers have also conducted a tightly integrated mix of experimental testing (involving precast concrete specimens) and analytical simulations (involving computer models of such specimens). At Lehigh University, which houses one of the 15 research facilities that make up the NSF-supported George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), the project team experimentally tested samples of diaphragm connections currently in use. The results were used at the University of Arizona to develop computer models of floor diaphragms, study the capacity of these diaphragms to resist seismic forces, and design improved connections. The new connections were used in diaphragm joints tested back at the Lehigh NEES facility, and the diaphragm models were incorporated into models of precast structures at UCSD.

Half-scale parking structure on the NEES shake table at UCSD in 2008. Courtesy of UCSD Jacobs School of Engineering.

UCSD researchers subjected these computer models to earthquakes by simulating the types of ground motions that would be expected to occur in four localities with differing seismic hazards (Berkeley, CA; Charleston, SC; Knoxville, TN; Seattle, WA). Based on these simulations, they developed estimates of the mathematical values or "design factors" that their methodological framework indicated were needed for the design of precast diaphragms.

Culmination and Outcomes

DSDM experiments culminated in the summer of 2008 at the NEES facility located in UCSD's Englekirk Structural Engineering Center, which features the largest outdoor shake table in the United States. The UCSD project team constructed a three-story, half-scale precast parking garage on the shake table utilizing the diaphragm design factors, connections, and joints developed in the project.

The researchers subjected this building to a series of 15 simulated earthquakes, each lasting about 20 seconds. The shake table generated the same range of ground motions that UCSD had earlier used in its computer simulations—but this time a real structure underwent real shaking. Hundreds of sensors installed throughout the building recorded a wealth of data about the seismic responses of the floor diaphragms and other elements of the structure.

By comparing these responses to those predicted by their computer models, the DSDM researchers can fine-tune the models to ensure that they accurately represent the seismic behavior of precast floor diaphragms. This critical process is now well under way, and as the models are finalized, they are being used to fine-tune the estimates of diaphragm design factors. These factors, in turn, are being incorporated into a new procedure for designing diaphragms, which the researchers are documenting in a comprehensive design document entitled "Draft Seismic Design Methodology for Precast Concrete Diaphragms."

The DSDM consortium expects to complete this document in 2010. In addition to the design procedure and a classification of prequalified diaphragm connections, the Methodology will feature design examples based on prototypical precast structures. Engineers nationwide will be able to use this resource to design reliable and economical precast diaphragm systems for regions of high seismicity as well as areas that are less seismically active.

The DSDM Task Group is working with PCI on plans for disseminating the Methodology through PCI's Web site and technical literature. Task group members have also begun to shepherd the design procedure through the standards-development processes of the American Society of Civil Engineers and American Concrete Institute. These organizations coordinate the development of key national standards relating to seismic design and construction; these standards, which are expected to be updated next in 2011, are incorporated by reference into the *International Building Code*, which U.S. states and localities use to regulate building design and construction.

For more information, visit www.nehrp.gov or send an email to info@nehrp.gov.

FEMA NIST National Institute of Standards and Technology U.S. Department of Commerce USGS science for a changing world

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How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Can Wood Buildings Safely Grow Taller in Seismic Regions?

The NEESWood Project Provides a Definitive Answer

This past summer in rural Japan, the largest building ever seismically tested was subjected to the maximum credible earthquake for Los Angeles on the world's biggest shake table. This "capstone" test of the tallest wood-frame building ever tested marked the culmination of the NEESWood research project. The project was launched in the fall of 2005 with ongoing support from the National Science Foundation (NSF) and NSF's George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).[1] Since then, NEESWood researchers have marshaled academic, industry, and international collaboration to successfully produce and validate a new design methodology that has major implications for wood-frame construction in seismic regions of the United States and around the world.

The capstone test structure is moved onto the E-Defense shake table in Japan on June 22, 2009. Photo courtesy of John van de Lindt, Colorado State University.

Competing with Steel and Concrete

Wood-frame buildings generally cost less to construct than do structures made with steel or concrete, and wood is heavily used for low-rise construction (four stories or less). In earthquake-prone regions, however, building codes have generally excluded wood framing from the market for mid-rise (five- to seven-story) structures. This is because not enough has been known about how such buildings respond to strong earthquake ground motions.

NEESWood researchers have sought to learn more about the seismic behavior of wood-frame structures and to use this knowledge to develop improved design methods and tools. Their objectives have been to enable the construction of safe and economical mid-rise wood buildings—and the mitigation of earthquake damage among low-rise wood structures—in seismically active regions.

Led by Principal Investigator Dr. John van de Lindt of Colorado State University, the research team includes co-principal investigators from the University at Buffalo (UB), University of Delaware, Rensselaer Polytechnic Institute (RPI), and Texas A&M University. A number of technical collaborators from government and industry have also participated in the project, contributing products, product-testing data, funding, materials, and services. Of particular note are the Simpson Strong-Tie Company, the U.S. Forest Products Laboratory, FPInnovations, and Japan's National Research Institute for Earth Science and Disaster Prevention (NIED).

New Design Philosophy Needed

In recent damaging earthquakes such as California's 1994 Northridge event, traditional engineering design procedures have been effective in limiting building collapses and loss of life, but have proven less effective in limiting building damage and ensuring that immediate re-occupancy is possible following the earthquake. These conclusions were reinforced by the first major NEES-Wood experiment in 2006. In this "benchmark" test led by Co-Investigator Dr. Andre Filiatrault, researchers subjected a full-scale, two-story wood-frame townhouse to a simulation of the Northridge earthquake produced by twin shake tables at UB's NEES laboratory. The result was damage that, although not life-threatening, was substantial and costly.

The benchmark test yielded reliable data on the seismic performance of wood buildings designed in accordance with prevailing building codes. NEESWood researchers used these data to further enhance software that they were developing, the Seismic Analysis Package for Woodframe Structures (SAPWood). This tool, in turn, enabled them to more accurately predict how changes in the design of wood buildings would affect the buildings' seismic performance, and supported their efforts to create a new method for designing these structures.

[1] Funding has been provided under NSF grant awards CMMI-0529903 and CMMI-0402490.

NSF-supported Discoveries and News from Grantees

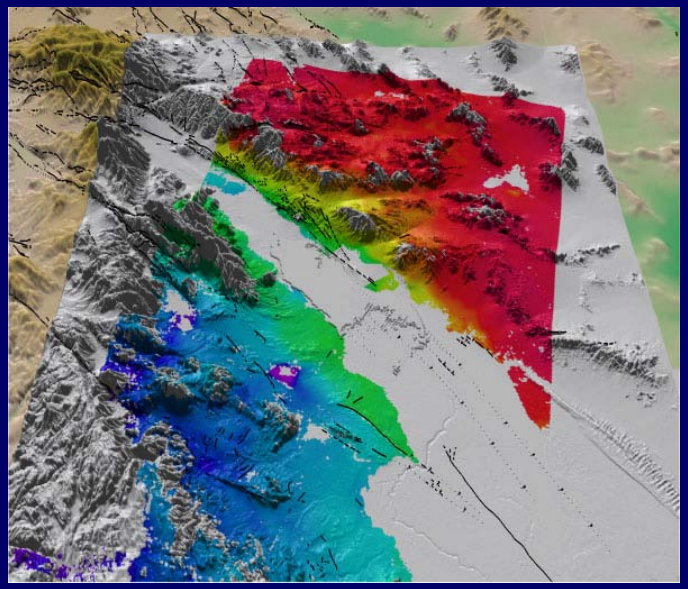
- **Japanese Quake Test**
  http://www.nsf.gov/news/special_reports/science_nation/japanquake.jsp
- **Building Tsunami-Resistant Cities**
  http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=115749&org=NSF
- **National Science Foundation-funded Projects Featured at Education Technology Showcase**
  http://www.nsf.gov/news/news_summ.jsp?cntn_id=115917&org=NSF&from=news
- **Community Education and Evacuation Planning Saved Lives in Sept. 29 Samoan Tsunami**
  http://www.nsf.gov/news/news_summ.jsp?cntn_id=115924&org=NSF&from=news
- **San Andreas Affected by 2004 Sumatran Quake**
  http://www.nsf.gov/news/news_summ.jsp?cntn_id=115721&org=NSF&from=news
- **UCSD Engineers to Shake Historic Masonry Building During Strong Simulated Earthquakes**
  http://www.nsf.gov/news/news_summ.jsp?cntn_id=115163&org=NSF&from=news

NEHRP Activities Supported by NSF

- **Directorate for Geosciences**
  - Fundamental Research on Earthquakes
  - Incorporated Research Institutions for Seismology
  - Southern California Earthquake Center
  - EarthScope (Related non-NEHRP activity)

Fundamental Research on Earthquakes

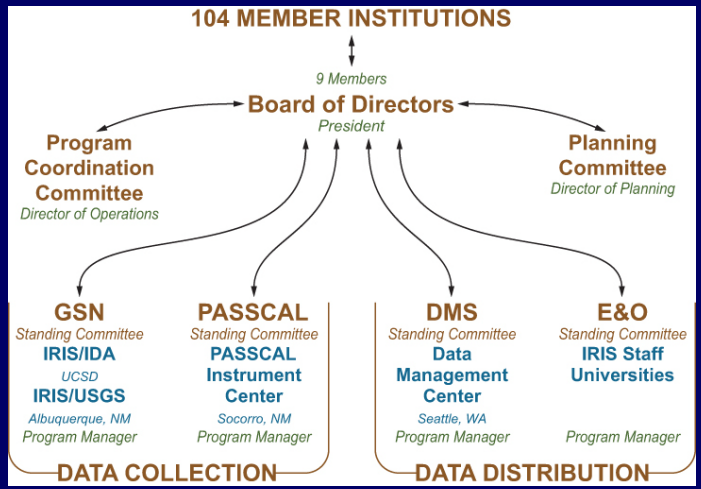
- GEO/EAR Programs fund fundamental earthquake-related science through general program solicitations
  - Geophysics, Tectonics, Continental Dynamics, Instrumentation and Facilities
- Areas of Current Research
  - Satellite radar information on surface deformation
  - Relationship of tremor, slow slip and other low frequency phenomena to large earthquakes
  - Fault zone modeling to understand earthquake dynamics
  - Study of material properties in fault zones
- Fundamental research is conducted and facilitated by centers such as SCEC, IRIS, UNAVCO, CIG and others



Satellite radar images are used to infer slippage on the Southern San Andreas Fault system. (Falko, UCSD)

Incorporated Research Institutions for Seismology (IRIS)

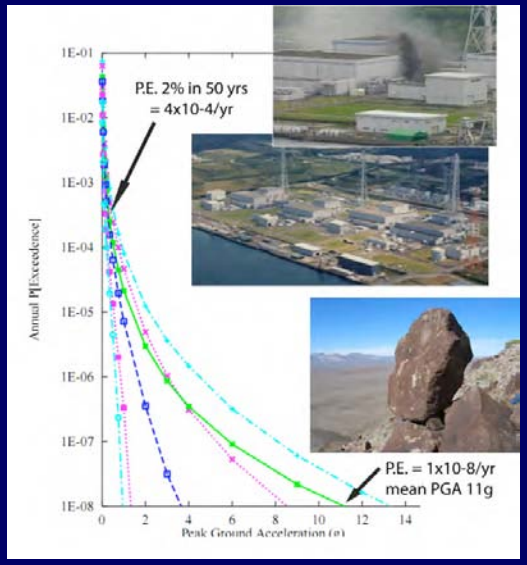
- **NSF-supported university research consortium dedicated to exploring the Earth's interior through the collection and distribution of seismographic data**
  - **PASSCAL - seismic sensors, data acquisition, telemetry and power systems for earth science research**
  - **DMS - 8 nodes that coordinate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



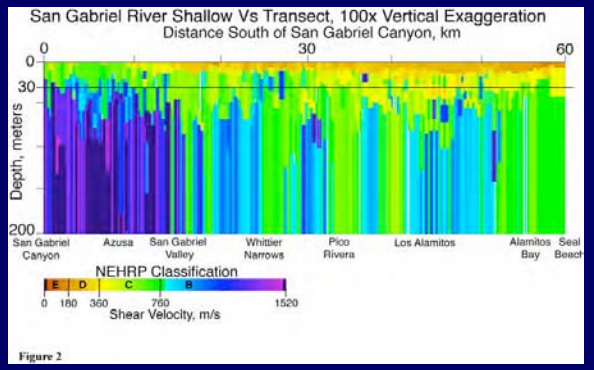
IRIS Activities

- **September 18-19, 2008: Long Range Science Plan For Seismology**
- **November 19th Draft Report "Grand Challenges in Understanding Earth's Dynamic Systems" available for comment**

  http://www.iris.edu/hq/lrsps/
- **10 Grand Challenges:**
  - **How do faults slip?**
  - **What is the relationship between stress and strain in the lithosphere?**
  - **How do processes in the ocean and atmosphere couple to the solid Earth?**
  - **How does the near-surface environment affect resources and natural hazards?**
  - **Where are water and hydrocarbons hidden beneath the surface?**
  - **How do magmas ascend and erupt?**
  - **What is the lithosphere-asthenosphere boundary?**
  - **How do plate boundary systems evolve?**
  - **How do temperature and composition variations control mantle and core convection?**
  - **How are Earth's internal boundaries affected by dynamics?**



Probabilistic seismic hazard curve for Yucca Mountain, Nevada. Kashiwazaki-Kariwa Nuclear Power Plant in Japan. Photo of precarious rock. (Image courtesy of R. Allen, with graph from J. C. Stepp and I. Wong)

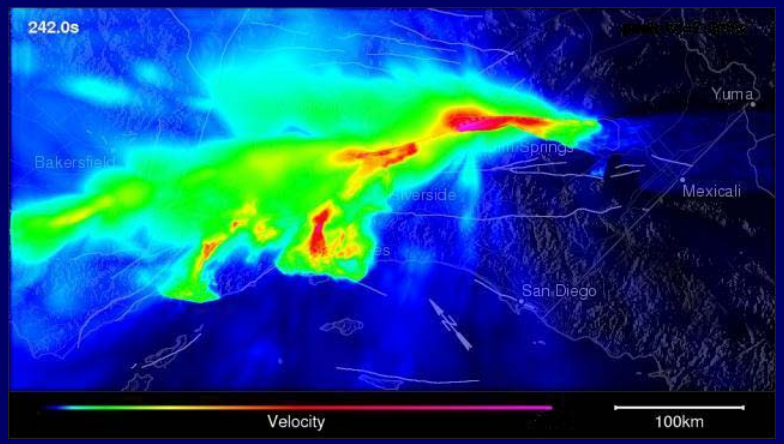


A 60-km long cross section of the upper 200 m of the Los Angeles basin, at 100X vertical exaggeration, showing shear-wave speed. The image was derived using seismic surface-wave background noise. (From W. Thelen, et al., BSSA, 96, 1055, 2006)

Southern California Earthquake Center

- SCEC: “collaboratory” funded in partnership by NSF and USGS
  - Tripartite mission: 1) gather data on earthquakes in Southern California; 2) integrate information into a comprehensive, physics-based understanding of earthquake phenomena; and 3) 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)
- SCEC-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**

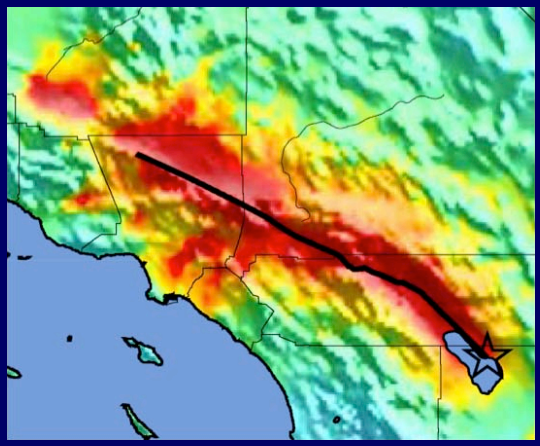
TeraShake simulations of M7.7 earthquake on southern SAF
(Image: Kim Olsen (SDSU), Geoffrey Ely (UCSD))



Geosciences Activities

Southern California Earthquake Center

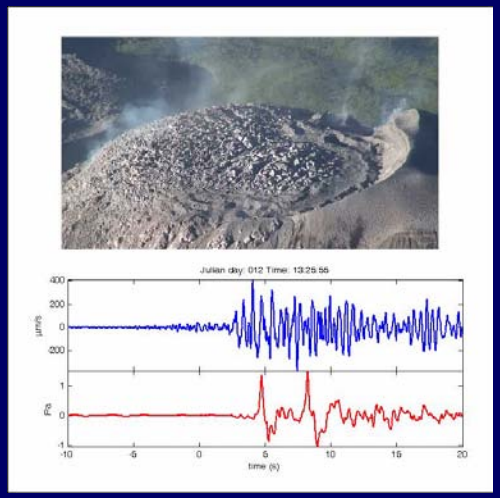
Participation in the Great ShakeOut 11/13/08
Coordinated by the USGS in collaboration with business, government, academic and educational partners
Basis of ShakeOut: SCEC PetaSHA high-performance simulation (Graves, et al.)



Ground shaking during the simulated Magnitude 7.8 southern San Andreas Fault Earthquake.

Seismo-acoustics View Volcanic Eruption

- **Jeffrey Johnson (New Mexico Institute of Mining and Tech.) et al. Published in Nature, 11/20/2008: "Long-period earthquakes and co-eruptive dome inflation seen with particle image velocimetry"**
  - **Links volcanic activity with long-period earthquakes. May be a means of understanding seismic and volcanic hazards and monitoring explosive gas and ash venting.**



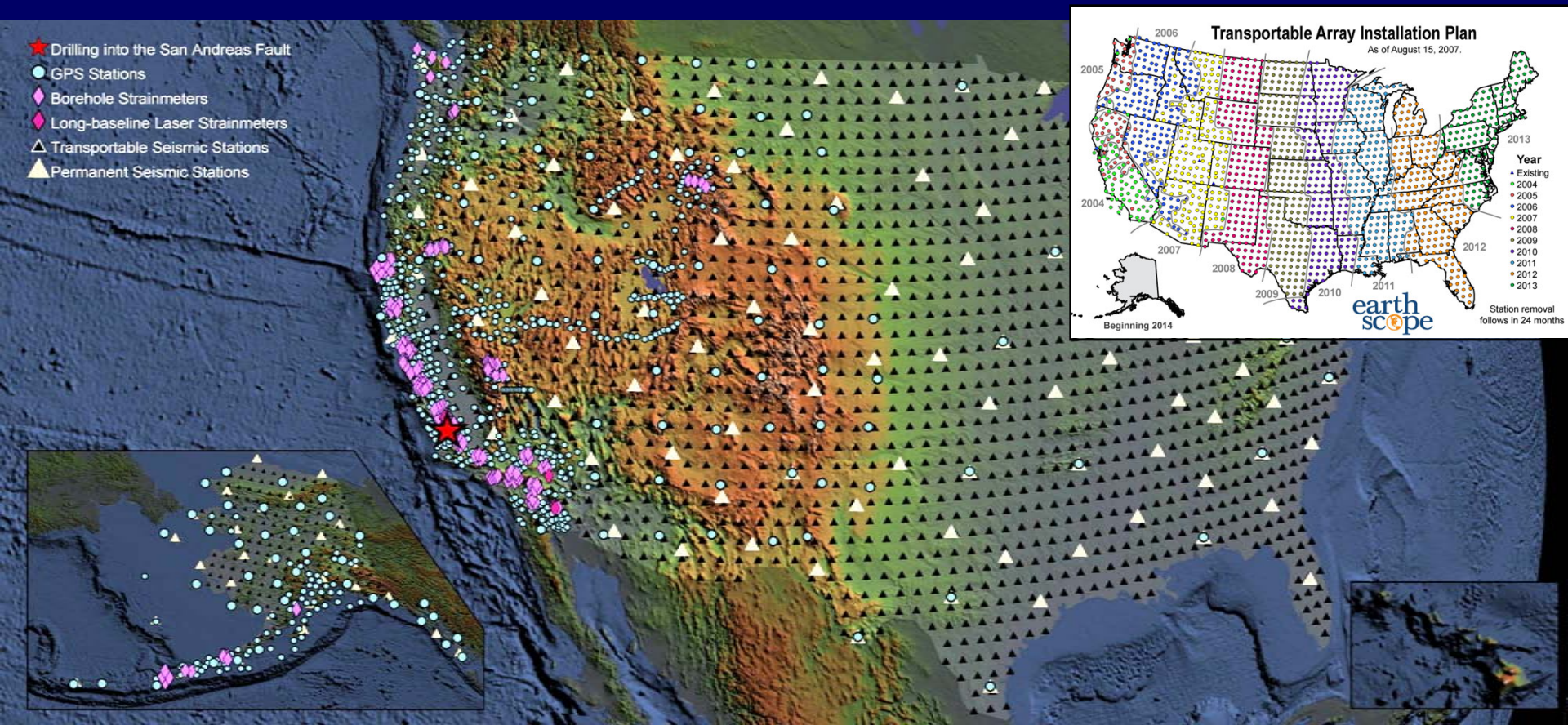
Santiagito explosion with seismo-acoustic recording

Related Non-NEHRP Activities

earthscope

EarthScope :

- Construction phase completed 09/30/2008
- Now entered 5-year Operations and Maintenance of the Facility
- Data Portal to all EarthScope data sources www.Earthscope.org
- USArray continues to rolling through the mid-continent (N. Dakota-Texas)



NEHRP Activities Supported by NSF

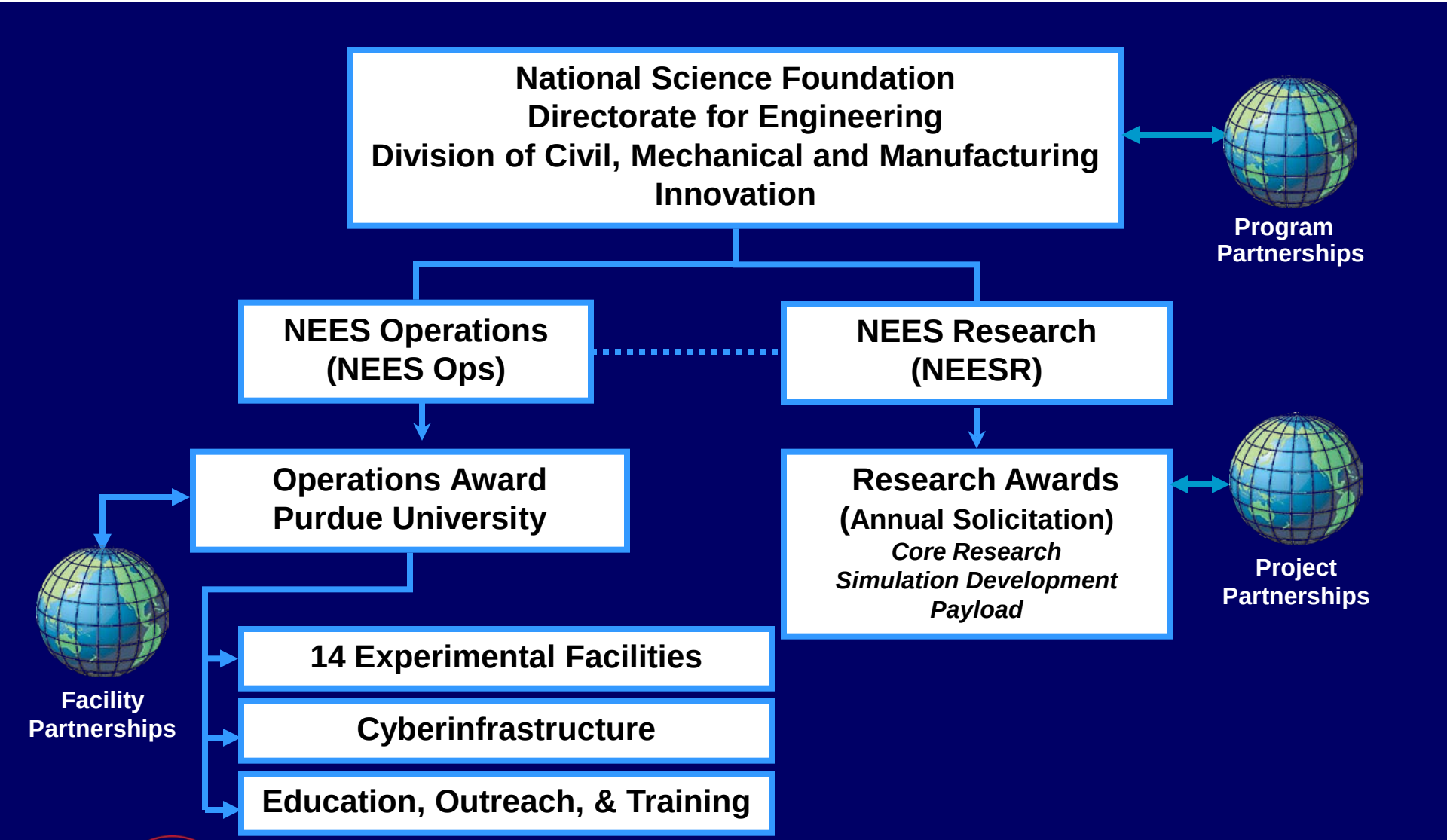
- **Directorate for Engineering**
  - George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Operations and Research
  - Fundamental Research Programs (unsolicited)
    - Hazard Mitigation and Structural Engineering
    - Geotechnical Engineering
    - Infrastructure Management and Extreme Response
  - Post-earthquake reconnaissance
  - National Hazards Research Center

NSF Inter/Multi/Cross - Disciplinary Funding Opportunities (most recent solicitation shown)

- NSF Engineering Directorate funding opportunity on *Interdisciplinary Research* (IDR) at http://nsf.gov/eng/general/IDR/index.jsp (PD 09-7951). The Division of Civil, Mechanical and Manufacturing Innovation (CMMI), which funds hazards research, participates in this program.
- NSF Program Solicitation 09-545, Engineering Research Centers (ERC) competition, included a focused topic on *Complex, Coupled Physical Civil Infrastructure Systems under Stress*. In addition to this focus area, investigators could propose an ERC addressing their own topic of choice, including hazard-related topics.
- Building Engineered Complex Systems (NSF 09-610)
- Innovations in Engineering Education, Curriculum, and Infrastructure (IEECI) NSF (10-502)
- Science and Technology Centers (STC)[1].
- Cyber-Enabled Discovery and Innovation (CDI) (NSF 10-506)
- Integrative Graduate Education and Research Traineeships (IGERT) (NSF 09-519)
- Research Experiences for Undergraduates (REU) sites (NSF 09-598)
- Research Experiences for Teachers in Engineering (RET) sites (NSF 07-557)
- Dynamics of Coupled Natural and Human Systems (CNH)
- Human and Social Dynamics (funded for five years; no longer a priority area)
- Partnerships for International Research and Education (PIRE) (NSF 09-505)
- Within the Division of Civil, Mechanical and Manufacturing Innovation, the unsolicited proposal program on Infrastructure Management and Extreme Events
-

[1] The Southern California Earthquake Center (SCEC) was originally funded through this mechanism.

NEES Program



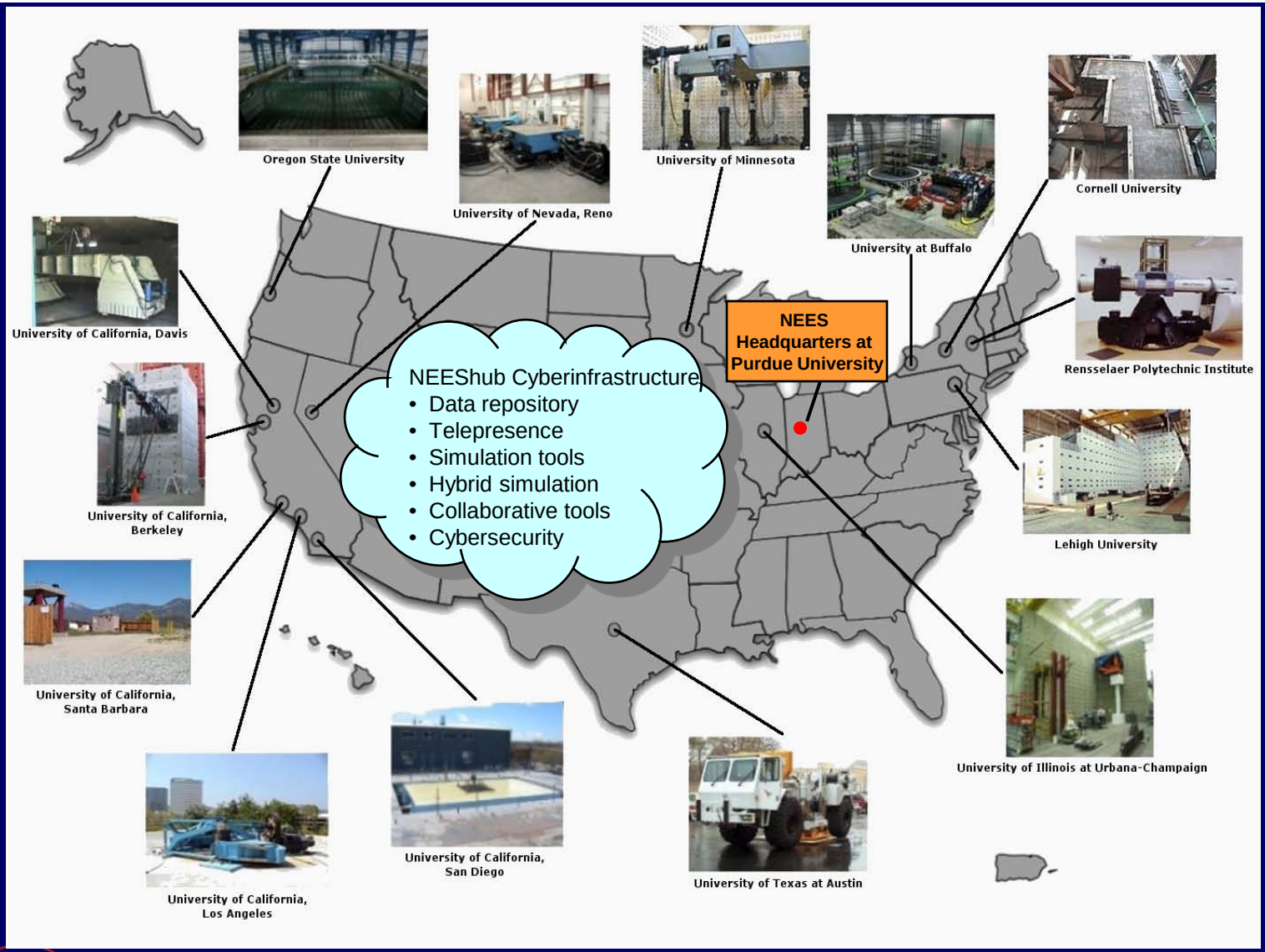
NSF 08-574 NEES Operations Competition

- NSF recompeted NEES operations during FY 2008-FY 2009 through NSF 08-574 program solicitation, George E. Brown, Jr. Network for Earthquake Engineering Simulation Operations (NEES Ops), FY 2010-FY 2014

- NSF 08-574 outcome: At its August 5-6, 2009 meeting, the National Science Board authorized NSF to make five-year award to Purdue University

- NSF awarded cooperative agreement CMMI-0927178 to Purdue University for FY 2010 – FY 2014, effective October 1, 2009 (PI: Julio Ramirez)

NEES for the Engineering Community



NEES Operations Activities led by Purdue University

- "NEEScomm" is management team
- Equipment site operations and maintenance for 14 facilities
  - Many facilities are near/at usage capacity: Oregon State University; University at Buffalo; University of California, Berkeley; University of California, Davis; University of California, Los Angeles; University of Illinois at Urbana-Champaign; University of Minnesota; University of Nevada, Reno; and University of Texas, Austin.
  - Sponsored research: NSF, FHWA, USGS, FEMA, California Department of Transportation, San Francisco Public Utilities Commission, State of Connecticut, State of Pennsylvania, and private foundations.
- *NEEShub* - requirements-driven cyberinfrastructure
- *NEES Academy* - engineering education excellence
  - Continue REU program; NEES Consortium, Inc., supported 34 REU students in 2009
- Engaged global multi-hazard *NEES Community* and a Community Forum
- *Governance Board* – independent oversight
- Continue Annual Meetings (8th Annual Meeting, TBD 2010)
- Continuance of domain name/web site: http://www.nees.org

Earthquake Engineering Research Directions

- *Strategic Plan for the National Earthquake Hazards Reduction Program FY 2009-2013 (Note: NEES is authorized under NEHRP legislation)*
- *Grand Challenges for Disaster Reduction: Priority Interagency Earthquake Implementation Actions,* A Report of the Subcommittee on Disaster Reduction, National Science and Technology Council
- *Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering. A Research Agenda for the Network for Earthquake Engineering Simulation (NEES),* a 2003 report from a panel organized by the National Research Council of the National Academies to develop a long-term agenda for earthquake engineering research requiring NEES experimental resources
- *Prioritized Research for Reducing the Seismic Hazards of Existing Buildings* (Applied Technology Council, ATC-73, 2007)
- *Research Required to Support Full Implementation of Performance-Based Seismic Design* (NIST GCR-09-917-2, 2009)
- 2010 Workshops on NEES Transformative Research
  - CMMI-1004951/0957567, *Workshop/Collaborative Research: Vision 2020 – An Open Space Technology Workshop on the Future of Earthquake Engineering*, St. Louis, MO, January 25-26, 2010 (PIs: Shirley Dyke, Purdue University, and Bozidar Stojadinovic, University of California, Berkeley)
  - *Workshop on Geotechnical Engineering Research using NEES*, tentatively planned for February 2010 (TBD)
- 2010 - 2013 NEES/E-Defense Collaboration Workshops
  - CMMI-0958774: *Coordinating Workshops for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering (Phase 2)* (PI: Stephen Mahin, University of California, Berkeley)

Timeline for NEES Post-FY 2014 Assessment

Date By (approx)	Activity
2010 Feb	Award(s) made for NEES assessment • Accomplishments of NEES research and operations • Viability of NEES to remain state of the art beyond FY 2014 • Needed equipment and cyberinfrastructure upgrades • Earthquake engineering experimental capabilities worldwide
2011 Dec	Assessment report completed and submitted to NSF
2012 Oct	Decision by NSF regarding NEES post-FY 2014 conveyed to earthquake engineering community

Post-Earthquake Reconnaissance Support

- Learning from Earthquakes Program (CMMI-0758529)
  http://www.eeri.org/site/projects/learning-from-earthquakes
- Geo-Engineering Extreme Events Reconnaissance
  http://research.eerc.berkeley.edu/projects/GEER/
- Natural Hazards Center
  http://www.colorado.edu/hazards/
- NSF RAPID (formerly SGER) awards

Recent NSF Awards for International Workshops and Travel

- CMMI-0943793: Travel Support for the 9th US National and 10th Canadian Conference on Earthquake Engineering: Reaching Beyond Borders, July 25-29, 2010 in Toronto, Canada (PI: Susan Tubbesing)
- CMMI-0939300: Travel Support to E-Defense for US Wood Researchers (PI: John van de Lindt)
- CMMI-0958198: 7th International Conference on Urban Earthquake Engineering and the 5th International Conference on Earthquake Engineering; held in Tokyo, Japan, March 3-5, 2010 (PI: Amr Elnashai)
- CMMI-0914008: International Workshop: Toward Understanding the Effects of the Wenchuan Megaquake of 12 May 2008, Guangzhou, People's Republic of China, February 2009 (PI: Mete Sozen)
- CMMI-0823773: 14th World Conference on Earthquake Engineering (14WCEE); Beijing, China, October 12-17, 2008 (PI: George C. Lee)

Recent NSF Awards on Seismic Vulnerability of Steel Building Structures

- CMMI-0936633: NEESR-CR: Collapse Simulation of Multi-Story Buildings through Hybrid Testing (PI: Eduardo Miranda)
- CMMI-0936599: NEESR-CR: Multi-Scale, Mechanistic Fracture Prediction and Optimal Panel Zone Participation in Steel Moment Frame Buildings (PI: Gary Fry)
- CMMI-0936563: NEESR-CR: Steel Truss Systems with Enhanced Seismic Safety and Performance (PI: Shih-Ho Chao)
- CMMI-0936547: NEESR-CR - An Innovative Seismic Performance Enhancement Technique for Steel Building Beam-Column Connections (PI: Tasnim Hassan)
- CMMI-0928547: Robustness of Steel Buildings Under Extreme Seismic Events: Study of Building Systems Collapse Through Multi-scale Computational Methods (PI: Kapil Khandelwal)
- CMMI-0928193/0928593): Collaborative Research: Framework for Quantifying Structural Robustness through Modeling and Simulation (PIs: Sherif El-Tawil and Sashi Kunnath)
- CMMI-0926962: Quantifying the Risk Posed to Tall Steel Frame Buildings in Southern California from Earthquakes on the San Andreas Fault (PI: Swaminathan Krishnan)

Recent NSF Awards on Seismic Vulnerability of Reinforced Concrete Structures

- CMMI-100268: RAPID: NEES and E-Defense Collaboration for E-Defense Shake Table Tests of High Performance Reinforced Concrete Buildings in 2010 (PI: John Wallace)
- CMMI-0936519: NEESR-CR: Assessment of Punching Shear Vulnerability of Slab-Column Connections with Shear Stud Reinforcement (PI: Gustavo Parra-Montesinos)
- CMMI-958455: Collaborative Research: Development of Innovative, Replaceable Coupling Beam Systems for Damage Mitigation in Coupled Walls (PI: Bahram Shahrooz)
- CMMI-0830364: NEESR-SD: ExVis Tool and Case Study Implementation for the Visualization, Fusion, and Analysis of Experimental Test Data on Concrete Structural Walls (PI: Daniel Kuchma)
- CMMI-0829978: NEESR-SG: Performance-Based Design of Squat Reinforced Concrete Shear Walls (PI: Andrew Whittaker)
- CMMI-0825347: Lateral Load Behavior and Modeling of Shear-Dominant RC Walls for Performance-Based Design (PI: John Wallace)
- CMMI-0755333: SGER: Field Testing of a Non-ductile Reinforced Concrete Building in Turkey (PI: Ertugrul Taciroglu)

Recent NSF Awards on Liquefaction

- CMMI-0936421: NEESR-CR Properties of Cohesionless Soil Subsequent to Liquefaction and Resedimentation (PI: Ronaldo Borja)
- CMMI-0936408: NEESR-CR: Evolutionary Intensity Measures for More Accurate and Informative Liquefaction Hazard Evaluation (PI: Steven Kramer)
- CMMI-0928679: Engineering the Pore Fluid of Sands with Highly Plastic Nano-Particles for Liquefaction Prevention (PI: Maria Caterina Santagata)
- CMMI-0846449: CAREER: Impact of Liquefaction-Induced Water Layers on Forward and Inverse Geoengineering Analyses (PI: Scott Olson)
- CMMI-0830182: NEESR-II: Biological Improvement of Sands for Liquefaction Prevention and Damage Mitigation (PI: Jason DeJong)

Recent NSF Awards on Seismic Vulnerability of Foundations

- CMMI-0936627: NEESR Payload: Characterization of Dynamic Soil-Pile Interaction by Random Vibration Methods (PI: Jeremy Ashlock)
- CMMI-0936503: NEESR-CR: Design of Soil and Structure Compatible Yielding to Improve System Performance (PI: Bruce Kutter)
- CMMI-0926473: Earthquake Surface Fault Rupture Interaction with Building Foundations (PI: Jonathan Bray)
- CMMI-0830331: NEESR-SG: Seismic Performance Assessment in Dense Urban Environments (PI: Jonathan Bray)
- CMMI-0830328: NEESR-SG: Understanding and Improving the Seismic Behavior of Pile Foundations in Soft Clays (PI: Kanthasamy Muraleetharan)
- CMMI-0927743: RUI: Pervious Concrete Piles: An Innovative Ground Improvement Alternative (PI: Muhannad Suleiman)
- CMMI-0729483: CAREER: Substructure Damage Characterization for Performance-Based Earthquake Engineering (PI: Tara Hutchinson)

Infrastructure Management and Extreme Events
Program Element 1638

PROGRAM DESCRIPTION

The program supports basic, multidisciplinary research on the mitigation of, preparedness for, response to and recovery from natural, technological, and human-induced disasters. The program supports research involving engineering, social science, and physical sciences.

PROGRAM AREAS

- Structural and Non-structural Hazard Mitigation
- Emergency Preparedness and Response to Extreme Events and Slow Onset Disasters
- Resilient and Sustainable Disaster Recovery

CURRENT HIGH PRIORITY TOPICS

- Infrastructure Interdependencies and Cascading Disasters
- Physical and Social Vulnerability Analyses
- Innovation and Improvisation in Emergency Management
- Risk Communication and Coastal and High Rise Evacuation
- Satellite Post-Impact Damage Assessment
- Linking Disaster Recovery to Mitigation, Resilience, and Sustainability
- Comparative Cross-hazard Analysis

Infrastructure Management and Extreme Events Awards

- Social Science and Multidisciplinary Research
- Currently over 60 active awards
- Repeat Disaster Impacts to Infrastructure Networks and their Effects on Economic Agent Recovery; Scott Miles
- EAGER: Decision Making in Emergency Responders: Innovation in Naturalistic Decision Making Research; Nir Keren
- RAPID: Recovery Process and Progress Following the 2009 L'Aquila Earthquake; Abbie Liel
- Enabling the Next Generation of Hazards and Disasters Researchers; Tom Birkland
- New Methods for Measuring, Monitoring and Evaluating Post-Disaster Recovery; Ron Eguchi

Infrastructure Management and Extreme Events Awards (cont.)

- Small Business Demise and Recovery After a Natural Disaster; Maria Marshall
- Preparing Cities for Climate Change: An International Comparative Assessment of Urban Adaptation Planning; JoAnn Carmin
- Agent-Based Modeling for Planning Emergency Response to Contamination Emergencies in Water Utilities; Emily Zechman
- Dynamics of Hurricane Risk Perception; Craig Trumbo
- Effects of Environmental Cues and Informal and Official Warnings on Protective Action Decision Making: A Case Study for Earthquakes and Tsunamis in the Indian Ocean; Christopher Gregg
- Managing Evacuee Ingress: Network Interactions and Community Hosting Performance; Brian Gerber
- Developing a "Living Laboratory" for Examining Community Recovery and Resilience After Disaster; Shannon Van Zandt
- Detection and Mitigation of Hazardous Releases in Infrastructure Systems; Nikolaos Katopodes

Infrastructure Management and Extreme Events Awards (cont.)

- New Approaches to Protecting Transportation Infrastructure; Sheldon Jacobson.
- IT-Enabled Continuous Risk Assessment of Bridge Networks for Customized and Actionable Multi-Hazard Interventions Developments on Natural Hazard Mitigation; Jamie Padgett.
- The Network Governance of Crisis Response: Analyzing the Incident Command System, Don Moynihan.
- CAREER: Vulnerability of Water Infrastructure to Climate Variability and change, Sajjad Ahmad
- Communicating Hurricane Information to Local Officials for Protective Action Decision Making; Michael Lindell and Donald House
- Communicating Forecast Information to Optimize Evacuation Behavior; Pallab Mozumder
- Behavioral Response to the I-35W Disruption: Gauging Equilibration; Henry Liu
- Modeling Building Downtime Due to Hurricane Impacts; Judith Mitrani-Reiser.

Infrastructure Management and Extreme Events Awards (cont.)

- Workshop on the Concept of a National Hazard Vulnerability and Resiliency Observatory (RAVON); Walter Peacock
- Rebuilding New Orleans: Evaluating the Post-Disaster Planning Process; Robert Olshansky
- Displacement Due to Catastrophic Hurricanes; Assessing Potential Magnitude and Policy Implications for Housing and Land Development; Ann-Margaret Esnard
- Interdependent Response of Complex Urban Infrastructures subjected to Multiple Hazards; Leonardo Duenas Osorio

HUMAN AND SOCIAL DYNAMICS

- HSD provided significant support for research on hazards and disasters.
- It made 50 awards for hazards and disaster research that total about $39 million.
- These awards include 7 SGER awards to study the Indian Ocean Tsunami and 16 to study Hurricane Katrina.
- This solicitation has had a profound impact on multidisciplinary research.

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