Annual Report
of the
National Earthquake Hazards Reduction Program
for Fiscal Year 2009

October 2010

FEMA

NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

USGS
science for a changing world

This report about the National Earthquake Hazards Reduction Program (NEHRP) during fiscal year 2009 is submitted to Congress by the Interagency Coordinating Committee (ICC) of NEHRP, as required by the Earthquake Hazards Reduction Program Reauthorization Act of 2004 (42 U.S.C. 7701 et. seq., as amended by Public Law 108–360).

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Section 1
Introduction

The National Earthquake Hazards Reduction Program (NEHRP) is a multiagency program established by Congress "to reduce the risks of life and property from future earthquakes in the United States." The four federal agencies participating in NEHRP are the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). NIST serves as the lead agency for NEHRP.

NEHRP was initially authorized by Congress in 1978 and has been subsequently reauthorized at 2- to 5-year intervals. The latest reauthorization of NEHRP (Public Law 108–360) authorized funding through fiscal year (FY) 2009. This legislation also required that the NEHRP Interagency Coordinating Committee (ICC), which directs the program, submit an annual report on NEHRP budgets and activities. The ICC submits this annual report in accordance with Section 103(1) of Public Law 108–360.

Previous NEHRP annual reports provide detail on the organizational structure of NEHRP and agency responsibilities. This information will not be repeated here. Prior reports are available at http://www.nehrp.gov/about/reports.htm.

Section 2
Program Budgets

Public Law 108–360 requires that NEHRP annual reports include, for each agency participating in the program and for each program "activity" defined in the legislation, a program budget for the current fiscal year and a proposed program budget for the next fiscal year. The *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009–2013,* published in October 2008 (http://www.nehrp.gov/pdf/strategic_plan_2008.pdf), defined three major goals for the program that encompass all but one of the program activities defined in Public Law 108–360. The remaining activity, concerning the development, operation, and maintenance of NEHRP facilities, was incorporated directly into the plan. Table 2.1 shows the relationships between the congressionally defined activities and the goals and activity included in the NEHRP strategic plan.

Program budgets for the current fiscal year (FY 2010) are presented in Table 2.2, showing the funds that each participating agency is directing toward the goals and activity specified in the strategic plan. Table 2.3 identifies the agency funding requested or anticipated for NEHRP in FY 2011. Funds budgeted for the development, operation, and maintenance of NEHRP facilities are apportioned among the Advanced National Seismic System (ANSS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network (GSN).

Table 2.1
Relationships of NEHRP Strategic Goals to Statutory Program Activities

NEHRP Strategic Goals	Statutory Program Activities*
Goal A: Improve understanding of earthquake processes and impacts.	Improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines, through interdisciplinary research that involves engineering, natural sciences, and social, economic, and decision sciences.
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	Develop effective measures for earthquake hazards reduction.
Goal C: Improve the earthquake resilience of communities nationwide.	Promote the adoption of earthquake hazards reduction measures by federal, state, and local governments, and others.
Develop, operate, and maintain NEHRP facilities.	Develop, operate, and maintain ANSS, NEES, and the GSN.

* As defined by Congress in Public Law 108–360.

2.1 NEHRP FY 2010 Budgets by Program Goal

Table 2.2 lists the FY 2010 NEHRP budgets, by program goal, for the following NEHRP agencies: Federal Emergency Management Agency (FEMA), National Institute of Standards and Technology (NIST), National Science Foundation (NSF), and U.S. Geological Survey (USGS).

Table 2.2
NEHRP Agency Budgets for FY 2010

Program Goal	FY 2010 Funds Allocated to Goal ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.2	29.8	11.4	**41.5**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	3.3	2.6		19.9	**25.8**
Goal C: Improve the earthquake resilience of communities nationwide.	5.6	1.3		17.4	**24.3**
Develop, operate, and maintain NEHRP facilities:					
ANSS—USGS				8.3	**8.3**
NEES—NSF			22.0		**22.0**
GSN—NSF and USGS			3.5	5.8	**9.3**
Total:	**9.0**	**4.1**	**55.3**	**62.8**	**131.2**

Notes on Table 2.2:

[1] Budgets are rounded to the nearest $0.1 million. FY 2010 funds do not include funding from the American Recovery and Reinvestment Act (ARRA). ARRA funding amounts for NEHRP facilities are reported in Section 3.5. Large changes from previous reports in USGS funding for Goals B and C reflect the movement of funding for seismic monitoring from Goal B to Goal C.

[2] The FEMA FY 2010 budget is an allocation from the Department of Homeland Security (DHS) appropriation, which covers program activities but excludes salaries and expenses (S&E).

2.2 NEHRP FY 2011 Requested Budgets by Program Goal

Table 2.3 lists the FY 2011 NEHRP planning budgets for each agency by program goal. These figures are based on agency submissions included in the President's FY 2011 budget request to Congress.

Table 2.3
NEHRP Agency Requested Budgets for FY 2011

Program Goal	FY 2011 Funds Requested or Anticipated for NEHRP Goals ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.2	28.3	12.1	**40.7**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	3.3	2.6		18.8	**24.7**
Goal C: Improve the earthquake resilience of communities nationwide.	5.6	1.3		17.1	**24.0**
Develop, operate, and maintain NEHRP facilities:					
ANSS—USGS				8.9	**8.9**
NEES—NSF			22.5		**22.5**
GSN—NSF and USGS			3.5	5.4	**8.9**
Total:	**9.0**	**4.1**	**54.3**	**62.3**	**129.7**

Notes on Table 2.3:

[1] Budgets are rounded to the nearest $0.1 million. FY 2011 funds do not include funding from the American Recovery and Reinvestment Act (ARRA). ARRA funding amounts for NEHRP facilities are reported in Section 3.5. Large changes from previous reports in USGS funding for Goals B and C reflect the movement of funding for seismic monitoring from Goal B to Goal C.

[2] The FEMA FY 2011 budget is an estimated allocation from the Department of Homeland Security (DHS) appropriation, which covers program activities but excludes salaries and expenses (S&E).

Section 3
Program Highlights

This section briefly describes major accomplishments of NEHRP during FY 2009. These highlights are presented under the relevant goal or activity from the current NEHRP strategic plan. As shown earlier in Table 2.1, these goals and activities are directly related to the NEHRP program activities as defined by Congress in Public Law 108–360.

3.1 Goal A: Improve Understanding of Earthquake Processes and Impacts

Advances in the computation and application of scenario ground shaking

The development of the scenario earthquake for the California ShakeOut exercise (see Section 3.3 below) gave scientists at the Southern California Earthquake Center (SCEC) an opportunity to compare and calibrate various methods to compute theoretical seismograms. SCEC, funded by NSF and USGS, is a community of over 60 institutions headquartered at the University of Southern California (USC).

Recording strong ground motions from large earthquakes is essential to advancing understanding of earthquake sources and the response of buildings and other structures to seismic shaking. However, long-term seismic monitoring efforts, such as those conducted by the Advanced National Seismic System (ANSS), are needed to obtain records of strong ground shaking from a wide range of large earthquake source types. To advance understanding of the nature and causes of strong shaking, scientists have developed various numerical methods to compute theoretical ground motion from large earthquakes. During FY 2009 the ShakeOut scenario earthquake, a magnitude 7.8 event set in southern California, was used by SCEC scientists to test and compare various means of computing theoretical seismograms. Using supercomputers at Carnegie Mellon University, USC, and the University of California at San Diego, three different groups computed the seismic shaking that would be generated throughout southern California by the scenario earthquake. Not only did the groups use the same scenario source model, they also used the same community model, developed by SCEC scientists, for seismic wave velocities in the Earth's crust.

The test showed that all three simulation methods give equivalent results, with only insignificant differences, for ground shaking in southern California. This is an important step that provides reassurance that the current methods are valid and can be applied to a wider range of practical problems. These problems include the response of buildings and structures to theoretical ground shaking from a wide variety of earthquake types and sizes.

NEES research

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), supported by NSF, is a shared national system comprising 14 experimental facilities, a centralized data repository, connectivity through a cyber-infrastructure, and shared collaborative tools and earthquake simulation

software. Together, these resources provide the means for collaboration and discovery through advanced research involving experimentation and computational simulations of the response and performance of buildings, bridges, utility systems, coastal regions, earthen structures, and materials during seismic events.

In 2009, two major NSF-supported NEES research projects built upon their initial tests at NEES facilities by conducting capstone tests using the world's largest shake table at the E-Defense research facility in Miki, Japan, operated by that country's National Research Institute for Earth Science and Disaster Prevention.

Advances in wood-frame building design: NEESWood

In June and July of 2009, the largest building ever seismically tested was subjected to a simulation of the "maximum credible earthquake" (MCE) for Los Angeles. 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 NSF as a major element of the NEES research effort in earthquake engineering. Since then, NEESWood researchers, led by Colorado State University, 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 testing built upon tests of two-story, wood-frame structures conducted at the NEES facility at the University at Buffalo in 2006. Both series of tests 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 to predict the seismic performance of buildings constructed of wood. This tool, in turn, enabled them to predict more accurately how changes in the design of wood buildings would affect seismic performance and supported their efforts to create new designs for mid-rise (4- to 6-story) structures appropriate for use in seismic areas. Wood frames are the most common type of structural system used in residential housing in the United States.

Advances in steel-frame building design: self-righting structures

In collaboration with researchers in Japan, a research team led by Stanford University successfully completed shaking table tests of a three-story, steel-braced building frame that incorporated high-strength post-tensioning tendons and replaceable energy dissipating fuses to resist earthquake effects. Japan's E-Defense facility provided the shaking capacity to assess the reliability of the newly developed structural system under simulated ground motions in excess of the MCE that defines the extreme (rare) earthquake hazard in modern building codes. Data from the tests have been used to validate nonlinear computer models (models of non-elastic, or permanent, damage) that are applied to generalize the results to other building configurations.

The shake table tests culminated 3 years of research and development that produced the self-righting rocking frame system along with its specially designed butterfly-shaped fuses, post-tensioning anchorages, rocking column bases, and other framing details. The dynamic shake table tests were preceded by quasi-static and pseudo-dynamic testing of large-scale framing subassemblies at the NEES facility at the University of Illinois, and by fuse tests conducted at Stanford University.

Experience from past earthquakes and growing realization of the advantages of structural resilience, beyond that required for basic life-safety considerations,[1] suggest the need for buildings that are less vulnerable to damage and easier to repair after a major earthquake. The self-righting rocking frame system was designed based on performance-based engineering concepts to minimize, and potentially eliminate, damage to steel-braced frame systems for buildings. This is in contrast to conventional steel-braced frame systems, where it is accepted that costly damage, including buckling and fracture of structural members, is likely to occur in severe earthquakes. The newly proposed system prevents such damage through the mechanism of controlled rocking, which permits the building frame columns to rock and shield the frame members from excessive forces. The specially configured steel fuses are employed to dissipate earthquake-induced energy and damp out the rocking vibrations. Designed as replaceable elements, the fuses facilitate rapid repairs that may be necessary after extreme earthquakes.

USGS support for targeted research in earthquake studies

USGS annually funds targeted research in earthquake hazards, physical processes, and effects. This assistance adds a significant range of expertise to the USGS Earthquake Hazards Program within NEHRP and leverages support from other federal and state agencies, universities, and the private sector. In 2009, USGS funded more than 90 grants and cooperative agreements, supporting seismic monitoring and research on earthquake hazards in regions with seismic risk nationwide. This work included studies of the effects of earthquake shaking and the physical conditions and processes that cause earthquakes.

The greatest funding allocated to a single effort provides multiyear support to SCEC through a cooperative agreement funded jointly with NSF. SCEC, in turn, supports workshops and small grants that serve to develop a comprehensive and coordinated research approach to advance the understanding of earthquakes in southern California and elsewhere, and to communicate useful knowledge for reducing earthquake risk. All recent USGS grant and cooperative agreement awards and reports that describe research results are available at http://www.earthquake.usgs.gov/research/external.

The Hayward Fault earthquake of 1868

The 1868 magnitude 6.8 earthquake on the Hayward Fault, in the eastern portion of the San Francisco Bay region, was one of the most destructive in California's history. Studies of prehistoric earthquakes identified in the geologic record show that the Hayward Fault has repeatedly jolted the region in the past, with the most recent five earthquakes occurring an average of 140 years apart. USGS scientists, who have studied this fault system extensively, project that another magnitude 6.8 to 7.0 earthquake can occur on it at any time. Because such an event could cause hundreds of deaths, leave thousands homeless, and devastate the region's economy, USGS and other organizations are working together with new urgency to help prepare Bay Area communities for the inevitable recurrence of an earthquake on the Hayward Fault.

[1] The "life safety" standard in current model building codes provides criteria that minimize the likelihood of deaths in buildings designed in accordance with code provisions but, in severe earthquakes, can leave buildings so severely damaged that they must be demolished or repaired at great expense and with significant loss of service.

Leading up to the 140th anniversary of the 1868 earthquake on October 21, 2008, USGS and its partners released several new scientific findings and reports about the Hayward Fault, the 1868 quake, and the likely effects of a repeat of that event in the heavily urbanized East Bay. Historical data were combined with modern understanding of earthquake effects to create a ShakeMap that depicts the intensity of shaking that occurred throughout the region in 1868. Comparing this map to that from the 1989 magnitude 6.9 Loma Prieta earthquake that occurred south of San Francisco shows that a repeat of the 1868 quake would cause much higher levels of shaking and destruction in the East Bay. A sophisticated fault rupture scenario for the earthquake was developed to calculate the propagation of strong shaking through the region. This model used a new three-dimensional seismic velocity model based on detailed geologic mapping and geophysical data, and a fault friction model based on laboratory sliding tests on the various rock types that occur on the fault.

3.2 Goal B: Develop Cost-Effective Measures to Reduce Earthquake Impacts on Individuals, the Built Environment, and Society at Large

Research efforts in support of performance-based seismic engineering

It has been widely recognized in the structural engineering profession that substantial research will be needed to facilitate the full implementation of performance-based seismic design (PBSD). In early 2009, NEHRP released a prioritized research plan developed by the earthquake professional community entitled *Research Required to Support Full Implementation of Performance-Based Seismic Design* (NIST GCR 09-917-2). The NEHRP agencies began using the plan to formulate further research efforts in support of PBSD and to supplement ongoing work being done by the Applied Technology Council under FEMA's PBSD-development project.

As a part of NEHRP's efforts to support PBSD, NIST continued its research staff buildup in 2009, adding new personnel for research and administrative support.

Continued publication of NEHRP "Techbriefs"

NEHRP released the second in its series of "Techbriefs," concise publications designed to help transfer research results into practice. The latest in the series is *Seismic Design of Steel Special Moment Frames* (NIST GCR 09-917-3). Efforts to produce two more Techbriefs in FY 2010 were also initiated.

Publication of seismic design and construction guidelines

NEHRP has continued its long-standing commitment to developing and publishing seismic design and construction guideline documents for design professionals. Of the several documents published by FEMA in FY 2009, one particularly significant and innovative document was *Quantification of Building Seismic Performance Factors* (FEMA P-695, June 2009). This publication provides, for the first time, a standard methodology to establish consistent and rational building-system performance and response parameters for the linear design methods traditionally used in building codes. The primary application of this methodology is in the evaluation of the seismic performance of structural systems for new construction. This publication is already being referenced by the Nation's building codes and standards to set minimum acceptable criteria for the seismic performance evaluation of standard, code-approved

systems. It is also being used to provide guidance in the selection of appropriate seismic performance parameters for other systems when linear design methods are applied. The methodology provides a basis for the future evaluation of how well code-approved structural systems achieve their seismic performance objectives.

Seismic hazard maps for urban regions of Nevada and Utah

USGS is working to produce sets of local and regional seismic hazard maps for selected urban centers and corridors in the Intermountain West. These maps will contain a level of detail that is appropriate for urban planning and development and that can be used to promote risk mitigation and assist emergency planning. Current efforts focus on the three largest and most vulnerable urban regions in the Intermountain West: the Ogden-Salt Lake City-Provo corridor of Utah, the Reno-Carson City area of Nevada, and the region in and around Las Vegas, NV. The objective is to produce a set of next-generation seismic hazard maps for each urban region. These maps will integrate data and information on the effects of near-surface rocks and soils on ground amplification, the uncertainties in the input data, the effects of time-dependent probabilities of large earthquakes on individual fault segments, and the impacts of scenario earthquakes involving multiple fault ruptures.

In 2009 USGS collaborated with the Nevada Bureau of Mines and Geology on a study of Quaternary-aged (3 million years ago to the present) fault scarps northwest of Reno. USGS also collected and analyzed data to derive earthquake ground-motion parameters in the Reno-Carson City urban region, and completed analysis and interpretation of data from segments of the Wasatch Fault zone that threaten Salt Lake City and environs. In the latter study, analysis yielded the extent and timing of at least five Holocene-age (10,000 years ago to the present) prehistoric earthquakes, refined the long-term movement rate across the Weber Fault segment, and confirmed the existence of a previously equivocal prehistoric earthquake, thus substantiating that a portion of the Wasatch Fault zone has not ruptured in the past several centuries.

Supporting Washington State hazard mitigation planning

USGS is assisting the Washington State Emergency Management Division in developing hazard statements for the 2011 update of the state's hazard mitigation plan. The 2011 update is concentrating on earthquakes, tsunamis, floods, winter storms, and wildfires. USGS is helping to integrate new ground-motion computations into the earthquake hazard descriptions and update the tsunami hazard section. (The ground-motion computations are determined for earthquakes of specific source types and magnitudes in contrast with probabilistic ground-motion computations that sample a variety of source types and magnitudes.) By combining the new deterministic ground-motion models with existing probabilistic hazard descriptions from the state's 2007 plan, Washington Emergency Management hopes to trigger a stronger local planning response by counties, cities, and special districts than was generated through sole reliance on probabilistic hazard maps.

3.3 Goal C: Improve the Earthquake Resilience of Communities Nationwide

California ShakeOut of November 2008

The Great Southern California ShakeOut was an unprecedented achievement in planning and conducting public awareness events for earthquake safety. It was 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 objectives were to conduct earthquake safety drills, emergency-response 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, and awareness of the need for, earthquake preparedness.

Multidisciplinary teams of more than 300 experts drawn from government, academia, and industry developed the ShakeOut earthquake scenario, the most comprehensive earthquake scenario ever created. The scenario revealed how a very large (magnitude 7.8), but plausible, earthquake would impact southern California, describing in detail what would happen if the southernmost 320 kilometers (200 miles) of the San Andreas Fault were to rupture.

Social scientists evaluated how this information could be used to overcome the common attitude toward preparedness characterized by "it won't happen to me" passivity. ShakeOut organizers then planned a group of events that reflected recommendations by social scientists for motivating behavioral change. These events included a southern California-wide earthquake drill, state and local response and recovery exercises, an international earthquake conference, a public preparedness rally, and several innovative follow-on activities.

To prepare for the ShakeOut, the Earthquake Country Alliance came together as a southern California-wide, public-private partnership of individuals and organizations representing government, the business community, disaster responders, academics, and the news media. The Alliance organized ShakeOut events using managerial and technical support provided by USGS and SCEC, along with additional support from FEMA. The Alliance launched the Web site http://www.shakeout.org to provide an online clearinghouse of ShakeOut information for organizers, participants, the news media, and the public.

Other earthquake preparedness exercises

In addition to ShakeOut, NEHRP contributed to other earthquake preparedness exercises in 2009. In northern California, the 140th anniversary of the 1868 Hayward Fault earthquake (see above) marked an opportunity to educate families, schools, government organizations, and businesses about the hazards posed by Bay Area earthquakes. USGS and partnering agencies and organizations formed the 1868 Hayward Earthquake Alliance (http://1868alliance.org/), a nonprofit, public-private coalition of more than 140 member groups, to coordinate and promote earthquake risk mitigation efforts and activities throughout the greater San Francisco Bay Area. Activities included an earthquake safety drill involving 80,000 schoolchildren, several press conferences attracting extensive media coverage, publication of a

guide for touring the Hayward Fault using public transportation, and a broadly attended conference featuring the latest scientific and engineering findings related to Hayward Fault earthquake hazards.

USGS calculated earthquake ground-motion maps for 15 earthquakes in Washington State for use in a statewide earthquake drill conducted on September 16, 2009.

Completion of a key resource for national model building codes and standards

One of the objectives in the NEHRP strategic plan is to support the development of seismic standards and building codes and to advocate for their adoption and enforcement. FEMA developed the 2009 edition of the *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* (FEMA P-750 or *Provisions*) in support of this objective. The 2009 edition is the seventh update of this key resource document published since 1985.

The *Provisions* document supports the revision of national model building codes and standards and serves as a vehicle for translating NEHRP research results into recommended practices and applications. The Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences engaged national experts in the seismic design and construction community, and related stakeholders, to develop the *Provisions* under FEMA sponsorship and management.

In contrast to previous 3-year update cycles for the *Provisions,* the 2009 edition was developed on a 5-year update cycle, permitting BSSC's Provisions Update Committee to develop major changes in both the substance and format of the *Provisions*. In addition to the new update cycle, a significant change involved the "adoption by reference" of the national standard, *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 7-05), published by the American Society of Civil Engineers (ASCE). Instead of restating all of the ASCE/SEI 7-05 requirements, both those recommended to be retained and those recommended for changes, the *Provisions* first "adopt" the entire ASCE/SEI 7-05 requirements by direct reference to them and then only discuss recommended changes to them or provide illuminating commentary or research discussion about them. This change enables the *Provisions* not only to serve as a clear and succinct basis for code revisions, but also to become a research-to-practice and educational resource.

QuakeSmart means business

A community cannot fully recover from an earthquake or other disaster until its businesses are back in operation. Following a disaster, local businesses are often not as prepared to resume commercial activity as are large businesses and national organizations. Enhancing the resilience of small businesses to disasters has become a national priority. In 2008, FEMA created the QuakeSmart program to address this priority. Underlying this program is FEMA's recognition that partnerships are key to raising awareness and encouraging actions aimed at making businesses more "QuakeSmart."

Activities to date have centered on partnerships with local chambers of commerce in Emeryville and Encino, CA; Reno, NV; Cape Girardeau, MO; and Evansville, IN. Forums held in these communities have included 1-hour presentations on knowing earthquake risk, making and implementing mitigation plans, and dispelling popular myths such as the notion that mitigation is unaffordable or even that it is

unnecessary because government will come to the rescue. Speakers have noted that many effective mitigation measures cost very little, and that most federal assistance available to qualifying businesses following disasters is provided in the form of loans that must be repaid. The forums have been well attended and have received extensive press coverage in print and on radio and television.

The QuakeSmart Web site (http://www.quakesmart.org) is being used to provide valuable information on earthquake hazard mitigation and on additional FEMA resources.

Undergraduate education

The NEES Research Experience for Undergraduates (NEESreu) program is a dynamic 10-week summer research program for upper division undergraduate students interested in civil engineering, computer science/engineering, electrical engineering, and other fields related to the testing of seismic risk mitigation measures. NEESreu participants are paired with a faculty advisor, join a NEES research team, and participate in enrichment activities including attending the NEES Annual Meeting and the Young Researchers' Symposium. In 2009, 30 NEESreu students joined faculty mentors at many NEES research facilities including those at the University of California, San Diego; the University of California, Los Angeles; Lehigh University; Oregon State University; the University at Buffalo; and the University of Illinois, Urbana-Champaign. Students' papers detailing the results of individual research projects are available at https://nees.org/neesreuprogramsummer2009.

SCEC is very active in the earth science education community, participating in organizations such as the National Association of Geoscience Teachers, the Coalition for Earth System Education, and local and national science educator organizations. In addition, SCEC supports three student intern programs: Summer Undergraduate Research Experiences (SURE), Undergraduate Studies in Earthquake Information Technology (USEIT), and Advancement of Cyberinfrastructure Careers through Earthquake System Science (ACCESS). In 2009, 20 USEIT interns participated in the summer program at USC, 18 participated in the SURE program, and 15 took part in the ACCESS program.

3.4 NEHRP Statutory Activity: Program Leadership

During FY 2009 the NIST NEHRP Secretariat continued to provide the support and leadership needed to move forward on earthquake safety and risk reduction issues nationwide. NIST served as the primary point of contact with the U.S. House of Representatives Committee on Science and Technology, Subcommittee on Technology and Innovation, serving as a source of technical expertise during the NEHRP reauthorization process. The director of NEHRP testified at a reauthorization hearing held by the subcommittee on June 11, 2009. In carrying out routine program management, coordination, and oversight functions, the NEHRP Interagency Coordinating Committee met one time, the Advisory Committee on Earthquake Hazards Reduction met three times, and the working-level Program Coordination Working Group met seven times during FY 2009.

NEHRP supported a major study by the National Research Council to develop a 20-year road map that will support implementation of the goals of the NEHRP strategic plan. This study continues, with its completion anticipated in mid–FY 2011.

3.5 NEHRP Statutory Activity: Develop, Operate, and Maintain NEHRP Facilities

Public Law 108–360 requires NEHRP to "develop, operate, and maintain" certain facilities essential to the NEHRP mission. The facilities are the Advanced National Seismic System (ANSS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network (GSN). Highlights of FY 2009 activities relevant to these facilities are given below.

NEHRP facilities benefit from American Recovery and Reinvestment Act of 2009

NEHRP agencies were able to use the opportunities presented by the American Recovery and Reinvestment Act (ARRA) to help stimulate the economy and at the same time strengthen national resilience to earthquake risks. The current ARRA-based investments in earthquake monitoring are meeting stated ARRA criteria for spending that will flow directly into the U.S. economy. These investments are providing jobs among U.S. equipment manufacturers and geophysical contractors, and at the colleges and universities that operate regional earthquake monitoring networks. Examples of ARRA-supported activities undertaken by NEHRP agencies are provided below.

Advanced National Seismic System

Funding allocated through ARRA to USGS is being used to improve the timeliness and accuracy of earthquake information. By upgrading seismic and geodetic monitoring networks and data processing centers, USGS is strengthening critical infrastructure that provides the situational awareness required for effective emergency response, saving lives, and reducing economic losses.

Of the $140 million in ARRA funding provided to USGS in 2009, $29.5 million was allocated for NEHRP-related improvements to seismic and geodetic monitoring networks. By the end of FY 2010, USGS had obligated 100 percent and spent 58 percent of this allocation, with the remainder to be spent by the close of FY 2011. This funding has gone to university partners that operate regional networks monitoring earthquakes and Earth surface deformation. Thirteen U.S. universities have received a total of more than $5 million for seismic upgrades, and are receiving an additional $8 million worth of new government-furnished equipment. To upgrade deformation monitoring networks, $3 million in direct funding has been provided to three universities and a university consortium (UNAVCO). This funding is being supplemented with over $1 million in new, government-purchased geodetic equipment. Other ARRA funds are being used for improvements to the USGS National Earthquake Information Center located in Golden, CO.

In total, awards are now in place to upgrade 813 monitoring sites: 613 seismic stations, 198 global-positioning-system monitoring stations, and 2 strain monitoring observatories. The 613 subtotal includes 135 new, low-cost NetQuakes strong-motion recording stations, which are now being installed

nationwide (for more information on the NetQuakes effort, see http://earthquake.usgs.gov/earthquakes/waveforms/netq/). In California, ARRA-funded network improvements will speed implementation of "earthquake early warning"—a technology in operation in Japan, Taiwan, and Mexico that uses seismic detections near the earthquake epicenter to broadcast warnings to more distant areas before strong shaking arrives.

Global Seismographic Network

Both USGS and NSF have allocated ARRA funds for the life-cycle replacement and upgrade of equipment at stations of the GSN. ARRA funds have already greatly accelerated the deployment of so-called "next generation" recording systems at GSN seismic station sites. The complete refreshment of the network is now expected by 2014, except for the primary sensors, for which replacements have not yet been selected.

Now exceeding 150 stations worldwide, the GSN is considered complete for land areas except for North Africa and the Indian subcontinent. USGS, NSF, and the Incorporated Research Institutions for Seismology are continuing to work on filling the remaining coverage gaps, on expanding into ocean areas, on developing replacements for the primary sensors, and on improved calibration practices.

NEES operations award to Purdue University

In 2009, following a competitive procurement process, NSF selected Purdue University to lead, manage, operate, and maintain NEES during FY 2010–2014. With NSF support, NEES began operations in 2004 to enable research and innovation in earthquake and tsunami loss reduction, to create an educated workforce in hazard mitigation, and to conduct broader outreach and lifelong learning activities. In addition to the new headquarters at Purdue, NEES includes 14 experimental facilities, the NEEShub cyberinfrastructure, and the NEES Academy for science and engineering education and outreach.

Sharing experimental data and running simulations are critical to the success of NEES operations. The innovative HUBzero technology developed at Purdue is being used in the deployment of the NEEShub cyberinfrastructure.

3.6 State Activities to Promote Implementation of Research Results

FEMA Earthquake Hazards Reduction State Assistance Program (cooperative agreements)

The Earthquake Hazards Reduction State Assistance Program is a FEMA responsibility under Public Law 108–360, which directs the agency to support state efforts to mitigate seismic risks and reduce future losses from earthquakes. Under the program, FEMA provides funds each year to eligible states and U.S. territories with high seismic risk. The funds can be used to support a range of eligible activities: (1) developing seismic mitigation plans; (2) preparing inventories and conducting seismic safety inspections of critical structures and lifelines; (3) updating building codes, zoning codes, and ordinances; (4) increasing earthquake awareness and education; and (5) encouraging the development of multistate groups for such purposes.

In FY 2009, FEMA awarded $2.3 million to 29 states and territories. This support is being used to strengthen earthquake risk-reduction efforts that are both traditional and innovative. Some of the more traditional uses include preparing and distributing information for the public that describes seismic hazards within a state, as well as recommended preparedness and mitigation strategies and resources. Program funds also are helping states to train personnel in the use of FEMA's HAZUS earthquake risk-assessment software; to update state and county hazard mitigation and preparedness plans; to support detailed, geologic seismic-hazard mapping in at-risk regions; to cosponsor earthquake awareness and mitigation conferences; and to review the adequacy of building codes and land use regulations in relation to seismic safety.

Examples of innovative applications include **Missouri's** plan to develop a manual and video for school administrators and facility managers to use in assessing seismic vulnerabilities in school buildings across the state. Similarly, **Utah** and **Washington** are screening samples of their public schools for seismic vulnerabilities; this is to help officials gauge the need for statewide inspections and seismic rehabilitation of school buildings. **Hawaii** is devoting some of its FY 2009 program support to an earthquake outreach program targeting the general public and schoolteachers. This program will be offered in conjunction with similar state outreach efforts aimed at tsunami and volcano hazards.

California plans to use some of its funding for research on value-based messaging that can motivate residents to take responsibility for earthquake readiness. Additionally, funds are being used to strengthen the Earthquake Country Alliance, California's statewide public-private coalition of earthquake-education stakeholder groups.

FEMA headquarters and regional staff are collaborating to refine and streamline the state assistance program's application, implementation, monitoring, and reporting processes for FY 2010. These efforts include the review of policies and the development of guidance, job aids, and standards to support the effective delivery of the program.

Appendix
List of Acronyms

ACCESS	Advancement of Cyberinfrastructure Careers through Earthquake System Science
ANSS	Advanced National Seismic System
ARRA	American Recovery and Reinvestment Act
ASCE	American Society of Civil Engineers
BSSC	Building Seismic Safety Council
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
GSN	Global Seismographic Network
ICC	NEHRP Interagency Coordinating Committee
MCE	Maximum Credible Earthquake
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEESreu	NEES Research Experience for Undergraduates
NEHRP	National Earthquake Hazards Reduction Program
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
PBSD	Performance-Based Seismic Design
SCEC	Southern California Earthquake Center
SURE	Summer Undergraduate Research Experiences
USC	University of Southern California
USEIT	Undergraduate Studies in Earthquake Information Technology
USGS	U.S. Geological Survey