March 15, 2010 Update
National Science Foundation
National Earthquake Hazards Reduction Program

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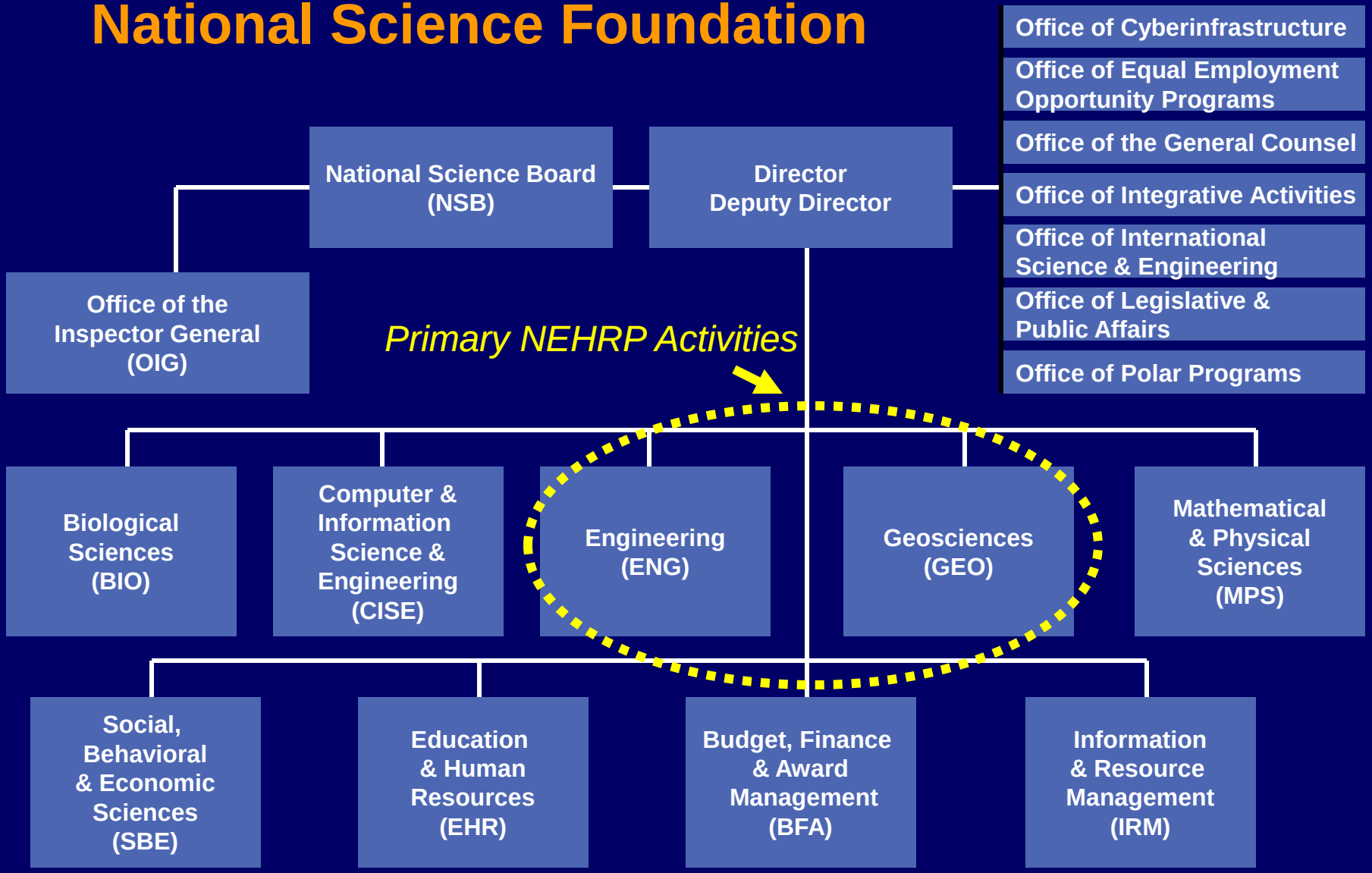

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national earthquake hazards reduction program

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
  - Unsolicited Proposal Research Programs
    - Hazard Mitigation and Structural Engineering
    - Geotechnical Engineering
    - Infrastructure Management and Extreme Events
  - Post-earthquake reconnaissance
  - National Hazards Center

NEHRP (NSF) Success Stories *Seismic Waves*

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

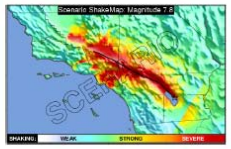
nehrp SeismicWaves May 2009
How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

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 12–16, 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

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

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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 2006 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 NSF USGS science for a changing world

nehrp SeismicWaves October 2009
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.

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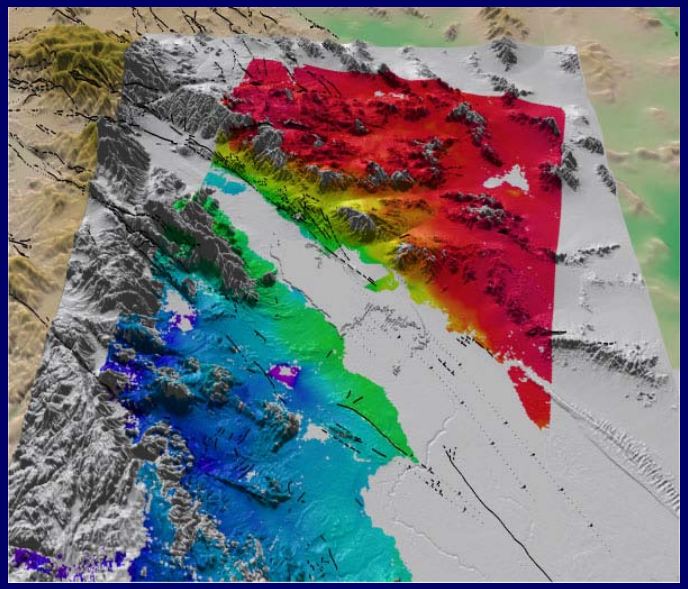
NSF

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)

NEHRP Activities Supported by NSF

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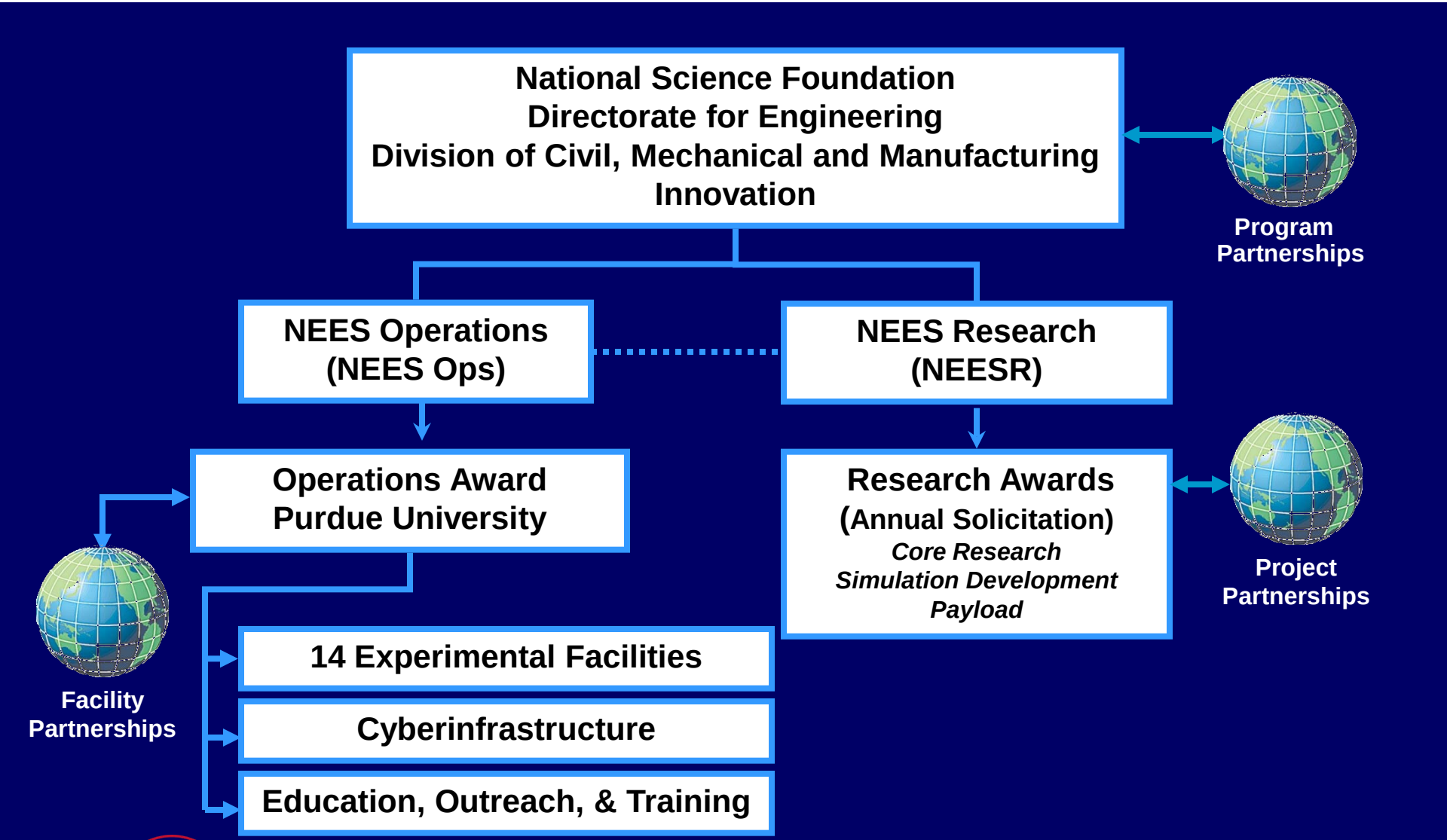
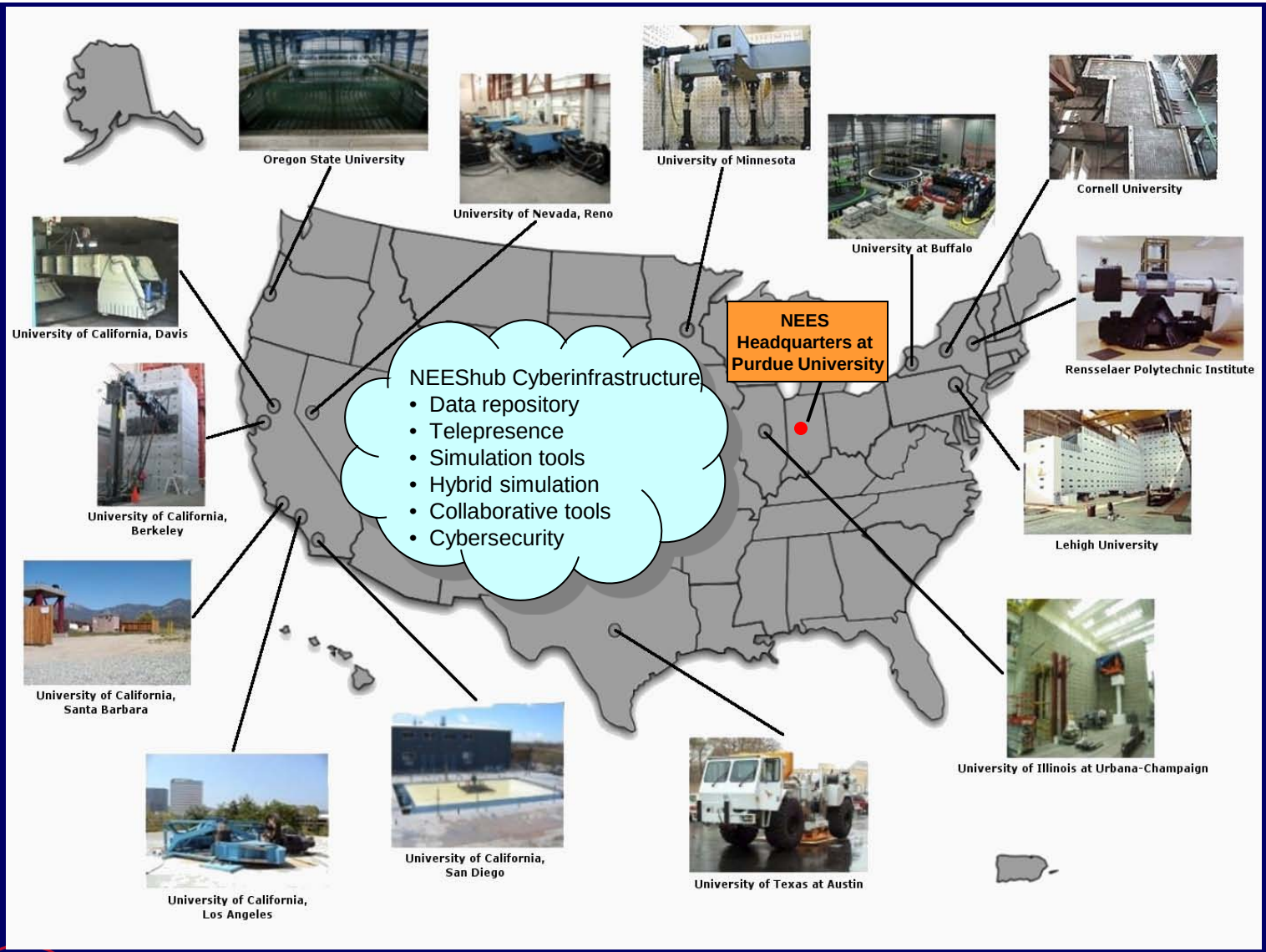
  - George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Operations and Research
  - Fundamental Research Programs (unsolicited)
    - Hazard Mitigation and Structural Engineering
    - Geotechnical Engineering
    - Infrastructure Management and Extreme Events
  - Post-earthquake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

NEES Program



NEES for the Engineering Community



Post-Earthquake Reconnaissance Support

- Earthquake Engineering Research Institute (EERI) Learning from Earthquakes Program (CMMI-0758529) http://www.eeri.org/site/projects/learning-from-earthquakes
- Geo-Engineering Extreme Events Reconnaissance (CMMI-0825760, -0825734, -0825507) http://www.geerassociation.org/
- Natural Hazards Center (CMMI-0734304) http://www.colorado.edu/hazards/
- NSF RAPID (formerly SGER) awards

National Science Foundation – Directorate for Engineering
Activities Supported to Study the January 12, 2010 Haiti Earthquake

NSF-supported "RAPID" Research Investigation Teams

2010 Date	Team	Purpose
Jan 26-Feb 3	USGS/EERI/NEES/GEER, with assistance from U.S. Military Southern Command (SOUTHCOM)	▪ Advance field reconnaissance and four portable seismographs installed ▪ Report: http://www.eqclearinghouse.org/20100112-haiti/wp-content/uploads/2010/02/USGS_EERI_HAITI_V1.pdf
Jan 31-Feb 5	GEER	▪ Geological and geotechnical field observations ▪ Report: http://www.geerassociation.org/GEER_Post%20EQ%20Reports/Haiti_2010/Cover_Haiti10.html
Feb 28-March 6	EERI	▪ Team of architects, engineers, planners, and social scientists for broader coverage/study of earthquake effects (e.g., hospitals, schools, port, lifelines)
Varies by project	Individual Investigators Natural Hazards Center	▪ Several quick response studies for social scientists to capture perishable research data
March and beyond	Teams to be supported through NSF RAPID awards	NSF 10-024: Engineering/International "Dear Colleague Letter" In-depth field studies to gather perishable research data http://www.nsf.gov/pubs/2010/nsf10024/nsf10024.jsp?WT.mc_id=USNSF_33&WT.mc_ev=click
Summer/Fall in DC area	Haiti Earthquake RAPID Awards Workshop	Dissemination of field observations and research findings

NSF-supported RAPID Research and Field Response Investigation Teams

NSF Award Number	Directorate	Project Title, PI and Institution
1030002	CISE/IIS	RAPID: Supporting Family Reunification for the Haiti Earthquake and Future Emergencies PI: Chen Li, University of California-Irvine Project web site: http://fr.ics.uci.edu/haiti
1028001	GEO/OCE	RAPID: Collaborative Research: Off-shore coseismic effects of the Port au Prince earthquake, Haiti PI: Sean Gulick, University of Texas at Austin
1028045	GEO/OCE	RAPID: Collaborative Research: Off-shore coseismic effects of the Port au Prince earthquake, Haiti PI: Cecilia Gonzalez-McHugh, Columbia University
1024990	GEO/EAR	Geodetic and Geologic Field Response to the January 12, 2010, Magnitude 7.0 Haiti Earthquake PI: Eric Calais, Purdue University

National Science Foundation – Directorate for Geosciences
Activities Supported to Study the January 12, 2010 Haiti Earthquake

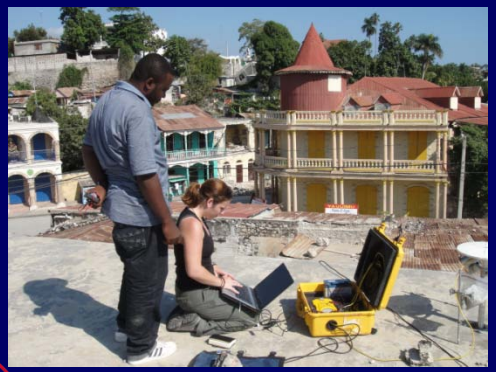
RAPID Award to Dr. Eric Calais, Purdue University

- Research team from Purdue University, University of Texas, University of Arkansas, Haitian Bureau of Mines and Energy
- Mapping and precisely measuring the displacement on the fault
- Re-measuring existing network of 30 GPS benchmarks in Haiti and the Dominican Republic to determine co-seismic deformation
- Installing continuous GPS instruments in key locations to measure post-seismic deformation

OpenTopography Portal (UC San Diego/San Diego Supercomputer Center)

- Joint support from EAR-Instrumentation and Facilities and Office of Cyberinfrastructure
- Hosts EarthScope and other imagery data (www.opentopography.org)
- With NSF concurrence, hosts airborne imagery collected over Haiti by the U.S. National Geospatial Intelligence Agency

Checking GPS receiver on the roof of Jacmel's police station.



Teaching about earthquakes to students at Mirebalais' high school.

NSF-supported Research Investigation Teams to Date

2010 Date	Team	Purpose
March 9 - 21	EERI Learning from Earthquakes	Seismic performance of engineered structures, building components and interior furnishings, hospital and health care system; tsunami impact on structures; social impacts and recovery policy; instrumentation of selected structures http://www.eeri.org/site/images/stories/news/EERI_CHILE_PRESS_RELEASE_REVISED.pdf http://www.eqclearinghouse.org/20100227-chile/
March	GEER	Soil and geological investigations

Recent NSF-Supported Workshops

- *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, CMMI-1004951/0957567
  - https://www.nees.org/training/workshop_detail/eqev2020/

- *Coordinating Workshops for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering (Phase 2; 2010 - 2013)*
  - Annual and topical meetings during 2010-2013
  - PI: Stephen Mahin, University of California, Berkeley, CMMI-0958774
  - Japan's E-Defense to consider Payload Projects for NEESR Proposals
  - https://www.nees.org/news/detail/japan_edefense_to_consider_payload_projects_for_march_neesr/

- *Earthquake Source Dynamics and Data-Constrained Numerical Modeling*
  - Smolenice Castle, Slovakia, June 27-July 1, 2010
  - PI: Ralph Archuleta, University of California-Santa Barbara, EAR-0944317
  - http://www.nuquake.eu/ESD2010/main.html

Earthquake Engineering Research Frontiers

- External factors
  - Hazard information/earthquake early warning
  - New materials (high performance, sustainable)
  - High performance computing capabilities
  - Advances in multi-scale, multi-physics modeling
  - Sensor technologies
  - IT/cyber advances
  - Others?
- Research frontiers, e.g., Vision 2020 Workshop
  - Real-time risk assessment
    - Smart sensors; networked sensor systems
    - Advanced analysis tools
  - New structural systems
  - Cost-effective rehabilitation strategies
  - Modular construction/deconstructibility
  - Advanced numerical simulation
  - Full-scale field testing
- Research frontier ideas from the NEHRP ACEHR?

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