Annual Report of the National Earthquake Hazards Reduction Program For Fiscal Year 2014

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FEMA

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

NSF

USGS science for a changing world

This report about the National Earthquake Hazards Reduction Program (NEHRP) during fiscal year (FY) 2014 is submitted to Congress by the Interagency Coordinating Committee of NEHRP, as required by the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124, 42 U.S.C. 7701 *et. seq.*), as amended by the Earthquake Hazards Reduction Program Reauthorization Act of 2004 (Public Law 108-360).

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Executive Summary

This is the annual report of the National Earthquake Hazards Reduction Program (NEHRP) covering fiscal year (FY) 2014,[1] presented by the NEHRP Interagency Coordinating Committee. This report, required by Public Law 108–360, describes the FY 2014 activities of the NEHRP agencies and their progress toward reducing the impacts of future earthquakes in the United States. This report also summarizes actual program budgets for FY 2015 and budgets requested by the Administration for FY 2016.

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 NEHRP lead agency. The NEHRP agencies have distinct roles and responsibilities that are mutually supportive.

The NEHRP Interagency Coordinating Committee is composed of the Administrator of FEMA, the Directors of NIST, NSF, and USGS, and the Directors of the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB). The Director of NIST chairs the Interagency Coordinating Committee.

The year 2014 marked the 50th anniversary of the Great Alaska Earthquake of 1964. Commemoration events held in Anchorage, including the annual meeting of the Seismological Society of America (SSA) and the quadrennial meeting of the U.S. National Conference on Earthquake Engineering, reminded participants of the significant toll of the 1964 event and of the potential toll that a similar event could take today.

In August 2014, an earthquake of magnitude 6.0 (M6.0) struck near Napa, California. Referred to as the South Napa earthquake, this was the largest earthquake to strike the San Francisco - Oakland area since 1989. Significant damage occurred in private homes, commercial buildings, and essential facilities such as hospitals. Also during FY 2014, public attention became focused on dramatic increases in the occurrence of human-induced earthquakes in areas of the central and eastern U.S. where large volumes of wastewater from oil and gas production processes were injected in deep wells. Many small to moderate earthquakes have occurred in such areas. The NEHRP agencies are actively engaged in assessing both the specific details of the South Napa event, including publication of three FEMA reports (FEMA P-1024 and two Recovery Advisories), and the evolving issues associated with injection-induced earthquakes.

[1] This report covers FY 2014 as defined by the Federal Government, a period that began on October 1, 2013, and ended on September 30, 2014.

The SSA reports that scientists associated with FEMA, USGS, and the California Geological Survey have assessed earthquake hazards in the 48 contiguous United States and determined that over 143 million Americans are exposed to potentially damaging earthquakes, with as many as 28 million Americans likely to experience strong shaking in their lifetimes[2].

A primary role of NEHRP is to provide leadership and resources for developing new, cost-effective measures to reduce the damage and disruption that earthquakes cause, and to advocate for their implementation. Some of the significant NEHRP activities of FY 2014 that are covered in this report are listed briefly below.

In support of NEHRP Strategic Plan Goal A, *Improve Understanding of Earthquake Processes and Inputs*, researchers at several major universities investigated cost-effective retrofit technologies for existing buildings; one project focused on wood construction typically found in apartments and commercial properties, while another focused on reinforced concrete buildings. Two new Science Across Virtual Institutes (SAVI) projects linked researchers in the U.S. with their counterparts in other countries; one of the projects focused on reinforced concrete wall buildings that are common in many countries and were among the buildings heavily damaged in the 2010 Maule, Chile earthquake. NSF completed ten years of support for operation of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) and began new efforts to support the future Natural Hazards Engineering Research Infrastructure (NHERI).

In support of NEHRP Strategic Plan Goal B, *Develop Cost-Effective Measures to Reduce Earthquake Impacts on Individuals, the Built Environment, and Society at Large*, the USGS completed its update of the U.S. National Seismic Hazard Model for the contiguous 48 States and also began developing improved products for communicating seismic hazard information to the public. USGS also continued its efforts to update methods for evaluating seismic hazards induced by human activity. NIST provided new design guidance reports addressing light-frame structural wood diaphragm systems and special reinforced masonry walls, and it provided an assessment of the use of higher-strength steel reinforcement in earthquake-resistant reinforced concrete structures that can lead to improved cost-effectiveness in such structures. FEMA produced updated guidance on assessing and mitigating damage in non-structural components in buildings; this guidance will be helpful in improving the abilities of buildings to support societal resilience.

In support of NEHRP Strategic Plan Goal C, *Improve the Earthquake Resilience of Communities Nationwide*, FEMA and USGS supported major earthquake safety exercises, most notably the "Alaska Shield" National-Level Exercise, which took place on the 50th anniversary of the Great Alaska Earthquake and tsunami of 1964 (see page 14 of this report). FEMA and USGS also

[2] SSA News Release, More Americans at risk from strong earthquakes, says new report, http://www.seismosoc.org/society/press_releases/SSA_2015_EarthquakeThreat_Press_Release.pdf . Further details are found in Jaiswal et. al, http://earthquakespectra.org/doi/10.1193/111814EQS195M

continued to support the expanding ShakeOut activity participation. ShakeOut is the world's largest earthquake preparedness drill. USGS continued its ShakeAlert project that is working in cooperation with others to initiate and operate a limited earthquake early warning (EEW) system for the West Coast. In the August 2014 South Napa earthquake, the embryonic EEW system successfully sent alerts to test users in the San Francisco Bay area. FEMA continued its long-standing work to support the inclusion of seismic provisions in the 2015 editions of the International Code Council (ICC) publications, and it worked to complete development of the 2015 *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* that will be incorporated in the ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, which is the national consensus design standard for new buildings. NIST completed and released a comprehensive study of the costs and benefits of earthquake-resistant design and construction in the Memphis, Tennessee, area; its findings have been directly applicable and useful in the public discussion of building code adoption issues in the Memphis area. NSF supported a number of initiatives that enhance education and training for future researchers and practitioners in the earthquake and other hazards fields.

To monitor earthquakes worldwide and in the U.S. and its Territories, the USGS National Earthquake Information Center (NEIC) receives worldwide data from the Global Seismographic Network (GSN) and other international sources, and domestically from the Advanced National Seismic System (ANSS). More than a gigabit per second of data from these stations streams in to NEIC continuously where it is automatically processed. The results of the processing are reviewed by seismologists serving on a 24 hours a day/7 days a week basis. Domestically, the USGS partners with 13 regional seismic networks operated by universities that provide detailed coverage for the areas of the country with the highest seismic risk.

The USGS NEIC publishes locations for about 70 earthquakes per day on average, or about 25,000 annually. The USGS NEIC publishes worldwide earthquakes with a magnitude of 4.5 or greater, and U.S. earthquakes of 2.5 or greater wherever feasible. On average, since about 1900, 18 earthquakes worldwide of magnitude of 7.0 or higher have occurred annually.

Section 1

Introduction

The National Earthquake Hazards Reduction Program (NEHRP) is a four-agency program established by Congress "to reduce the risks of life and property from future earthquakes in the United States."[3] 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.

Since NEHRP was initially authorized, Congress has periodically reauthorized the program, generally at two- to five-year intervals. The latest reauthorization of NEHRP (Public Law 108–360, the Earthquake Hazards Reduction Program Reauthorization Act of 2004) authorized funding for the four participating agencies through fiscal year (FY) 2009. Pending passage of new reauthorizing legislation, the NEHRP agencies continue to perform duties outlined in Public Law 108–360 within agency-established budget allocations.

Public Law 108–360 requires that the NEHRP Interagency Coordinating Committee, through which agency directors direct the program, submit an annual report to Congress on NEHRP budgets and activities. The Interagency Coordinating Committee submits this annual report, covering FY 2014, pursuant to that requirement.

Previous NEHRP annual reports provide details on the organizational structure of NEHRP and agency roles and responsibilities. This NEHRP annual report for FY 2014 provides information on NEHRP agency budgets, highlights of statutory program activities, State activities promoting implementation of research results, and non-NEHRP related activities that support NEHRP goals. This report and prior NEHRP annual reports are available at www.nehrp.gov/about/reports.htm.

The year 2014 was a landmark year: it marked the 50th anniversary of the Great Alaska Earthquake of 1964. Commemoration events that were held in Anchorage, including the annual meeting of the Seismological Society of America (SSA) and the quadrennial meeting of the U.S. National Conference on Earthquake Engineering, reminded earthquake science and engineering professionals and the public of the significant toll of the 1964 event and of the potential toll that a similar event could take today.

In August 2014, an earthquake of magnitude 6.0 (M6.0) struck near Napa, California. The South Napa earthquake was the largest to strike the San Francisco - Oakland region since the 1989 Loma

[3] The Earthquake Hazards Reduction Act of 1977 (Public Law 95-124, 42 U.S.C. 7701 *et seq.*), as amended by Public Laws 101-614, 105-47, 106-503, and 108-360. See http://www.nehrp.gov/about/PL108-360.htm .

Prieta earthquake. The NEHRP agencies have been engaged with State, local, and private sector experts in thoroughly assessing the damage that occurred in this moderately strong earthquake in private homes, commercial buildings, and essential facilities such as hospitals.

During 2014, public attention was focused on dramatic increases in the occurrence of human-induced earthquakes in areas of the central and eastern U.S. where large volumes of wastewater used in oil and gas production are injected in deep wells. Many small to moderate earthquakes have occurred in such areas. The USGS is actively assessing this hazard and developing new understanding of earthquakes caused by injection practices, with the goal of reducing the occurrence of, and risks from, induced earthquakes.

The SSA announced[4] that seismologists and engineers associated with FEMA, USGS, and the California Geological Survey have assessed earthquake hazards in the 48 contiguous United States and found that over 143 million Americans are exposed to potentially damaging earthquakes, with as many as 28 million Americans likely to experience strong shaking in their lifetimes. The report authors identified over 6,000 fire stations, 800 hospitals, and almost 20,000 schools that could be subjected to strong ground motions from earthquakes. The SSA news release also notes that this new data is in sharp contrast to the 1994 FEMA estimates of 75 million Americans in 39 States at risk of exposure to damaging earthquakes. As described by the USGS in the SSA news release, the significantly higher revised projections reflect both improved seismic hazard assessments and the continued movement of the American population to urbanized areas in all regions of the country, including those most significantly impacted by seismic activity.

As has been stated in previous NEHRP annual reports, future earthquakes in the United States are inevitable. The continued efforts of NEHRP are essential for the Nation to prepare for their eventual occurrence, to prepare individuals for safely surviving them, and to mitigate and reduce their impacts on life, property, and economic and social systems. This work is needed to support the Nation's efforts to become earthquake-resilient.

[4] SSA News Release, More Americans at risk from strong earthquakes, says new report, http://www.seismosoc.org/society/press_releases/SSA_2015_EarthquakeThreat_Press_Release.pdf. Further details are found in Jaiswal et. al, http://earthquakespectra.org/doi/10.1193/111814EQS195M

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, the budget for the current fiscal year (i.e., the year following that which is covered in the report) and the proposed program budget for the next fiscal year. *See* 42 U.S.C. § 7704(a)(4). The *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009–2013* (http://nehrp.gov/pdf/strategic_plan_2008.pdf), published in October 2008[5], defined three major goals for NEHRP that encompass all but one of the program activities defined in Public Law 108–360. The remaining activity, which concerns the development, operation, and maintenance of NEHRP facilities, was incorporated directly into the strategic plan. Table 2.1 shows the relationships between the congressionally defined program activities and the goals and activities that are included in the strategic plan.

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[6], and the GSN.

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

Program budgets for FY 2015 are presented in Table 2.2, which shows the funding reported by each participating agency that is directed towards accomplishing the goals and objectives specified in the Strategic Plan. Table 2.3 similarly identifies reported agency funding requested or anticipated

[5] The Strategic Plan continues to be relevant and remains in effect. It will be updated in accordance with the provisions of any future NEHRP reauthorization, or as future need for additional strategic planning may dictate.

[6] NSF completed its planned ten years of support for the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) at the end of 2014. See further discussion in Section 3.5.

for NEHRP in FY 2016. Funding for the development, operation, and maintenance of NEHRP facilities supports the Advanced National Seismic System (ANSS) and the Global Seismographic Network (GSN).

2.1 NEHRP Enacted FY 2015 Budgets by Strategic Goal

Table 2.2 lists the FY 2015 NEHRP budgets, by strategic goal, for the NEHRP agencies: FEMA, NIST, NSF, and USGS.

Table 2.2 – *NEHRP AGENCY BUDGETS for FY 2015*

Strategic Goal	FY 2015 Funds Allocated to Goal ($M)[1]				
	FEMA[2]	NIST[3]	NSF[4]	USGS[5]	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.3	48.7	11.3	**60.4**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	4.0	3.3		2.4	**9.7**
Goal C: Improve the earthquake resilience of communities nationwide.	3.3	0.3		16.0	**19.6**
Develop, operate, and maintain NEHRP facilities:					
ANSS				29.8	**29.8**
GSN			3.5	4.9	**8.4**
Total:	**7.4**	**3.9**	**52.2**	**64.4**	**127.9**

Notes on Table 2.2:

[1] Budgets are rounded to the nearest $0.1 million.

[2] The FEMA FY 2015 budget is an allocation from the U.S. Department of Homeland Security (DHS) appropriation that covers NEHRP activities but excludes employee salaries and expenses (S&E).

[3] The NIST FY 2015 budget is an allocation from the NIST appropriation that covers all NEHRP-related activities, including the NEHRP Lead Agency role and Earthquake Risk Reduction R&D activities.

[4] The NSF FY 2015 budget is NSF's estimated allocation from the NSF appropriation that covers NEHRP activities but excludes Agency Operations and Award Management (AOAM). The NSF budget includes support for the earthquake engineering research infrastructure and activities that are included in the Natural Hazards Engineering Research Infrastructure.

[5] The USGS FY 2015 budget is a line item in the USGS appropriation that covers NEHRP activities. The amount reported for ANSS here also includes all domestic seismic and geodetic monitoring costs supported by the Earthquake Hazards Program, even though geodetic monitoring is not formally part of ANSS.

2.2 NEHRP FY 2016 Budget Requests by Strategic Goal

Table 2.3 lists the FY 2016 NEHRP planning budgets for each agency by strategic goal. These figures are based on agency submissions included in the President's FY 2016 budget request to Congress.

TABLE 2.3 – *NEHRP AGENCY BUDGET REQUESTS for FY 2016*

Strategic Goal	FY 2016 Funds Requested or Anticipated for NEHRP Goals ($M)[1]				
	FEMA[2]	NIST[3]	NSF[4]	USGS[5]	**Total**
Goal A: Improve understanding of earthquake processes and impacts.	0.1	0.4	50.7	11.3	**62.5**
Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.	4.0	5.1		2.4	**11.5**
Goal C: Improve the earthquake resilience of communities nationwide.	2.3	0.4		16.0	**18.7**
Develop, operate, and maintain NEHRP facilities:					
ANSS				28.3	**28.3**
GSN			3.5	9.8	**13.3**
Total:	**6.4**	**5.9**	**54.2**	**67.8**	**134.3**

Notes on Table 2.3:

[1] Budgets are rounded to the nearest $0.1 million.

[2] The FEMA FY 2016 budget is a planned allocation from the U.S. Department of Homeland Security (DHS) appropriation that covers NEHRP activities but excludes employee salaries and expenses (S&E).

[3] The NIST FY 2016 budget is a planned allocation from the NIST appropriation that covers all NEHRP-related activities, including the NEHRP Lead Agency role and Earthquake Risk Reduction R&D activities.

[4] The NSF FY 2016 budget is NSF's estimated allocation from the NSF appropriation that covers NEHRP activities but excludes Agency Operations and Award Management (AOAM). The NSF budget includes support for the earthquake engineering research infrastructure and activities that are included in the Natural Hazards Engineering Research Infrastructure.

[5] The USGS FY 2016 budget is a line item in the USGS appropriation that covers NEHRP activities. The amount reported for ANSS includes all domestic seismic monitoring costs supported by the Earthquake Hazards Program, as well as real-time geodetic monitoring.

Section 3
Statutory Program Highlights

This section summarizes major activity highlights and accomplishments of the NEHRP during FY 2014. The organization of this chapter follows that of the NEHRP strategic plan http://nehrp.gov/pdf/strategic_plan_2008.pdf). The strategic plan defines NEHRP in terms of broad strategic goals and more specific objectives and related strategic priorities. The goals are directly linked to the NEHRP activities defined in Public Law 108–360, Section 103(2). By following the structure of the strategic plan, this report allows the reader to directly assess how accomplishments are furthering progress toward the program's stated goals and objectives. Accomplishments are not categorized by NEHRP agency but, rather, are cast in terms of collective progress toward NEHRP goals.

3.1 Goal A: Improve Understanding of Earthquake Processes and Impacts

Understanding how and why earthquakes occur, and what happens to our communities when they do, is an essential step in building the knowledge required to reduce the consequences of future earthquakes. For this reason, NEHRP supports basic research related to earthquakes in geoscience, engineering, and social science. The research supported and undertaken under Goal A provides a strong foundation for the development and implementation of practical earthquake risk-reduction measures pursued under the other strategic goals.

Strategic Goal A is directly related to the congressionally defined NEHRP program activity, "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 decisions sciences." 42 U.S.C. § 7704(a)(2)(C). Strategic Goal A activities include advancing understanding of earthquake phenomena and generation processes, earthquake effects on the built environment, and the social, behavioral, and economic factors linked to implementing risk reduction and mitigation strategies in both the public and private sectors. Strategic Goal A also covers efforts to improve post-earthquake information acquisition and management.

In FY 2014, the NEHRP agencies supported work to improve the fundamental understanding of earthquakes and their impacts. Representative accomplishments and activities under this goal are presented below.

Reducing the Seismic Risk of Soft-story Wood-frame Buildings

An NSF-supported research project led by Colorado State University evaluated the seismic performance of a type of residential structure that is particularly susceptible to earthquake damage. As early as 1970, the structural engineering and building safety communities recognized that a large

number of two- and three-story buildings with less rigid first floors (often used for parking or commercial space) are prone to collapse during significant ground shaking in earthquakes. NSF-supported researchers approached this problem by investigating the effects of retrofits on damage to the upper stories and collapse risk of entire structures through computer modeling, design method development, and full-scale system-level experiments. Experiments included shake table tests of a full-scale, four-story, soft-story wood-frame building using the NEES outdoor shake table facility at the University of California, San Diego. The collected data has yielded insights into the constructability and performance of different retrofit methods and techniques, and supports a better understanding of the amount of deformation these buildings can undergo before becoming unsafe. This project yielded a landmark data set that can be used freely by researchers worldwide to extend the understanding of seismic risk and retrofit performance for soft-story buildings.

Engineering Innovative Seismic Retrofits

With support from the NSF, researchers at the Structural Engineering and Materials Laboratory at the Georgia Institute of Technology used a full-scale model building to test new ways to protect structures from earthquakes and potentially save lives. The three-story concrete building was constructed using designs common through much of the 20th century. The building was subjected to multiple rounds of simulated temblors, using the portable eccentric mass shakers from the NEES site at the University of California, Los Angeles, to assess whether materials such as carbon fiber or new shape-memory alloys could be used to reinforce the structure so it would remain standing in moderate to strong earthquakes. The research team developed a series of retrofits of varying cost and intrusiveness to give building owners in earthquake-prone areas a range of choices for strengthening their properties. This research is highlighted in a Science Nation video available at: http://www.nsf.gov/news/special_reports/science_nation/reinforcedbuildings.jsp.

Post-Tensioned Coupled Shear Wall Systems

Experimental work at the NEES site at Lehigh University, conducted by researchers from the University of Notre Dame, Lehigh University, and University of Texas at Tyler, demonstrated that a simplified type of reinforced concrete coupled wall system can provide both better seismic performance and greater ease of construction over conventional coupled wall systems. This new system uses a single un-bonded, post-tensioned tendon in each coupling beam that links individual shear walls in each story. During a large earthquake, damage would be minimized since the deformations in the coupling beams occur as gaps open at the ends. After the earthquake, the post-tensioned tendons would provide a restoring force, closing the gaps and returning the building back to its original position. This system is also a significant innovation in that it is easier to construct in the field than conventional coupling beams, which require a large amount and complex diagonal arrangement of reinforcing steel.

NSF-Supported International Collaborations

During FY 2014, NSF supported two Science Across Virtual Institutes (SAVI) awards, one a collaborative award to the University of Southern California (USC) and University of Connecticut (UCONN), and the other to the University of California, Los Angeles (UCLA). The awards join researchers in the United States with collaborators in Chile, Japan, and New Zealand to coordinate research on seismic protective systems (USC, UCONN) and the seismic performance assessment of structural walls (UCLA). Both awards enable U.S. researchers to learn from their counterparts in Pacific Rim countries about the performance of buildings during recent earthquakes and laboratory tests.

Seismic protective systems –such as base isolation, passive energy dissipation, and semi-active and active control –can be applied to new and existing buildings to provide significant reductions in building motion and damage during earthquakes. The SAVI led jointly by USC and UCONN links researchers on 13 active NSF awards in the areas of seismic protective systems, as well as 20 to 30 early career participants, to form long-term global research relationships with their international collaborators, who are supported by their respective government research agencies.

Given recent observations of unexpected damage to reinforced concrete structural walls in the 2010 Chilean and 2011 New Zealand earthquakes, considerable research on the seismic performance and design of structural walls has been initiated or is planned in the U.S. and around the world. Many of the research needs identified for structural walls require a large-scale laboratory. Large-scale testing is expensive; therefore, the ability of any one country to address the breadth of issues that have been identified is limited. Through the SAVI led by UCLA, researchers from Chile, Japan, New Zealand, and the U.S. will share research test plans and test data; develop, improve, calibrate, and validate component and system models used for building design; achieve consensus, where possible, on critical performance issues; prepare joint reports, papers, and design recommendations; and develop collaborative new research directions.

Studies of Seismicity Induced by Wastewater Injection

The USGS continued to monitor earthquakes in Oklahoma, Kansas, Texas, and Colorado that are presumed to be caused by wastewater injection. A new analysis by the USGS and Oklahoma Geological Survey found that the rate of earthquakes in Oklahoma has increased by about a factor of five since 2008. By April 2014, Oklahoma's heightened activity since 2009 includes twenty magnitude 4.0 to 4.8 quakes. USGS has statistically analyzed the recent earthquake rate changes and found that they are not due to typical, random fluctuations in natural seismicity rates. The analysis indicates that the most likely contributing factor to the increase in earthquakes is the injection of wastewater from oil and gas production into deep geologic formations. A publication by the USGS suggests that fluid injection induced a magnitude 5.0 earthquake near Prague, Oklahoma, in 2011 and that earthquake then triggered a larger magnitude 5.6 earthquake one day later, the largest earthquake in Oklahoma's history.

A USGS study published in 2014 indicates that the earthquake hazard increases with total volume of injected waste fluid. Other factors that modulate the hazard include the net fluid balance between injection and withdrawal, the rate and pressure of the injection, the permeability of the rock strata involved, and access of the injected fluids to critically stressed, buried faults.

Seismic Monitoring of a Pilot Carbon Sequestration Site

The USGS has installed a 14-station network of surface and shallow borehole seismometers and accelerometers surrounding a pilot carbon capture and sequestration (CCS) project in Decatur, Illinois. This network is being used to study seismicity associated with underground storage of CO_2 in an undisturbed saline formation, to see if such operations can be undertaken safely before full-scale implementation of CCS can be realistically considered as a viable option to combat global warming. To push the detection threshold to smaller magnitudes, this network is now being augmented by a state-of-the art deep borehole seismic array.

Dynamic Fault Rupture Modeling for Strong Seismic Motions

Recordings of extreme seismic motions from large earthquakes are rare. In FY 2014, the USGS actively pursued the development of physics-based models of earthquake fault ruptures and associated ground shaking. These analytical models are contributing to our understanding of the rupture process, and helping us to better understand factors that affect the severity and frequency content of ground motions. More powerful computers and better algorithms allow more detailed and realistic analyses of the rupture process; wave propagation through realistic, 3-D geologic structures; and variations in site properties as they affect ground motions caused by major earthquakes.

Operational Aftershock Forecasting

For many years, the USGS has been generating automated aftershock forecasts for earthquakes in California. These forecasts are based on statistical analyses of many aftershock sequences recorded over decades of observations. Recently, the USGS has been developing analytical tools and analyzing global seismicity data, working toward an automated capability for forecasting the expected size and frequency of aftershocks that occur after large earthquakes anywhere in the world. Such forecasts could be of value to a wide variety of users, including local officials, emergency responders and engineers in planning response and recovery efforts, and other risk-mitigating activities following damaging earthquakes.

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

NEHRP activities under Goal B are designed to develop practical and cost-effective methods and measures for earthquake risk assessment and mitigation that build upon the research results obtained under Goal A. Goal B is directly linked to the congressionally-defined NEHRP program

activity, "Develop effective measures for earthquake hazards reduction." 42 U.S.C. § 7704(a)(2)(A). Goal B includes activities by the NEHRP agencies to assess earthquake hazards for research and practical application, and to develop tools for advanced loss estimation and risk assessment, improved seismic performance of buildings and other structures, and improved seismic performance of critical infrastructure. Selected accomplishments of the NEHRP agencies that relate to developing resources to assess and reduce risk are presented below.

National Seismic Hazard Assessment Update

During FY 2014, the USGS updated the U.S. National Seismic Hazard Model for the lower 48 States and began developing new products to better communicate seismic hazard information to users. The seismic hazard assessment is based on the best available science at the time of the update, and incorporates a broad range of new datasets, shaking versus magnitude relationships, and revised seismic wave propagation parameters. For the Central and Eastern U.S., USGS scientists used a new catalogue of historical seismicity based on moment magnitude (Mw), updated maximum magnitude determinations, revised the smoothing algorithms for estimating earthquake rates away from faults, and modified the sizes and rates of earthquakes in the New Madrid Seismic Zone. Scientists also updated methods for addressing induced seismicity triggered by manmade activities. In the Intermountain West, scientists implemented new smoothing algorithms, fault geometries for normal faults, multiple Wasatch fault (Utah) earthquake scenarios, and fault slip rates based on models obtained by inverting geodetic and geologic data. For the Pacific Northwest, they developed new Cascadia subduction zone rupture models that incorporate additional earthquakes to the south and modified the model for earthquake-capable faults. For California, scientists released the new Uniform California Earthquake Rupture Forecast source model (version 3) based on new crustal deformation models, revised fault segmentation assumptions, and included considerations of simultaneous, multi-fault ruptures during a single earthquake event. They also applied several new ground motion models for shallow crustal earthquakes, earthquakes at the subduction zone interface, and deep earthquakes. The improvements in input models resulted in small changes across most of the country, but have yielded significant changes in localized areas of up to ± 25% in forecasted ground shaking levels (accelerations).

Structural Design Technical Briefs

With support from NIST, the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering produced NEHRP Seismic Design Technical Briefs 9 and 10, *Seismic Design of Special Reinforced Masonry Shear Walls: A Guide for Practicing Engineers* (NIST GCR 14-917-31)[7] and *Seismic Design of Wood Light-Frame Structural Diaphragm Systems: A Guide for Practicing*

[7] The term "special" denotes the use of structural design requirements that improve resistance to strong earthquake ground shaking, such as that which may occur in areas of high seismic risk.

Engineers (NIST GCR 14-917-32)[8]. The techbrief volumes are part of a continuing series of topical, succinct discussions of solutions to practical problems faced by engineering practitioners. As implied in the title for each techbrief, these volumes provide state-of-the-art guidance to practicing engineers that combines clarification on requirements in building codes and standards, techniques employed by leading practitioners, and recent research results. The volumes are used as references by practicing engineers and in graduate engineering classes in universities.

Earthquake-Resistant Reinforced Concrete Buildings

FEMA and NIST have worked cooperatively to address earthquake vulnerabilities in older (constructed pre-1990) "non-ductile" reinforced concrete (NDRC) buildings. With the substantial number of NDRC buildings located in U.S. areas of moderate to high seismic activity, accurate assessment of the vulnerabilities of these buildings is essential for risk mitigation activities.

Through the NEHRP Consultants Joint Venture (NCJV), NIST produced *Review of Past Performance and Further Development of Modeling Techniques for Collapse Assessment of Existing Reinforced Concrete Buildings* (NIST GCR 14-917-28). The report addresses common deficiencies found in NDRC buildings that have often collapsed in past earthquakes, as well as collapse mitigation strategies and analytical modeling techniques. The report also summarizes the major structural components that require further study.

In recognition of the need to develop a low-cost, easily implementable methodology to identify collapse-hazard concrete buildings, four years ago FEMA began funding an annual series of task orders with the Applied Technology Council (ATC) to develop a new evaluation methodology that will more easily and accurately predict the seismic collapse potential of NDRC-frame and -wall buildings.

The FEMA-ATC project began by studying many "collapse indicators" from lists in the NIST report and other sources; many insights into the behavior of this building type have been obtained. In 2012, several complexities were identified regarding the development of an efficient evaluation technique using "collapse indicator" relationships that led the project to examine a new way of assessing performance.

A follow-on study that commenced in early FY 2013 focused primarily on the development of an evaluation methodology specifically for NDRC-frame buildings, but also included preliminary efforts to develop a comparable evaluation methodology for NDRC buildings with structural walls. By January 2014, the evaluation methodology for concrete-frame structures was approximately 80

[8] The term "diaphragms" denotes structural elements in buildings or other structures that transfer lateral forces, such as those from earthquakes or wind loads, to vertical structural elements. Diaphragm elements in buildings are most commonly floor or roof systems.

percent complete, while the evaluation methodology for wall structures was approximately 20 percent complete.

In early 2014, another follow-on study commenced, focusing on finalizing the draft evaluation methodology for NDRC-frame buildings and continuing development of the NDRC-wall evaluation methodology. The final product of the studies will be a technical report entitled, *Seismic Evaluation for Collapse Potential of Older Concrete Buildings*, to be identified as FEMA P-1000 and completed within the next two years.

In addition to the extensive work on NDRC buildings, NIST produced, through the NCJV, *Use of High-Strength Reinforcement in Earthquake-Resistant Concrete Structures* (NIST GCR 14-917-30), a report on the potential utilization of higher strength (specified yield strengths exceeding 60,000 psi) reinforcing steel in special[9] reinforced concrete moment frames and shear walls. As a result of this initial assessment, the reinforced concrete industry is supporting extensive new research exploring the use of higher strength reinforcement in these structures, which can ultimately lead to more cost-effective reinforced concrete buildings, especially in areas having high seismic activity.

Earthquake Hazard Assessment Tools

FEMA completed an updated, interactive fourth edition of *Reducing the Risk of Nonstructural Earthquake Damage* (FEMA E-74) designed primarily for online use but which is also available in a CD version. FEMA E-74 includes information on the behavior of nonstructural[10] components in earthquakes and the types of damage they typically cause; survey and assessment procedures for nonstructural components in existing buildings; nonstructural hazard reduction measures for existing buildings and new construction; and detailed illustrations of possible earthquake damage and mitigation measures for a variety of nonstructural components. The updated fourth edition covers about 70 different examples of nonstructural components, compared to about 12 examples in the previous edition, and incorporates examples from three major earthquakes in Chile, New Zealand, and Japan. The new FEMA E-74 CD also includes a training resource developed by ATC: instructor and student materials for 4- to 5-hour live training classes.

FEMA also released Version 2 of *Rapid Observation of Vulnerability and Estimation of Risk* (FEMA P-154 ROVER CD Version 2) which is free, mobile software for pre-earthquake building screening for potential seismic hazards and post-earthquake rapid building evaluation for safe occupancy. It is available through online download or on CD-ROM. ROVER directly applies paper-and-clipboard screening and evaluation standards developed by ATC: FEMA 154, *Rapid Visual Screening of*

[9] See footnote 7.

[10] The term "nonstructural systems" refers to building components that are not integral parts of the lateral of gravity load-bearing systems, but are potential life safety risks (e.g., light fixtures and other falling hazards) and/or are essential to building functionality (e.g., HVAC systems, fire sprinkler systems, critical medical equipment).

Buildings for Potential Seismic Hazards, A Handbook, 2nd Edition; and ATC-20-1 *Field Manual: Postearthquake Safety Evaluation of Buildings*, 2nd Edition. The new ROVER Version 2 includes many productivity-enhancing features, including mobile device compatibility, and the ability for users to transmit field data immediately to the software, which can reside in the user's office or virtually anywhere in the world. Version 2 also enables unlimited photos to be added to the ATC-20 rapid and detailed post-earthquake forms. When a building that has been screened before an earthquake is evaluated after an earthquake using ATC-20, ROVER puts overlapping data in the ATC-20 form: address, occupancy, number of stories, and pre-earthquake photos. Overall, the new ROVER Version 2 also improves photo handling, which is useful for high-resolution images, limited data rates, and when large numbers of people are inserting data at the same time. In addition, the training material and user manual have both been updated and now include instructions on batch-loading a pre-existing database and instructions on the use of the RedROVER software, which exports ROVER data to HAZUS-MH's Advanced Engineering Building Module. Additional guidance has been developed on how to get "ROVER Ready," *i.e.,* how to be prepared to use ROVER either before or after an earthquake.

3.3 Goal C: Improve the Earthquake Resilience of Communities Nationwide

Through activities supported under Goal C, NEHRP agencies work to apply research results developed under Goal A and risk-reduction methodologies developed under Goal B to practical measures that will increase public safety and reduce losses in future earthquakes. Work under this goal includes the monitoring and reporting of seismic activity worldwide. Goal C is directly related to the congressionally-defined NEHRP program activity, "Promote the adoption of earthquake hazards reduction measures by Federal, State, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with a role in planning and constructing buildings, structures, and lifelines." 42 U.S.C. § 7704(a)(2)(B).

Goal C includes numerous NEHRP-wide activities to improve the accuracy, timeliness, and content of earthquake information products; to develop comprehensive earthquake risk scenarios and risk assessments; to support development of improved seismic standards and building codes, and advocate their adoption and enforcement; to promote the implementation of earthquake-resilient measures in professional practice and in private and public policies; to increase public awareness of earthquake hazards and risks; and to develop the nation's human resource base in earthquake safety fields. Some representative accomplishments are described below.

Building the Future Professional Base

Four NSF awards (1996, 2003, 2009, and 2014) have supported partnering senior researchers with promising young faculty working in the areas of hazards, disasters, and risk research. Senior researchers mentor junior faculty and provide technical training and professional development to build their research skills and foster a broad understanding of emerging issues in disaster research. The current project, *Enabling the Next Generation of Hazards and Disaster Researchers*, has drawn

researchers from other fields to disaster research, enhancing the community's depth and enabling multidisciplinary collaborations in order to promote innovation. The program has supported potentially transformative research on topics such as homeland security, enhanced emergency response, emergency medical services, protecting power and other lifelines, community resilience, and frameworks to reduce losses and speed recovery in vulnerable areas. Almost 800 scholarly publications having been produced. NSF has also supported Research Experiences for Undergraduates (REU) programs focused on earthquake issues, including programs through NEES operations at Purdue University.

Applied Earthquake Research Grants

Approximately one-quarter of the total USGS NEHRP funding is directed toward research grants and cooperative agreements with universities, State agencies, and private technical firms to support research and monitoring activities. This external funding is leveraged with funds from other Federal agencies, States, and the private sector. In FY 2014, USGS supported external activities including: mapping seismic hazards in urban areas; developing credible earthquake planning scenarios including loss estimates; defining the prehistoric record of large earthquakes; investigating the origins of earthquakes; improving methods for predicting earthquake effects; operating ANSS regional seismic networks; and testing the prototype system for an earthquake early warning system (see previous paragraph). The NSF and USGS also fund cooperative agreements with the Southern California Earthquake Center (SCEC), a 40-institution earthquake research consortium.

Public Earthquake Safety Exercises

The 50th anniversary of the Great Alaska earthquake and tsunami of 1964 provided Federal and State agencies a prime opportunity to raise awareness of earthquake hazards and encourage planning and activities to reduce losses from future earthquakes and tsunamis. To this end, the NEHRP agencies participated in a large number of activities including the "Alaska Shield," an element of a larger Federal emergency response National Level Exercise (CAPSTONE-14 NLE). The exercise included partnerships with the NOAA National Weather Service, the State of Alaska, and local tsunami response working groups. The USGS created the earthquake scenario and related ShakeMap and PAGER products for use in "Alaska Shield," compiled a new Fact Sheet on the 1964 disaster and the lessons learned therefrom, and compiled and republished a significant number of educational resources at a new USGS web portal.

ShakeOut

NEHRP agencies again supported ShakeOut, the world's largest earthquake preparedness drill for governments, schools, businesses, other organizations, and homes. In FY 2014, more than 26.5 million people participated in ShakeOut activities worldwide, of which over 20.2 million were from the U.S., including participants from 43 States and U.S. Territories. For the first time, American Samoa, Northern Mariana Islands, Delaware, Hawaii, West Virginia, U.S. Virgin Islands, and nine States of the Northeast participated. NEHRP provides financial support to SCEC to provide

personalized State/Territory and regional ShakeOut websites, templates, drill guides, registration support, and technical planning assistance. All ShakeOut exercises benefit from the direct involvement of staff from the NEHRP agencies.

National Building Safety Month

National Building Safety Month is a public awareness campaign held each May for the last 34 years. Founded by the International Code Council (ICC), the National Building Safety Month campaign focuses on public outreach and education to increase the overall safety and sustainability of buildings through the adoption of modern building codes and the promotion of code enforcement. In FY 2014, FEMA hosted community events and conducted an array of outreach activities in support of the 2014 theme, "Building Safety: Maximizing Resilience, Minimizing Risks." Beginning in May 2014, FEMA supported the "Designing for Disaster" exhibition at the National Building Museum in Washington, D.C. The exhibition, which ran through August 2015, investigated how and where to build communities that are safer and more disaster-resilient. Activities at the National Building Museum sponsored by FEMA included the distribution of teaching kits to educators from the District of Columbia, Maryland, and Virginia to teach students in grades 7-9 about the tools used by design professionals to lessen the effects of natural disasters. With FEMA support, a Presidential Proclamation for National Building Safety Month was issued for the fourth time in FY 2014.

Earthquake Early Warning

As described in the published 2014 technical implementation plan, the vision of the USGS ShakeAlert project is to build and operate a reliable, public EEW system for the West Coast of the United States. In January 2012, the USGS and its partners began testing a limited-capability, demonstration EEW system in California that builds upon prior USGS investments in the ANSS. Approximately 625 ANSS stations were contributing to the system in FY 2014, including more than 100 stations that were upgraded in southern California with funding from DHS.

Because earthquake shaking travels more slowly than electronic signals, it is possible to broadcast warnings to communities after an earthquake has occurred, but before strong shaking arrives. EEW is aimed to warn residents and operational entities of imminent strong ground shaking immediately after a large earthquake has occurred. The warning time, measured in seconds, is proportional to distance from the hypocenter.

The demonstration EEW system in California now has more than 75 test users receiving alerts and has successfully sent test alerts for several damaging earthquakes, including the M5.1 La Habra and the M6.0 South Napa events. One user, the San Francisco Bay Area Rapid Transit District (BART), is using the system to slow and stop trains automatically if test alerts of damaging ground shaking are received. Research and development efforts supported by the Gordon and Betty Moore Foundation will be completed by the end of calendar year 2015. The demonstration EEW system has attracted significant interest. For example, in FY 2013, the Governor of California

signed into law California Senate Bill 135. This legislation directs the California Governor's Office of Emergency Services (Cal OES), in collaboration with the USGS, the California Integrated Seismic Network, other State agencies, and private partners, to "develop a comprehensive State-wide earthquake early warning system in California" and Cal OES is pursuing this goal.

Cost and Benefit Studies for Earthquake-Resistant Construction in Memphis

With support from NIST, NCJV produced a detailed study of the construction costs of six typical buildings in the Memphis area, *Cost Analyses and Benefit Studies for Earthquake-Resistant Construction in Memphis, Tennessee* (NIST GCR 14-917-26). The study included complete designs of structural and non-structural systems and subsequent detailed construction cost analysis. For each building, the construction cost for three alternative designs was determined: (a) no earthquake resistance (*i.e.*, for wind loads only) provided; (b) earthquake resistance in accordance with provisions of the Memphis/Shelby County building codes that were effective at the time of the study (which used a locally modified form of the 2003 International Building Code (IBC)) that permitted the use of the 1999 Standard Building Code, except for hospitals and other critical facilities); and, (c) earthquake resistance in accordance with the 2012 IBC. Construction costs were assessed in detail, as were the relative earthquake performances of each design. The study showed that buildings designed in accordance with the 2012 IBC performed better in earthquakes, with very modest (3% or less) cost premiums over buildings with no specific earthquake design at all and extremely modest (1% or less) cost premiums over buildings with the locally modified older provisions. This information, along with information provided by FEMA and USGS on the earthquake hazard and on building code adoption issues, contributed to decisions made in Memphis/Shelby County regarding the adoption of the earthquake provisions of the IBC.

Support for 2015 International Codes Process

To promote disaster-resilient communities, NEHRP, through FEMA, supports national building code and standards organizations, such as the International Code Council (ICC). This work is important to helping the Nation prepare for and protect against all natural and man-made hazards that pose threats to life and property. First released in 2000, the International Codes (I-Codes) are a set of construction codes that address structural systems, fire protection, plumbing, mechanical systems, fuel (gas, etc.), property maintenance, zoning, and energy efficiency. The 2015 I-Codes reflect the most advanced building science construction methods and practices to achieve resiliency, safety, innovation, and affordability in the built environment. FEMA monitors the Nation's model building codes by reviewing proposed changes for the I-Codes (International Building Code (IBC), International Residential Code (IRC), International Existing Building Code (IEBC), and others) to identify those which have a positive or negative impact on disaster resistance. In FY 2014, FEMA successfully advocated for the inclusion of a group of enhanced disaster-resistant provisions in the Nation's model building codes, specifically the ICC codes. FEMA did this by providing technical input to the ICC through their regular hearing process where they periodically update their model code books. FEMA's advocacy resulted in passage of enhanced disaster-resistant provisions for ninety percent of the proposed changes.

Updates in the 2015 NEHRP Recommended Seismic Provisions

The *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* ("Provisions") is a widely recognized seismic code resource document issued by FEMA. The Provisions play a vital supporting role in the development of national consensus building codes and standards, and serve as a research-to–practice (implementation) platform for NEHRP. Building occupants' most important and effective earthquake protection tools are earthquake-resistant building codes. When States and communities adopt and enforce national building codes, the built-in protection against loss of life and property damage from earthquakes helps to achieve NEHRP goals. FEMA is working to complete the 2015 edition of the Provisions. The 2015 Provisions translate and incorporate new research results to improve the ASCE/SEI 7 *Minimum Design Loads for Buildings and Other Structures*, the national design standard that is directly referenced by the IBC, which is the model code adopted by all 50 States and approximately 40,000 local communities. The 2015 Provisions provide 43 recommended technical changes developed and consensually approved by the Provisions Update Committee, Issue Teams, and member organizations of the Building Seismic Safety Council (BSSC). All of the recommended changes will be brought to the ASCE 7 Seismic Subcommittee to be considered for adoption into ASCE/SEI 7-16.

Promoting and Monitoring the Adoption of Building Codes

FEMA promotes building code adoption by cooperating with the ICC, standards groups, the design industry, and research institutes, and through cooperative agreements with the Federal Alliance for Safe Homes (FLASH), the four Regional earthquake consortia, and the Earthquake Engineering Research Institute (EERI). FEMA uses the *Building Code Effectiveness Grading Schedule*, a tool owned by the Insurance Services Organization, to evaluate and score local building code departments for code adoption and enforcement for insurance credit every five years, with the performance goal to increase the number of communities in hazard-prone areas (earthquake, flood, and wind) that have adopted disaster-resistant building codes. In FY 2013, 57 percent of the communities in high-earthquake-, flood-, and wind-prone areas had adopted disaster-resistant building codes; by FY 2014, the percentage of those adopting had increased to 62 percent.

Cooperative Agreements

FEMA works closely with national (EERI, FLASH, SCEC, and Applied Technology Council (ATC)) and regional (Northeast States Emergency Consortium (NESEC), Central U.S. Earthquake Consortium (CUSEC), the Western States Seismic Policy Council (WSSPC), and the Cascadia Regional Earthquake Workgroup (CREW)) partnerships thru Cooperative Agreements. The earthquake consortia and partners play an invaluable role in coordinating multi-State response and recovery planning, as well as public awareness, education, and outreach in preparedness and mitigation. All of the Earthquake Consortia and Partners, and the States are very active in the ShakeOut earthquake drills that take place across the U.S. In FY 2014, the cooperative agreements provided support to the States in numerous ways (see Section 4 of this report for details).

Earthquake Awareness and Hazard Mitigation Training

The National Earthquake Technical Assistance Program (NETAP) is FEMA's program for delivering earthquake education and awareness training to the public, a FEMA statutory responsibility under NEHRP. NETAP helps State, local, and Indian tribal governments, non-profit organizations, and the private sector obtain the knowledge and tools needed to plan and implement effective earthquake mitigation strategies. FEMA continually develops and updates training courses for its many audiences, sponsoring, conducting, and hosting training in venues across the U.S. and via webinars.

Through NETAP, FEMA supports training conducted by the ATC in earthquake mitigation topics at the State and local level, for building inspectors, facility managers, emergency managers, school administrators, hospital staff, engineers, and other groups. In FY 2014, in-person training was provided through NETAP via 80 courses to participants in 14 States and U.S. Territories. Such NEHRP-related training reached more than 5,000 constituents in FY 2014.

3.4 NEHRP Statutory Activity: Program Leadership

There are several statutory NEHRP program management, coordination, and oversight functions. 42 U.S.C. §§ 7704(a)(3) & (5). In FY 2014, the Advisory Committee on Earthquake Hazards Reduction (ACEHR)[11] met twice, including one teleconference. The Interagency Coordinating Committee[12] did not meet in FY 2014. The working-level Program Coordination Working Group, established by the NEHRP Secretariat, met face-to-face seven times and held two teleconferences.

Responses to ACEHR Recommendations

The ACEHR provided several observations and recommendations regarding NEHRP activities to the NIST Director, as the Interagency Coordinating Committee Chair, in FY 2014. The full text of the recommendations and corresponding NEHRP agency responses are available on the NEHRP website.[13] The ACEHR plans to provide a new report with observations and recommendations before the end of FY 2015.

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[11] ACEHR is composed of 11 to 17 nationally recognized, leading earthquake professionals who are not Federal employees and who are appointed to 3-year staggered terms of service. The Chair of the USGS Scientific Earthquake Studies Advisory Committee (SESAC) serves as an ex-officio member of ACEHR.

[12] The Interagency Coordinating Committee is composed of the Directors/Administrators of the four NEHRP agencies and the Directors of the Office of Management and Budget and the Office of Science and Technology Policy of the Executive Office of the President.

[13] See http://www.nehrp.gov/pdf/2013ACEHRReportFinal.pdf and http://www.nehrp.gov/pdf/Agency%20Responses%20to%202013%20ACEHR%20Recommendations%20081414.pdf.

NEHRP Secretariat Operations

The NIST NEHRP Secretariat continued to provide support and leadership for program coordination. The office organized and conducted the ACEHR and PCWG meetings and maintained the NEHRP website (www.nehrp.gov). This website provides information on NEHRP management efforts and products, as well as links to the four program agencies where further information on earthquake research results, current seismic activity, seismic hazard and risk, and earthquake mitigation practices can be found.

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

Public Law 108–360 requires that NEHRP "develop, operate, and maintain" certain facilities essential to the NEHRP mission. 42 U.S.C. § 7704(a)(2)(D). These facilities are the ANSS, maintained and operated by USGS; the George E. Brown, Jr. NEES, maintained and operated by NSF; and the GSN, maintained and operated cooperatively by USGS and NSF. Below are reports on the FY 2014 activities and status of these facilities.

Advanced National Seismic System

The ANSS is an effort led by the USGS to support, coordinate, and modernize earthquake monitoring nationwide. The ANSS consists of USGS national-level monitoring and data analysis facilities, and 13 regional monitoring facilities supported by universities, States, and the USGS. In FY 2014, the ANSS station count increased to 2,977, including 156 instrumented structures.

In FY 2014, the ANSS and its partner at UC Berkeley successfully detected, monitored, and analyzed the M6.0 South Napa earthquake, providing rapid situational awareness products and collecting valuable recordings of ground motion data. This large earthquake served as a valuable test case for the prototype ShakeAlert earthquake early warning system described earlier in this report. The ANSS also completed installation of advanced structural monitoring systems in 28 Department of Veterans Affairs' hospitals in seismically active areas. These systems will allow determination of the structural integrity and safety of these hospitals immediately following an earthquake and provide valuable information on the responses of buildings to earthquake shaking.

Global Seismographic Network

The GSN consists of 150 stations worldwide. It is jointly supported by the USGS and the NSF, and is operated by the USGS in partnership with the Incorporated Research Institutions for Seismology (IRIS). The GSN provides high-quality seismic data to support earthquake alerts, tsunami warnings, hazard assessments, national security (through nuclear test treaty monitoring), earthquake loss reduction, and research on earthquake sources and the structure and dynamics of the Earth.

By the end of FY 2014, 93% of the planned equipment upgrades for the entire GSN were completed. The upgrades have improved station reliability and improved data return from all of the GSN stations from 71.9% in FY 2005 to 85.6% in FY 2014. This effort included initiating the upgrade of ten seismic recording stations in the China Digital Seismographic Network, which is a part of the GSN. The USGS and the China Earthquake Administration have cooperated on earthquake monitoring and research for 34 years.

The USGS developed and implemented new software to automatically assess the quality of GSN data, allowing staff at the USGS Albuquerque Seismological Laboratory to identify, diagnose, and fix station performance problems quickly. This has resulted in unprecedented data quality and availability for the USGS-operated stations of the network.

George E. Brown, Jr. Network for Earthquake Engineering Simulation

From FY 2005 to FY 2014, the George E. Brown, Jr. NEES was a network of state-of-the-art laboratories and testing facilities, linked by a shared cyberinfrastructure, for research in earthquake and tsunami engineering. During FY 2010 to FY 2014, NEES consisted of a managing headquarters (known as NEES*comm*) located at Purdue University; 14 state-of-the-art earthquake engineering experimental facilities located at and locally operated by universities across the U.S.; the NEEShub cyberinfrastructure framework; and the NEES Academy for education, outreach, and informal science education. NEES experimental facilities and other infrastructure have enabled more than 100 projects over ten years of operation, testing various aspects of earthquake and tsunami risk.

NEES*comm* organized NEES annual meetings that brought together NSF-supported researchers who used the NEES infrastructure and NEES operations team members to share research findings, information about NEES experimental and cyberinfrastructure resources, and effective methods for education and outreach in earthquake engineering. The 2014 annual meeting, Quake Summit 2014, was held in conjunction with the 10th U.S. National Conference on Earthquake Engineering, in Anchorage, Alaska, on July 21-25, 2014.

NEES completed its planned ten years of NSF support at the end of FY 2014. During FY 2014, NSF issued program solicitation NSF 14-605, Natural Hazards Engineering Research Infrastructure 2015-2019 (NHERI), to re-compete the components of NEES and to support experimental resources for engineering research related to windstorms. During 2015 to 2019, NHERI will be a distributed, multi-user, national facility to provide the natural hazards engineering community with access to research infrastructure (earthquake and wind engineering experimental facilities, cyberinfrastructure, computational modeling and simulation tools, and research data), coupled with education and community outreach activities. NHERI will be formed by up to ten NSF awards: one award for a Network Coordination Office; one award for Cyberinfrastructure, including an archival data repository; one award for a Computational Modeling and Simulation Center; and up

to seven awards for earthquake engineering and wind engineering experimental facilities, including a post-disaster, rapid response research facility. NHERI will enable research and educational advances that can contribute knowledge and innovation for the nation's civil infrastructure and communities to prevent natural hazard events from becoming societal disasters. The NSF awards for NHERI will contribute to NSF's roles in the NEHRP and the National Windstorm Impact Reduction Program (NWIRP). NHERI's earthquake engineering components and activities will form the successor to NEES. Awards are anticipated to be made in calendar year 2015.

Section 4

FEMA Activities to Promote Implementation of Research Results and Hazard Mitigation Efforts

4.1 FEMA Earthquake State Support

FEMA provides support for States and Territories to accomplish various relevant earthquake safety and mitigation activities. These are designed to increase and enhance implementation of earthquake risk reduction at the State and local level. Eligible risk-reduction activities include developing seismic mitigation plans; preparing inventories and conducting seismic safety inspections of critical structures; updating building codes, zoning codes, and ordinances to enhance seismic safety; increasing earthquake awareness and education; and encouraging the development of multi-jurisdiction groups that focus on these activities.

Brief highlights of successful efforts by State, Territorial, and local governments; and multi-State consortia and partners are presented below, as required by PL 108-360. The States and Territories with moderate to high earthquake risk provides the success stories that are summarized. The activities reported here may be supported in part by FEMA funds and in part by State funds. They are all included as part of the NEHRP. More complete information on these activities is available in FEMA's annual report, *The FEMA National Earthquake Hazards Reduction Program Accomplishments in Fiscal Year 2014*.[14]

Alabama

Alabama FY 2014 NEHRP and State-funded activities included the New Madrid CAPSTONE-14 Earthquake Exercise, the ShakeOut campaign and drill, and planning for the FY 2015 ShakeOut campaign and drill. During the New Madrid CAPSTONE-14 Earthquake Exercise, Alabama supported Mississippi and Tennessee by moving resources through the State, assisting evacuees in need of shelter, and supporting mass care issues. The State Emergency Operations Center was activated for the exercise. Various stages of the exercise emphasized Situational Awareness and Pre-scripted Mutual Aid and Mobilization, Mobilization and Response, Medical Surge and Evacuation with full Emergency Management Assistance Compact (EMAC) Operations, Mass Care, Voluntary Organizations Active in Disaster (VOAD), and Donated Goods, Demobilization, and Recovery.

Alaska

At the October 2013 Fall Preparedness Conference, about 80 people from tribal governments and various State-wide jurisdictions attended trainings from FEMA's National Earthquake Technical

[14] See http://www.fema.gov/media-library/assets/documents/33730.

Assistance Program which included FEMA's *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (FEMA P-154) and *Reducing the Risks of Nonstructural Earthquake Damage* (FEMA E-74). In early FY 2014, Alaska began working with the Alaskan Seismic Hazards Safety Commission (ASHSC) on a Rapid Visual Screening (RVS) pilot study of Alaska K-12 schools. Alaska increased earthquake awareness and education for the 50th Anniversary of the 1964 Good Friday Earthquake with a goal of developing, planning, and implementing an earthquake and tsunami outreach campaign. As part of the campaign, the Alaska Division of Homeland Security Preparedness and Planning Teams developed new outreach tools to demonstrate the effects of earthquakes and tsunamis, and to educate school children, citizens, and local jurisdictions on what they can do to mitigate those effects.

American Samoa

Activities in American Samoa focused on education, outreach, training, drills, exercises, media campaigns, and regional collaboration. Island-wide participation in the Great American Samoa ShakeOut continued, with a focus on schools and government employees. American Samoa promoted ShakeOut and recruited 5,102 participants, with numerous public outreach activities throughout the year.

Arizona

More than 116,000 Arizonians participated in the Great Arizona ShakeOut, an 86 percent increase from the previous year. Arizona built a new promotional campaign using ShakeOut "superhero" kids to engage and excite the K-12 community and aggressively recruited schools, resulting in more than 84,000 K-12 students and faculty participating in ShakeOut 2014. Regional outreach continued. ShakeOut partners expanded to include the Arizona Division of Emergency Management, Arizona County Emergency Management offices, American Red Cross, EarthScope, municipal emergency management offices, State agencies, and the K-12 community.

Arkansas

Arkansas created the INSPect ARKansas (INSPARK) program to provide a formalized, systematic approach to managing volunteer, post-disaster building inspectors. Arkansas also hosted a successful Shake-Out event, continued the Arkansas Governor's Earthquake Advisory Council meetings, and purchased earthquake related books for counties by request.

California

On August 24, 2014 a magnitude 6.0 earthquake occurred in Napa, resulting in one death, more than $87 million in public losses, and a disaster declaration. The California Earthquake Clearinghouse, along with the United States Geological Survey (USGS), and the Earthquake Engineering Research Institute (EERI) provided a centralized coordination center after the event where engineers, geologists, seismologists, sociologists, economists, and other professionals could coordinate the gathering of information. After the Napa Earthquake, the California Seismic Safety

Commission conducted public hearings to assess seismic safety issues and investigate earthquake damage and reconstruction efforts.

Over nine million people and organizations participated in the Great California ShakeOut. The California Office of Emergency Services (Cal OES), Southern California Earthquake Center (SCEC), at the University of Southern California, and the California Earthquake Authority (CEA) all promoted ShakeOut activities to improve the ways that people can protect themselves during earthquakes.

Cal OES continued its coordination with CEA to implement an incentive program to help homeowners seismically retrofit their homes. The resources for this program, called the California Residential Mitigation Program (CRMP), come from the CEA Earthquake Loss Mitigation Fund. The program focuses on helping with the retrofit of wood-frame family dwellings and has been piloted in two California communities, the Los Angeles neighborhood of Eagle Rock and the Rockridge neighborhood of Oakland. Cal OES and partner agencies also participated in the 3rd International Earthquake Early Warning (EEW) Conference, organized and sponsored by University of California at Berkeley, USGS, California Institute of Technology, the Gordon and Betty Moore Foundation, and the University of Washington. The three-day meeting assembled scientists, policy makers, engineers, social scientists, and business representatives from public and private sector institutions to examine the state-of-the-art in EEW and innovate new ways to push EEW forward. The CRMP utilizes FEMA's Simplified Seismic Assessment of Detached, Single Family, Wood-Frame Dwellings (FEMA P-50) as a key component of identifying eligible structures.

Colorado

Multi-hazard activities supported earthquake project work in Colorado. FEMA NEHRP funds were used for a State-wide hazard analysis (by county) and for local hazard mitigation planning. Colorado also participated in the first 2014 Rocky Mountain ShakeOut.

Guam

Since 2010, Guam has participated in the Great Guam ShakeOut. In FY 2014, there were 67,963 participating residents. Guam's Earthquake Program participated in multiple National Earthquake Technical Assistance Program (NETAP) training courses, including *Reducing the Risks of Nonstructural Earthquake Damage* (FEMA E-74), *Earthquake-Resistant Design Concepts* (FEMA P-749), *Earthquake Mitigation for Hospitals* (FEMA P-767), and *Home and Business Earthquake Safety and Mitigation* (FEMA P-909).

Hawaii

The focus of Hawaii's Earthquake Program included the activities of the Hawaii State Earthquake and Tsunami Advisory Committee (HETAC), earthquake public outreach projects, awareness and resilience projects, and participation in the Great Hawaii ShakeOut. Hawaii's goal is to promote seismic safety, education, mitigation, and awareness throughout the islands for citizens and tourists.

To accomplish this, Hawaii has partnered with members of the scientific and technical community, including universities, scientists, engineers, planners, and others in county, State, and Federal agencies.

Idaho
This year was the third Idaho ShakeOut and over 103,000 participants registered for the event. Idaho developed a new version of the "Putting Down Roots in Earthquake Country" handbook. NETAP training focused on schools in seven school districts and 140 buildings.

Illinois
February is Earthquake Preparedness Month in Illinois. Preparedness and awareness activities were conducted in February and throughout the year, including news releases and publication updates and distribution. Work continued and was completed on the Earthquake School Hazard Hunt. Illinois participated in February and October ShakeOut drills.

Indiana
Indiana (IN) state government employees participated with CUSEC on CAPSTONE-14 planning conferences, workshops and meetings, and worked with the Indiana Building Emergency Assessment and Monitoring Team to train for future events. In addition, IN state government employees and the Polis Center of Indiana University-Purdue University Indianapolis worked on the Indiana Earthquake Assessment for the 2014 State Mitigation Plan.

Kentucky
Approximately 430,000 participants registered for the October Great Central U.S. ShakeOut. With its earthquake assistance funds, Kentucky updated its Earthquake Program website and the Facebook Earthquake Program Page, and issued a Governor's Earthquake Awareness Week Proclamation and press release.

Maine
In Maine, a multi-student project that took two years to accomplish was completed. Data was collected by student interns over the course of two summers. The students were trained on FEMA P-154, *Rapid Visual Screening of Buildings for Potential Seismic Hazards*, and were provided electronic devices (smart phones) to record the data from the building screenings. They coordinated with county and local officials, visited all jurisdictions in Maine, and collected data on critical public buildings in each. The data was uploaded into a database, which was subsequently retrieved and used by the Northeast States Emergency Consortium (NESEC) to analyze potential damages State-wide, using HAZUS. The culmination of this project was the sharing of the analyses with the Maine Director of the State Emergency Management Agency by the Northeast States Emergency Consortium.

Mississippi

Activities in Mississippi focused on increased outreach and participation in the Great Central U.S. ShakeOut and CAPSTONE-14 Multi-State Exercise. Mississippi used speaking engagements, focused publications, social media, press releases, print ads, and media events to encourage State-wide participation in the ShakeOut Drill. Total ShakeOut participation in Mississippi was 226,552.

Missouri

The Missouri Seismic Safety Commission and State Geological Survey participated in the "Forces of Nature" event at the Columbia Public Schools Planetarium in Columbia. More than 400,000 people registered to participate in the 2014 Missouri ShakeOut.

Montana

The Montana Bureau of Mines and Geology (MBMG) used its earthquake assistance funding to make Montana's 1982-2014 earthquake catalog available as a data layer on MBMG's Online Mapping Application, providing visual, easy and versatile access to Montana's extensive historical earthquake record. Improved access to this data—including current seismicity—will enhance Montana's earthquake and seismic hazard education and outreach efforts.

Montana also participated in its first ShakeOut. More than 107,000 Montana residents, about 10 percent of the State's population, participated in this inaugural event coordinated by the Earthquake Country Alliance (ECA), the Governor's Office of Community Service, the MBMG, the State of Montana Disaster and Emergency Services, and the American Red Cross of Montana.

Nevada

Outreach in Nevada included the Great Nevada ShakeOut which has continued to increase in participation throughout Nevada from 116,000 in its inaugural year to over 560,000 participants in FY 2014. The Nevada Seismological Laboratory used the "Big Shaker" simulation truck to attract more attention to the ShakeOut event. Additional promotion included distribution of earthquake educational materials, press releases, and media events throughout the State.

Nevada completed an unreinforced masonry (URM)[15] verification project for unincorporated Clark County, which included sending two student engineers from the University of Nevada, Las Vegas (UNLV), under the supervision of Clark County staff engineers, into the field to conduct this URM survey. Clark County partnered with the Earthquake Engineering Research Institute (EERI) to utilize additional funds through NEHRP for this project, allowing Clark County to develop a more accurate listing of actual URM buildings.

[15] Unreinforced masonry (URM) refers to concrete block, brick, or other masonry walls, chimneys, etc., that have no reinforcement (steel, composites, or other materials) supplementing the mortar that binds the individual blocks or bricks together. URM buildings perform extremely poorly in earthquakes. They are considered by structural engineers to be "killer buildings" in earthquakes, because full or partial collapses of URM buildings in earthquakes are very common.

Nevada also supported a Pre-Disaster Mitigation (PDM) project with the Clark County School District. With over 316,0000 students and 37,000 employees, Clark County School District (CCSD) continues to be one of the fastest growing school districts in the United States and is the fifth largest school district in the Nation. In an effort to reduce the loss of life and property in an earthquake event, CCSD applied for and was awarded PDM funding to install automatic seismic gas shut-off valves on gas lines leading into their schools and administrative buildings in two phases, with the second phase to be completed by February 2016.

In June 2014, the University of Nevada, Reno (UNR) opened its new Earthquake Engineering Laboratory (EEL). The $19 million earthquake engineering lab expansion project was funded with $12.2 million from the U.S. Department of Commerce's NIST, $3 million from the Department of Energy, and $3.8 million of University and private donor funds. The expansion of the facility enables experiments that were not possible in the adjacent Large-Scale Structures Laboratory (LSSL), alleviates the backlog in projects the lab is currently experiencing, accommodates more students and their projects, and allows for more use of the facility by the local construction industry, other research institutions, and government agencies. The combined capabilities of the new EEL and LSSL provide UNR with one of the largest and most versatile large-scale structures/earthquake/seismic engineering research facilities in the United States, and possibly the largest University-based research facility of its kind in the world. UNR was also part of the NSF-supported NEES operations network 2005 – 2014.

Oklahoma

National Earthquake Technical Assistance Program (NETAP) training was provided in Oklahoma. The courses included *Rapid Visual Screening of Buildings for Potential Seismic Hazards, Post-Earthquake Safety Evaluation of Buildings*, and *Rapid Observation of Vulnerability and Estimation of Risk* (FEMA P-154, ATC-20, and ROVER). More than 100 engineers, architects, emergency managers, and first responders in Oklahoma participated. The training received excellent evaluations and generated more interest in the subject of earthquakes than ever before.

Oregon

The City of Portland, Bureau of Development Services, has developed a new Residential Seismic Strengthening Program to help residents make their homes more secure in the next earthquake. The program is designed to reduce the likelihood of severe damage to homes as a result of displacement from their foundations or crippling of walls in an earthquake. The program provides homeowners and contractors with a simple guide to evaluate existing homes and determine if certain improvements will reduce the risk of earthquake damage.

Oregon has continually supported preparedness and outreach efforts to local communities. More than 271,000 Oregonians participated in the State's 2014 ShakeOut exercise. In addition to preparedness initiatives, Oregon is working on long-term resiliency through the development of the

Oregon Resiliency Plan. The Oregon Seismic Safety Policy Advisory Commission has assembled eight task groups of volunteer subject-matter experts from government, universities, the private sector, and the public to develop the portfolio of chapters that make up the Resiliency Plan.

Puerto Rico

A primary focus in Region II Caribbean Area Division (CAD) was the Blue Surge functional exercise. The exercise, which was based on a catastrophic earthquake and tsunami in the Caribbean, about 90 miles from Puerto Rico, involved the participation of State, Territorial, and Federal agency staff. The objectives for the exercise included the testing of operational coordination and communication, situational assessment, and the management of public and private resources, and requests for resources. Puerto Rico also continued to be actively involved in ShakeOut activities.

South Carolina

South Carolina continued to coordinate and collaborate with State and local government agencies, non-government organizations, and universities to increase the State's readiness for an earthquake. The South Carolina Emergency Management Division (SCEMD) participated in the CAPSTONE-14 Multi-State Exercise as a supporting State for the New Madrid Earthquake States. This collaborative effort marked a critical milestone in the development and implementation of vital systems to greatly improve the collective response to earthquake disasters.

In partnership with the Citadel School of Engineering and FEMA, SCEMD conducted certified training classes: *Rapid Visual Screening of Buildings for Potential Seismic Hazards, Post-Earthquake Safety Evaluation of Buildings*, Reducing the Risks of Nonstructural Earthquake Damage, Home and Business Earthquake Safety and Mitigation, and *Rapid Observation of Vulnerability and Estimation of Risk* (FEMA P-154, ATC-20, FEMA E-74, FEMA P-909, and ROVER). As part of the courses, students put their training into practice with several days of hands-on experience.

South Carolina also participated in the second annual Southeast ShakeOut Earthquake Drill. Approximately 238,000 South Carolinians participated.

Tennessee

Tennessee coordinated the design and development of the multi-State New Madrid Seismic Zone response exercise, CAPSTONE-14. This regional exercise coordinated the work of hundreds of responders from FEMA Regions IV, V, VI, and VII, and developed the concept of State and local jurisdictional responders partnering with private sector assets. During the exercise the partners identified GIS-generated damage assessment information, which could, in a real life emergency, be shared through digital computer platforms. In a real life event the newly developed and tested information could be displayed in a manner that would allow decision makers at multiple levels to quickly determine where Mission-Ready-Packaged (MRP) equipment and personnel were located, thus allowing the equipment to be rushed to the area with the most need.

After nearly twenty years of study and negotiation, the Memphis/Shelby County government approved strengthened commercial seismic building codes which had been passed and recommended by Tennessee State government code officials.

Tennessee also coordinated the establishment of a State-wide volunteer Tennessee Structural Assessment and Visual Evaluation (TNSAVE) coalition to provide training and certification for post-disaster building assessment teams. The TNSAVE goal is to train volunteers so they can help with assessment within Tennessee and also support the post-disaster assessment needs of surrounding States through the Emergency Management Assistance Compact (EMAC) process.

Utah

FEMA and the Utah Department of Emergency Management (UDEM) are continuing their work on a joint FEMA Region VIII and State of Utah Catastrophic Earthquake Plan. Two years prior to the 2012 Great Utah ShakeOut, FEMA and the Utah Division of Emergency Management started gathering detailed data on the resource shortfalls of the State following a major earthquake.

Meetings were held with representatives from city, county, State, and Federal agencies along with some private sector partners. These meetings culminated in the development of the Joint Response Plan that was exercised in a 2012 Full Scale Exercise in Utah. In addition, in 2014 the success of this Joint Response Plan was reported in Utah's state annual Earthquake Program Reports.

Vermont

Vermont activities included the completion of soils mapping for a state-wide earthquake-risk analysis project, planning for mitigation outreach, and completing NETAP training in November. The risk analysis project will be completed primarily by NESEC. The State of Vermont's role is to provide geologic data and expertise to NESEC, and assist with coordination of FEMA and NESEC activities in Vermont this summer. The project will convert surficial geologic data into the NEHRP Soil Classifications A to E, and incorporate the data into HAZUS-MH (computer program for risk assessment and damage estimates) and ROVER, with a focus on critical facilities.

Virgin Islands

FEMA earthquake funding to the U.S. Virgin Islands was used to support and encourage participation in the Great U.S. Virgin Islands ShakeOut. Activities included updates to the ShakeOut web page, press releases, and media advisories, and updates to a calendar of ShakeOut-related events.

Washington

Staff from Washington Emergency Management helped to deliver NETAP training in *Rapid Visual Screening of Buildings for Potential Seismic Hazards (*FEMA P-154), Post-Earthquake Safety Evaluation of Buildings (ATC-20), *Earthquake Mitigation for Hospitals* (FEMA P-767), and *Reducing the*

Risks of Nonstructural Earthquake Damage (FEMA E-74). The courses were taught in Aberdeen, Spokane, Tacoma, and Everett, reaching about 200 participants.

Washington also held State and local tsunami workgroup meetings focused on the design and implementation of vertical evacuation safe havens along the Washington coast; tsunami public education Train-the-Trainer Courses; new public education products; evacuation and assembly area signage; NOAA/National Weather Service Updates; distribution of NOAA weather radios to low income families; training for hospitality industry employees; the Great Washington ShakeOut; and community evacuation drills. More than 864,000 Washingtonians registered for the Great Washington ShakeOut drill - an increase of 150,606 participants from the inaugural Washington ShakeOut in 2012.

Wyoming

Wyoming participated in ShakeOut for the second year, with its own "Great Wyoming ShakeOut". Participation increased more than 500 percent over 2013 (in FY 2013, Wyoming participated in The Great Rocky Mountain ShakeOut). The ShakeOut success was the direct result of more widespread promotional efforts. In addition to county outreach and the dissemination of a variety of promotional materials, the ShakeOut link was also on the Wyoming Office of Homeland Security's website and highlighted via social media. A press release resulted in several follow-up interviews with media outlets around the State.

4.2 Earthquake Consortia and Partners

FEMA worked in close partnership via cooperative agreements with four key earthquake consortia: the Cascadia Region Earthquake Workgroup (CREW), the Central United States Earthquake Consortium (CUSEC), the Northeast States Emergency Consortium (NESEC), and the Western States Seismic Policy Council (WSSPC), to coordinate the FY 2014 State support. The consortia are long-time partners of FEMA and play a valuable role in reducing risks to life and property by providing well-coordinated risk mitigation solutions for earthquakes and other hazards via creative outreach, stakeholder partnerships, and grassroots implementation.

Cascadia Region Earthquake Workgroup

CREW (http://www.crew.org/) is a coalition of private and public representatives in Northern California, Oregon, Washington, and British Columbia working together to improve the ability of communities throughout the Cascadia region to mitigate the impacts of earthquakes and related hazards. CREW supported Washington media partnerships with news outlets across the State of Washington for the 2014 Great Washington ShakeOut.

Central United States Earthquake Consortium

CUSEC (www.cusec.org) partner representatives of eight States (Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee) work with FEMA to reduce earthquake-related deaths, injuries, property damage, and economic losses in the Central U.S.

Among its 2014 efforts, CUSEC led the activities for the Great Central U.S. ShakeOut and the Great SouthEast ShakeOut, which had a combined participation of almost five million. CUSEC was the lead organizer of the 2014 National Earthquake Program Managers meeting in Denver. At that meeting, the managers developed a position paper on the importance of State earthquake management programs that was submitted to the National Emergency Management Association (NEMA). CUSEC was also the lead for the CAPSTONE-14 exercise which many central U.S. States were involved in.

Northeast States Emergency Consortium

NESEC (www.nesec.org) coordinates with eight States (Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont) to develop, promote, and coordinate all-hazards emergency management activities in the Northeast U.S.

NESEC participated in the Great Northeast ShakeOut for the first time, with 290,000 participants in the region. Among other activities, NESEC worked with the Maine Emergency Management Agency to assess earthquake and other hazard vulnerabilities of over 4,000 critical and essential facilities and to assess the locations of dams relative to sources of earthquake ground shaking.

Western States Seismic Policy Council

WSSPC (www.nesec.org) coordinates with thirteen States (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming), three U.S. Territories (American Samoa, Guam, and Northern Mariana Islands), one Canadian Territory (Yukon), and one Canadian province (British Columbia). WSSPC supports and enhances earthquake hazard mitigation by developing and advocating seismic policy options. WSSPC held its calendar year 2014 annual meeting in conjunction with EERI's annual meeting in Anchorage, AK; the EERI meeting commemorated the 50th anniversary of the 1964 Great Alaska earthquake.

Earthquake Engineering Research Institute

EERI is the Nation's leading technical society dedicated to the reduction of risk from earthquakes and is recognized as an authoritative voice for earthquake risk reduction information in the United States. EERI is a national nonprofit, multidisciplinary technical society of engineers, geoscientists, architects, planners, public officials and social scientists. More information on EERI is available at www.eeri.org. EERI organized the 10th U.S. National Conference on Earthquake Engineering (10NCEE) in July 2014 in Anchorage, Alaska, during the 50th anniversary year of the great Alaska earthquake and tsunami, http://10ncee.org/. Over 1100 earthquake professionals participated in the four-day program and proceedings include more than 800 technical papers that were presented at the conference. EERI also organized and ran the 10th Annual Undergraduate Seismic Design Competition at the 10NCEE, with 200 students from 28 universities participating. http://slc.eeri.org/SDC2014_2015.htm

EERI also supported projects for FEMA in four States: Alaska, California, Nevada, and Utah. In Alaska, EERI contracted with an engineering firm to use ROVER for seismic safety evaluations in Mat-Su School District. There were multiple projects in California, but none more timely than the support for the California Earthquake Clearinghouse where EERI serves as vice-chair. With FEMA NEHRP support, EERI was able to establish and manage the South Napa Earthquake Clearinghouse that served more than 100 responders and researchers over a three-day period. The California Geological Survey partnered with EERI in running the field clearinghouse. EERI also built and runs a virtual clearinghouse for the South Napa earthquake at http://www.eqclearinghouse.org/2014-08-24-south-napa/

Federal Alliance for Safe Homes

The nonprofit organization FLASH has been a partner of FEMA's for many years and in FY 2014 helped FEMA support the States and Territories. FLASH is a consumer advocate for strengthening homes and safeguarding families from natural and manmade disasters. They design and develop effective and easy-to-use tools and techniques to foster mitigation behavior change, and forge strategic partnerships with individuals and organizations that share a commitment to earthquake resiliency.

FLASH continued to promote the FEMA *QuakeSmart Business Toolkit*, FEMA P-811 DVD, the *QuakeSmart® Community Resilience Program* and the nonstructural assessment program. FLASH designed and held in-person training events entitled *Business Preparedness Summits* to promote the *QuakeSmart* program. The summits were hosted in partnership with private-sector, nonprofit and government organizations. Additionally, FLASH partnered with Clemson University to develop graduate level curriculum to teach residential building codes to construction, civil engineering and architectural disciplines, including a focus on the purpose and application of residential building codes, as well as the role of codes in disaster-preparedness. Presently, the course is being offered at Clemson and more universities are committed to using it whole or in modules. The course is promoted through the website, http://www.flash.org/buildingcodecourse/.

FLASH continued to administer the Texas State Collaborative (TSC). The members of the collaborative are a wide ranging, diverse group including code officials, flood plain managers, State and local government officials, meteorologists, non-profit disaster response and rebuilding organizations, leading insurers, reinsurers and design-build professionals. In partnership with the TSC members, FLASH completed and distributed Leadership Toolkits for Texas' ten most populous cities.

Southern California Earthquake Center

SCEC, headquartered at the University of Southern California, was founded in 1991 with a mission to: gather data on earthquakes in Southern California and elsewhere; integrate information into a comprehensive and physics-based understanding of earthquake phenomena; and communicate to society at large useful knowledge for reducing earthquake risk. FEMA provides support to SCEC for national ShakeOut coordination and for leading the Earthquake Country Alliance in California.

The ECA is a California-based public-private partnership of people, organizations, and regional alliances, each of which is committed to improving preparedness, mitigation and resiliency. (www.earthquakecountry.org/alliance).

SCEC created the ShakeOut.org website and registration system in 2008 for the first ShakeOut drill in southern California. In FY 2014, more States, Territories and countries joined the ShakeOut, with websites replicated by SCEC in partnership with State and local agencies who recruit participants. With the involvement of many partner organizations, ShakeOut in FY 2014 expanded to include 44 States and U.S. Territories, plus four other countries. In the US, approximately 20 million people registered to participate in the 2014 Annual ShakeOut Earthquake drill. ShakeOut is now an infrastructure for providing earthquake information to the public and involving them in community resiliency, teaching people life-saving response behavior while fostering a sense of community that facilitates further dialogue.

Section 5
NEHRP Response to Major Earthquakes in FY 2014

Worldwide seismicity was lower than average in FY 2014; 11 earthquakes in the range of magnitude 7.0-7.9 occurred and one registering magnitude 8.2 (near Iquique, Chile, on April 1) occurred. This is the lowest annual total of earthquakes magnitude 7.0 or greater since 2008. Earthquakes were responsible for about 664 deaths in 2014, with 617 having perished in the magnitude 6.1 Ludian Xian, Yunnan, China event on August 3, as reported by the United Nations Office for Coordination of Humanitarian Affairs. Deadly quakes also occurred in Chile, Nicaragua, Papua New Guinea, and the United States (see below).

The most significant domestic earthquake occurred 6 miles southwest of Napa, California, on August 24, 2014, at 3:20 AM local time. The magnitude of the event was 6.0 and it was felt throughout central California and east to western Nevada. It has been referred to as the "South Napa" earthquake.

One person was killed and at least 208 people were injured by the earthquake. The event caused severe damage to 150 buildings and moderate damage to 1,000 buildings in Napa County. In Solano County, the earthquake caused severe damage to 10 buildings and moderate damage to 34 buildings. There was minor damage to several roads, several water main and gas line breaks, and disruption of electric and water service in Napa and Solano Counties. Six fires occurred in Napa County, destroying at least 4 buildings.

The City of Napa estimated the earthquake caused at least $300 million in damage to privately owned homes and commercial properties, and $58 million in damage to public infrastructure. Additionally, there was significant widespread non-structural damage (e.g., collapse of overhead lighting, damage to storage shelving, damage to fire sprinkler systems, and destruction of winemaking facilities, etc.) that caused substantial business disruption and additional losses. On September 11, 2014, President Obama issued a Presidential Disaster Declaration, allowing Federal support for the recovery effort.

NEHRP agencies responded immediately, with teams of geologists and engineers arriving later on the day of the event to record and study its impacts; those efforts continued in the weeks following the earthquake. The NEHRP teams worked in close cooperation and collaboration with other teams representing the California Geological Survey, EERI, the Geotechnical Extreme Events Reconnaissance, and other academic and government organizations.

Several reports documenting the Napa earthquake impacts have been released, including FEMA P-1024, *Performance of Buildings and Nonstructural Components in the 2014 South Napa Earthquake*; along with two Recovery Advisories: FEMA P-1024/RA-1, *Repair of Earthquake-Damaged Masonry Fireplace Chimneys*; and FEMA P-1024/RA-2, *Earthquake Strengthening for Cripple Walls in Wood-Frame Dwellings*. A key positive finding of the post-earthquake studies is that several seismic retrofits of older URM buildings were effective in mitigating earthquake damage. With the large number of such buildings in the U.S., this may provide valuable "lessons learned" for future efforts to retrofit them.

Elsewhere in the United States, recently elevated seismic activity continued in central Oklahoma and south-central Kansas. According to the USGS, during FY 2014, 542 earthquakes above magnitude 3.0 occurred in this region. Although none of these events caused significant damage, they generated shaking felt by the local residents. Most, if not all, of these events were induced by the injection disposal into underground rock formations of waste fluids used in oil and gas recovery operations[16]. The USGS is working in cooperation with the Oklahoma Geological Survey and the Kansas Geological Survey in the deployment of temporary seismic equipment to record and study these earthquakes.

[16] See http://earthquake.usgs.gov/research/induced/

Section 6
Related Activities Supporting NEHRP Goals

Public Law 108–360, the Earthquake Hazards Reduction Program Reauthorization Act of 2004, requires that NEHRP's annual report to Congress include a description of activities being carried out by the NEHRP agencies that contribute to program goals, but are not officially included in the program. 42 U.S.C. § 7704(a)(4)(E). Highlights of these programs and activities are described below.

6.1 EarthScope

EarthScope is a multidisciplinary earth science program aimed at exploring, in unprecedented detail, the four-dimensional structure, dynamics, and evolution of the North American continent. EarthScope is supported by NSF, in partnership with the USGS and the National Aeronautics and Space Administration. The EarthScope Facility was composed of three core components: the Plate Boundary Observatory (PBO), constructed and operated by the University NAVSTAR Consortium (UNAVCO); the San Andreas Fault Observatory at Depth (SAFOD), constructed by Stanford University in cooperation with USGS, and operated from 2008-2013 by UNAVCO; and the United States Seismic Array (USArray), constructed and operated by IRIS.

In FY 2013, NSF completed the first of two stages in a plan to integrate elements of the EarthScope Facility with other seismic and geodetic facilities operated by IRIS and UNAVCO. The Geodesy Advancing Geoscience and EarthScope (GAGE) Facility unites PBO and the core geodetic facilities that UNAVCO historically operated and managed, while the Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE) unite USArray and the core seismic facilities IRIS has historically operated and managed. SAGE includes the Global Seismographic Network (GSN), a long-standing component of NEHRP jointly supported by NSF and USGS. In the second stage of this process, NSF intends to issue a solicitation for geophysical facility capabilities to succeed SAGE and GAGE at the end of the current awards in September 2018. NSF has been consulting with the community for several months and expects to issue a solicitation in FY 2016.

The EarthScope Facility has left a legacy of data, operational stations, and physical samples that are all being used for NEHRP-related research and operational activities today. For example, the Central and Eastern United States Seismic Network (CEUSN) project, which began in FY 2013 with funding from NSF and USGS, has converted 160 USArray Transportable Array stations to long-term operations and upgraded the instrumentation and data collection to support critical infrastructure monitoring and other needs. These stations will be jointly supported through FY 2017, at which point their long-term operation is unfunded. These stations greatly increase the density of long-term, continuously recording seismic stations in the region.

EarthScope seismic and geodetic stations in the western United States are being incorporated into nascent EEW systems under development by USGS and its regional network partners. For example, 15 USArray stations have been adopted by the State of Oregon for inclusion in its EEW system, while 12 further stations in California and Washington are being considered for future adoption. In addition, USGS is supporting efforts to incorporate into EEW systems real-time Global Navigation Satellite System (GNSS) data from geodetic stations originally installed as part of PBO, and now operated as part of GAGE.

NSF continues to oversee SAFOD via the EarthScope program, in collaboration with USGS. Since 2009, the USGS has been operating a seismometer immediately above repeating earthquakes at a depth of 3 km, probing the inner workings of the processes that initiate earthquakes on this major plate boundary fault. Through an award to Texas A&M University, NSF supports archiving and distribution of physical samples of the deep fault materials obtained in 2007; researchers around the world are analyzing these samples to understand a variety of physical properties related to fault deformation and earthquake generation. NSF has funded a new research project that will make use of both the main SAFOD borehole and the SAFOD pilot hole; the research team has been working with USGS scientists to refine their plan and gain access to the SAFOD hole beginning in November 2015.

6.2 Subcommittee on Disaster Reduction

The Subcommittee on Disaster Reduction (SDR) is an element of the President's National Science and Technology Council that facilitates the development of national strategies for reducing disaster risks and losses that are based on effective use of science and technology. Mitigating natural and technological disasters requires a solid understanding of science and technology, rapid implementation of research information into disaster reduction programs and applications, and efficient access to diverse information available from both public and private entities. Chartered in 1988, the SDR provides a unique Federal forum for information sharing; the development of collaborative opportunities; the formulation of science and technology-based guidance for policy makers; and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks.

Representatives of NEHRP participate in SDR meetings and provide briefings on program developments. The SDR serves as a forum that NEHRP agencies can use for reaching out to and coordinating with other Federal agencies doing work related to NEHRP goals and objectives.

6.3 International Activities

U.S.-Japan Panel on Earthquake Research

The UJNR Panel on Earthquake Research promotes advanced research toward a more fundamental understanding of the earthquake process and hazard estimation. The 10th joint meeting, which

took place on Sendai, Japan in October 2014, furthered cooperation and deepened understanding of earthquake and tsunami problems common to both Japan and the U.S. The meeting included productive exchanges of information on approaches to systematic observation and modeling of earthquake processes. In view of devastation caused by the earthquake and tsunami of March 2011 off the Pacific coast of Tohoku, the Panel recognized that further efforts are necessary to achieve our common goal of reducing earthquake risk through close collaboration and focused discussions at the 11th UJNR meeting.

U.S.-China Cooperation in Earthquake Studies

Highlights from cooperative research on earthquake hazards reduction with China include the completion of critical upgrades at each of the ten China-U.S. cooperative broadband seismic network stations that are operated in China. The exchange of strong ground motion data continued, with USGS receiving data from several magnitude 6 earthquakes in China. A bilateral workshop on earthquake research was held in California in September 2014 and was attended by a dozen scientists from each country. Two Chinese visiting scholars spent a year at the USGS in Menlo Park, California. In addition, several delegations from the China Earthquake Administration visited the U.S. to review and discuss earthquake research and hazard reduction policies. EEW was a topic of mutual interest and a delegation from China visited the USGS in Menlo Park, California, and the University of California at Berkeley to learn more about U.S. progress on this topic.

U.S.-India Cooperation in Earthquake Studies

Highlights of USGS cooperation with the National Geophysical Research Institute in Hyderabad, India, include studies in the Koyna region, site of the largest confirmed reservoir-induced earthquake. The 1967 Koyna earthquake had a magnitude of 6.3 and claimed about 200 lives and left thousands injured and homeless. The area continues to shake from reservoir-induced earthquakes to this day and has become the target of a major Indian Government project to drill research boreholes into the earthquake producing zone. At the international workshop held in Koyna in May 2014, advice from USGS was critical to the development of the research plan and the proposal now pending with the International Continental Scientific Drilling Program, of which the U.S. is a member. USGS also hosted Indian scientists in the summer of 2014 to further refine the research plan. Drilling of a pair of 3 to 4 km-deep pilot holes is expected to begin in calendar year 2015, and USGS will be scientific partners with the Indians in this effort.

Appendix A
List of Acronyms and Abbreviations

ACEHR	Advisory Committee on Earthquake Hazards Reduction
ANSS	Advanced National Seismic System
AOAM	Agency Operations and Award Management
ASHSC	Alaskan Seismic Hazards Safety Commission
ATC	Applied Technology Council
BART	Bay Area Rapid Transit District
BSSC	Building Seismic Safety Council
CAD	Caribbean Area Division
Cal OES	California Governor's Office of Emergency Services
CEUSN	Central and Eastern United States Seismic Network
CCS	carbon capture and sequestration
CCSD	Clark County School District
CEA	California Earthquake Authority
CO_2	carbon dioxide
CREW	Cascadia Region Workgroup
CRMP	California Residential Mitigation Program
CUSEC	Central United States Earthquake Consortium
DHS	U.S. Department of Homeland Security
ECA	Earthquake Country Alliance
EERI	Earthquake Engineering Research Institute
EEW	earthquake early warning
EMAC	Emergency Management Assistance Compact
FEMA	Federal Emergency Management Agency
FLASH	Federal Alliance for Safe Homes
FY	fiscal year
GAGE	Geodetic Advancing Geoscience and EarthScope
GEER	Geotechnical Extreme Events Reconnaissance
GIS	Geographic Information System
GSN	Global Seismographic Network
HAZUS	Hazards U.S.
HETAC	Hawaii State Earthquake and Tsunami Advisory Committee
I-Codes	International Codes
IBC	International Building Code
ICC	International Code Council
IEBC	International Existing Building Code
INSPARK	INSPect ARKansas Program
IRC	International Residential Code
IRIS	Incorporated Research Institutions for Seismology

MBMG	Montana Bureau of Mines and Geology
MRP	Mission-Ready-Packaged
Mw	moment magnitude
NCJV	NEHRP Consultants Joint Venture
NDRC	"non-ductile" reinforced concrete
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEHRP	National Earthquake Hazards Reduction Program
NEIC	(USGS) National Earthquake Information Center
NEMA	National Emergency Management Association
NESEC	Northeast States Emergency Consortium
NETAP	National Earthquake Technical Assistance Program
NHERI	Natural Hazards Engineering Research Infrastructure
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NWIRP	National Windstorm Impact Reduction Program
OMB	Office of Management and Budget
OSTP	White House Office of Science and Technology Policy
PBO	Plate Boundary Observatory
PCWG	(NEHRP) Program Coordination Working Group
PDM	Pre-Disaster Mitigation
REU	Research Experiences for Undergraduates
ROVER	Rapid Observation of Vulnerability and Estimation of Risk
RVS	Rapid Visual Screening
S&E	Salaries and Expenses
SAFOD	San Andreas Fault Observatory at Depth
SAGE	Seismological Facilities for the Advancement of Geoscience and EarthScope
SAVI	Science Across Virtual Institutes
SCEC	Southern California Earthquake Center
SCEMD	South Carolina Emergency Management Division
SDR	Subcommittee on Disaster Reduction
SESAC	(USGS) Scientific Earthquake Studies Advisory Committee
SSA	Seismological Society of America
TNSAVE	Tennessee State-wide volunteer coalition
UCLA	University of California, Los Angeles
UCONN	University of Connecticut
UDEM	Utah Department of Emergency Management
UJNR	U.S.-Japan Cooperative Program on Natural Resources
UNAVCO	University NAVSTAR Consortium, nonprofit university-governed

	consortium that facilitates geosciences research using geodesy
UNLV	University of Nevada, Las Vegas
URM	unreinforced masonry
USArray	United States Seismic Array
USC	University of Southern California
USGS	U.S. Geological Survey
VOAD	Voluntary Organizations Active in Disaster
WSSPC	Western States Seismic Policy Council