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A REVIEW OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

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A REVIEW OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

TUESDAY, JULY 29, 2014

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:04 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Larry Bucshon [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
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Subcommittee on Research and Technology

A Review of the National Earthquake Hazards Reduction Program

Tuesday, July 29, 2014
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Panel I:

Dr. John R. Hayes, Jr., *Director, National Earthquake Hazards Reduction Program, National Institute of Standards and Technology*

Dr. Pramod P. Khargonekar, *Assistant Director, Directorate of Engineering, National Science Foundation*

Dr. David Applegate, *Associate Director for Natural Hazards, U.S. Geological Survey*

Mr. Roy E. Wright, *Deputy Associate Administrator for Mitigation, Federal Emergency Management Agency*

Panel II:

Dr. Julio A. Ramirez, *Professor of Civil Engineering, NEES Chief Officer and NEEScomm Center Director, George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES), Purdue University*

Dr. William U. Savage, *Consulting Seismologist, William Savage Consulting, LLC*

Mr. Jonathon Monken, *Director and Homeland Security Advisor, Illinois Emergency Management Agency*

Dr. Andrew S. Whittaker, *Professor and Chair, Director MCEER; Department of Civil, Structural and Environmental Engineering, University at Buffalo, State University of New York*

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

HEARING CHARTER

A Review of the National Earthquake Hazards Reduction Program

Tuesday, July 29, 2014
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

On Tuesday, July 29, 2014 the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to examine strengths, weaknesses, challenges, and accomplishments of the National Earthquake Hazards Reduction Program (NEHRP). NEHRP is a cross-agency effort to reduce the long-term risks from earthquakes.

Witnesses

Panel I:

- **Dr. John R. Hayes, Jr.**, Director, National Earthquake Hazards Reduction Program, National Institute of Standards and Technology (NIST)
- **Dr. Pramod P. Khargonekar**, Assistant Director, Directorate of Engineering, National Science Foundation (NSF)
- **Dr. David Applegate**, Associate Director for Natural Hazards, U.S. Geological Survey (USGS)
- **Mr. Roy E. Wright**, Deputy Associate Administrator for Mitigation, Federal Emergency Management Agency (FEMA)

Panel II:

- **Dr. Julio A. Ramirez**, Professor of Civil Engineering, NEES Chief Officer and NEEScomm Center Director, George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES), Purdue University
- **Dr. William U. Savage**, Consulting Seismologist, William Savage Consulting, LLC
- **Mr. Jonathon Monken**, Director and Homeland Security Advisor, Illinois Emergency Management Agency
- **Dr. Andrew S. Whittaker**, Professor and Chair, Director MCEER; Department of Civil, Structural and Environmental Engineering, University at Buffalo, State University of New York

Hearing Overview

Every state has the potential for earthquakes, but "42 of the 50 states have a reasonable chance of experiencing damaging ground shaking from an earthquake in 50 years (the typical lifetime of a building)." [1] Researchers have found that 16 states, which have historically experienced earthquakes with a seismic magnitude of 6 or greater (a "strong" earthquake) on the Richter scale, have a relatively high likelihood of experiencing damage.

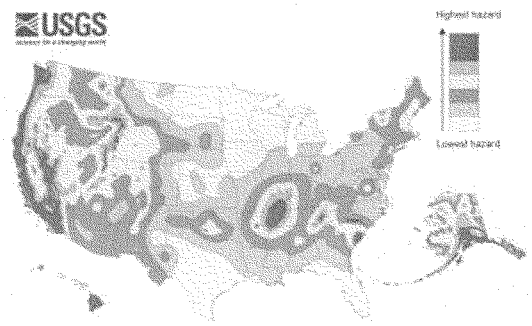
Earthquakes are unique among natural hazards in that they strike without warning compared to hurricanes, tornados, and other storms. Earthquakes proceed as cascades, in which the primary effects of the earth's faulting and ground shaking induce secondary effects such as landslides, liquefaction, and tsunami—which set off destructive processes with manmade structures and the local populace. The death and destruction from strong, major, and great earthquakes (ranging from 6 to 9+ on the Richter scale) can reverberate for decades.

***Update of the United States National Seismic Hazards Maps*[2]**

Earlier this month the USGS updated the U.S. National Seismic Hazard Maps. These maps reflect the current understanding of where earthquakes will occur in the future, how often they will occur, and their severity. Portions of all 50 states are vulnerable to earthquake hazards, although risks vary across the country and within individual states. The hazard is especially high along the west coast, intermountain west, and in several active regions of the central and eastern U.S., such as near New Madrid, MO, and Charleston, SC.

The USGS offers seismicity maps and historical data that can be viewed by region and state at the following sites:

- http://earthquake.usgs.gov/earthquakes/states/seismicity/
- http://earthquake.usgs.gov/earthquakes/region.php



[1] http://www.usgs.gov/blogs/features/usgs_top_story/new-insight-on-the-nations-earthquake-hazards/
[2] http://www.usgs.gov/blogs/features/usgs_top_story/new-insight-on-the-nations-earthquake-hazards/ and http://pubs.usgs.gov/of/2014/1091/

The National Earthquake Hazards Reduction Program (NEHRP)

In 1977, Congress passed the Earthquake Hazards Reduction Act (P.L. 95-124) establishing NEHRP as a long-term earthquake risk reduction program for the United States. The original program focused on research to understand and predict earthquakes. NEHRP's focus was changed in 1990, when Congress decreased the emphasis on earthquake prediction, expanded the program objectives, and required federal agencies to adopt seismic safety standards.

Currently, four federal agencies have responsibility for long-term earthquake risk reduction under the NEHRP program: NIST, FEMA, NSF, and USGS. Program activities are focused on four broad areas: supporting the development of effective earthquake hazard reduction measures; promoting the adoption of these measures by federal, state, and local governments; improving the basic understanding of earthquakes and their effects on people and infrastructure; and developing and maintaining the Advanced National Seismic System (ANSS), the George E. Brown Jr. Network for Earthquake Engineering and Simulation (NEES), and the Global Seismic Network (GSN).

An Interagency Coordinating Committee on Earthquake Hazards Reduction is responsible for the strategic planning, management, and coordination of NEHRP. Each agency's primary responsibilities within NEHRP are as follows:

- **NIST** is the lead NEHRP agency and has responsibility for the planning and coordination of the program. NIST also promotes earthquake resistant design and construction practices through building codes, standards, and construction practices.
- **FEMA** assists other agencies and private-sector groups to prepare and develop earthquake risk modeling tools, and aids the development of performance-based codes for buildings and other structures.
- **NSF** supports basic research to improve the safety and performance of buildings and structures using the research facilities of NEES and other institutions engaged in earth sciences, engineering, and social sciences relevant to understanding the causes and impacts of earthquakes.
- **USGS** conducts research to assess the causes and effects of earthquakes, produces national and regional seismic hazards maps, and monitors and rapidly reports on earthquakes and their shaking intensities in the U.S. and abroad. The USGS maintains the ANSS and the GSN.

National Earthquake Hazards Reduction Program (NEHRP) Funding
(dollars in millions)

Agency	FY09 Authorized*	FY09 Enacted	FY10 Enacted	FY11 Enacted	FY12 Enacted	FY13 Enacted	FY13 Enacted	FY15 Request
NIST	*14.6*	*4.1*	*4.1*	*4.1*	4.1	3.9	3.9	**3.9**
NSF	*64.7*	*56.0*	*55*	*55.3*	*53.2*	*52.2*	*51*	***52.2***
USGS	*88.9*	*61.2*	*62.8*	*61.4*	*59*	*55.6*	*58.7*	***59***
FEMA	*23.6*	*9.1*	*9.0*	*7.8*	*7.8*	*7.8*	*7.8*	***7.8***
Total:	**191.8**	**130.4**	**130.9**	**128.6**	**124.1**	**119.5**	**121.4**	**122.9**

The last year to provide an authorization for NEHRP was fiscal year 2009. The House passed reauthorization legislation (H.R. 3820) in the 111th Congress, but the bill was not considered by the Senate. In the 112th Congress, the Committee on Science, Space, and Technology favorably reported reauthorization legislation (H.R. 3479).

The National Research Council's "National Earthquake Resilience" Report[3]

In 2011, the National Research Council released a report titled "National Earthquake Resilience: Research, Implementation, and Outreach." The report defined earthquake resilience to "encompass both pre-and post-disaster actions that, in combination, will enhance the robustness and the capabilities of all earthquake vulnerable regions of our nation to function adequately following damaging earthquakes."[4]

The report identified 18 tasks ranging from basic research to community-oriented applications to make up a roadmap of goals for NEHRP. Tasks range from conducting additional research on the physics of the earthquake process to conducting collaborative research on earthquake resilient lifeline systems. The report recommended the immediate initiation of these tasks, based on availability of funds. The report further concluded that while the four NEHRP agencies comprise the core for earthquake research, they only constitute a portion of the overall national research enterprise. Other agencies also operate facilities and support research that contributes to NEHRP goals. State and local governments and the private sector play a critical role in the implementation of NEHRP information. "NEHRP will have accomplished its fundamental purpose – an earthquake-resilient nation – when those responsible for earthquake risk and for managing the consequences of earthquake events use the knowledge and services created by NEHRP and other related endeavors to make our communities more earthquake resilient."[5]

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[3] National Research Council, *National Earthquake Resilience: Research, Implementation, and Outreach.* National Academy of Sciences, 2011. http://www.nehrp.gov/pdf/nrc2011.pdf
[4] Ibid, p. 2-3.
[5] Ibid. p. 189.

Chairman BUCSHON. Good morning. The Subcommittee on Research and Technology will come to order.

Welcome to today's hearing entitled "A Review of the National Earthquake Hazards Reduction Program." In front of you are packets containing the written testimony, biographies, and truth-in-testimony disclosures for today's witnesses. I recognize myself for five minutes now for an opening statement.

Earthquakes present a potential hazard to every State in our Nation. The U.S. Geological Survey recently updated its National Seismic Hazards Maps with research identifying that in the next 50 years, 42 of our 50 states have a chance of experiencing damaging ground shaking from an earthquake. There are 16 States in the United States that have a high likelihood of experiencing damage because they have sustained earthquakes with a seismic magnitude of 6 or greater. My home State of Indiana is at risk of experiencing the effects of earthquakes stemming from the New Madrid fault.

Earthquakes are unique among natural hazards because they strike without warning. The cascading nature of an earthquake can induce secondary effects such as landslides, liquefaction, and tsunamis. Earthquakes impact people and communities worldwide from the devastation of loss of life and property to the turmoil caused by the disruption of important services, including water, electricity, and other utilities or lifelines including roads and bridges.

In 1977 the Congress passed the Earthquake Hazards Reduction Act establishing the National Earthquake Hazards Production Program, or NEHRP, as a long-term earthquake risk-reduction program for the United States. Four federal agencies contribute to NEHRP research and activities: the National Institute of Standards and Technology, the National Science Foundation, the United States Geological Survey, and the Federal Emergency Management Agency. Program activities are focused on supporting the development of earthquake hazard reduction measures, promoting the adoption of these measures by federal, state, and local governments, improving the understanding of earthquakes and their effects on people and infrastructure, and developing and maintaining the Advanced National Seismic System, the George E. Brown, Jr. Network for Earthquake Engineering Simulation, or NEES, and the Global Seismic Network.

In Indiana, Purdue University leads the collaborative George E. Brown, Jr. Network for Earthquake Engineering Simulation, or NEES. The mission of NEES is "to accelerate improvements in seismic design and performance by serving as an indispensable collaboratory for discovery and innovation." Support for research and activities that strengthen preparedness for, reduce the impact of, and aid in recovery from earthquakes will fortify the Nation's ability to respond to earthquake hazards.

Today's hearing is a bipartisan effort to learn about NEHRP and understand the Nation's level of earthquake preparedness. We worked across the aisle to bring together two panels of experts who can shed light on these important issues. I look forward to hearing from all the witnesses on both of our panels to understand the

work of the NEHRP agencies and how that work intersects with engineers, emergency managers, and lifeline experts.

[The prepared statement of Mr. Bucshon follows:]

For Immediate Release
July 29, 2014

Media Contacts: Zachary Kurz
(202) 225-6371

Statement of Research and Technology Subcommittee Chairman Larry Bucshon (R-Ind.)
Hearing on A Review of the National Earthquake Hazards Reduction Program

Chairman Bucshon: Earthquakes present a potential hazard to every state in our nation. The U.S. Geological Survey recently updated its *National Seismic Hazard Maps* with research identifying that in the next 50 years, 42 of our 50 states have a chance of experiencing damaging ground shaking from an earthquake. There are 16 states in the U.S. that have a high likelihood of experiencing damage because they have sustained earthquakes with a seismic magnitude of 6 or greater. My home state of Indiana is at risk of experiencing the effects of earthquakes stemming from the New Madrid fault.

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[1] https://nees.org/aboutnees/overview

Chairman BUCSHON. At this point I ask unanimous consent to put two letters in the record regarding the NEHRP program: a letter from the American Society of Civil Engineers and a letter from the BuildStrong Coalition. Without objection, so ordered.

[The information appears in Appendix II:]

Chairman BUCSHON. At this point I now recognize the gentleman from California, Mr. Peters, for an opening statement.

Mr. PETERS. Thank you, Mr. Chairman. Thank you for holding this hearing today on the National Earthquake Hazards Reduction Program, or NEHRP, an unfortunate acronym for an important program. I want to thank witnesses on both panels for being here today.

Though infrequent, earthquakes are unique among natural hazards in that they strike without warning. While areas like my home State of California, in addition to Oregon, Washington, and Alaska, are the most well-known for earthquakes, earthquakes are not a hazard confined to the West Coast. A 2011 earthquake here in Washington, D.C., caused over $200 million in damages, including damage to the Washington Monument and the Smithsonian, and it is estimated that 75 million Americans in 39 States are exposed to significant seismic risk and nearly all states in the United States have some level of risk.

In an effort to mitigate the harmful impacts and better prepare for future earthquakes, Congress authorized the National Earthquake Hazards Reduction Program, an interagency program that includes the National Institute of Standards and Technology, the National Science Foundation, Federal Emergency Management Agency, and the United States Geological Survey.

Since NEHRP was founded in 1977, we have learned a lot about how to prepare for, mitigate, and respond to a large-scale earthquake. Research programs, including ones at the University of California San Diego and San Diego State University, are underway to help us better understand earthquakes, develop safer building construction standards, and ensure that affected communities can respond to and recover from earthquakes as quickly as possible. But more work is needed.

I am pleased we have representatives today from all four agencies here to testify about their activities to reduce the risks of life and property from earthquakes in the United States. I am also pleased that we will hear from outside stakeholders, both private sector and academic, about how the program is working and what if any changes are needed to improve its effectiveness.

As my colleagues may know, the reauthorization of these risk-reduction programs is long overdue. The authorization for this program expired in 2009. Interagency programs like these improve our understanding of earthquakes and then turn that knowledge into mitigation and outreach activities that will save lives and reduce economic damages. While we can't prevent natural disasters, we can do more to lessen the cost to human life and property.

Over the last two years the federal government has spent more than $136 billion, much of it off-budget, on relief for hurricanes, tornadoes, droughts, wildfires, and other extreme weather events. It is time that the government stops working in a reactive way to natural disasters and instead gets to work efficiently to get ahead

of the issue and help States and localities find the best steps to prepare, plan for, and recover more quickly from these events.

We know that for every $1 spent now in resiliency we can avoid at least $4 in future losses. It makes more sense to approach this by thinking how we can make our communities better prepared. If we are focused on reducing spending, let's do it in a way that saves us in the long run.

Mr. Chairman, our goals are the same: to decrease the vulnerability of communities across the country including mine in San Diego. I look forward to working with my colleagues on both sides of the aisle on a bipartisan bill that would reauthorize the National Earthquake Hazards Reduction Program and welcome any comments from the witnesses about changes and updates that should be made to the authorization language.

Thank you, Mr. Chairman, for holding the hearing. I look toward to hearing the testimony, and I yield back the balance of my time.

[The prepared statement of Mr. Peters follows:]

OPENING STATEMENT

Rep. Scott Peters (D-CA)
Subcommittee on Research & Technology
Committee on Science, Space, and Technology

"A Review of the National Earthquake Hazards Reduction Program"

July 29, 2014

Thank you Chairman Bucshon for holding this hearing to review the National Earthquake Hazards Reduction Program or NEHRP. I want to thank the witnesses on both panels for being here today. I look forward to hearing your testimony.

Though infrequent – earthquakes are unique among natural hazards in that they strike without warning. While areas like my home state of California, in addition to Oregon, Washington, and Alaska are the most well-known areas for earthquakes. However, earthquakes are not a hazard that is confined to the west coast. A 2011 earthquake in DC caused over $200 million in damages, including damage to the Washington Monument and Smithsonian. It is estimated that 75 million Americans in 39 states are exposed to significant seismic risk and nearly all states in the U.S. have some level of risk.

In an effort to mitigate the harmful impacts and better prepare for future earthquakes, Congress authorized the National Earthquake Hazards Reduction Program, an interagency program that includes National Institute of Standards and Technology, National Science Foundation, Federal Emergency Management Agency, and United States Geological Survey.

Since NEHRP was founded in 1977, we have learned a lot about how to prepare for, mitigate, and respond to a large-scale earthquake. Research programs, including ones at University of California San Diego and San Diego State University, are underway to help us better understand earthquakes, develop safer building construction standards, and ensure that affected communities can respond to, and recover from, earthquakes as quickly as possible. But more work is needed.

I am pleased that we have representatives from all four NEHRP agencies here today to testify about their activities to reduce the risks of life and property from earthquakes in the United States. I am also pleased that we will hear from outside stakeholders, both private sector and academic, about how the program is working and what, if any, changes are needed to improve its effectiveness.

As my colleagues may know, the reauthorization of these risk reduction programs is long overdue. The authorization for this important program expired in 2009. Interagency programs, like National Earthquake Hazards Reduction Program, improve our understanding of earthquakes and then turn that knowledge into mitigation and outreach activities that will save lives and reduce economic damages.

While we can't prevent natural disasters, we can do more to lessen the costs to human life and property. Over the last two years the Federal government has spent more than $136 billion – much of it off-budget – on relief for hurricanes, tornadoes, droughts, wildfires, and other extreme weather events. It's time that the government stops working in a reactive way to natural disasters and instead gets to work efficiently helping states and localities find the best steps to prepare, plan for, and more quickly recover from these events.

We know that for every dollar spent now on resiliency, we can avoid at least $4 in future losses. It makes more sense to approach this by thinking how we can make our communities better prepared. If we are focused on reducing spending, let's do it in a way that saves us more money in the long run.

Mr. Chairman, my goal is the same yours – to decrease the vulnerability of communities across the country, including mine in San Diego. I look forward to working with my colleagues on both sides of the aisle on a bipartisan bill that would reauthorize National Earthquake Hazards Reduction Program and welcome any comments from the witnesses today about changes and updates that should be made to the NEHRP authorization language.

I want to thank the Chairman for holding this important hearing. I look forward to hearing the testimony and I thank you all for being here today. I yield back the balance of my time.

Chairman BUCSHON. Thank you, Mr. Peters. I now recognize the Ranking Member of the full Committee for a statement, Ms. Johnson.

Ms. JOHNSON OF TEXAS. Thank you very much, Mr. Chairman, for holding this important hearing on the National Earthquake Hazards Reduction Program, or NEHRP. I also want to thank the Chairman of the full committee, Mr. Smith, for agreeing to this hearing. Chairman Smith agreed to hold a hearing on NEHRP and work on the NEHRP reauthorization bill while we were discussing the National Windstorm Impact Reduction Program. This hearing is a good first step in fulfilling that agreement. I want to thank the Chairman and majority staff for working with my staff on putting together this hearing.

Though infrequent, earthquakes are unique among natural hazards in that they strike with little or no warning. In 1964 Alaska was hit with a great earthquake that measured 9.2 in magnitude. That was the second-strongest earthquake in recorded history and resulted in significant damage from both the earthquake itself and the tsunamis that followed.

California has numerous active faults that have produced large earthquakes in the last two decades, from 1971, the San Fernando earthquake to the 1989 Loma Prieta and the 1994 Northridge earthquakes. In fact, NEHRP was established in Congress in response to the 1964 Alaska and the 1971 San Fernando earthquakes.

Since its creation, NEHRP has accomplished a great deal. It has improved our understanding of earthquake processes, improved our earthquake hazard and risk assessments, improved earthquake safety for new and existing buildings, and increased public awareness of earthquake risk and mitigation techniques. But more work is still needed, including improving the earthquake resilience of communities nationwide and developing cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society.

To ensure that this work is accomplished, we need to reauthorize NEHRP, which has not had Congressional authorization since 2009. That is why I am a cosponsor of H.R. 2132, the Natural Hazards Risk Reduction Act of 2013, which was introduced by Representative Wilson last May. H.R. 2132 would reauthorize NEHRP program, as well as the National Windstorm Impact Reduction Program, and would make changes to the Fire Research Program. This legislation is modeled after bipartisan legislation that passed the House by an overwhelming margin in the 111th Congress. And I am pleased that the windstorm program is reauthorized in a separate bill, H.R. 1786, that was introduced by Representative Neugebauer, and I supported that bill when it passed the House earlier this month.

However, I do believe we need to take a multi-hazards approach to disaster mitigation. Taking a multi-hazards approach could create opportunities for synergy among the various research and mitigation activities. Further, a multi-hazard approach could help achieve the goal of producing communities that are resilient to any and all disasters. I hope that as we work on a NEHRP reauthoriza-

tion bill we look for opportunities to create synergies and coordination across the hazards program.

I want to thank the witnesses from both panels for being here today, and it is important to hear from you as we consider reauthorizing this important program. I look forward to your testimony.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT

Ranking Member Eddie Bernice Johnson (D-TX)
Committee on Science, Space, and Technology

Subcommittee on Research & Technology Hearing
"A Review of the National Earthquake Hazards Reduction Program"

July 29, 2014

Thank you, Mr. Chairman for holding this important hearing on the National Earthquake Hazards Reduction Program, or NEHRP.

I also want to thank the Chairman of the full Committee, Mr. Smith, for agreeing to this hearing. Chairman Smith agreed to hold a hearing on NEHRP and work on a NEHRP reauthorization bill while we were discussing the National Windstorm Impact Reduction Program. This hearing is a good first step in fulfilling that agreement. I want to thank the Chairman and Majority staff for working with my staff on putting together this hearing.

Through infrequent, earthquakes are unique among natural hazards in that they strike with little or no warning. In 1964, Alaska was hit with a great earthquake that measured 9.2 in magnitude. That was the second strongest earthquake in recorded history and resulted in significant damage from both the earthquake itself and the tsunamis that followed.

California has numerous active faults that have produced large earthquakes in the last few decades—from the 1971 San Fernando earthquake to the 1989 Loma Prieta and 1994 Northridge earthquakes.

In fact, NEHRP was established by Congress in response to the 1964 Alaska and 1971 San Fernando earthquakes. Since its creation, NEHRP has accomplished a great deal. It has improved our understanding of earthquake processes; improved our earthquake hazard and risk assessments; improved earthquake safety for new and existing buildings; and increased public awareness of earthquake risks and mitigation techniques.

But more work is still needed, including improving the earthquake resilience of communities nationwide and developing cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society. To ensure that this work gets accomplished, we need to reauthorize NEHRP, which has not had Congressional authorization since 2009.

That is why I am a co-sponsor of H.R. 2132, the *Natural Hazards Risk Reduction Act of 2013*, which was introduced by Representative Wilson last May.

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Taking a multi-hazards approach could create opportunities for synergy among the various research and mitigation activities. Further, a multi-hazard approach could help achieve the goal of producing communities that are resilient to any and all disasters. I hope that as we work on a NEHRP reauthorization bill, we look for opportunities to create synergies and coordination across the hazards programs.

I want to thank the witnesses from both panels for being here today. It is very important to hear from you as we consider reauthorizing this important program. I look forward to your testimony.

Chairman BUCSHON. Thank you. Just as a sideline, I have been in three earthquakes myself: one in Southern California in the late '80s; one in Illinois, southern Illinois when I was a kid; and one in Evansville, Indiana, in about 2001. So it is a fairly—if you have never been in an earthquake, it is a fairly unique experience.

At this point if there are Members who wish to submit additional opening statements, your statements will be added to the record.

[The prepared statement of Mr. Lipinski appears in Appendix II:]

Chairman BUCSHON. At this time I would like to introduce our first panel of witnesses. Our first witness today is Dr. John Hayes, Jr. Dr. Hayes is the Director of the National Earthquake Hazards Reduction Program of the Engineering Laboratory at the National Institute of Standards and Technology.

Our next witness is Dr. Pramod—I said this before and now I will get it correct—Khargonekar is the Assistant Director for the Directorate of Engineering at the National Science Foundation. Welcome.

Our third witness is Dr. David Applegate. Dr. Applegate is the Associate Director for Natural Hazards at the U.S. Geological Survey.

And our final witness on the first panel is Mr. Roy Wright. Mr. Wright serves as the Federal Emergency Management Agency's Deputy Associate Administrator for Mitigation.

As our witnesses should know, spoken testimony is limited to five minutes each. I now recognize Dr. Hayes for five minutes to present his testimony.

TESTIMONY OF DR. JOHN R. HAYES, JR., DIRECTOR, NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dr. HAYES. Chairman Bucshon, Congressman Peters, and other Members of the subcommittee, thank you for inviting me to testify as you review the National Earthquake Hazards Reduction Program, or NEHRP, for possible reauthorization.

Mr. Peters, I can assure you that the acronym NEHRP grows on you after a while so it works.

In your invitation to me you asked me to address several topics and I will try to address each one of those briefly in my testimony this morning.

NIST fulfills two broad roles within NEHRP. First, NIST performs statutory lead agency duties, including supporting an Interagency Coordinating Committee and the Advisory Committee on Earthquake Hazard Reduction, drafting and updating NEHRP's strategic plans, submitting annual NEHRP reports to Congress, and fostering interagency coordination and cooperation.

Second, NIST performs applied research related to earthquake engineering, including developing performance-based design tools, guidelines, and standards for practitioners who design buildings to resist earthquake effects.

A 2003 applied Technology Council report identified a major earthquake engineering technology gap between performing basic research and developing earthquake-related provisions for national model building codes and standards. NIST bridges this gap with its Applied Earthquake Engineering Research Program. In 2008 the

NEHRP agencies produced a NEHRP strategic plan which guides NIST's way forward. The National Research Council, or NRC, developed a 20-year action plan for improving U.S. earthquake resilience, and in the process endorsed the NEHRP strategic plan. The Building Seismic Safety Council, or BSSC, formulated recommendations for applied research that point NIST toward addressing the broad research directions that were set by the NRC plan.

NIST research projects address issues identified by leading earthquake engineering practitioners and researchers, as well as the work that was suggested by BSSC in its plan. NIST's research includes significant interactions with the NEHRP partners and continuous engagement with other leading earthquake researchers and practitioners. Alongside FEMA and USGS, NIST participates in the technical committees that develop new building codes and standards. This provides direct access to practicing engineers' needs and facilitates the effective transfer of new knowledge gained through NIST's research back to the practitioners.

NIST's work is subdivided into program elements that includes seismic design technical briefs, codes and standards support projects, structural and geotechnical engineering-related projects, and planning projects that support both NIST and NEHRP-wide activities. Since 2008 NIST has produced approximately 30 reports on these topics that are in widespread use by practitioners and researchers alike. Webinars have also been developed to inform practitioners in the United States and around the world about these tech briefs.

Coordination among the NEHRP agencies fosters synergies that complement agency capabilities. FEMA and USGS work closely on earthquake hazards definitions, hazard mapping, and earthquake monitoring. NIST and FEMA work closely in fulfilling the respective roles for engineering research and implementation and NIST has formed a very special partnership that involves frequent exchanges of project information and in some instances direct collaboration on critical projects. FEMA, USGS, and NIST work closely with NSF-supported researchers to ensure effective transfer of basic research knowledge into NIST's research programs.

In closing, I note that NEHRP was created to address the reality that earthquakes are inevitable and occur without warning. NIST has done much to minimize their consequences but much more needs to be done. The NEHRP agencies translate NIST's research results into actions to ensure that Americans are less threatened by the effects of devastating earthquakes. The NEHRP agencies fulfill unique but complementary roles in a partnership not duplicated elsewhere.

It is also important that I note that the NEHRP family extends well beyond the four NEHRP program agencies to other federal agencies, state and local governments, nongovernmental professional organizations, model building codes and standard organizations, and earthquake professionals both in the private sector and academia. Without these dedicated professionals, the NEHRP agencies could not satisfy the statutory responsibilities.

Thank you again for the opportunity to testify this morning. This concludes my remarks and I am happy to answer any questions that you may have.

[The prepared statement of Dr. Hayes follows:]

Testimony of
Dr. John R. Hayes, Jr.
Director

National Earthquake Hazard Reduction Program (NEHRP)
Engineering Laboratory (EL)
National Institute Of Standards and Technology (NIST)
U.S. Department Of Commerce

Before the
Subcommittee on Research and Technology
Committee on Science, Space, and Technology
U.S. House of Representatives

A Brief Review of NEHRP and the NIST Role in NEHRP

July 29, 2014

Introduction

Chairman Bucshon, Ranking Member Lipinski and other Members of the Subcommittee, on behalf of Secretary of Commerce Penny Pritzker and the Department of Commerce, thank you for inviting me to testify on the current activities of the National Earthquake Hazards Reduction Program (NEHRP), and, specifically, on current contributions of the National Institute of Standards and Technology (NIST) to NEHRP.

My testimony briefly summarizes my perspective as NEHRP Director regarding the statutory four-agency NEHRP partnership that includes the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST) – my home agency, the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). My testimony also briefly summarizes specific activities at NIST that are conducted in support of NEHRP. You will hear in more detail from my partners in the other NEHRP agencies about their ongoing activities.

In the slightly more than three years since I last testified, the U.S. has fortunately continued to experience a relatively quiet period of major seismic activity, though there has been a noteworthy increase in small to moderate earthquake activity in areas where large volumes of waste fluids are being injected in the ground. But, this year brings three milestone anniversaries of devastating U.S. earthquakes – the 1964 Alaska earthquake (50 years), the 1989 Loma Prieta earthquake (25 years), and the 1994 Northridge earthquake (20 years). Earthquake professionals are participating in commemorations of those events that serve as reminders of the devastation and lives lost that can and will occur, summarize progress that has been made in making our Nation safer, and remind us of the great need for us to do more that will make our Nation truly earthquake-resilient. As the seismology experts in USGS often remind us, the question of future major earthquake occurrence in the U.S. is not one of "if," but "when." And, since the last major U.S. earthquakes occurred, our Nation has continued to "urbanize," with more people concentrated in urban areas, which exposes higher portions of the population in earthquake-prone areas, built environment, and commercial activities to devastation from a single large earthquake or other disaster.

While the U.S. has not suffered widespread major earthquake damage in recent years, devastating earthquakes around the world hold significant lessons that can be used to inform our risk mitigation efforts.

The first significant lesson is that mitigation efforts, through such measures as improved building codes, make a significant difference in life safety, which has long been the primary purpose of earthquake-related provisions in U.S. building codes and standards. In 2010, the Haiti and Chile (Maule) earthquakes illustrated the effectiveness of modern building codes and sound construction practices. In Haiti, where such standards were minimal or non-existent, and construction quality was poor, tens of thousands were killed in the collapses of homes and other buildings. In Chile, with much more modern building codes and engineering practices that were

substantially based on U.S. model building codes and standards that have been substantially derived from NEHRP research and development, the loss of life, while still tragic, was far smaller (about 500) despite the fact that the Chile earthquake had a significantly higher magnitude than the Haiti earthquake.

A second lesson, one that is becoming better understood and appreciated, is that major earthquakes (and other natural disasters) that strike areas that are not yet fully prepared for them can have significant long-term deleterious economic impacts. Consider several brief examples:

- The 1995 earthquake that struck Kobe, Japan, severely damaged its major port facilities. What was once one of the world's busiest (top ten) ports, especially for containerized cargo has not regained its pre-earthquake significance almost 20 years later.

- The 2011 earthquake that struck Christchurch, New Zealand, which was "moderate" in terms of its magnitude, caused extensive devastation, much of which was due to older construction and to soil liquefaction. The Christchurch City Centre, or central business district (CBD), was so seriously damaged that it was cordoned off from public access for over two years, and much reconstruction remains to be done for the area to regain its prior vitality. Some estimates postulate that it may take 50 years for Christchurch to recover completely.

- The 2011 earthquake and resulting tsunami that struck Tohoku, Japan, caused tragic death and damage, with the devastation to a major nuclear power facility being the most long-lasting impact.

The "second lesson" shows that the need for local, and indeed national, *resilience*, the ability to recover in a timely manner from the occurrence of an earthquake or other hazard event, is vital. Moving to enhanced resilience goes well beyond the essential, but focused, measure of ensuring life safety in buildings and other locations. Efforts to improve resilience must consider serious cascading failures that will likely extend impacts well beyond immediate damage to individual facilities due to strong shaking. The long-term economic impacts of these tragedies can be crippling, primarily to local economies, but also extending nationally and internationally.

A third lesson is that assuming that we already "know it all" (everything we need to know to mitigate, respond, and recover) is the surest strategy for catastrophe. We still have much to learn about the earthquake hazards we face, as well as the engineering measures needed to minimize the risks from those hazards. Japan and New Zealand are international leaders in seismology and earthquake engineering – we in the U.S. cooperate with our counterparts in both countries, because we have much to learn from one another. Despite their advanced technical knowledge, leaders in both countries were taken aback by the amount of damage that occurred in the events mentioned above.

A fourth lesson that we saw locally in 2011 is that we can sometimes experience damaging earthquakes in areas where they are not taken seriously and for which preparations are therefore

minimal. The earthquake whose epicenter was near Mineral in central Virginia, is believed to be the largest to have struck the U.S. east of the Rockies since the beginning of the 20th century and was unquestionably felt by more people than any previous earthquake in U.S. history. Various damage estimates for the earthquake all show at least $100M in direct damage, and some show damage costs far higher. Iconic structures like the Washington Monument and the National Cathedral were damaged. Even my organization, NIST, experienced minor damage in its main building.

The earthquakes I mentioned above all followed decades or even centuries of little activity on the faults where they struck and are sobering reminders of the unexpected tragedies that can occur. As it continues to gain new knowledge, the USGS updates assessments of earthquake hazards in the U.S. that provide appropriate perspectives for us. In 2008, the USGS, the Southern California Earthquake Center (SCEC), and the California Geological Survey (CGS), with support from the California Earthquake Authority (CEA), jointly forecast a greater than 99% certainty of California's experiencing a M6.7 or greater earthquake within the next 30 years. The 2011 New Zealand earthquake, at M6.3, was slightly less severe than that which is postulated for California. And, the 2010 Chile and Japan earthquakes occurred in tectonic plate collision zones that are very comparable to those which generated the 1964 Alaska earthquake and more ancient earthquakes off the coasts of Oregon and Washington. Seismologists believe that the Chile and Japan earthquakes serve as clear warnings to us for what may occur again someday off the coasts of Alaska, Oregon, and Washington.

While concern for future earthquake activity is always great along our West Coast, the National Research Council has noted in its publications that 39 states in the U.S. have some degree of earthquake risk, with 18 of those having "high" or "very high" seismicity. For example, we know that the New Madrid sequence of earthquakes in 1811 and 1812 included at least four earthquakes with magnitudes estimated at 7.0 or greater centered in the "boot heel" of Missouri, and the 1886 Charleston, SC, earthquake caused widespread damage.

NEHRP was created to address the reality that earthquakes are inevitable and will occur without warning, but that there is much the Nation can do to minimize their consequences. The NEHRP agencies strive to perform needed research and translate the research results into actions that ensure that U.S. citizens are less threatened by devastating earthquakes. The NEHRP agencies work in partnership to perform a national service that cannot be duplicated by others, with each agency fulfilling its unique role without overlapping the roles and responsibilities of its partners. It is helpful to think of the NEHRP agencies and their partners as different organs in one body, vital and complementary. The studies and monitoring of the earthquake hazard cuts across both governmental and commercial boundaries. The research and implementation in both science and engineering by the NEHRP agencies is made possible by the "critical mass" they provide, which would not otherwise be possible if all responsibilities were left to the many states and (for the most part) small corporate entities that work in this field.

However, the NEHRP "family" extends beyond the four partner Federal agencies to include other Federal agencies, state and local governments, non-governmental professional organizations, model building code and standards organizations, and earthquake professionals in the private sector and academia. Without this extended "family" of dedicated earthquake professionals, the NEHRP agencies could not fully fulfill our statutory responsibilities. The earthquake professional "community" is relatively small and tightknit, but it is one of the most dedicated, technically competent, and integrated professional groups in the U.S.

NEHRP Organization, Leadership, and Reporting

NEHRP was established by the Earthquake Hazards Reduction Act of 1977 (Pub. Law 95-124; 42 U.S.C. § 7701 *et. seq.*), as amended by Public Laws 101-614, 105-47, 106-503, and 108-360. One of the great strengths of NEHRP over time has been the partnership that the legislation has fostered between the Legislative and Executive branches. The four NEHRP agencies look forward to continued close partnership with Congress through enactment of new authorizing legislation.

The National Earthquake Hazards Reduction Program Reauthorization Act of 2004 (Pub. Law 108-360), made significant changes to the earthquake hazards reduction program, establishing the NEHRP Interagency Coordinating Committee (ICC) and the external Advisory Committee on Earthquake Hazard Reduction (ACEHR), which continue to provide leadership to the program.

Interagency Coordinating Committee

The ICC has provided NEHRP leadership since 2006. This has resulted in a significant increase in program visibility in each agency and in the Executive Office of the President and has elevated key interagency decisions directly to the agency leader level. The direct involvement of, and interactions among, the agency leaders has improved program coordination and efficiency.

The ICC oversaw the development of the new NEHRP Strategic Plan that was released in October 2008, remaining engaged with its entire development. The ICC also oversees the development of NEHRP's annual reports, which summarize major activities of the Program.

Advisory Committee on Earthquake Hazards Reduction

By statute, the ACEHR assesses "trends and developments in the science and engineering of earthquake hazards reduction," as well as the effectiveness of the NEHRP Program in carrying out Program activities. The ACEHR also assesses Program management, coordination, implementation and activities, and the need for Program revision. The ACEHR first met in 2007, and consists today of 16 leading earthquake professionals from across the U.S., from all

walks of the non-Federal earthquake practitioner sector. The NEHRP agencies consider the ACEHR's expert advice as they formulate and implement their programs. In fact, the ACEHR is key in providing strategic vision to ensure that the NEHRP agencies align their efforts to address the most pressing issues concerning earthquake hazard assessment and risk mitigation.

Lead Agency

Public Law 108-360 designated NIST as the NEHRP Lead Agency with primary responsibility for planning and coordinating the Program. Lead Agency responsibilities are performed by the NEHRP "Secretariat" at NIST and include supporting the NEHRP Interagency Coordinating Committee (ICC) and the Advisory Committee on Earthquake Hazards Reduction (ACEHR); drafting and updating NEHRP strategic plans; submitting annual reports to Congress on NEHRP activities; and fostering interagency coordination and cooperation at the working level. NIST performs this work via a small in-house staff that is supplemented as needed by a contractor who provides administrative support; NIST also receives assistance from the other NEHRP agencies, especially from USGS, with routine Secretariat work. While NIST "leads" NEHRP activities, it is only with the teamwork of all the agencies working together under well-defined roles and responsibilities that NEHRP accomplishments occur. There is a genuine sense of common purpose, professionalism, and dedication to improving earthquake safety and resilience among the agency representatives, all of whom have worked together since my arrival at NIST in 2006.

NEHRP Strategic Plan

Public Law 108-360 required that the NEHRP agencies develop a new Strategic Plan. The agencies developed the Plan, starting with internal reflection supplemented by inputs from the earthquake professional community. Following over a year of comprehensive work, the agencies released a new Strategic Plan in 2008. The Strategic Plan presented a new NEHRP vision for our Nation:

A Nation that is earthquake-resilient in public safety, economic strength, and national security.

This vision recognizes the importance of not only improving public safety in future earthquakes but also enhancing national economic strength and security. The vision highlighted the need for improving our national *resilience* in future damaging earthquakes. The NEHRP vision was one of the first recognitions of the vital national need for achieving *resilience*, which requires coordinated application of mitigation, redundancy, robustness, and response and recovery activities.

The Strategic Plan set three overarching program goals that involve synergies among the agencies:

- Improve understanding of earthquake processes and impacts (basic research);

- Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large (applied research and development); and,
- Improve the earthquake resilience of communities nationwide (knowledge transfer and implementation).

The Plan also outlines nine areas of *strategic priority* for the program, areas of great importance to the Nation that will be emphasized more prominently *as resources become available to address them*: fully implement the Advanced National Seismic System (ANSS); improve techniques for evaluating and rehabilitating existing buildings; further develop performance-based seismic design (PBSD); increase consideration of socioeconomic issues related to hazard mitigation implementation; develop a national post-earthquake information management system; develop advanced earthquake risk mitigation technologies and practices; develop guidelines for earthquake-resilient lifeline components and systems; develop and conduct earthquake scenarios for effective earthquake risk reduction and response and recovery planning; and, facilitate improved earthquake mitigation at state and local levels. The strategic priorities are essential to NEHRP's vision of moving the Nation towards greater earthquake resilience.

NEHRP Operational Structure

While it would be very difficult to characterize all of the NEHRP agency interactions graphically, Figure 1 (following page) provides a "snapshot" of many of the scientific and engineering interactions among the agencies needed to accomplish the NEHRP mission. Because each NEHRP agency is providing an overview of its specific activities during this hearing, I will only provide a brief summary here regarding agency roles and responsibilities.

USGS

The USGS is the applied earth science component of NEHRP. USGS delivers rapid characterization of earthquake size, location, and impacts; develops seismic hazard assessment maps and related mapping products; builds public awareness of earthquake hazards; supports targeted research to improve monitoring and assessment capabilities, and leads the NEHRP agencies' post-earthquake investigations. This brief statement is misleadingly short, because it covers so much activity and major contribution. USGS is also moving ahead with major new activities in assessing issues related to possible seismicity induced by the injection of large volumes of waste fluids into the ground during oil and gas recovery operations, and to working with other parties to initiate earthquake early warning activities for the U.S.

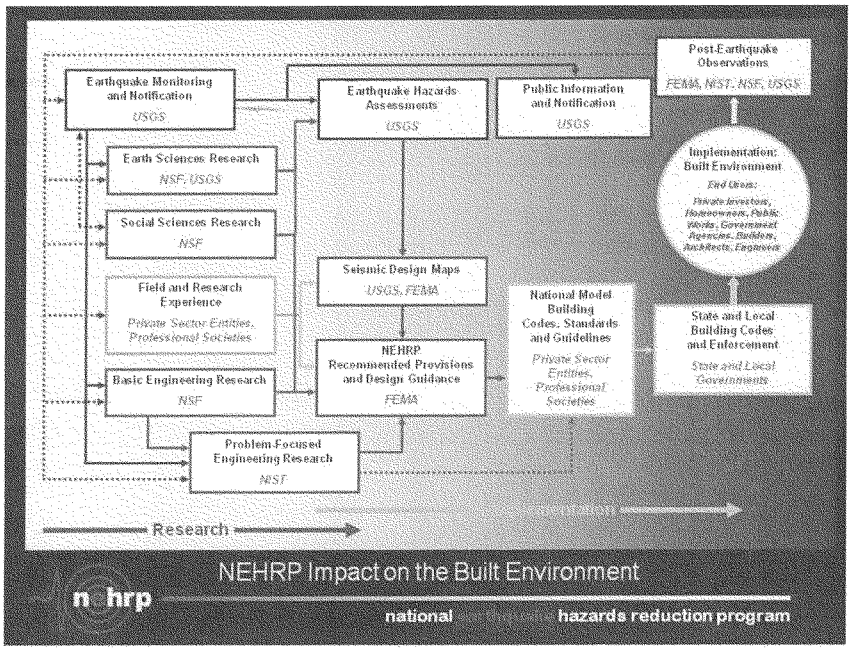

Figure 1. Primary NEHRP Activity Areas

NSF

NSF is NEHRP's primary basic research arm, supporting research that addresses earth science, geotechnical and structural engineering, lifeline engineering, and the social sciences, and integrating those disciplines. As a part of its support for basic research, NSF has provided resources to support operation of the 14 world-class experimental research facilities and cyber infrastructure in the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), which is now nearing the end of its initial ten year operational life. In addition to providing the basic research component of NEHRP, NSF supports the education of future generations of earthquake professionals across the Nation.

NIST

NIST's technical role in NEHRP is chiefly one of linking the basic research products that come from NSF-supported university research with the implementation activities that are largely led by FEMA. NIST's "linking" role primarily involves performing applied research. Such research translates and transfers the engineering products of basic research activities at major national

universities into tools that can be used directly or indirectly in building codes and standards, and in engineering practice. The NIST role is covered in more detail later in this testimony.

FEMA

FEMA is NEHRP's primary implementation and outreach arm. FEMA has the NEHRP leadership role in working with the practitioner community, the American Society of Civil Engineers (ASCE), and the International Code Council (ICC) to support the development of model building code and standards provisions that form the basis for most state and local building codes in the U.S. This work that results in development, publication, dissemination, and promotion of building design and construction materials is where much of NEHRP's "rubber meets the road."

To support and increase the adoption of NEHRP earthquake resilience measures, FEMA leads NEHRP efforts to maintain strong partnerships with other earthquake and hazards-related agencies, state and local governments, academia, the research community, code enforcement officials, design professionals, and the remainder of the private sector.

In addition to portraying graphically many of the activities on the NEHRP agencies, Figure 1 emphasizes that NEHRP is incomplete without the significant contributions made by those outside the four agencies. The non-Federal earthquake community has been and remains a major factor in the historic success of NEHRP.

In addition to benefitting from the efforts of non-Federal players in the U.S., the NEHRP agencies work within their designated mission areas to foster appropriate ties to the international earthquake professional community. Not only can NEHRP-developed technologies be applied to help others, but the U.S. can learn from advances that are being made abroad. Members of NEHRP agency staffs, allied with the greater U.S. earthquake community, remain engaged with the international community in sharing information, methodologies, and technologies.

NEHRP Interactions with the Multi-hazard Community

In 2008, the Earthquake Engineering Research Institute (EERI) released a unique and informative report, *Contributions of Earthquake Engineering to Protecting Communities and Critical Infrastructure from Multihazards*. This report was commissioned by FEMA, and it addresses NEHRP-related activities. The report makes clear that its purpose was essentially two-fold. At one level, the report was formulated to inform the earthquake community, as well as the general public, of the leadership that has already been provided by NEHRP and those associated with it in improving "civil infrastructure and community resilience," and thus the "importance on long-lasting benefits of programs made possible through NEHRP." However, at a second, forward-looking, level, the report was written to "help define and encourage leadership." The report notes that leadership in earthquake engineering, largely involving NEHRP, sets a high

standard of performance. The report also notes that "future performance will be viewed increasingly in a multi-hazard context."

The NEHRP agencies have long fostered synergies among many diverse but necessarily interrelated disciplines to improve earthquake safety. Moving forward, the NEHRP agencies will seek new synergies with those who work to mitigate risks associated with other hazards (*e.g.*, wind, flood, and fire). This will be complex – while the ultimate goals of improved safety and resilience are common across hazards, there are similarities, differences, and linkages among the hazards that are being worked out in the multi-hazard community. Most of the technical issues that are tied to monitoring hazard occurrence, assessing the resulting risks, and developing tools, standards, and guidelines for design and construction differ substantially from hazard to hazard. However, there are opportunities for the coordination of NEHRP activities with those that have parallels for other hazards. The 2008 EERI report provides a good start on considering some of those opportunities, and the NEHRP agency leaders hope to strengthen multi-hazard synergies across both technical and organizational lines in the future.

NIST Activities within NEHRP

NIST "wears two hats" within NEHRP.

First, NIST performs statutory Lead Agency duties for the NEHRP. These Program-wide activities were described in more detail previously in this testimony.

Second, NIST performs applied research to develop and deploy advances in measurement science related to earthquake engineering - including performance-based tools, guidelines, and standards for designing buildings to resist earthquake effects and improve building safety; and to enhance disaster resilience of buildings, infrastructure, and communities. NIST NEHRP applied research develops the scientific basis required to enable technological innovation, improve predictive capabilities, and improve building codes, standards, and practices for the cost-effective improvement of disaster resilience, including life-safety and reduction of property loss and economic disruption.

After a number of years of reduced earthquake engineering research activity, NIST began rebuilding its earthquake research program in 2006. A 2003 Applied Technology Council (ATC) report, *The Missing Piece: Improving Seismic Design and Construction Practices* (ATC 57), identified a major technology transfer "gap" between the basic earthquake-related research supported by the National Science Foundation (NSF) and the efforts of the Federal Emergency Management Agency (FEMA) to assist in developing earthquake-related provisions of national model building codes and standards. The ATC report highlighted this gap as a serious national deficiency that hampers transferring new technologies into design and construction, which is manifested by a lack of measurement science in several key areas of engineering for both new

and existing buildings, as well as for lifelines (*e.g.*, transportation networks, water and sewer supply and distribution, energy supply and distribution, communications and data transfer).

The last point is becoming particularly important. As national leaders realize the need for improved resilience with respect to all hazards, the criticality of lifeline resilience in sustaining quality of life and economic strength will become more prominent. The Nation's infrastructure is aging and, in many areas, deteriorating. Maintaining the serviceability of lifeline systems is critical to societal resilience, and the interconnectedness of separate (not independent) lifeline systems is a major factor in their serviceability and in societal resilience.

NIST set out to "bridge" the technology transfer gap with an applied earthquake engineering research program that was formulated with the NEHRP partner agencies and with leading researchers and practitioners in a multi-step process. First, the NEHRP agencies jointly developed the *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009-2013*, which was briefly describe earlier in this paper. In 2011, the National Research Council (NRC) completed a NIST-commissioned study that produced a twenty-year "roadmap" for improved U.S. earthquake resilience, *National Earthquake Resilience: Research, Implementation, and Outreach*. The roadmap endorsed the broad goals and objectives of the NEHRP Strategic Plan and provided a comprehensive perspective on accomplishing the Strategic Plan goals and objectives that was developed by leading North American earthquake professionals outside the Federal agencies. Following the release of the NRC report, NIST commissioned the Building Seismic Safety Council (BSSC) to develop a ten-year research roadmap for recommended NIST-specific research that encompasses the ATC 57 philosophical goals, the NEHRP Strategic Plan, and the broad research directions set by the NRC study. BSSC released this roadmap report, *Development of NIST Measurement Science R&D Roadmap: Earthquake Risk Reduction in Buildings* (NIST GCR 13-917-23) in early 2013.

Electronic files (Adobe pdf format) of all the reports mentioned above are available on the NEHRP web site (www.nehrp.gov).

From 2006 through 2013, individual NIST NEHRP research projects followed the "ATC 57 roadmap philosophy" and satisfied needs that were identified by leading earthquake engineering practitioners and researchers in various national publications and validated through interactions with engineers who are actively developing national standards for seismic design, primarily the American Society of Civil Engineers (ASCE) Standard, *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 7-10), which forms the basis for the structural design provisions for the most widely recognized U.S. model building code, *The International Building Code*. The 2013-2014 NIST NEHRP program began a transition to the BSSC roadmap work and this transition continues for FY 2014. Key features of the ongoing and proposed work are significant interactions with the partner NEHRP agencies, integrated analytical and experimental research, and continuing engagement with leading earthquake researchers and practitioners in the private sector and in academia. In addition, NIST memberships in the BSSC Provisions Update Committee (which is supported by FEMA and USGS); the American Society of Civil

Engineers/Structural Engineering Institute (ASCE/SEI 7) Seismic Subcommittee; ASCE Standards Committee on Evaluation and Retrofit of Existing Buildings (ASCE/SEI 41); and corresponding American Concrete Institute (ACI) and American Institute of Steel Construction (AISC) technical committees brings the latest technical ideas to the NIST program. These same memberships also facilitate more effective transfer of new knowledge gained through NIST research into the practitioner community.

The ATC 57 report also recommended that NIST continuously engage the earthquake engineering research and practitioner communities in its activities, to ensure effective knowledge transfer into and out of NIST. To implement this, NIST R&D is performed through a partnership of core in-house and world-class extramural expertise. The contractor partnership affords NIST access to leading, world-class U.S. and, on occasion, international earthquake researchers and practitioners within the required technical disciplines. Since 2007, NIST has accomplished its research through two task order contracts, first with the NEHRP Consultants Joint Venture (NCJV), and then with the Applied Technology Council (ATC). In the life of the two contracts to date, 243 individual consultants (leading practitioners and researchers, outstanding graduate students) have filled 473 research positions in 38 research task order projects for NIST. The work in those projects has directly contributed to 27 PhD dissertations or MS theses around the U.S. In addition, the NIST engagement has provided technical information for application by graduate students in their research and by practitioners around the U.S. and the world.

Paralleling the BSSC-recommended approach, the NIST NEHRP program is subdivided into five complementary research program elements:

- Program Element 1: *Improved Building Codes and Standards Provisions.* Program Element (PE) 1 consists of short-term practical, applied research projects that improve seismic design practice and building standard and code development. National model building codes contain prescriptive seismic provisions, many of which have evolved from practitioner experience, without specific research results to substantiate them, and PE 1 is devised to provide those research results.

- Program Element 2: *Performance-Based Seismic Engineering (PBSE) for New and Existing Buildings.* PE 2 emphasizes developing the technical basis for performance-based seismic engineering (PBSE) and focuses on developing metrics for measuring performance and acceptance criteria for different performance objectives. A major factor in PBSE is the requirement for performing accurate nonlinear analysis of building performance during different earthquake shaking intensities, which enables more cost-effective and creative design approaches than those possible by applying the prescriptive rules that are predominant in current building codes.

- Program Element 3: *Lateral Force-Resisting Structural Elements and Systems.* PE 3 focuses on developing higher fidelity models for predicting the seismic performance of Lateral Force-Resisting Structural Elements and Systems through experimental and/or

experiential validation. PE 3's primary goal is to improve seismic engineering practice via performing and analyzing laboratory testing.

- Program Element 4: *Tools and Guidelines for Improved Earthquake Engineering Practice.* PE 4 develops synthesis documents, most of which are known as "techbriefs," that distill research findings, findings of professional committees and task groups, and cost-effective and code-compliant detailing practices into forms usable by practitioners. Techbriefs have been produced extramurally at the rate of one or two per year. The techbriefs that have been produced to date have been received most positively by practitioners and educators. Practicing engineers keep the reports on their desk as direct references in their design work. Educators use the techbriefs as information sources in their classes – this is particularly true for graduate classes.

- Program Element 5: *National Earthquake Hazards Reduction Program (NEHRP) Coordination.* PE 5 supports all activities of the NEHRP "Secretariat", which was described previously in this paper. The Office also supports NIST's role as lead agency for the U.S.-Japan Cooperative Program in Natural Resources (UJNR) Panel on Wind and Seismic Effects and the federal Interagency Committee on Seismic Safety in Construction (ICSSC).

Program Elements 1-4 address major topical areas of earthquake engineering research for improved design and construction of new and existing buildings, with primary emphasis now placed on research related to new buildings. Research in the existing buildings area will ultimately be needed to support earthquake resilience in communities, since a large percentage of the existing building stock will remain in use. Similarly, research in the lifelines area will be needed in the future to support community earthquake resilience. NIST has funded a lifelines research and implementation road-mapping effort with the Applied Technology Council that should be completed by the end of FY 2014. That effort is showing the criticality of lifelines to ensuring community resilience across all hazards, natural and man-caused, not just earthquakes.

Given the unique and fundamental nature of the necessary interaction between FEMA and NIST in fulfilling their respective roles, the two agencies have formed a special partnership with their programs that involves complete, frequent exchanges of project information and in some instances actual direct collaboration on critical projects that involve complementary topic areas. A current example of the partnership in action is FEMA and NIST are cooperating on structural engineering research and implementation projects that support work underway in Los Angeles involving older nonductile ("brittle") concrete buildings; the Los Angeles work also involves earlier work funded by NSF and ongoing work by USGS in directly supporting the City of Los Angeles.

Practical Observations on Possible NEHRP Reauthorization Legislation

Finally, i will offer some personal thoughts on possible reauthorization legislation for NEHRP. I provide the following brief general reflections on implementing Public Law 108-360, which has guided the NEHRP agencies since my arrival at NIST in early 2006. I intend my remarks to be constructive in continuing the NEHRP partnership.

In recent years, both the House of Representatives and the Senate have considered new reauthorization language. Rather than assessing any of those bills that we have seen, I shall focus on Public Law 108-360.

First, the agencies will welcome the reinvigorated partnership with the Legislative Branch of our government that reauthorization would reflect. This program, which has existed for over 35 years, is vital to all aspects of improving earthquake safety in our Nation. Earthquakes cross state boundaries, so that state-Federal partnership is vital. Solutions to earthquake-related problems can best be handled in a coordinated manner that crosses those boundaries. In addition, the engineering community that addresses almost all earthquake problems is composed of many small entities, not corporate giants, so that private sector mass is simply inadequate to address major challenges in hazard assessment and research. Federal leadership is critical to this endeavor.

Second, as a practical matter for clarity of Congressional authorization for major natural hazard assessment and risk mitigation activities in the government, I believe it is most sensible to combine the legislation for the different hazards into a single bill. Particularly when the growing interests in broader resilience and multi-hazard activities are considered, a single authorization would enable the most efficient implementation of Congress's intent.

Next, allow me to address a number of NEHRP operational issues:

The creation of the Interagency Coordinating Committee (ICC) is a strength of Public Law 108-360, facilitating the exchange of information and fostering senior level coordination among the agencies. However, the experience we have gained since 2006 indicates that the requirement for agency leaders to meet thrice yearly is impractical, given the leaders' busy schedules and work demands. An alternative goal is keeping the ICC as a body alive and planning one scheduled meeting per year for those leaders, with other meetings called on an as-needed basis, possibly for leaders' designated representatives. And, since there has been a discussion of creating a "combined" ICC that joins the senior leaders of both the NEHRP and the National Windstorm Impact Reduction Program (NWIRP) agencies, the manner in which the ICC is organized bears re-consideration.

The creation of the Advisory Committee on Earthquake Hazards Reduction (ACEHR) is another genuine strength of Public Law 108-360. The ACEHR should be continued, with its providing biennial reports to the ICC Chairperson (NIST Director) on the "state of NEHRP" also continued. NEHRP has also set a policy of including the Chairperson of the USGS Scientific

Earthquake Studies Advisory Committee (SESAC) as an *ex-officio* member of the ACEHR. Paralleling the ongoing consideration of a "combined" ICC, some effort to examine the "pros" and "cons" of having an advisory committee that jointly addresses both NEHRP and NWIRP, as opposed to separate advisory committees for the two programs, might be considered. Issues to be weighed include efficiency of managing advisory committee logistics, provision of multi-hazard perspectives, and level of focused technical depth for each hazard area.

The ICC and indeed NEHRP are required by Public Law108-360 to produce two documents, a Strategic Plan and an Annual Report. NEHRP produced its Strategic Plan in late 2008 and initially labelled it as a plan covering FY 2009-FY 2013. As has been mentioned above, the earthquake community in general and the National Research Council (NRC) in particular have strongly endorsed the Plan for its strategic direction. The NRC laid out a 20-year "roadmap" for earthquake research and implementation work, essentially endorsing the Plan as a long-range document. With this in mind, it would be wise to consider the need for periodic reviews of the Plan, with accompanying updates, as opposed to creating a completely new Plan in the near term.

Prior to the enactment of Public Law 108-360, the NEHRP agencies had been required by statute to produce a biennial report on NEHRP activities, but Public Law 108-360 increased the requirement to annual reporting. Given the substantial effort required to produce an informative report covering four agencies' activities, a return to biennial reporting is a cost-effective measure to consider. Recognizing the interest in both Congress and the public-at-large in knowing the NEHRP agencies' budgets, it would be realistic to continue reporting budget data annually.

As a part of the basic annual report requirement, Public Law 108-360 requires that the report be submitted at the time each year when the President submits the annual budget request. It would be beneficial to weigh the merits of the current annual reporting requirement against a less frequent reporting requirement. For example, prior to Public Law 108-360, NEHRP reports were statutorily required on a biennial basis. This consideration is one of balancing effort required to develop these reports with frequency of Congressional need for Program updates. Regardless of the required frequency of reports, a "due date" that is a reasonable time period after the President's budget request submission would be helpful to the agencies in collecting data and developing a well-structured report.

Closely tied to the annual reporting requirement is the requirement in Public Law 108-360 for the NEHRP agencies to "coordinate" their budgets. It would be helpful for Congress to clarify its direction to the agencies on this point. Given the many complexities of the appropriations process, it seems likely that the original intent of the current requirement was really intended to focus on *Program* coordination, rather than budget coordination, both to avoid duplications of effort and to maximize leveraging of agency efforts

Public Law 108-360 contains language that designates USGS as the NEHRP Lead Agency for post-earthquake investigations. NIST believes that USGS is best qualified among the NEHRP agencies to fulfill that role. Its expertise, experience, strategically placed geographic locations for

its offices, and well-established relationships with critical state offices are key to rapid engagement following future U.S. earthquakes. In addition, its international focus gives USGS established relationships with its peers around the world, thus enabling rapid contact and deployment, almost regardless of location. In the end, all of the NEHRP agencies will work together on future post-earthquake investigations, but we strongly believe leadership for future investigations is best provided by USGS.

An important feature of Public Law 108-360 was the statement of congressional support for major NEHRP-related research and monitoring systems, such as the Advanced National Seismic System (ANSS), Global Seismographic Network (GSN), and the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). Past reports of the NEHRP ACEHR (see http://www.nehrp.gov/committees/reports.htm) have provided assessments of these systems, as well as of other features of NEHRP.

There have been numerous technical and policy developments in the years since Public Law 108-360 was enacted. These include a growing national focus on resilience in natural disasters – restoring normality with a minimum of social and economic disruption. In considering NEHRP re-authorization, Congress may wish to review and comment on relevant resilience-related topics such as evaluation and strengthening of existing buildings, functionality of lifelines, earthquake early warning, and the interaction of the social sciences with research and implementation work in the more traditional engineering fields.

Conclusion

Recent earthquakes serve to remind us of their episodic nature – especially their inevitability and unpredictability. There is nothing we can do to stop them. But the impacts of earthquakes, while not completely avoidable, can be greatly reduced. The NEHRP agencies and their partners, given comprehensive direction by Congress, have accomplished much in hazard assessment and risk mitigation since the 1970's. The NEHRP agencies stand ready to continue their work to improve the resilience of our country.

Chairman Bucshon, Ranking Member Lipinski and other Subcommittee members, thank you again for the opportunity to testify on NEHRP activities. This concludes my remarks. I shall be happy to answer any questions you may have.

Dr. John (Jack) R. Hayes, Jr. is the Director of the National Earthquake Hazards Reduction Program (NEHRP) of the Engineering Laboratory (EL) at the Department of Commerce's National Institute of Standards and Technology (NIST). Dr. Hayes joined NIST in early 2006. NEHRP is the Federal government's program to reduce risks to life and property from earthquakes. As director, Dr. Hayes provides overall program management, coordination and technical leadership; strengthens program effectiveness by facilitating implementation of earthquake risk mitigation measures; and builds and maintains effective partnerships with NEHRP program agencies and stakeholders in industry, academia and government. Dr. Hayes also leads in-house NIST efforts to perform earthquake engineering research in support of NEHRP.

Dr. Hayes joined NIST after serving as leader of seismic and structural engineering research at the U.S. Army Engineer Research and Development Center's (ERDC) Construction Engineering Research Laboratory (CERL) in Champaign, IL, from 1988 until early 2006. At CERL, Dr. Hayes was actively involved in earthquake engineering research for the U.S. Army Corps of Engineers. He also collaborated extensively with the earthquake engineering program at NSF, including work within the Mid-America Earthquake Center, and was directly involved with a number of significant earthquake mitigation projects for FEMA. Working with key personnel at USGS, Dr. Hayes helped develop the seismic provisions for the American Society of Civil Engineers' ASCE 7-05 standard and a new Department of Defense tri-services seismic design manual.

Prior to his tenure at CERL, Dr. Hayes was Research Civil Engineer and Senior Scientist at the Engineering Research Division of the U.S. Air Force Engineering and Services Laboratory (1984-1988); Structural Engineer at the U.S. Air Force Armament Division (1982-1984); Assistant Professor of Civil Engineering at the Virginia Military Institute (1980-1982); Civil Engineer and NATO Infrastructure Staff Officer at the Headquarters U.S. Air Forces in Europe (1977-1980); and Civil Engineer Officer at Tinker AFB, OK (1975-1977). Dr. Hayes is a retired U.S. Air Force Lieutenant Colonel and is a registered Professional Engineer in Virginia.

Education: University of Illinois at Urbana-Champaign, Ph.D., Civil Engineering, 1998; University of Virginia, M.E. (Tau Beta Pi), Civil Engineering, 1975; Virginia Military Institute, B.S. (Distinguished Graduate), Civil Engineering, 1973.

Chairman BUCSHON. Thank you, Dr. Hayes.

I now recognize Dr. Khargonekar for his testimony.

TESTIMONY OF DR. PRAMOD P. KHARGONEKAR, ASSISTANT DIRECTOR, DIRECTORATE OF ENGINEERING, NATIONAL SCIENCE FOUNDATION

Dr. KHARGONEKAR. Chairman Bucshon, Ranking Member Lipinski, and other distinguished Members of the Subcommittee, it is my pleasure to be able to testify before you today on the topic of National Science Foundation's activities in earthquake hazards reduction. I am Pramod Khargonekar, Assistant Director for Engineering at NSF.

Since the start of NEHRP, NSF has supported a broad range of fundamental research in geosciences, engineering, and social sciences relevant to the understanding of the causes and impacts of earthquakes. The Foundation also provides support for education of new scientists and engineers, the integration of research and education, and outreach to professionals and the public. Today, I would very briefly like to outline NSF's NEHRP efforts related to facilities, research, and coordination.

NSF funds three distributed multiuser national facilities that support critical fundamental research relevant to NEHRP. The George E. Brown, Jr. Network for Earthquake Engineering Simulation, or NEES, the Geodesy Advancing Geosciences and EarthScope, or GAGE, and the Seismological Facilities for the Advancement of Geoscience and EarthScope, or SAGE.

NEES currently provides access to 14 earthquake simulation experimental facilities located in eight States. The NEES facilities include shake tables, large-scale labs, geotechnical centrifuges, field testing equipment, and a tsunami wave basin. NEES operations are currently supported through an award to Purdue University covering the fiscal years 2010 to 2014. Following 2014, NSF has updated its strategy for the future of NEES operations, which will include NSF support for multiple NEES awards managed under a single program. This strategy maintains the NSF commitment earthquake research and infrastructure while aligning it more strategically under a multi-hazards approach.

The GAGE and SAGE facilities provide key data, instrumentation, and educational information and basic research and education in the Earth sciences. Of particular relevance to NEHRP, SAGE supports the Global Seismographic Network, GSN, a worldwide array of 153 permanent seismic stations funded by NSF and USGS with additional support from the Departments of Energy, State, and Defense.

Complementing these facilities, NSF funds a wide range of fundamental research into the processes that drive and control earthquakes and into the impacts of earthquakes on the built environment. This includes individual investigative grants, research centers, and a variety of research collaborations.

NSF also supports rapid response activities to gather data from disaster sites using its RAPID funding mechanism. In the response to recent earthquakes in New Zealand and Japan, NSF supported over 30 RAPID awards.

Another research effort conducted in partnership by NSF and USGS is EarthScope, an Earth science program to explore the structure of North America and provide a framework of broad integrated studies. Scientists using EarthScope data are developing a comprehensive understanding of the structure, dynamics, and evolution of North America.

NSF supports multiagency collaboration on NEHRP activities through a variety of matters. In addition to research collaboration, NSF actively contributes to the NEHRP Program Coordination Working Group and the Interagency Coordinating Committee.

Finally, NSF staff regularly briefs the NEHRP Advisory Committee for earthquake hazards reduction and responds to recommendations for NSF.

In closing, I would like to leave you with two quick examples of some recent achievements of NSF-funded grantees. NSF-funded researchers have discovered how to make underground water lines that bend and move rather than snap and rupture in an earthquake. The Cornell team found that medium and high density polyethylene pipelines remain intact even when the Earth liquefies and shifts. The City of Los Angeles is now installing these pipelines the in Elizabeth Tunnel, which provides half the city's water supply.

The second example concerns ports. In 2005 NSF supported a research project led by Georgia Tech which examined the seismic vulnerability of ports. Project researchers found that a majority of the ports located in the areas of high seismic risk had either no or only informal seismic risk mitigation plans. Utilizing unique NEES facilities, the project team developed a new approach for assessing and managing seismic risk in container ports.

Mr. Chairman, NEHRP is a strong and dynamic program at NSF and we hope to continue to support research, education, and facilities to mitigate the impacts of earthquake hazards. I thank the Subcommittee for considering priorities for reauthorization of the program and appreciate the opportunity to testify today. Thank you.

[The prepared statement of Dr. Khargonekar follows:]

Testimony of
Dr. Pramod Khargonekar
Assistant Director, Directorate for Engineering
National Science Foundation

Before the
U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Research and Technology

The National Earthquake Hazards Reduction Program (NEHRP)

July 29, 2014

INTRODUCTION

Chairman Bucshon, Ranking Member Lipinski and other distinguished members of the Subcommittee; it is my pleasure to be able to testify before you today on the topic of the National Science Foundation's (NSF) activities in earthquake hazards reduction. I am Pramod Khargonekar, Assistant Director for the Directorate for Engineering at the National Science Foundation.

The primary mission of the Foundation is to support fundamental research and education in science, technology, engineering and mathematics. This mission contributes to the national health, prosperity and welfare, and to the national security against such threats as natural hazards, including earthquakes and wind. Although our national security efforts often focus on terrorism, natural hazards are an even greater threat to our security. In 2012, the United States (U.S.) suffered 3,836 earthquakes, of which 32 were of magnitude 5 or greater. The U.S. also experiences over 1,200 tornadoes annually, many resulting in substantial destruction of property and loss of life. Every state has been a recent victim of earthquakes and/or tornadoes. In addition, coastal regions of the nation are subject to the annual season of hurricanes, with devastation such as that caused by Hurricane Sandy in 2012. As you know, the nation is still engaged in the process of recovery from that storm.

NEHRP is a strong and dynamic program at NSF, and we hope to continue to support research, education, and facilities to mitigate the impacts of earthquake hazards. We thank the Subcommittee for considering priorities for reauthorization of the program and appreciate the opportunity to testify today. NSF-supported research in this area is driven by the need for new

scientific and engineering knowledge and effective technologies that can significantly reduce the impacts of hazards to our built environment and our personal safety, as well as substantially reduced costs of emergency and recovery actions.

THE NSF ROLE IN NEHRP

Pursuant to the Earthquake Hazards Reduction Act (EHRA) of 1977, the National Earthquake Hazards Reduction Program (NEHRP) was established in 1978 and operates as a multi-agency partnership of which NSF is a member. NSF supports a broad range of fundamental research in geosciences, engineering, and social, behavioral and economic sciences relevant to the understanding of the causes of earthquakes, and mitigation of and resilience to their impacts. We support research on the dynamics of earthquakes, plate tectonics and crustal deformation as well as the seismic performance of geotechnical, structural, nonstructural and infrastructure-lifeline systems. This support includes research on social, behavioral and economic phenomena such as risk perception, mitigation decision making, incentive systems related to risk and mitigation, and factors that can promote community resilience. The Foundation also provides support for the education of new scientists and engineers, the integration of research and education, and outreach to professionals and the public.

Multi-User Facilities

NSF supports three distributed, multi-user, national facilities that support critical fundamental research relevant to NEHRP: the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), the Geodetic Facilities for the Advancement of Geoscience and EarthScope (GAGE) and the Seismological Facilities for the Advancement of Geoscience and EarthScope (SAGE).

NEES currently provides access to 14 earthquake simulation experimental facilities located in several universities across eight states, with headquarters at Purdue University in West Lafayette, Indiana. The Purdue facility includes the NEEShub, which provides cyberinfrastructure for a data repository, telepresence, simulation tools, collaboration tools and cybersecurity. The NEES facilities include shake tables, large-scale laboratories, geotechnical centrifuges, field testing equipment and a tsunami wave basin. It is very important to note that, in addition to NEES facility funding, the Foundation funds fundamental engineering research using the NEES facilities under an activity referred to as NEES Research (NEESR).

The GAGE and SAGE facilities provide key data, instrumentation, and educational information in support of national goals in basic research and education in the Earth sciences. Of particular relevance to NEHRP, SAGE supports the Global Seismographic Network (GSN), a worldwide array of 153 permanent seismic stations funded by NSF and USGS, with additional support from the Departments of Energy, State, and Defense. GSN provides high-quality digital seismic data for use in a wide range of research and educational activities, and for key international treaty obligations including nuclear verification.

Funded Research, Centers, and Collaborations

Continued progress toward the goal of a more earthquake resilient nation is built on a foundation of **fundamental research** into the processes that drive and control earthquakes and into the impacts of earthquakes on the built environment. NSF supports such research through multiple research programs in the Directorate for Engineering and the Directorate for Geosciences. In Engineering, the Hazard Mitigation and Structural Engineering (HMSE) program, Geotechnical Engineering (GTE) program, and Infrastructure Management and Extreme Events (IMEE) programs support a wide range of NEHRP-relevant research. In Geosciences, relevant programs include EarthScope, Geophysics, GeoPRISMS, Marine Geology and Geophysics, Petrology and Geochemistry, and Tectonics.

NSF also supports a variety of **centers and research collaborations** relevant to NEHRP. For example, in partnership with several other Federal agencies, NSF supports the Natural Hazards Center at the University of Colorado, Boulder. The Natural Hazards Center works to reduce losses from all natural hazards, including earthquakes. It does this primarily by strengthening communications among hazards researchers, practitioners, and policy makers. It hosts an annual natural hazards research and applications workshop, issues several relevant publications, and it includes a quick-response research program for social and behavioral scientists to visit sites of recent disasters to gather perishable research data.

Through its research programs, NSF also supports rapid response activities to gather data from disaster sites using its **RAPID (Rapid Response Research) funding mechanism**. In the aftermath of the Darfield and Canterbury, New Zealand, earthquakes in 2010 and 2011 respectively, and the March, 2011, Tohoku, Japan, earthquake, tsunami and the Fukushima nuclear power plant crisis, NSF acted quickly to fund more than 30 RAPID awards, many with collaborators from the affected countries. On August 23, 2011, an earthquake of magnitude 5.8 struck near Mineral, Virginia, significantly affecting the Washington, DC, area. This earthquake was felt by over 30 million people from Georgia to southeastern Canada, and provided an opportunity for the study of the causes and effects of earthquakes in the Eastern United States. NSF funded awards to the Geotechnical Extreme Events Reconnaissance (GEER) Organization at UC Berkeley, Cornell University, Virginia Tech, and Lehigh University to study this earthquake. This rapid-response research found a clear correlation between geotechnical conditions and structural damage. Soil amplification in soft sediments overlying hard rock influenced damage and shaking intensity patterns, as did the underlying geologic structure associated with the Appalachian Mountains and the strike of regional geologic faulting.

The **Southern California Earthquake Center (SCEC)** began in 1991, and continued through 2001 as an NSF Science and Technology Center; since 2001, SCEC has continued with support from both NSF and USGS. SCEC is based at the University of Southern California and unites 13 core university partners and 36 other U.S. universities, private industry, and state and local governments in an integrative and multidisciplinary research and education partnership. SCEC's primary mission is to (a) gather new information about earthquakes in Southern California; (b) integrate this information into a comprehensive and predictive understanding of earthquake phenomena; and (c) communicate this understanding to end-users and the general public in order to increase earthquake awareness and reduce earthquake risk. SCEC has also led

the major ShakeOut earthquake response drills, which had over 20 million participants nationwide in 2013 alone; ShakeOut has been supported by Federal Emergency Management Agency (FEMA), state and local governments, and private organizations.

EarthScope is an Earth science program to explore the continental structure of North America and provides a framework for broad integrated studies, including research on fault properties and the earthquake process. EarthScope was initiated in 2003, in partnership with the USGS and NASA. The last increment for support of the EarthScope facility (via SAGE and GAGE) will be allocated at the end of FY 2017, providing for operation and maintenance of seismic and geodetic observations through September 2018. The EarthScope Facility is a multi-purpose array of instruments that greatly expands the observational capabilities of the Earth sciences and permits us to advance our understanding of the structure, evolution, and dynamics of North America. The EarthScope Facility comprises the Plate Boundary Observatory (PBO) that monitors Earth deformation with GPS, strainmeters, and other geodetic systems; the San Andreas Fault Observatory at Depth (SAFOD) that defines the conditions and physics of an active plate boundary fault at depth, and USArray, a continental-scale network that maps Earth's interior in three dimensions using seismic and magnetotelluric systems. EarthScope research and instrumentation provides unprecedented accessibility to rich data sets. Scientists using EarthScope data are developing a comprehensive understanding of the structure, dynamics, and evolution of North America that goes beyond the insights possible without this multidisciplinary and integrated capability.

Selected achievements of NSF-funded grantees:

- NSF-funded researchers have discovered how to make underground water lines that bend and move rather than snap and rupture in an earthquake. The team, led by Cornell University, found that medium and high-density polyethylene pipelines remain intact even when the Earth liquefies and shifts. Based on positive laboratory tests and successful real-world performance in Christchurch, the city of Los Angeles is now installing these pipelines in the Elizabeth Tunnel, which provides half the city's water supply[1].

- Recognizing the apparent imbalance between ports' economic value and seismic vulnerability, in 2005 NSF supported a research project to a consortium of universities and firms led by the Georgia Institute of Technology. Project researchers found that a majority of the ports located in areas of high seismic hazard had either no—or only informal—seismic risk mitigation plans. The project team developed a new approach for assessing and managing seismic risk in container ports, an approach more useful to the facility stakeholders. To develop the framework, the team conducted interdisciplinary research that utilized the full range of resources that were uniquely available through the NSF-supported

[1] http://www.purdue.edu/newsroom/releases/2013/Q1/earthquake-resilience-pipeline-of-innovation-to-keep-water-flowing-to-los-angeles.html

NEES facilities, including state-of-the-art computer simulation tools, shake tables, centrifuges, and field testing equipment[2].

- Researchers conducted a series of tests using the large outdoor shake table at the University of California, San Diego (part of NEES) to learn how to help high-value buildings, such as hospitals and data centers, remain operational after earthquakes[3]. These were the first shake table tests of entire nonstructural systems at full scale, and they also examined the interaction between structural and nonstructural systems. This research project (led by UCSD and supported by NSF, FEMA, and industry) is expected to improve modeling tools, educational programs, and standards and practices in the fields of performance-based building design and construction; design and installation practices, building codes, and standards related to nonstructural components and systems.

MULTI-AGENCY COORDINATION

The NEHRP agencies work closely to coordinate efforts. Beyond the earthquake research NSF funds by itself, we also co-fund joint projects with the other NEHRP agencies (examples previously mentioned include SCEC with USGS; Natural Hazards Center with FEMA and USGS). In 2013, NSF and USGS began a cooperative project to convert to long-term operations selected former Transportable Array seismic stations in the central and eastern United States, working in collaboration with the National Research Council, Department of Energy, and interested state governments and university partners. This Central and Eastern United States Seismic Network (CEUSN) project will convert 150-200 seismic stations to enhance regional seismic monitoring, improve oversight of critical facilities, expand our understanding of seismic hazard in the CEUSN, improve detection and expand understanding of earthquakes induced by the injection of wastewater and other fluids, and provide additional data for Earth science research. NSF is supporting conversion and initial operations of the stations; if funding permits, USGS will support long-term operations and integration of these stations into the USGS Advanced National Seismic System.

NSF-funded research is frequently utilized by other agencies to further applied research and produce reports on the seismic performance of buildings and other structures[4]. The NSF-funded NEES infrastructure has also been utilized by NIST to support the development a prototype post-disaster database[5]. Beyond other avenues for publication of research, many results are also disseminated through the NEHRP "Seismic Wave" publication, which highlights success stories of the program[6].

The day-to-day coordination of NEHRP takes place through a number of formal and informal mechanisms. NSF actively contributes to the NEHRP Program Coordination Working

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[2] http://www.nehrp.gov/pdf/SeismicWavesMay13.pdf
[3] http://bncs.ucsd.edu/index.html
[4] http://www.fema.gov/media-library-data/20130726-1730-25045-1580/femap_750.pdf
[5] http://wtcdata.nist.gov/index2.htm
[6] http://www.nehrp.gov/library/success.htm

Group, and the NSF Director participates on the Interagency Coordinating Committee (ICC). To engage directly with the NEHRP community, NSF staff also brief the NEHRP Advisory Committee for Earthquake Hazards Reduction (ACEHR) and responds to its recommendations for NSF.

Finally, post-earthquake investigation activities are coordinated across the NEHRP agencies, with USGS leading these efforts. NSF-supported RAPID awardees and other NSF-supported post-earthquake investigators participate on the NEHRP post-earthquake teleconferences to share deployment information and get updates on aftershock activity. For example, NSF worked with NEHRP partner agencies to coordinate responses to major earthquakes such as the 2008 Wenchuan, China earthquake, 2010 Haiti earthquake, 2010/2011 New Zealand earthquakes, and the 2011 Japan earthquake.

FUTURE DIRECTIONS

NSF appreciates the Congressional support for NEHRP and that the Committee is considering reauthorizing the program. As you consider your legislation, I would like to highlight some specific areas of importance to NSF.

NEES

NSF has supported NEES operations and the complementary NEES Research program since FY 2005. NEES *operations* are currently supported through an award to Purdue University covering the fiscal years 2010-2014. In anticipation of the expiration of the current NEES operational award in September 2014, in 2010 NSF began a process of external evaluation and planning for continued investment in earthquake engineering facilities. This planning resulted in a call for greater emphasis on frontier research and computational simulation capabilities for multi-hazards risk and sustainability for civil infrastructure, a strong emphasis on continued provision of cyberinfrastructure and data sharing, and closer ties among research efforts supported across relevant Engineering research programs. These plans were shared broadly with the research community in 2012 via a Dear Colleague Letter, NSF 12-107.

In accordance with these plans, NSF hosted a competition to support an updated "NEES2" infrastructure for the FY 2015-2019 period under a single umbrella award. The outcome of the subsequent merit review of the proposals was that that no award was made. Following this outcome, NSF began a different programmatic approach to meet our scientific and engineering research goals and to better capitalize on related research programs within NSF and those supported by our Federal agency partners.

This updated strategy maintains our commitment to balance NSF investments in research infrastructure and fundamental research with the following provisions. First, there will be no single umbrella award. Rather, NSF will support multiple separate awards, and it will manage these awards under a program named Natural Hazards Engineering Research Infrastructure (NHERI). NHERI will consist of (1) a single award for a national office to facilitate coordination among the NHERI awardees and community outreach, (2) a single award for cyberinfrastructure

that will enable sharing of data, models, and simulation tools for all research supported by the Directorate for Engineering in the area of natural hazards and civil infrastructure (this award will be supported by a second single award for a simulation center to develop the computational and simulation tools delivered by the cyberinfrastructure platform), and (3) up to seven awards for earthquake and wind engineering experimental facilities.

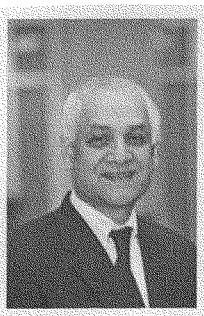
NHERI will be supported under a single, unified natural hazards research program in the Civil, Mechanical and Manufacturing Innovation Division of the Directorate for Engineering. The program will support earthquake engineering, wind engineering and other natural hazards research. These modifications will allow NSF to more effectively and efficiently support the research and facilities needed to address the multiple hazards faced by our nation every day.

GAGE and SAGE

NSF also plans to support the GAGE and SAGE facilities through FY 2017, and is working closely with USGS and other Federal, State, and university partners to ensure that the facilities continue to provide the critical data required. For example, geodetic data provided through GAGE are being included in nascent earthquake early warning systems under development on the west coast with support from USGS and other Federal agencies and from private foundations. Such systems can provide a few seconds to minutes of warning, which is enough time to take short-term protective actions like stopping trains and heavy equipment, opening fire station doors, pausing delicate surgical procedures, and moving to nearby safer zones. These same data are also being incorporated into the latest generation of the National Seismic Hazard Maps developed by USGS.

SUMMARY

Our understanding of earthquakes and other natural hazards has improved greatly over the past forty years, and the benefits of this understanding are clearly evident in the substantial reduction in both fatalities and damage to civil infrastructure. Throughout this period, the National Science Foundation has been at the forefront in supporting research that covers the full breadth of science, engineering and social sciences as they relate to natural hazards. NEHRP is a critical part of this research. Our plan for the future is to continue our leadership role in earthquake research, and to broaden the scope of our activities to include multiple hazards simultaneously. Indeed, our infrastructure is not designed to cope with one or another hazard alone, but rather to cope with the full panoply of potential hazards in a single design. Infrastructure must be hardened against all natural disasters, not just earthquakes. The challenges that remain are substantial, but it is clear that continued research investments to mitigate the impacts of natural hazards will yield returns to society that greatly outweigh the costs.



The National Science Foundation (NSF) selected Dr. Pramod P. Khargonekar to serve as assistant director for the Directorate of Engineering (ENG). In this position, Khargonekar will lead the ENG Directorate with an annual budget of more than $800 million. The ENG Directorate invests in frontier engineering research and education, cultivates an innovation ecosystem, and develops the next-generation of engineers.

Prior to his position at NSF, Khargonekar was the deputy director for technology at the U.S. Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E). He is the Eckis Professor of Electrical and Computer Engineering at the University of Florida, a position he has held since 2001, and one he will retain while at NSF. He served as the dean of the University of Florida's College of Engineering from 2001 to 2009.

"Dr. Khargonekar brings to NSF extensive leadership, creativity and initiative in engineering research," said NSF Director Subra Suresh. "He has helped pioneer interdisciplinary efforts between the biological and engineering research communities and demonstrated a deep appreciation for developing the STEM workforce, which is an NSF priority."

NSF's investments in engineering research and education aim to build and strengthen a national capacity for innovation that can lead, over time, to the creation of new shared wealth and a better quality of life. The ENG Directorate also supports NSF's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

Khargonekar's engineering research encompasses control systems theory and applications, smart grid and renewable energy, semiconductor manufacturing, and modeling and control of neural systems, among other areas. He has received many awards and honors including the IEEE Baker Prize, the American Automatic Control Council's Donald Eckman Award, the Distinguished Alumnus Award from the Indian Institute of Technology, Bombay, and was named a Web of Science Highly Cited Researcher. Khargonekar is a fellow of IEEE. Most recently, he has been a member of NSF's Engineering Advisory Committee, where he provided guidance to ENG on strategic directions.

Khargonekar began his NSF appointment in March 2013.

Credit: *NSF/Sandy Schaeffer Photography*

Chairman BUCSHON. Thank you very much.

I now recognize Dr. Applegate for his testimony.

TESTIMONY OF DR. DAVID APPLEGATE, ASSOCIATE DIRECTOR FOR NATURAL HAZARDS, U.S. GEOLOGICAL SURVEY

Dr. APPLEGATE. Great. Well, thank you, Chairman Bucshon and Congressman Lipinski, other Members of the Subcommittee. I very much appreciate the invitation for the U.S. Geological Survey to testify at this hearing.

The USGS is proud to be part of the NEHRP four-agency partnership effort. I think it has been highly successful and continues to make valuable contributions to the Nation's resilience to earthquakes.

As Jack Hayes noted, NEHRP is predicated on the recognition that while earthquakes are inevitable, their consequences are not and there is much that we can do as a nation to improve public safety when it comes to earthquakes and related hazards. Within NEHRP, each agency performs a distinct and complementary role essential for the overall success of the program. The heart of this partnership is a broadly shared commitment to translate research results into implementation actions that can reduce earthquake losses. That commitment involves collaboration that goes well beyond the four NEHRP agencies to include other federal partners, plus state, tribal, and local governments, universities, nongovernmental organizations, and the private sector, as reflected in the second panel.

Carrying out its role within NEHRP, the USGS strives to deliver the data and information tools that engineers and design professionals, emergency managers, government officials, and the public need to prevent earthquake hazards from becoming earthquake disasters. With its partners, the USGS provides rapid and authoritative information on earthquake size and location, shaking intensity, and potential impacts. We develop hazard assessment maps and related products, we support targeted research to improve our monitoring and assessment capabilities, and we build public awareness of earthquake hazards.

When damaging earthquakes strike here in the United States or around the world, the USGS delivers a broad suite of information tools that are made possible by our Advanced National Seismic System and the worldwide coverage of the Global Seismographic Network, which is a program involving USGS, the National Science Foundation, and the Incorporated Research Institutions for Seismology.

The ANSS consists of a national backbone network, regional networks that are operated by state and university partners, the USGS National Earthquake Information Center, and ground and structure-based instruments concentrated in high-hazard urban areas. With funding from Congress since 2000, USGS and its partners have installed more than 2,800 new and upgraded stations out of a total of 7,100 that are targeted in the ANSS plan for full implementation of the system. Investments in ANSS have greatly improved the information available for emergency responders, engi-

neering performance studies, and long-term earthquake hazard assessments.

Recent earthquakes in Colorado, Oklahoma, and Virginia, that last one felt up and down the East Coast, have underscored the national nature of earthquake risk. One of the most important achievements that NEHRP has made is the translation of research into national models of the location and expected severity of earthquake shaking within specified time periods. These models are in turn used to generate maps that are incorporated into the seismic safety elements of building codes and standards.

As you noted in your opening statement, earlier this month the USGS released the latest update of the National Seismic Hazard Maps, the timing coordinated with the consequent release of the next generation of model building codes and seismic safety standards, a process that involves close collaboration among USGS, FEMA, the Building Seismic Safety Council, American Society of Civil Engineers, International Code Council, and other organizations. Complementing the national maps, urban seismic hazard maps provide more detailed information on local site conditions for use in engineering and planning, most recently delivered for Evansville, Indiana.

Looking forward, the Administration's 2015 budget continues several initiatives that Congress supported in 2014. In particular, I wish to highlight Earthquake Early Warning, which we see as representing the next advance in public safety. Modern seismic networks can in favorable circumstances provide a minute or more of warning before the onset of strong shaking. In a number of countries around the world, operational earthquake early warning systems exist today. The USGS has supported research and development toward establishing such a capability in California, and the test system is now operating and delivering warnings to a small group of test users. Considerable additional testing and equipment deployment will be required to create a robust and reliable warning system, but we are on our way.

In conclusion, USGS and the Department of the Interior strongly support reauthorization of NEHRP. It has proven to be a successful partnership that continues to make valuable contributions to the Nation's resilience to earthquake and other hazards.

Thank you, Chairman, for the opportunity to provide the Subcommittee with the USGS views, and I would be pleased to answer any questions.

[The prepared statement of Dr. Applegate follows:]

STATEMENT OF
DR. DAVID APPLEGATE
ASSOCIATE DIRECTOR FOR NATURAL HAZARDS
U.S. GEOLOGICAL SURVEY
U.S. DEPARTMENT OF THE INTERIOR
BEFORE THE
HOUSE COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
REGARDING
THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

July 29, 2014

Chairman Bucshon, Congressman Lipinski, Members of the Subcommittee, thank you for inviting the U.S. Geological Survey (USGS) to testify at this hearing on the National Earthquake Hazards Reduction Program (NEHRP). The USGS is proud to be a partner in NEHRP, which is led by the National Institute of Standards and Technology (NIST) and includes the Federal Emergency Management Agency (FEMA) and the National Science Foundation (NSF). We greatly appreciate the collective opportunity to provide you a comprehensive update on NEHRP, a highly successful partnership that continues to make valuable contributions to the Nation's resilience to earthquakes.

NEHRP is predicated on the belief that while earthquakes are inevitable, their consequences are not, and there is much that we can do as a Nation to improve public safety and our resilience to earthquakes and related hazards. Within NEHRP each agency performs a distinct and complementary role essential for the overall success of the program. The program is conducted with a high degree of cooperation and collaboration without competition for responsibilities or resources. The heart of this partnership is a broadly shared commitment to translate research results into implementation actions that can reduce earthquake losses. That commitment involves collaboration that goes beyond the four agencies to include other Federal partners, plus State, Tribal and local governments, universities, and the private sector.

USGS NEHRP Activities

Carrying out its role within NEHRP, the USGS strives to deliver the data and information tools that engineering and design professionals, emergency managers, government officials and the public need to prevent earthquake hazards from becoming earthquake disasters. USGS activities supporting NEHRP are implemented through our Earthquake Hazards Program (EHP) and Global Seismographic Network (GSN) Programs. With its partners, the USGS provides rapid and authoritative information on earthquake size, location, shaking intensity, and potential impacts; develops regional and national hazard assessment maps and related products; supports

targeted research to improve our monitoring and assessment capabilities; and builds public awareness of earthquake hazards. In what follows, I discuss the current status of these activities.

Earthquake Monitoring - Delivering Rapid Information for Emergency Response. The USGS provides rapid reports of potentially damaging earthquakes to the White House; the Departments of Defense, Homeland Security (including FEMA), State, Transportation, Energy, Commerce, and the Interior; State, Tribal, and local emergency managers; numerous public and private infrastructure management centers (for example railroads and pipelines); the news media; and the public. Over 430,000 people in the United States and around the world have signed up to receive earthquake notifications via e-mail or text message. The suite of information tools available through the USGS Earthquake Hazards Program website receives tens of millions of hits in the wake of damaging earthquakes.

The USGS Advanced National Seismic System (ANSS) is the technical foundation that allows delivery of these products. The 2000 reauthorization of NEHRP established the ANSS to modernize and expand the Nation's seismic monitoring infrastructure in order to improve the delivery of earthquake information to those who need it most. The ANSS consists of a national backbone network, regional networks operated by State and university partners, the USGS National Earthquake Information Center (NEIC), and ground- and structure-based instruments concentrated in high-hazard urban areas. With funding appropriated by Congress since 2000, the USGS and its partners have installed more than 2,800 new and upgraded stations, out of a total of 7,100 targeted in the ANSS plan for full implementation of the system (USGS Circular 1188). The USGS also initiated 24/7 on-site operations at NEIC in 2006 and supports development of new information tools for enhanced situational awareness such as the ShakeCast, Prompt Assessment of Global Earthquakes for Response (PAGER), and Tweet Earthquake Dispatch (TED) systems (see *earthquake.usgs.gov* for details). These investments have greatly improved the information available for emergency responders, engineering performance studies, and long-term earthquake hazard assessments. A 2005 report by the National Research Council on the costs and benefits of improved seismic monitoring found that the benefits of fully deploying ANSS outweigh the costs many times over.

Substantial improvements in ANSS infrastructure were realized in 2010 and 2011 as a result of economic stimulus funding. The USGS allocated $19 million of the $140 million dollars it received under the American Recovery and Reinvestment Act (ARRA) to the modernization component of ANSS. Outdated equipment at hundreds of legacy seismic stations was replaced with modern digital equipment. Funds were also used to upgrade communications and processing software and to develop critical software components for the system as a whole. ARRA funding was allocated to 13 cooperating State and university partners that performed the station and network upgrades

Assessing the Nation's Earthquake Hazards. Earthquakes are a national challenge, with about 142 million people living in moderate- to high-hazard areas stretched across 42 States. Recent

earthquakes in Colorado, Oklahoma, and Virginia have underscored the national nature of earthquake risk. One of the most important achievements that NEHRP has made is the translation of research into national models of the location and expected severity of earthquake shaking within specified time periods. These models are used to generate maps that are incorporated into the seismic safety elements of building codes and for other purposes. Each major update of the maps is the culmination of a multi-year process to incorporate the best available science, including geologic information about faults, evidence of prehistoric earthquakes, instrumental and historical earthquake catalogs generated by seismic monitoring, and ground deformation measurements.

Earlier this month, the USGS released the latest update of the National Seismic Hazard Maps reflecting the current state of understanding. The release of the updated seismic hazard maps is coordinated with the consequent release of the next generation of model building codes and seismic safety standards, a process that involves close cooperation among the USGS, FEMA, the Building Seismic Safety Council, the American Society of Civil Engineers, the International Code Council, and other organizations. The 2014 maps have now been approved by the NEHRP Recommended Seismic Provisions Update Committee of the Building Seismic Safety Council, a major step towards incorporation into the International Building Code and International Residential Code, which is adopted in almost all States. The maps are also used by insurance companies to set rates for properties, by civil engineers to estimate the stability and landslide potential of hillsides, by the U.S. Environmental Protection Agency to set construction standards that ensure the safety of waste-disposal facilities, and by FEMA to plan the allocation of assistance funds for earthquake education and preparedness. The USGS also works closely with the U.S. Nuclear Regulatory Commission on seismic safety of nuclear power plants, including review of seismic hazard assessments in license applications.

Complementing the national maps, urban seismic hazard maps provide more detailed information on local site conditions for use in engineering and planning. Urban seismic hazard maps have been released for Memphis, Seattle, and Evansville (Indiana), and are near completion for the St. Louis area. Those maps show how forecasted earthquake shaking levels vary, at scales useful for urban planning, earthquake response planning, engineering guidance for major structures, and public education. Such maps require detailed mapping of surficial geology and knowledge of subsurface geology in order to incorporate the local effects into estimates of shaking. Developing these maps would not be possible without significant involvement of local and regional scientists, engineers, emergency managers, and the business community.

Targeted Research. USGS assessment and monitoring activities depend on targeted geoscience research. USGS internal research is augmented by external research supported by the USGS through grants to and cooperative agreements with universities, State geological surveys, and geotechnical consultants. Proposals for external work are submitted in response to an annual solicitation that identifies the scientific problems on which the USGS seeks assistance and progress. Each proposal undergoes a rigorous peer-review process. This targeted research is

funded on the basis of merit and provides a bridge from the NSF's investments in fundamental research in order to generate critical advances in understanding that underpin development of the national and urban seismic hazard maps and rapid earthquake response products. Ongoing collaboration with the academic community is one of the great strengths of the USGS with regard to earthquake research. Key examples are the jointly USGS-NSF supported Southern California Earthquake Center (SCEC) and our important partnership with the NSF's EarthScope facility.

Using Earthquake Outreach and Education to Better Prepare. The USGS works to make earthquake hazards understood through education and outreach products developed in concert with NEHRP, university, and local government partners, including the FEMA-supported regional earthquake consortia; the NSF-supported IRIS consortium; and the SCEC university and government consortium. Millions of copies of earthquake preparedness handbooks have been distributed in Alaska, California, Tennessee, Utah, and many other states. As part of an effort to reach non-English-speaking populations, both the southern California and Bay Area versions of *Putting Down Roots in Earthquake Country* have been translated into Spanish, and a shortened version of the Bay Area *Putting Down Roots* has been translated into a number of Asian languages and distributed through Asian-language newspapers. Additional versions of *Putting Down Roots* have been developed for Utah and Idaho, and a version for the Central United States was published for the bicentennial commemoration of the New Madrid sequence of earthquakes that struck the heartland in the winter of 1811-12.

This past October, nearly 25 million people participated in the United States and around the world in the sixth annual Great ShakeOut earthquake drills – a public participation exercise in earthquake awareness and safety. The first ShakeOut, in 2008, was based on a comprehensive, science-based earthquake scenario for the impacts of a major rupture of the southern section of the San Andreas Fault; this formed the basis for the Great Southern California ShakeOut, involving over 5 million people. Through the leadership of SCEC and many others, the ShakeOut approach has been adopted by all 50 U.S. States and several territories as well as several foreign countries, and annual ShakeOuts have led to a number of positive outcomes, including efforts to reduce lifeline vulnerability, retrofit critical structures, improve monitoring systems, and educate residents. More generally, scenarios have proven to be powerful tools for making earthquake hazards real to people ahead of a disaster. The USGS recently entered into a partnership with the City of Los Angeles to use the vulnerabilities identified in the ShakeOut scenario to guide the city's overall resilience efforts.

Post-earthquake coordination and investigations

Following major earthquakes in the United States and abroad, detailed scientific and engineering investigations are carried out in order to improve our knowledge of earthquake processes and impacts in order to hone the nation's earthquake resilience. The 2004 authorization of NEHRP (P.L. 108-360) tasks the USGS with responsibility for coordinating post-earthquake

investigations. The legislation required analysis by NSF and USGS of the causes of the earthquake and the nature of the resulting ground motion, analysis by NSF and NIST of the behavior of structures and lifelines, both damaged and undamaged, and analysis by each NEHRP agency of the effectiveness of the earthquake hazards mitigation programs and actions relating to its area of responsibility, and of how those programs and actions could be strengthened.

The USGS has carried out its post-earthquake coordination responsibility using the guidelines established in USGS Circular 1242, *The Plan to Coordinate NEHRP Post-Earthquake Investigations*, which was developed by the NEHRP agencies and other partners. Since 2010, the USGS has responded to and coordinated the national scientific and technical response for U.S. earthquakes in Arkansas, Colorado, Oklahoma, and Virginia as well as overseas in Chile, Haiti, Japan, Mexico, New Zealand, and Turkey.

The earthquakes that struck Haiti and Chile in 2010 and Japan in 2011 were some of the most devastating in recent history, and the shaking from the Virginia earthquake in 2011 was felt by more people than any previous earthquake in U.S. history. Each of these responses required immediate action by USGS staff, who were diverted from other work, often for weeks or months. Immediate demands included briefings for government officials and responses to the media. The USGS rapidly organized community-wide conference calls to coordinate the scientific and engineering response by Federal, State, university, and other institutional interests. All of the geospatial data collection was coordinated by the USGS. For each of the domestic earthquakes, the USGS deployed either portable seismometers to record aftershocks, or teams of geologists to conduct field studies, or both. For larger foreign earthquakes (Haiti, Chile, Japan, New Zealand), NEHRP agencies sent reconnaissance teams followed by more substantial deployments of USGS/USAID Earthquake Disaster Assistance Teams with portable seismometers and geologic expertise, as well as NSF-supported engineering teams, to determine the causes of building and ground failures.

Opportunities to further reduce earthquake losses in the United States

The Administration's 2015 budget requests $59 million for the USGS' two NEHRP Programs; this is slightly above the FY 2014 level. The proposed budget continues the initiatives that Congress supported in FY 2014: for the further development of an earthquake early warning system, for research on induced seismicity, and for improved ANSS products for situational awareness. The additional funding provided in FY 2014 and FY 2015 allows the USGS to build in these areas, particularly after facing budget reductions due to sequestration in FY 2013.

Earthquake Early Warning: The next advance in public safety

Modern seismic networks can, in favorable circumstances, provide seconds to a minute or more of warning before the onset of strong shaking, enabling Earthquake Early Warning (EEW). Over the past 11 years, the USGS has invested nearly $10 million in both research and development

toward establishing an earthquake early warning capability in California. Funds from the 2009 American Recovery and Reinvestment Act were used in 2010 and 2011 to support the modernization of seismic instrumentation necessary to support the generation of warnings. A test system is operating now; two of the university partners (CalTech and the University of California Berkeley) have been delivering warnings to a small group of test users since January 2011.

The current test system is still in the development phase, however, and considerable additional testing and equipment deployment is required to create a robust and reliable operational warning system. Further work is needed to demonstrate reliability, improve accuracy, establish products for public warning, and expand geographic coverage. The additional funding for EEW that was appropriated by Congress in FY 2014 is being used to complete the R&D phase for the seismic system (an effort that is jointly supported by the Gordon and Betty Moore Foundation) and to improve the operational robustness of the system. The next steps will require expanding coverage throughout California, Oregon, and Washington, integrating global positioning system (GPS) technology into the EEW system, and operating the system continuously on a 24x7 basis.

Induced Seismicity. Potentially damaging earthquakes can be triggered by disposal of waste fluids from oil and gas production operations by injection into deep underground wells. Smaller earthquakes can also be triggered by enhanced geothermal energy production operations and, potentially, by deep geologic carbon sequestration. Although the basic geophysical mechanisms are well known, the specific subsurface conditions that are conducive to triggering are not, and it is not yet possible to make site-specific hazard predictions in advance. Thus, there is a need for more data and research on induced seismicity, to understand how these events may depend on specific operational parameters and geologic conditions and to develop monitoring and mitigation plans for decision-makers attempting to minimize seismic risks.

With the support of Congress and the Administration, the USGS is now working with the Department of Energy and the Environmental Protection Agency to undertake this research and working with industry on case studies that will illuminate the physical factors controlling induced earthquakes. Top-priority efforts are to develop methods to forecast whether or not a particular type of injection operation in a specified geologic setting would be likely to induce or trigger earthquakes, to perform comprehensive studies at two field sites, and to establish procedures to adapt the National Seismic Hazard Maps to take account of the additional hazard due to earthquakes induced in association with wastewater from the production of oil and gas.

NEHRP's Global Reach

The Global Seismographic Network—a program involving the USGS, the National Science Foundation, and the Incorporated Research Institutions for Seismology, IRIS)—provides worldwide coverage for monitoring of earthquake and non-earthquake seismic activity, and supports basic and applied research in Earth science. GSN data are also critical to the NOAA

tsunami warning system (and the tsunami warning systems of other nations) and support research on nuclear explosion detection and treaty verification.

With support from Congress in 2005, and again in 2009 under ARRA, the USGS and NSF have made significant progress maintaining the GSN at a state-of-the-science level, expanding real-time communications throughout the 150-station network and upgrading and standardizing the computers and other components at each station site. Even so, many GSN stations are now more than 20 years old. In 2012, Congress provided additional funding to the Department of Energy (DOE) to replace aging and failed seismic sensors and, under an agreement with DOE, the USGS is currently procuring those new sensors. The USGS and DOE are exploring options to fund installation of the new equipment.

Conclusion

The Department strongly supports reauthorization of NEHRP. It has proven to be a successful partnership that continues to make valuable contributions to the Nation's resilience to earthquakes and other hazards.

Thank you, Chairman Bucshon, for the opportunity to provide the Subcommittee with the USGS views on NEHRP. I would be pleased to answer any questions the Subcommittee may have.

For More Information

The National Earthquake Hazards Reduction Program http://www.nehrp.gov/

Holzer, T.L., and others, 2003, The plan to coordinate NEHRP post-earthquake investigations: U.S. Geological Survey Circular 1242, 27 p. (http://pubs.er.usgs.gov/publication/cir1242)

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U.S. Geological Survey, 1999, *An Assessment of Seismic Monitoring in the United States: Requirement for an Advanced National Seismic System*: U.S. Geological Survey Circular 1188, 55 p. (http://pubs.er.usgs.gov/publication/cir1188)

David Applegate is the Associate Director for Natural Hazards at the U.S. Geological Survey. In that role, he leads USGS hazards planning and response activities and oversees the Coastal & Marine Geology, Earthquake Hazards, Global Seismographic Network, Geomagnetism, Landslide Hazards, and Volcano Hazards Programs. He co-chairs the National Science and Technology Council's interagency Subcommittee on Disaster Reduction and co-leads the Department of the Interior's Strategic Sciences Group. Applegate is an adjunct full professor in the University of Utah's Department of Geology and Geophysics. Prior to joining USGS in 2004, he spent eight years directing science policy at the American Geological Institute, a federation of geoscience societies. During the last four years there, he also served as the editor of *Geotimes*, AGI's newsmagazine of the earth sciences (now renamed *Earth*). Before coming to AGI, Applegate served with the U.S. Senate Committee on Energy and Natural Resources as the American Geophysical Union's Congressional Science Fellow and as a professional staff member for the minority. Born and raised in Chambersburg, Pennsylvania, Applegate holds a B.S. in geology from Yale University and a Ph.D., also in geology, from the Massachusetts Institute of Technology.

Chairman BUCSHON. Thank you very much.

I now recognize Mr. Wright for his testimony.

TESTIMONY OF MR. ROY E. WRIGHT, DEPUTY ASSOCIATE ADMINISTRATOR FOR MITIGATION, FEDERAL EMERGENCY MANAGEMENT AGENCY

Mr. WRIGHT. Good morning, Chairman Bucshon, Ranking Member Lipinski, and Members of the Subcommittee. I thank you for having me here today.

I am Roy Wright, the Deputy Associate Administrator for Mitigation within the Department of Homeland Security's Federal Emergency Management Agency. It is my pleasure to be here today to discuss the National Earthquake Hazards Reduction Program and FEMA's principal responsibilities within that program.

I want to start by giving you my simple bottom line. By including science into building codes, conducting outreach, and advancing mitigation, the NEHRP funds enable state-level efforts to better prepare for earthquakes. These actions make the Nation more resilient and better able to address this threatening hazard. As others have said this morning, these are no-notice events and they can be catastrophic. And we share the view that while earthquakes may be inevitable, disasters caused by earthquakes are not. This really guides everything that we do.

FEMA and our NEHRP partners have made significant progress in earthquake safety since NEHRP was established 37 years ago. Although changing demographics and economic conditions present challenges, the program is committed to building on our progress, developing practical solutions to reduce or eliminate the earthquake risk, and ensuring our nation's continued resilience.

I would briefly like to talk with you this morning about two areas of our focus: building codes and education. In terms of building codes, NEHRP primarily works with the National Codes and Standards to promote implementation of research results. That is, we work with stakeholders to ensure the promotion of and use of those building codes so that we all can be safer. For example, FEMA worked with the International Code Council and other partners in the 2009 edition of the International Residential Code to develop updated provisions for braced sheer wall panels which help ensure the stability of a structure.

As you can see from the maps on the screens, adoption of these codes strong in some areas of the country, particularly those where they are most likely to experience an earthquake. It is something we are proud of and we have worked hard with our partners to achieve, but there is more to do. There are still too many areas where the risk is high but adequate building codes have not yet been adopted. This leaves these communities vulnerable to the impacts of potential earthquakes. We still have much more that needs to be done and we are committed to educating these communities on best practices and the importance of earthquake hazard mitigation, which brings me to our second area of focus: education.

FEMA develops and supports public education and awareness programs on earthquake loss reduction, sharing best practices, and encouraging mitigation. We pursue all of this of course to create resilience and help ensure the safety of our citizens. I would like to

give you but one example of our work in this area. After we were approached by the City of San Francisco, FEMA commissioned a study to examine whether it was possible to retrofit only the first story of a weak-story building without altering the rest. So a weak-story building is a multistory wood-framed building where the first floor is much weaker than the upper stories due to a garage or a storefront opening. FEMA published its findings and created an electronic tool that allows an engineer to assess the strength of walls on the first floor and upper floors. Then the engineer can virtually strengthen these walls and recalculate the strength. The goal is to strengthen the first floor just enough so the entire building can withstand an earthquake.

As a Nation, our architects, engineers, local officials, homeowners, and our federal partners, we all have an indispensable role to play in preparing for earthquakes and mitigating their impacts. The NEHRP has done a commendable job in identifying the hazards, communicating the risks, and researching how we can protect our citizens. As we look forward to reauthorization, more must be done. It is not enough to educate the public about what earthquakes can do. Until we are able to convince the public to take action to address that risk, we have not truly implemented this program. We must continue to work together across the whole community to move beyond understanding risks to making concrete steps to mitigate and strengthen our collective resilience.

Thank you and I appreciate the opportunity to come before you this morning and I look forward to your questions.

[The prepared statement of Mr. Wright follows:]

STATEMENT

OF

ROY WRIGHT
DEPUTY ASSOCIATE ADMINISTRATOR
MITIGATION DIRECTORATE
FEDERAL EMERGENCY MANAGEMENT AGENCY
U.S. DEPARTMENT OF HOMELAND SECURITY

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"A REVIEW OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP)"

Submitted
By

Federal Emergency Management Agency
500 C Street, S.W.
Washington, D.C. 20472

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Introduction

Chairman Bucshon, Ranking Member Lipinski, and Members of the Subcommittee, I am Roy Wright, Deputy Associate Administrator of the Mitigation Directorate at the Department of Homeland Security's (DHS) Federal Emergency Management Agency (FEMA). It is my pleasure to be here today to discuss FEMA's recent earthquake hazards reduction activities through the National Earthquake Hazards Reduction Program (NEHRP).

By including science into the development of building codes and conducting outreach and mitigation, the NEHRP funds state-level efforts to better prepare communities for earthquakes. These actions make the nation more resilient and better able to respond to this increasingly threatening hazard.

The Earthquake Hazard

Of all the natural hazards threatening the United States, earthquakes pose one of the greatest single source risks for casualties and damage in the United States.

According to a 2006 National Research Council (NRC) report[1], 42 States have some degree of earthquake potential and 18 States have areas of high or very high seismicity. More than 75 million people live in urban areas with moderate to high earthquake risk.

Although damaging earthquakes occur infrequently in the United States, they are no notice events that strike without warning, with potentially catastrophic consequences. As such, earthquakes require a higher level of preparedness on the part of everyone; from individuals to businesses to governments. Correspondingly, mitigation of the risk becomes that much more important. The 2006 NRC report observed that for the 1994 Northridge, California earthquake, direct losses were estimated at between $45 billion to $55 billion. Had this event occurred during working hours instead of the early morning hours of a Federal holiday, casualties would have been far greater. Exactly one year later, a similar earthquake struck Kobe, Japan. With a built environment somewhat similar to that of southern California, this event caused more than 6,300 deaths, with estimated direct losses exceeding $120 billion. Both earthquakes were under magnitude 7 (M7).

While it has been 20 years since the Northridge earthquake, according to the U.S. Geological Survey (USGS), there are several faults, including the Hayward Fault in East Bay of San Francisco and the southern San Andreas Fault east of Los Angeles, that are past due for experiencing a significant event. In fact, recent findings from the USGS show a significantly increased potential for damaging earthquakes in hazard-prone areas. According to the new forecast recently prepared by the USGS, there is a 99.7 percent chance that the State of California will experience a M6.7 or larger earthquake during the next 30 years.

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[1] National Research Council, *Improved Seismic Monitoring, Improved Decision Making – Assessing the Value of Reduced Uncertainty, 2006.*

In the history of the United States, earthquakes M6.5 or greater have occurred in Alaska, California, South Carolina, and Utah as well as the Central and New England Regions. Geological evidence, confirmed by Japanese historical records, indicates that earthquakes as large as M9 have occurred in the Pacific Northwest. Because few large magnitude earthquakes have struck the United States since it became urbanized, American society tends to underestimate the true risk from earthquakes.

Given the urbanization of the past century, the NRC concludes that a major earthquake located under one of several key urban regions in the United States could potentially cause thousands of casualties and losses approaching $200 billion. Accordingly, reducing earthquake losses is a matter of significant national concern. Even a localized earthquake could have national economic consequences; for example, several economic and engineering analyses have indicated that an event in the central United States on the New Madrid fault could significantly affect our economy by shutting down oil and gas distribution lines to the Northeast as well as shutting down commercial traffic that crosses the Mississippi River.

Recent findings from the USGS show a significantly increased potential for damaging earthquakes in hazard-prone areas. Many citizens in these areas have not acknowledged the threat. Our goal is to provide information, education, and tools that will result in reduced potential losses if damaging earthquakes occur. The earthquake risk that our nation faces is serious, but it can be reduced, and this responsibility is shared by Federal, state, local, and tribal governments, along with the private sector.

The National Earthquake Hazards Reduction Program

The NEHRP is the federal government's coordinated approach to addressing earthquake risks. The Program involves the coordinated efforts of four federal agencies - FEMA, USGS, the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST). Congress first authorized the National Earthquake Hazards Reduction Program (NEHRP) in 1977 (Public Law 95-124) to "reduce the risks of life and property from future earthquakes in the United States." The most recent reauthorization, Public Law 108-360, authorized NEHRP funding through Fiscal Year (FY) 2009.

The premise of the program is that while earthquakes may be inevitable, earthquake disasters are not. NEHRP activities reach beyond basic and applied research to technology development and transfer, training, education and advocacy for seismic risk reduction measures. The program is a collaborative one, with NEHRP agencies working together with other federal and state agencies, universities, and private, regional, voluntary and professional organizations.

Since NEHRP was first authorized in 1977, the population of the United States has increased from 200 million to more than 315 million, with much of this increase in high seismic areas. Many elements of our aging national infrastructure are reaching the end of their service life without replacement, and have never been tested by strong earthquake shaking. Ensuring this nation's resiliency and maintaining global competitiveness requires that practices to mitigate earthquake impacts in the United States, both in new construction and in its existing structures, be cost-effective for all levels of government and private interests.

FEMA and our NEHRP partners have made significant progress in earthquake safety since the NEHRP was established 36 years ago. Although changing demographics and economic conditions present challenges, the program is committed to building on that progress to develop practical solutions to reduce the earthquake risk and ensure our nation's continued resiliency.

The NEHRP Vision and Mission are the basis for program direction and planning, and provide the structure and focus for all NEHRP activities.

> The NEHRP Vision is: *A nation that is earthquake-resilient in public safety, economic strength, and national security.*
>
> The NEHRP Mission is: *To develop, disseminate, and promote knowledge, tools, and practices for earthquake risk reduction—through coordinated, multidisciplinary, interagency partnerships among the NEHRP agencies and their stakeholders—that improve the Nation's earthquake resilience in public safety, economic strength, and national security.*

Three overarching, long-term goals, with 14 associated objectives, support the NEHRP mission:

- Goal A: Improve understanding of earthquake processes and impacts.
- Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.
- Goal C: Improve the earthquake resilience of communities nationwide.

The activities of the four NEHRP agencies are part of a process referred to as the "research-to-practice pipeline." NSF and the USGS support the basic research that produces scientific advances. NIST and FEMA incorporate these advances into applied research that contributes to the development of mitigation tools and information. FEMA and NIST then promote and facilitate use of these tools and information by those involved in implementing earthquake mitigation measures. FEMA leads related program implementation efforts including training, dissemination and outreach.

FEMA's Role in the NEHRP

Other than agency-specific implementation work (such as USGS earth science implementation activities), FEMA is responsible for the majority of the program's general implementation activities. In this role, we work to translate the results of research and technology development from NEHRP partners and other sources into effective earthquake loss reduction measures for Federal, state, local, territorial and tribal governments, as well as industry and individuals.

Historically, we have provided technical and financial assistance to states and multi-state consortia to increase awareness of the earthquake hazard risk and to foster plans to reduce seismic vulnerability. FEMA also develops and supports public education and awareness programs on earthquake loss reduction. Further, we support the development and dissemination of improved seismic design and construction criteria for new buildings and retrofit guidance for

existing buildings. All of this material is made available to building design professionals, and all government entities for voluntary use through model building codes and standards and through educational materials and courses for the public.

FEMA prides itself on maintaining strong partnerships with the other NEHRP agencies, state governments, academia, the research community, code enforcement officials, building design professionals and the private sector. These partnerships have been vital to the success of NEHRP during the past 30 years, and they will be pivotal to our continued success in what lies ahead to reduce the exposure of our people, our economy, and our overall security as a nation to the threats of earthquakes and other related hazards.

Under the current NEHRP reauthorization, FEMA has nine specific responsibilities:

1. Work with the developers of national codes and standards to promote implementation of research results;
2. Promote better building practices within the building design and construction industry;
3. Operate a grant program to assist states in developing mitigation, preparedness, and response plans; prepare inventories and conduct seismic safety inspections of critical structures and lifelines; update building and zoning codes and ordinances to enhance seismic safety; increase earthquake risk awareness and education; and encourage development of multi-State groups;
4. Support implementation of a comprehensive earthquake education and public awareness program, including development and dissemination of materials to all appropriate audiences;
5. Prepare, maintain, and disseminate seismic resistant design guidance and related information on building codes, standards, and practices for new and existing buildings, structures, and lifelines, and inform the development of performance-based design guidelines and methodologies supporting model codes for buildings, structures, and lifelines;
6. Execute the National Response Framework when required after an earthquake and support state planning;
7. Combine earthquake hazards risk reduction with other natural and technological hazards;
8. Provide preparedness, response, and mitigation recommendations to communities after an earthquake prediction has been made by the USGS; and
9. Establish demonstration projects on earthquake hazard mitigation.

FEMA Earthquake Program Successes

Under the NEHRP, FEMA has had many successes since we last appeared before this committee. I would like to take the opportunity to tell you about some of them.

Translating Research Results into Design Guidance

FEMA has a long history of working with our partners to develop and put into place earthquake resistant provisions in the nation's model building codes and consensus standards. Since 1985,

FEMA has periodically updated and published the *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*. The current 2009 edition (FEMA P-750) continues to serve as the basis for the seismic provisions of the consensus building design standards published by the American Society of Civil Engineers and the nation's model building code promulgated by the International Code Council (ICC).

In addition to the primary resource document, FEMA has also published the *2009 NEHRP Recommended Seismic Provisions: Design Examples* (FEMA P-751CD) and the *2009 NEHRP Recommended Seismic Provisions: Training and Instructional Materials* (FEMA P-752CD). These products present a series of design examples and related instructional materials and programs for training purposes.

Working with National Model Codes and Standards
FEMA was instrumental in helping the ICC develop the seismic provisions of the International Building Code. When it was published in 2000, this code became the first single nationally applicable U.S. building code. The International Codes now serve as the basis for state and/or local building codes in all 50 States and six territories. FEMA's involvement with the code change process dates back more than 30 years, and our work is well respected within the code community. FEMA's ongoing work with the International Building Code has kept it substantially equivalent to the *NEHRP Recommended Seismic Provisions* for more than 15 years, thereby satisfying the requirements of Executive Order 12699.

For the 2015 edition of the International Codes, FEMA developed and submitted several changes. Among the most significant: changes to the International Residential Code (IRC) to improve seismic wall-bracing requirements. FEMA and other organizations also successfully testified against several changes that would have weakened the IRC.

FEMA also had a significant role in the update of ASCE 41-13, Seismic Evaluation and Retrofit of Existing Buildings. With our support, this update was able to combine two different standards, ASCE 31 for Seismic Evaluation and ASCE 41 for Seismic Rehabilitation, and eliminate numerous conflicts between the two previous standards.

State and Local Adoption of Building Codes
FEMA promotes and monitors the adoption of building codes to help ensure that communities are adopting disaster-resistant provisions of the building codes, resulting in improved resilience and better building construction practices in areas prone to natural hazards. FEMA uses the Building Code Effectiveness Grading Schedule, a tool owned by the Insurance Services Organization that evaluates and scores local building code departments for code adoption and enforcement for insurance credit every five years. FEMA has purchased the use of the data to track the rate of code adoption. In 2012, 55 percent of the jurisdictions in hazard-prone regions (earthquake, wind, and flood) adopted disaster-resistant building codes equivalent to the International Codes. By 2013, that percentage had increased to 57 percent.

Promoting better building practices within the design and construction industry
FEMA has developed and published more than 100 earthquake-related publications under NEHRP funding to promote better building practices. They are all available free of charge

through FEMA. These publications address everything from non-linear seismic analysis procedures to homeowner safety tips. Some of these publications, like the *Rapid Visual Screening of Buildings for Potential Seismic Hazards* (FEMA 154) and *Homebuilders Guide to Earthquake-Resistant Design and Construction* (FEMA 232), have distribution numbers of more than a thousand per year.

Developing Performance-Based Seismic Design Guidelines

The previous NEHRP reauthorization required FEMA to fund the development of Performance Based Seismic Design (PBSD) Guidelines. This is also an area identified as a NEHRP Strategic Priority. The FEMA PBSD project is a multi-year effort to develop a next generation Performance Assessment Methodology and Guidelines for new and existing buildings, and builds on research funded by NSF, particularly the Pacific Earthquake Engineering Research Center (PEER), and conducted by NIST.

Ultimately, PBSD will allow a building owner to go beyond the current life safety code level performance and actually evaluate how their building is likely to perform in a given earthquake, considering uncertainties inherent in both the potential hazard and the actual building response. This would permit the design of new buildings or the upgrade of existing buildings with a realistic understanding of the risk of casualties, occupancy interruption and economic loss that may occur as a result of future earthquakes.

FEMA, through a contract with the Applied Technology Council (ATC), has completed a multi-year project to develop a methodology for assessing how a building is likely to perform in an earthquake, given the uncertainties inherent in the potential hazard and the actual building response, and to communicate performance in ways that better relate to the decision-making needs of stakeholders. This project will permit the design of new buildings or the upgrade of existing buildings with a realistic understanding of the risk of casualties, occupancy interruption, and the economic loss that may occur as a result of future earthquakes.

The three FEMA P-58 volumes are the first phase in the development of Performance-Based Seismic Design Guidelines. To allow for practical implementation of the methodology, project work included the collection of fragility and consequence data for the most common structural systems and building occupancies, and the development of an electronic Performance Assessment Calculation Tool (PACT) for performing the probabilistic computations and accumulation of losses. The three volumes are FEMA P-58-1, *Seismic Performance Assessment of Buildings, Volume 1 -Methodology;* FEMA P-58-2, *Seismic Performance Assessment of Buildings, Volume 2 – Implementation Guide;* and FEMA P-58 CD, *Seismic Performance Assessment of Buildings, Supporting Electronic Materials and Background Documentation.*

FEMA is now in the second year of the Phase 2 contract with ATC, which will use the Performance Assessment Methodology to develop a series of PBSD Design Guidelines for use with different structural systems and building occupancies. It will also develop a series of non-technical Stakeholder Guides to show building owners and regulators how to best utilize PBSD for their building.

Weak Story Buildings
At the request of the City of San Francisco, FEMA contracted with the ATC to examine whether it was possible to seismic retrofit just the first story of a weak story building to achieve seismic safety. A weak story building is a multi-story, wood frame residential building where the first floor is much weaker than the upper stories due to extensive garage or store front openings. The Marina District apartment buildings that collapsed in the 1989 Loma Prieta earthquake and the garden style apartment buildings with first floor "tuck under" parking that collapsed in the 1994 Northridge earthquake are both examples of weak story buildings.

As a result of that study, FEMA published *Seismic Evaluation and Retrofit of Multi-Unit Wood Frame Buildings with Weak First Stories* (FEMA P-807) last year. This document and its electronic Weak Story Tool have served as the basis for a recently passed City of San Francisco ordinance requiring the seismic retrofit of the first story of these hazardous buildings.

Software for Seismic Evaluation of Buildings
Rapid Observation of Vulnerability and Estimation of Risk (ROVER) is a free mobile software for pre- and post-earthquake building safety screening. ROVER automates two paper-based seismic safety screening procedures: FEMA P-154, *Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards,* and ATC-20, *Post-earthquake Safety Evaluation of Buildings.*

ROVER's pre-earthquake module can be used by field inspectors to quickly compile an electronic inventory of buildings, record important seismic features of a building, and generate an automatic estimate of the need for detailed seismic evaluation. ROVER's post-earthquake module can be used to quickly perform and manage the safety tagging (red, yellow, and green tags) almost universally applied to buildings after earthquakes. ROVER has been successfully pilot tested in Salt Lake City by the Utah Seismic Safety Commission and the Structural Engineers Association of Utah and by the Los Angeles Unified School District.

The ROVER Server is capable of operating as an online service for the smartphone client and as a website for direct access by any web browser. The website service is optimized for the small screens found on a smartphone or on any Internet-connected tablet. An updated edition of FEMA P-154 ROVER CD, *Rapid Observation of Vulnerability and Estimation of Risk*, will soon be available from the FEMA Publications Warehouse. The beta version of ROVER and an updated user manual are available from the user group ROVER Ready Alliance at http://www.roverready.org.

Non-Structural Mitigation Guidance
The nonstructural portions of a building can account for as much as 75 to 80 percent of a building's total cost. Given the importance of nonstructural building components, FEMA has completed the fourth edition of FEMA E-74, *Reducing the Risks of Nonstructural Earthquake Damage*. This e-publication significantly updates and expands the content and, for the first time, provides this material in an internet web-based format. FEMA E-74 contains more than 70 examples of different nonstructural components, complete with photos of actual damage and details illustrating correct mitigation and installation measures. The new web format makes it simple to browse and print out the relevant details.

Recent earthquakes in Chile, New Zealand and Japan provided many examples of buildings that performed well structurally but still suffered significant nonstructural damage and were rendered unusable for significant amounts of time. Some of the lessons learned from these earthquakes, such as the collapse of 70 percent of the elevators impacted by the earthquake in Chile, the collapse of emergency exit stairways in Christchurch, and the collapse of suspended ceilings in Japan, have been incorporated into FEMA's most recent update of this publication.

Multi-hazard Mitigation Guidance
In 2008, FEMA completed the *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis* (FEMA P-646), a document jointly funded by FEMA under NEHRP and the National Oceanic and Atmospheric Administration under the National Tsunami Hazard Mitigation Program. Vertical evacuation from tsunamis is a critical issue for several coastal communities along the West Coast of the United States that are vulnerable to tsunami, and would not be able to evacuate to high ground for a near source tsunami such as from the Cascadia Subduction Zone. A large tsunami could result in a significant loss of life, and communities are looking for alternatives such as vertical evacuation structures. The first of these Vertical Evacuation Structures is now under construction: a gymnasium addition to an elementary school located on the coast in Grays Harbor, Washington.

Training Programs
Under the NEHRP, FEMA funds the National Earthquake Technical Assistance Program (NETAP) to support and make available earthquake mitigation training for state, local, and tribal and territorial officials, businesses and others throughout the United States. The NETAP training courses include: Procedures for Post-Earthquake Safety Evaluation of Buildings (ATC-20); Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154); Earthquake Hazard Mitigation for Nonstructural Elements (FEMA E-74); and Seismic Evaluation and Retrofit of Multi-Unit Wood Frame Buildings with Weak First Stories (FEMA P-807). In FY 2013, in-person training was provided through NETAP to about 4,500 people via 93 courses in 14 States and U.S. Territories.

Another FEMA training product, *Seismic Rehabilitation Training for One and Two Family Dwellings* (FEMA P-593) was recently adopted by the California Earthquake Authority (CEA), which is California's residential earthquake insurance carrier, as the basis for their mitigation contractor training program.

Assisting States in Developing Mitigation, Preparedness and Response plans
FEMA administers the all-hazards Pre-Disaster Mitigation (PDM) Grant Program for States and communities; the Hazard Mitigation Grant Program (HMGP), an all-hazards post-disaster grant program; and the Emergency Management Performance Grants (EMPG) Program, which is administered by FEMA's Preparedness Directorate and provides grants to states to improve emergency management performance. With these grants, state agencies can fund planning activities and projects to protect their citizens from earthquake hazards.

Both of these programs have been used to fund more than 170 seismic retrofitting projects since 2000, including:

- Structural retrofit of Southern Illinois Hospital's three campuses;
- Ten different school seismic retrofit projects across California;
- Ten different hospital seismic retrofit projects across California; and
- More than 30 seismic retrofitting projects of local government buildings and facilities across California.

Multi-State Consortia
Under the NEHRP, FEMA continues to work closely with its partner organizations and multi-state consortia and organizations to support earthquake-related outreach and educational activities to promote earthquake mitigation and awareness. These partners include:

- Earthquake Engineering Research Institute (EERI), the largest earthquake membership organization;
- Federal Alliance for Safe Housing (FLASH);
- Southern California Earthquake Center (SCEC), which operates the ShakeOut training;
- Cascadia Regional Earthquake Working Group (CREW), which serves states in the Pacific Northwest in the Cascadia subduction zone;
- Central United States Earthquake Consortium (CUSEC), which serves the states in the New Madrid seismic zone;
- Northeast States Emergency Consortium (NESEC), which serves northeastern states on a multi-hazard basis; and
- Western States Seismic Policy Council (WSSPC), which serves states with a seismic hazard.

These long-time partners of FEMA play an invaluable role in coordinating multi-state response and recovery planning and in public awareness, education, and outreach. They are also active partners in the ShakeOut earthquake drills that take place in schools, businesses and homes across the United States.

In FY 2013, these cooperative agreements were focused on providing support to states. FEMA is collaborating and coordinating with these grantees to ensure substantial involvement and mutual partnership in executing local and regional risk reduction outreach and implementation activities for earthquakes and other hazards. This includes earthquake mitigation planning, property inventory and seismic inspection of critical facilities, updating building codes and zoning ordinances, earthquake outreach and education, and the development of multi-state groups in support of local earthquake and other multi-hazard initiatives.

Outreach and Awareness
Under the NEHRP, FEMA produces several earthquake outreach products that have been very successful. For example, FEMA distributes nearly 8,000 copies of its Home Hazard Hunt poster every year.

ShakeOut, which started in Southern California in 2008, is now serving as a framework for related outreach activities. It has grown exponentially and in 2013, almost 19 million people

participated in ShakeOut activities worldwide, including participants from 42 States and U.S. Territories.

ShakeOut aligns well with NEHRP goals to improve understanding of earthquake processes and impacts, develop cost-effective measures to reduce these impacts and improve the earthquake resilience of communities nationwide. In particular, ShakeOut has become a vehicle for providing earthquake information to the public and involving them in improving community resiliency. While assessing participation via registration and showcasing ShakeOut activities have been essential from the start, evaluation results to be published in 2014 will document what participants have been learning and improving with respect to preparedness and mitigation.

The success of ShakeOut is due in part to the direct financial support from FEMA under NEHRP, which provides funds to the states and U.S. Territories for activities such as the development of ShakeOut websites, templates, drill guides, registration support, and for technical planning assistance. The success of ShakeOut also is a tribute to the very active involvement and support from FEMA Preparedness, Regional Staff, the Earthquake Country Alliance (ECA), SCEC, the four regional earthquake consortia, State Earthquake Program Managers, the private sector, and many others.

Lifelines

Lifelines are systems that are necessary to provide electric power, oil and natural gas, water and wastewater, communications and transportation facilities and services that are essential to the well-being of communities. Although lifelines are unique in that they are distributive systems that must be considered as an entire system rather than a series of individual isolated components, they are also interdependent in many ways. Put simply, the failure of one system can cause failures in others. Lifeline systems often serve multiple communities crossing jurisdictional boundaries.

In the early 1990's, FEMA researched and developed several publications that addressed the issue of seismic safety of different lifeline systems. This culminated in the development of *A Plan for Developing and Adopting Seismic Design Guidelines and Standards for Lifelines* (FEMA 271). Based on that plan, FEMA funded the American Lifelines Alliance (ALA) to begin developing these proposed standards. However, with staffing and funding cuts in the late 1990s, FEMA halted all lifelines-related work to focus its limited resources on buildings.

The most recent lifelines work is a new Lifelines Action Plan currently being completed by ATC for NIST. FEMA staff did participate in this project and helped author portions of the plan. One key element to come out of that plan is the need to improve the resiliency of lifelines, including power, water, and communications, as lifelines are a critical component for ensuring a community's resiliency.

Earthquake State Assistance

Several years ago, FEMA requested and received additional resources to provide Earthquake State Assistance funding directly to participating states through a series of cooperative

agreements. These cooperative agreements were used to support state activities to reduce future earthquake losses. Section IV of the NEHRP Annual Report of the National Earthquake Hazards Reduction Program for 2012, published in February 2014, provides a thorough listing of these state accomplishments.

Some examples include:

- Using FEMA's ROVER to assess the safety of schools in Utah along the Wasatch Fault. A similar program of assessing the seismic safety of public schools has been undertaken in Oregon.
- Using FEMA funds, the California Critical Infrastructure Review for Seismic Vulnerabilities (Cal VIVA) project identified, evaluated and developed basic retrofit actions for seismically vulnerable state buildings that are essential to post-earthquake response and recovery effort.
- The State of Illinois held four post-earthquake inspection training classes using FEMA funds, resulting in 189 additional trained inspectors. At present, Illinois has 466 trained inspectors in their database.

A subsequent legal interpretation in FY 2012 linked this program to the original NEHRP state grant program and required that the state cooperative agreements include a 50 percent cash match. Nearly half of the 33 participating states were unable to meet that requirement. This led FEMA to decide to prioritize funding toward the earthquake consortia and other partners to more effectively reduce earthquake risk.

This year, FEMA will prioritize funding through its earthquake consortia and other partners as a means to more effectively focus earthquake hazard preparedness and education efforts nationally, regionally and across states and territories most vulnerable to earthquakes.

FEMA will continue to work with our partners and emergency management colleagues to further support the NEHRP mission and to identify ways to leverage resources to further reduce earthquake risk.

FEMA's Vision for the Future of the NEHRP

We believe that for the NEHRP to remain relevant in the 21st century, it is not enough to just study the earthquake problem; we must also develop and implement effective mitigation solutions. To do this, we must continue to evaluate our program priorities and focus our activities to emphasize implementation. We must be able to provide not only the tools needed to reduce future losses, but also the tools, education and incentives to encourage their use.

The NEHRP has been extremely successful in developing an impressive array of products that have been used effectively by engineers, architects and building regulators when they have been given the resources to address the hazard. There needs to be additional efforts applied to creating incentives and public demand, and securing the time and resources necessary to reduce the risk from earthquakes.

Part of the challenge is a lack of understanding or knowledge of the actual seismic threat that exists in a given area. There has traditionally been public perception that building to the code will result in a structure that will not be damaged and, even if it is, the federal government will make it "whole" again through disaster assistance. Both assumptions are false. Building codes only provide the minimum level necessary to protect lives, and do little to prevent damage, and federal disaster assistance was never meant to be a substitute for insurance.

Changing perceptions is key to serving the basic mission of NEHRP. Just as the American consumer has come to consider the safety of a vehicle to be a significant factor when buying a car, we envision a future where one of the key criteria in buying a house or building will be its safety from all hazards – how well was the building designed and constructed and whether it is certified to meet or even exceed a certain level of code performance and an associated level of safety.

Unfortunately, one of the major weaknesses of the NEHRP is our lack of leverage for local and state levels of government to implement earthquake risk-reduction measures. So we must look for and find ways to provide this leverage with incentives and rewards for communities at risk that adopt and enforce adequate mitigation standards.

That is not to say we have not had any success working at the local level. An excellent example of what can be done is currently taking place in Los Angeles, where a senior USGS official is on loan to the Mayor of Los Angeles's office to develop a city seismic safety program. Several aspects of this plan, which are currently being developed, are based on FEMA building design guidance publications. This effort is being supported by FEMA-funded subject matter experts. For example, concrete buildings constructed prior to the mid-1970s may not have sufficient reinforcing steel to confine the concrete during earthquake ground shaking. Some of these buildings are a collapse hazard, but not all of them, and determining which ones need to be retrofitted has been a significant problem. FEMA is currently working on a guidance document that would allow an engineer to evaluate a building to make this distinction. Although it will likely be completed in two years, the City of Los Angeles is eager to receive the guidance and is planning to reference the report in a proposed ordinance to address these buildings.

The current public policy emphasis on improving the resiliency of our nation's built environment through pre-disaster mitigation offers new avenues that we need to pursue in order to get our earthquake disaster-resistance message into the hands of those who can best use this information. Our hope is that the current emphasis on improving our resiliency will serve both as the catalyst and the foundation for future risk-reduction activities by public and private sector interests.

Ultimately, the program will need to explore possible incentives that will encourage the use of our technology by the American public. Several years ago a study done by the Earthquake Engineering Research Institute, with NEHRP funding from FEMA and the State of California, provided some possible incentives. The findings of that study need to be pursued.

It is important to note, however, that all of this is taking place in the context of diminishing federal budgets. This requires a careful review to ensure the best use of the resources of all of the parties, both public and private. This means that we need to emphasize those aspects of our

program that offer the greatest promise of helping communities and individuals acknowledge their risk, accept responsibility for reducing that risk and take appropriate actions to become more disaster-resistant.

One issue that remains challenging is that under NEHRP, the breakout between research and implementation continues to be roughly three to one. We continue to leverage the resources we have, not just within our agency, but at all levels, including private industry, by coordinating with our partners to put our collective resources to their best use. One of the best examples we can use to illustrate how we leverage our resources is in updating the *NEHRP Recommended Provisions for New Buildings*. This document serves as the basis for the nation's seismic code provisions and is updated for us periodically to maintain its consensus backing. To achieve this, we rely heavily on the efforts of volunteers, and it has been estimated that we in fact get eight dollars of work for every dollar we spend on this initiative.

Another challenge is communicating risk to different audiences in different parts of the country. Competing for the attention of the public to promote earthquake preparedness and mitigation is difficult in an environment where other hazards occur with greater frequency, even with less consequence. This is especially true in areas where earthquakes occur infrequently, even though they may be a very high hazard, such as the New Madrid Fault Zone, and in Charleston, South Carolina. The perception of the earthquake threat in California, where earthquake loss reduction is viable and risk perceived as probable, is far different than in other areas of the country, such as the New Madrid region with its high potential of loss but with a lower probability of occurrence, where the perception of risk is minimal. The general population of New England and other areas on the East Coast represent an even greater contrast in that there is still a significant hazard but little perception of earthquake risk. A risk communications strategy will need to acknowledge these differences. The NEHRP will need to shift its focus to put a greater emphasis on behavior to understand how to influence perceptions, how to effectively communicate information in a way that helps those affected to not only understand their risk but begin to manage it as well.

Conclusion

In conclusion, NEHRP has been a very successful program and has done much to improve this nation's ability to prepare for, respond to, recover from, and mitigate against future earthquakes.

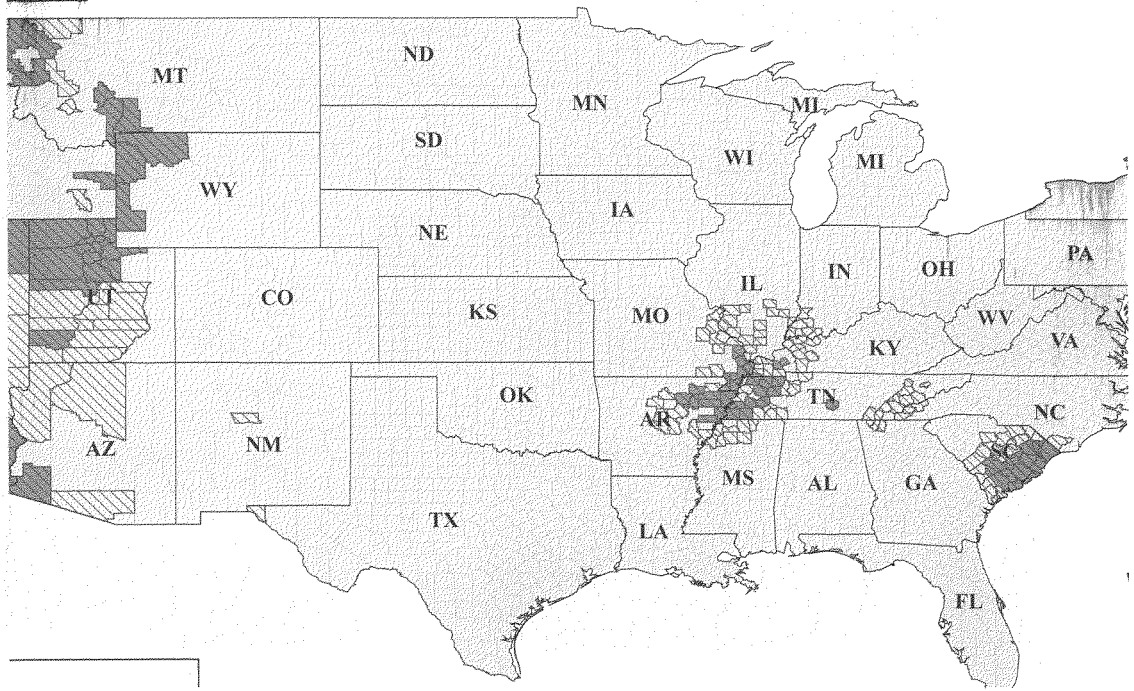
It is beneficial to look back and celebrate our successes over the program's history, and we have many of which we are proud. But it is also healthy, if not necessary, to look forward and plan where we are going in the future. We at FEMA can assure you that we will continue to play a key role in the NEHRP to help prepare and protect the American people from the earthquake hazard.

I want to express my appreciation for the consistent support and counsel of this Subcommittee and look forward to our continuing association in addressing the challenges before us.

Thank you, and I will be happy to answer any questions that the Subcommittee may pose.

Have Adopted Seismic-Resistant Building Codes

June 27, 2014



Roy E. Wright

Roy E. Wright serves as FEMA's Deputy Associate Administrator for Mitigation. He is responsible for FEMA's risk analysis and risk reduction programs. These include FEMA's Stafford Act authorities for mitigation, the National Earthquake Hazards Reduction Program, the National Dam Safety Program, and the National Flood Insurance Program. Mr. Wright is also responsible for FEMA Disaster Reservists within the Mitigation Cadre as well as the delivery of environmental and historic preservation technical assistance and compliance across all FEMA programs. Collectively, these programs promote a risk-conscious culture and address long-term vulnerabilities in communities across the Nation.

Mr. Wright led the interagency development of the National Mitigation Framework required by the Presidential Policy Directive on National Preparedness (PPD-8). In the Directive the President said, "Mitigation stands as a critical linchpin to reduce or eliminate the long-term risks to life, property, and well-being."

When Mr. Wright joined FEMA in 2007, he served as the Program Executive for Risk MAP (Mapping, Assessment, and Planning). In a prior role, Mr. Wright served as a policy advisor to the Secretary of the Interior focused on land conservation measures. He has also led management consulting teams that improved the performance of government programs.

Mr. Wright was appointed to the Federal Senior Executive Service in 2013. He holds a Master of Public Administration from The George Washington University and a Bachelor of Arts in Political Science from Azusa Pacific University. His post-graduate studies include the Senior Executive Fellows program at Harvard University's Kennedy School of Government and the Executive Leaders Program at the Naval Postgraduate School's Center for Homeland Defense and Security. A native of California, Roy and his family live in northern Virginia.

Chairman BUCSHON. Thank you very much. I would like to thank the witnesses for their testimony.

I am reminding the Members that Committee rules limit questioning to five minutes. The Chair at this point will open the round of questions. The Chair recognizes himself for five minutes.

Dr. Hayes notes in his testimony that maintaining the serviceability of lifeline systems is critical to societal resilience. What research and development is being supported through NEHRP related to lifelines in a seismic event and what more needs to be done? I will address that to Dr. Khargonekar first.

Dr. KHARGONEKAR. Chairman Bucshon, that is a very, very important question. We are funding research in this area at a number of institutions across the research universities in the United States. I don't have a list of projects that we are funding, but just to go back to the example I gave about high density polyethylene pipes, this is a major impact of the kind of work that NSF has supported in this space.

Chairman BUCSHON. You might just—when you do have that list might just submit that for the record so we will have that in the Congressional record what you are doing.

Anyone else have any other comments?

Dr. Hayes, you mentioned this in your testimony.

Dr. HAYES. Yes, sir. If I could just comment briefly, the NEHRP agencies are currently in the process of wrapping up a study with a contractor who is examining all of the issues related to lifelines research and implementation. That report should be out sometime within 60 to 90 days, and it outlines what NSF-supported researchers at the basic level need to do, what NIST needs to do at the applied level, the kinds of things that USGS needs to do, and the kinds of things that FEMA needs to do to implement lifelines safety efforts as well.

And one of the key issues there is that lifelines are absolutely critical to societal resilience in any given community around the country, and one of the main findings so far has been that no matter whether it is an earthquake or some other hazard, the disruptions to lifelines are really critical and we hope the study will help point all of us in the future on what we should be doing in that area.

Dr. APPLEGATE. Just very briefly, one area that we have been working on is developing scenarios that sort of play out the impacts of events, trying to make the hazard real to people before they have to go through the catastrophic event. And lifelines have been a very important part of that, getting the operators together, getting their input, understanding what those consequences—those cascading consequences are going to be, and particularly in California and Southern California and now with the new focus on the Hayward Fault in the Bay Area, what those impacts—what can be done before the event to change those outcomes.

Chairman BUCSHON. Thank you.

Mr. Wright, part of the preparedness puzzle is learning how to work together and forming a seamless response and recovery effort. Can you comment on the coordination between federal, state, and local stakeholders and their roles in earthquake response? You had some of that in your testimony, but kind of talk about that a little

more, and how do NEHRP stakeholders coordinate efforts with emergency responders?

Mr. WRIGHT. Absolutely. It is FEMA's responsibility to look across all hazards and ensure that we are prepared for them. And as we look at these seismic elements, very specific investments have been made. In 2011 there was a national-level exercise that looked across the New Madrid area where we brought together the totality of the federal family, but particularly working with the state emergency managers as well as the state and locals. We do this across the West Coast. And there is a particular relationship we share with the USGS on this by which we are directed to ensure that the kind of warnings and insights that can be given to us from the USGS then move its way out. That helps from a response and from a recovery. Obviously you look at these larger earthquakes that played out in California, Loma Prieta, and Northridge where significant dollars were made available under the Disaster Relief Fund after the event. But collectively, it is that kind of integrated respond that we do, and it is a long-standing relationship, particularly between myself and Dr. Applegate and others across our agencies to make that happen as cooperation with the state and locals.

Chairman BUCSHON. Yeah, because I think that is critically important along with the lifelines. The last earthquake I was in I was on the 6th floor of the hospital in Evansville, Indiana, and nothing happened but if that was an area where a hospital lost access to water and power that couldn't be restored quickly, it is a big issue. I didn't think it was an earthquake and the patient did. She was an elderly lady and she said I think it is an earthquake. I said no, it can't be an earthquake. So I turned on the TV and sure enough, it was an earthquake.

I now recognize Mr. Lipinski for five minutes.

Mr. LIPINSKI. Thank you, Mr. Chairman. Thank you for holding this hearing. I am very hopeful that we can do a NEHRP reauthorization soon.

It was good to hear all the testimony today. I want to thank Dr. Applegate for work USGS has done with my staff and with me. We have gone through a few conversations about an earthquake that I felt sitting at my kitchen table at home that was—we believe was induced by some quarrying activity and there is more work going on with that. But it was very helpful for me to be able to have those discussions to try to get at and understand what had happened there, so I thank you for—thank USGS for that.

I wanted to ask Dr. Khargonekar about social science research. You mentioned in your testimony of the involvement of social science research and NSF's efforts on earthquake research. How does social, behavioral, and economic research help with planning effective risk mitigation efforts and how does—how is SBE research integrated into NSF's NEHRP activities?

Dr. KHARGONEKAR. Congressman Lipinski, thank you very much for that question, which is evidently very important.

If you think about resiliency, which is certainly one of the major objectives, people's behavior plays a huge role in terms of how we can achieve systems that can recover from a major disaster. NSF is funding a number of projects in that area out of the Directorate

of Engineering. We have a program on Infrastructure Management and Extreme Events that funds social science type of research. For example, how do we communicate risk? How do people respond to those types of communications?

And things are changing. I mean with the mobile phones and cellular technologies and so forth, people are getting their information in very different ways than used to be the case before. We are funding research into the next frontier that can allow us to leverage all the advances in technology and couple it to people's perception of risk, the reactions to risk, and those types of activities. So we believe this to be a very important part of the research program. It is no good to come up with technological solutions that people don't use for improved public safety and the safety of themselves and their property and so on and so forth.

Mr. LIPINSKI. Thank you.

And I wanted to—the next thing I want to address is building codes and address this to Dr. Hayes and Mr. Wright. We know that strong and modern building codes are often cited as the most effective tools for limiting the impact of earthquakes. How do model building codes in the United States compared to building codes in other countries such as Chile, Haiti, Japan, and New Zealand? And what have we—what lessons have we learned about the design of resilient structures from the recent earthquakes in these countries that I mentioned?

So, Dr. Hayes, do you want to begin?

Dr. HAYES. I think our current building codes are actually quite comparable to those that you would see in some of the countries you mentioned, particularly New Zealand and Japan. They are not identical. They have evolved in slightly different ways, but the earthquake professional community around the world is extremely close-knit and the provisions that are in one country will bear a striking resemblance quite often to provisions in another country.

The NEHRP agencies study the earthquake events that occur in other countries to try to learn from them, particularly when the building codes in those countries lead to construction that is very similar to what we see in our country. And we are very conscious of the earthquake that occurred down in Chile that led to a lot of interest here in the United States and also the one in New Zealand that occurred in Christchurch.

And in Christchurch, we haven't yet had a chance to study that much about it, but a couple of things that have leaped out at us about Christchurch is that the liquefaction that occurred in the area is very similar to liquefaction that could occur in many earthquake-prone areas in our country, particularly in the middle United States. And the older buildings in Christchurch that were severely damaged bear a striking resemblance to the kinds of brittle or non-ductile buildings that you would see in many cities in the United States, and I think there is a lesson there that we all carry that these older buildings are really something that really need to be looked at very carefully in the future as we look at how we make our society more resilient.

In New Zealand also I think that there was a realization that a moderate earthquake which people had thought might happen could be much more damaging than perhaps it was expected to be

in Christchurch. That was a devastating event there and the area has not fully recovered yet over two years later. It is still working on doing that.

In Chile, their primary means of engineered construction was in reinforced concrete, and it turns out that in Chile they have adopted much of the American Concrete Institute's provisions for seismic design in our country, but not all, and we have been studying what happened down there to learn from what went well and what didn't go so well in their buildings and have produced a couple of reports on that already.

Mr. LIPINSKI. End of my time but if the Chairman would allow Mr. Wright—do you have anything to add?

Mr. WRIGHT. Just briefly to build on that. I think that what we learned from the work we see in Japan and Chile, we work with the other agencies that are here after those events and in particular to see how those elements will perform. Again, we are on a three-year cycle with the building codes in this nation by which we are continuing to make sure that those are being updated. The 2015 ones have now been set, and we would look to the kinds of things that we will learn from Christchurch and Chile in terms of what it would mean to inform the next cycle.

Mr. LIPINSKI. Thank you.

Chairman BUCSHON. Thank you.

I will just—sure—Dr. Khargonekar, go ahead.

Dr. KHARGONEKAR. Well, In the spirit of the question, I would like to offer an example. We supported a RAPID response team in Hawaii and Oregon State to perform a high resolution survey of damaged coastline around Japan after the Tohoku Earthquake. Now, cutting long story short, they have collect data and their results are now being used by the committee working on Chapter 6 on tsunami loads and effects for ASCE 7 standards. So we think that that is a great example where we fund research to go collected data, do all the work, and it comes back in effect. So we think that once the ASCE 7 standards are adopted, it will improve the whole building code in that particular section. Thank you.

Mr. LIPINSKI. Thank you.

Chairman BUCSHON. Thank you.

I now recognize Mr. Johnson for his line of questioning.

Mr. JOHNSON OF OHIO. Thank you, Mr. Chairman. And I want to thank our panel for being with us today.

You know, while your agencies are the four NEHRP agencies as defined in statute, I understand that other agencies such as NASA also conduct seismic or earthquake-related research and activities. Have there been any related earthquake-related collaborations that your agencies participated in with other agencies? And if so, what were those agencies and can you give us any idea of the work that was done to help us better prepare for earthquakes? Any of you?

Dr. APPLEGATE. I can start on that one. Yeah, absolutely. It is a very good point. There are many different agencies that are involved in the earthquake arena and we actually have a White House Subcommittee on Disaster Reduction that brings together all of those agencies looking at different hazards and it is a way to bring this partnership in and coordinate with the broader effort.

With NASA, the USGS works very closely on, for example, SAR technology, Synthetic Aperture Radar, where you can use overlapping images to see change patterns. And so using that remote sensing technology that has been developed through NASA has been very valuable for understanding the damage patterns, for example, after events.

We also work very closely with the U.S. Nuclear Regulatory Commission. Of course they have very specific concerns and issues as they ensure the safety of the Nation's nuclear power plants and they have supported some tremendous research looking at particularly some of these sort of very long-term—you know, the Black Swan type events and events in the eastern and central United States. So there are a number of other agencies that play a key role here.

Mr. JOHNSON OF OHIO. Okay. Thank you.

Anybody else?

Dr. KHARGONEKAR. On the disaster recovery side of the problem, we work closely with other agencies such as Department of Transportation on developing plans on how one would recover from disasters. We have ongoing research projects and activities that bring together these communities.

Mr. JOHNSON OF OHIO. Okay. All right. Well, thank you.

Shifting gears just a little bit, talking about earthquake hazard mitigation, what type of research in your opinion is needed to better understand and encourage people to adopt earthquake hazard mitigation measures? I mean what is our greatest weakness in terms of our current approach to earthquake mitigation?

Mr. WRIGHT. Well, I will start. It is—the country's understanding of risk is a very difficult thing to somehow pierce through. We see this across many of the natural hazards by which they may understand that there is a hazard that could affect them but they somehow believe that it won't necessarily impact them the day that it occurs, this kind of cognitive dissonance that sits there. And so it is that kind of partnership that goes towards that social science research that helps us get past those next kind of pieces.

You look across the Nation and, as I was showing the map of it earlier, about—there are high seismic risks in parts of the country, yet the element that we know does the most to help mitigate that related to building codes, many have not chosen yet to adopt those. And so these elements are things we continue to collaborate, particularly with the National Science Foundation, but others as well in terms of how do we link what we know on the seismic side with the social science side?

Mr. JOHNSON OF OHIO. So it is kind of "it is not likely to happen to me" syndrome that we are dealing with?

Mr. WRIGHT. That is exactly the case. And we struggle with this across a whole range of hazards that we would deal with in an emergency management space, but these kind of no-notice events that happen on sort of a severe or catastrophic level on a far less frequent basis really allow people's attention to them to erode.

Dr. KHARGONEKAR. I would like to just add a few comments to what was stated. You know, one of the questions you may ask is what is the impact of having insurance on people's behavior in adoption of solutions? So we funded again collaborative research

with colleagues in New Zealand because their situation is very similar to the United States' situation with respect to insurance, and we are funding research, we are collecting data from Christchurch to see what was the impact of having different kinds of insurance on people's behaviors and decisions, so it is sort of the social, behavioral science type of activity, and that complements what was said earlier.

Mr. JOHNSON OF OHIO. So do you have any examples of low-hanging fruit in overcoming that risk avoidance or lackadaisical attitude if you will? I guess that is a good way to phrase it. Any ideas on how we go about penetrating that? You talked about some of them but——

Mr. WRIGHT. I think part of what we have found when we deal with these issues some of it happens from a grassroots perspective but local elected leaders and particularly the economic drivers in the community often are the kind of place by which they are able to provide the kind of leadership in a State—you look at—there are particular things that happen in some of the major industries that are in the Memphis area and how they began to really lean forward in this space and work with those local electives to pay more attention to this kind of risk.

Mr. JOHNSON OF OHIO. Okay. Well, thank you.

Mr. Chairman, I yield back.

Chairman BUCSHON. Thank you.

I would like to just comment on what you talked about briefly and I think in healthcare we are acutely aware of people's lack of understanding of statistical probability. I think it may start in grade school where we are not doing a good enough job for people, in all seriousness, understanding statistics, and that is very important. Without that understanding, you can't really figure out what the risk is so——

Mr. WRIGHT. Without question.

Chairman BUCSHON. Yes.

Mr. Collins, I recognize you for five minutes.

Mr. COLLINS. Thank you, Mr. Chairman.

I am kind of a private sector guy. I am new to Congress but I have spent decades in the private sector, and I always come to work and when I tour companies now, the first thing I look for on the wall is a vision statement. Why did you come to work today? And a mission statement, what are we going to try to accomplish? And I always talk about five-year strategic plan and so forth and so on, just very metric-driven and results-oriented.

So I guess with half the money—Dr. Applegate, for NEHRP, more or less half of it going to your agency, and I know you are natural hazards so that is beyond just earthquakes, but a simple question. Is there an underlying vision statement and/or mission statement related to the work that we are doing on earthquakes that somebody would see when they come to work and say this is the Holy Grail? Or—and is there a strategic plan within your organization? And if so, are there like three things you could point to, ABC, that you accomplished last year and three more this year and three more next year, just kind of hard things?

Dr. APPLEGATE. Sure, absolutely. Working in the broader hazards mission of the USGS, and I oversaw these earthquake efforts pre-

vious to that, yes, you know why you get up in the morning and it is about making the American people safer. It is as simple as that. It is a public safety mission. We are trying to ensure that science is there to help people when the event strikes so that we are providing the situational awareness, where the shaking is most intense, what the emergency managers need to be able to respond, what the public needs to know.

But the most important things we do are what happens before the event and that is what has been talked about a lot here. We use our seismic hazard assessments to bring everything that we know about the hazard both from the fundamental research coming through NSF, as well as the targeted research we do that feeds then into the building code process and helps to make people safer. So you have the one element is the monitoring, the situational awareness; the other is the assessment understanding so that you can build buildings that are going to be safe for people.

And the third piece of it is education. It is just what we were talking about. How do you make these hazards real to people? And so we do a lot with our agency partners in the public preparedness arena, the shakeout events which now—started in California but they now involve—I think we are up to about 38 of the States—FEMA has been a big supporter of this—to simply get people to participate in drop, cover, and hold drills and do one of the things to protect themselves.

Jack would be the best to talk about the broader NEHRP strategic plan. Within USGS, we have nested our earthquake hazards program plan within that broader NEHRP strategy as well as within our broader natural hazards mission.

Mr. COLLINS. Now, I would think early warning would go a long way. And I understand we have got a pilot program in California, but if there is probably anything that could truly save lives, you can't prevent the earthquake, but if somebody had even the one- or two-minute warning, it——

Dr. APPLEGATE. Absolutely. I mean I think what we saw in the Japan, there are three key elements. I mean there were relatively low—from the magnitude 9 earthquake, giant earthquake that struck that country, relatively low fatalities from the earthquake shaking itself, probably in the order of maybe 100, 150. That reflects three things. One of them is building codes. They were—people were in buildings that did not collapse, and that is I think the first thing and the most important. Then it is that public awareness, that culture. The third thing is they have early warning and so people did receive the notice before the shaking event so they could get themselves safe. There are a lot of things that can be done even with just a few seconds. And so we are trying to move towards that for that very reason.

Mr. COLLINS. Do you have a goal in mind there? Again, back to vision statements, is there a goal to have early warning at least in the most critical areas by date certain and is there a way to measure that? And——

Dr. APPLEGATE. Yes. We have just recently issued an implementation plan for earthquake early warning for the West Coast, so the beginning phase is the pilot effort in California expanding up the West Coast. But in many ways the high hazard areas, for example,

in the central United States where you are likely to have shaking experienced over very broad areas, you would actually get additional time before that shaking arrives, so less frequent events but the potential for damage over much broader areas. So, yes, absolutely, we have those plans in place. We would be very happy to share those.

Mr. COLLINS. Yeah. No, thank you very much.

It looks like my time is expired. I yield back, Mr. Chairman.

Chairman BUCSHON. Thank you.

And at this point I would like to thank the witnesses for your valuable testimony. It is a very fascinating subject.

The Members of the committee may have additional questions as we asked about the list of funding projects for you and we will ask you to respond to those in writing. The witnesses are excused, and at this point we will take a very short break prior to the next panel. Thank you very much.

[Recess.]

Chairman BUCSHON. Thank you very much. Now, I will introduce our witnesses for our second panel.

Our first witness of our second panel is Dr. Julio Ramirez. Dr. Ramirez is Professor of Civil Engineering, Chief Officer of the Network for Earthquake Engineering Simulation and NEEScomm Center Director at the George E. Brown, Jr. Network for Earthquake Engineering Simulation at Purdue University. And I have visited their facility; it is a great facility.

Our second witness is Dr. William Savage, Manager of William Savage Consulting, LLC. He is also an Adjunct Professor in the Department of Geoscience and Department of Civil and Environmental Engineering and Construction at the University of Nevada Las Vegas.

Our third witness is Mr. Jonathan Monken, Director of the Illinois Emergency Management Agency. Mr. Monken previously served as Acting Director of the Illinois State Police and possesses a distinguished military career having served in Kosovo and Iraq. Thank you for that service. It is much appreciated.

Our final witness is Dr. Andrew Whittaker. Dr. Whittaker is Professor and Chair of the Department of Civil, Structural, and Environmental Engineering at the University at Buffalo, and the Director of MCEER.

As our witnesses know, spoken testimony is limited to five minutes each, after which Members of the committee will ask questions for five minutes. Your written testimony will be included in the record of the hearing.

I now recognize our first witness, Dr. Ramirez, for five minutes.

TESTIMONY OF DR. JULIO A. RAMIREZ, PROFESSOR OF CIVIL ENGINEERING, NEES CHIEF OFFICER AND NEESCOMM CENTER DIRECTOR, GEORGE E. BROWN JR., NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION (NEES), PURDUE UNIVERSITY

Dr. RAMIREZ. Good morning and thank you for the opportunity, Chairman Bucshon, Congressman Lipinski, and distinguished

Members of the panel, to testify before the Congress as you work to reauthorize the National Earthquake Hazards Reduction Program, NEHRP.

I am Julio Ramirez, a Professor of Structural Engineering in the School of Civil Engineering of Purdue University in West Lafayette, Indiana, and the Chief Officer of the NSF-funded George E. Brown, Jr. Network for Earthquake Engineering Simulation, NEES.

Existing vulnerable buildings and infrastructure assets are the number one seismic safety problem in the United States and the world today. Since the 1980s, I have been involved in the development of building codes and conducted research in earthquake safety of buildings and bridges. I have lead or participated in some eight reconnaissance missions starting with the earthquake of Northridge, California. The central purpose of these missions was to gather perishable data on the performance of bridges and buildings following major earthquakes to distill lessons to improve the seismic resilience of our society.

The NEHRP vision is for a nation that is earthquake-resilient with regard to public safety, economic strength, and national security. NEHRP provides the critical support structure for seismic protection in the United States. The NSF provides the fundamental research arm of NEHRP supporting research in engineering, Earth, and the social sciences. To mitigate the earthquake risk by reducing the vulnerability of the built environment, the NSF-funded NEES originated in 2004 as a national multiuser research infrastructure, and its central mission aligns with the larger NEHRP national plan for earthquake risk reduction. May I have the first slide, please?

[Slide.]

Dr. RAMIREZ. NEES laboratories are used for research conducted or funded by the NSF, other government agencies, and by private industry. To date, more than 400 multiyear, multi-investigative projects have been completed or are in progress at NEES sites. These projects are yielding a wealth of valuable experimental data and continue to produce informational research and outcomes that impact the engineering practice from building models to design guidelines and codes.

Information on the impact of NEES work is submitted with my written testimony as Reference 3, "NEES, 2004–2014, A Decade of Earthquake Engineering Research." In this document there are—there is information regarding lifelines projects that have been funded by NSF and many other references as well.

The human capital gain in this activity represented by the more than 2,000 graduate and undergraduate students that have participated in on-site of NEES researchers also supports the United States in retaining a competitive edge in the STEM areas. Many of the world's global challenges such as the mitigation of earthquake risk can best be met with a strong presence of engineers working in teams with social scientists and other experts, yet the number of U.S. engineering students is declining.

Purdue University and our College of Engineering have taken a leadership role as part of a national call to graduate 10,000 more

engineers per year enhancing our state and national capacity for innovation, economic growth, and solutions to global challenges.

Next slide, please.

[Slide.]

Dr. RAMIREZ. Linking the NEES experimental facilities to its users in the community is the NEES cyber infrastructure. This unique system of IT resources enables researchers participating at the facilities or remotely to collect, view, process, and store data from NEES experiments and to conduct numerical simulations with access to key U.S. high-performance computing resources.

At the heart of this system is NEEShub, a platform designed to facilitate information exchange and collaboration among earthquake engineering research and other stakeholders. NEEShub features the NEES Data Repository with over 2.5 million data files. This public repository is used to store and share data of research and research results.

Final slide, please.

[Slide.]

Dr. RAMIREZ. Since the first release of NEEShub in August 2010 it has served tens of thousands of users of more than 200 countries.

In conclusion, maintaining a balanced program supporting research and the Earth science, engineering, and social sciences is important. In achieving resilience of communities against earthquakes and tsunamis, engineering-related research is of the highest priority as it directly impacts the mitigation of the extent of damage to the built environment and can reduce the time needed for recovery. Thank you.

[The prepared statement of Dr. Ramirez follows:]

Testimony: Prof. Julio A. Ramirez, PhD
School of Civil Engineering
Director of NEEScomm Center and NEES Chief Officer
Purdue University
West Lafayette, IN 47907

July 29, 2014

Hearing: *A Review of the National Earthquake Hazards Reduction Program*
U.S. House of Representatives
Committee on Science Space and Technology, Subcommittee on Research and Technology
Room 2318 Rayburn House Office Building
July 29, 2014 at 10:00 a.m.

TESTIMONY

Introductory Remarks

Good morning and thank you for the opportunity to testify before the Congress as you work to reauthorize the National Earthquake Hazard Reduction Program. I am Julio Ramirez, a Professor of Structural Engineering in the School of Civil Engineering of Purdue University in West Lafayette Indiana.

Many of the world's global challenges, such as the mitigation of earthquake risk, can be best met with a stong presence engineers working in well-integrated teams with social scientists and other experts, yet the number of U.S. engineering students is declining. Purdue University and our College of Engineering will take a leadership role as part of the national call to graduate 10,000 more engineers per year, enhancing our state and national capacity for innovation, economic growth and solutions to global grand challenges. The effort will go beyond the already approved five-year plan that called for:

- Increasing Engineering graduate student enrollment by 750.
- Increasing Engineering undergraduate enrollment by 691.
- Hiring 107 new engineering faculty.
- Lowering undergrad-to-faculty ratio from 21-to-1 to 17-to-1.

The National Earthquake Hazard Reduction Program (NEHRP) is a vital program to help train the next generation of engineers with real-time research experiences. NEHRP provides the critical support structure for seismic protection in the United States. It provides federal support for research, information dissemination, development and implementation of technology, and the application of planning and management procedures to reduce seismic risk. Through the contributions of its four agency members, it provides the resources and leadership for understanding and reducing United States vulnerability to earthquakes and tsunamis, and supplies the support base for seismic monitoring, mapping, research, testing, code/guideline development, mitigation and emergency preparedness. The NEHRP vision is a nation that is earthquake-resilient with regard to public safety, economic strength, and national security. This support is critically important because the United States faces serious earthquake risk. According to a 2006 National Research Council Report (NRC) (1) quoted in the 2009-2013 NEHRP Strategic Plan (2), 42 States have some degree of earthquake risk and 18 of those States have areas of high or very high hazard. This risk is growing because population density, economic activity and infrastructure are

increasing in locations affected by earthquakes. In the context of earthquakes and tsunamis, risk may be understood as the combination of two key factors: hazard and exposure. The hazard is represented by the probability of earthquake occurrence and magnitude. Exposure is represented by the vulnerability of the built environment. In this construct, regions of the nation where earthquakes are not frequent (i.e. low hazard), the risk is high if the exposure, represented by the civil infrastructure accumulated over the years designed without seismic considerations, is significant. Your letter of invitation asked me to respond to five specific items in my testimony, and each is addressed in the sections that follow.

Research and Code Development Experience

For the past 30 years I have been teaching and conducting research in structural engineering at the Purdue University School of Civil Engineering. My area of expertise is in the design, evaluation of performance and code development of reinforced and prestressed concrete bridges and buildings. I have been involved in the development of building codes since the late 1980s and conducted research on:

1. Durability of Concrete Bridges

2. Earthquake Safety of Buildings and Bridges

3. Bridge Design

4. Safety of Buildings and Bridges against man-made hazard

Since 1994, I have been involved in and led some eight-reconnaissance missions following the earthquakes of Northridge CA, Manzanillo Mexico, Kobe Japan, Duzce-Bolu Turkey, Puebla Mexico, Armenia Colombia, and Bingol Turkey. Many of us have seen firsthand how devastating an earthquake can be not only to the built infrastructure serving a society, but also to families, their businesses, the community and people's sense of security. Existing vulnerable buildings and infrastructure assets are the number one seismic safety problem in the world today. The central purpose of these missions was to gather perishable data on the performance of reinforced and prestressed concrete bridges and buildings immediately following major earthquakes in what constitutes a major real life and very costly test of the built environment in order to synthesize lessons that could help mitigate the impact of earthquakes on society.

I was engaged as project Co-PI in the recently completed NEESR- Grand Challenge research study aimed at identifying collapse triggers in non-ductile reinforced concrete buildings subjected to seismic actions. Presently, I am committed as project PI, Center Director and Chief Officer for the George E. Brown Jr. Network for Earthquake Engineering Simulation NEES Operations award for the period of 2010-2014 (NSF Award CMMI-0927178).

The focus of the NEESR Grand Challenge Project consisted of developing a consensus on the so-called "killer" buildings, project the scale of the problem, illustrate possible cost-effective retrofit, identify mitigation policy alternatives, and promote active mitigation programs. I was in charge of overseeing and coordinating the overall experimental program of column tests, beam-column subassembly tests, soil-structure-foundation interaction field tests and membrane tests. The test results were used to develop improved component models for use in the numerical analysis of building performance. The main code/specification contributions to date resulted from the work conducted by members of the research team of the NEESR Grand Challenge Project, "Mitigation of Collapse Risk in Vulnerable Concrete Buildings", through testing and numerical simulation of older concrete columns. The results of this phase of the overall research project expanded the database of laboratory tests in key gap areas thanks to the unique testing capabilities of the NEES MAST Facility at the University of Minnesota. Tests performed

provided new data to study the drift ratio at axial failure of shear critical and captive columns subjected to various different loading protocols. Our evaluation of the test results indicate that bidirectional loading can lead to a reduction of nearly 50% in the deformation capacity of a column. No data on the effects of bidirectional loading on the performance of non-ductile columns were available before this project. Those new data together with the re-use of other existing data contributed to at least two major impacts of the overall project.

Namely:

- Project team members led the development of revisions to the concrete provisions of ASCE/SEI 41, which were accepted as the ASCE/SEI 41 Supplement and eventually incorporated into ASCE/SEI-06. The supplement to ASCE/SEI 41 Seismic Rehabilitation of Existing Buildings was developed for the purpose of updating provisions related to existing reinforced concrete buildings. Based on experimental evidence and empirical models, the proposed supplement includes revisions to modeling parameters and acceptance criteria for reinforced concrete beams, columns, structural walls, beam-column joints, and slab-column frames. The results of this work also have been incorporated into the ATC 72 report in support of the Pacific Earthquake Engineering Research (PEER) Center Tall Buildings Initiative.

- Findings from the project have been used in the development of ACI committee document 369R, Guide for Seismic Rehabilitation of Existing Concrete Frame Buildings and Commentary, which was published in 2011 by the American Concrete Institute. This guide, developed based on the format and content of ASCE/SEI 41-06 "Concrete", describes methods for estimating the seismic performance of both existing and new concrete components in an existing building. Under a newly established agreement between ASCE and ACI, Committee 369 will develop revisions to the concrete Chapter in the ASCE/SEI 41 Standard, and work continues on the implementation of project findings into the next revision of the Standard.

To mitigate the earthquake risk by reducing the exposure represented by the vulnerability of the built environment, fundamentally to save lives, the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) originated as a national, multi-user, research infrastructure to enable research and innovation in earthquake and tsunami loss reduction, create an educated workforce in hazard mitigation, and conduct broader outreach and lifelong learning activities. The mission for NEES aligns with the larger NEHRP national plan (2) for earthquake and tsunami risk reduction.

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

NEHRP is administered through four government agencies, with the National Institute of Standards and Technology (NIST) as the lead agency and the U.S. Geological Survey (USGS), National Science Foundation (NSF), and Federal Emergency Management Agency (FEMA) as the other partnering agencies. The NSF is the fundamental research arm of NEHRP, which supports research in engineering, earth sciences, and the social sciences. It provides the engine that drives fundamental discoveries related to earthquake processes; seismic response and failure mechanisms of the ground, buildings, and lifeline networks; and human behavior, social response, and the economic conditions pertaining to earthquakes.

In November 1998, the National Science Board approved the George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES) for construction with funds totaling $82 million from the National Science Foundation (NSF) Major Research Equipment and Facilities Construction (MREFC) appropriation. Construction occurred during the period 2000-2004. As part of its contribution to the National Earthquake Hazards Reduction Program, the National Science Foundation (NSF) funds NEES

operations (Award # CMMI-0927178) as well as many of the research projects that are conducted in NEES facilities. The NEEScomm Center at Discovery Park of Purdue University houses the headquarters of operations of a nationwide network of 14 laboratories. Each of these university-based laboratories enable researchers to explore a different aspect of the complex ways that soils and structures behave in response to earthquakes and tsunamis. The laboratories are available not just to researchers at the universities where they are located, but to investigators throughout the USA who are awarded grants through NSF's annual NEES Research (NEESR) Program and other NSF programs.

NEES laboratories are also used for research conducted or funded by other federal, state, and local agencies, by private industry, and by international researchers under the partnerships that NEES has cultivated with research facilities and agencies in Japan, Taiwan, Canada, and China. To date, more than 400 multi-year, multi-investigator projects have been completed or are in progress at NEES sites. These projects are yielding a wealth of valuable experimental data and continue to produce transformational research and outcomes that impact engineering practice from analytical models to design guidelines and codes. This information is annexed to this testimony in Reference 3, *"George E. Brown, Jr. Network for Earthquake Engineering Simulation, NEES, 2004-2014, A Decade of Earthquake Engineering Research"*.

Summary of Research Impacts to Practice

- Simulation methods used in engineering practice are improving due to NEES laboratory results of testing and researcher improvements to nonlinear modeling
- Fragilities used for loss analyses—particularly the FEMA P58 methodology--have been improved for several structural systems and nonstructural components
- Several projects contributed to the development of improved evaluation guidelines for existing structures and improved design procedures for new construction
- Next generation of systems that provide high performance including the ability to self-center are being studied by NEES researchers

The family of NEES researchers, educators, and students encompasses an ever increasing group of universities, industry partners, and research institutions in the US and abroad. Project teams and the NEEScomm team have developed a rich set of resources for research and education. An estimated 1300 graduate students have participated along side NEESR researchers based on a 56% return rate (n=171) from a longitudinal study. This study was intended to capture data of NEESR research and educational impact from NEES-funded research. Undergraduate and Post-Doc data were also included indicating an estimated 770 undergraduates and 50 post-docs benefiting from the NEES research experience, bringing the estimated total student participation to well over 2100. The human capital gained in this activity also supports the US in retaining a competitive globally in the STEM areas.

Linking the NEES experimental facilities to each other, to NEEScomm, and to off-site users is the NEES cyberinfrastructure. This unique system of information technology resources enables researchers participating on-site or remotely to collect, view, process, and store data from NEES experiments, to conduct numerical simulation studies, and to perform hybrid (combined experimental and numerical) testing involving one or more NEES equipment sites increasing research efficiency. At the heart of this system is NEEShub, a platform designed to facilitate information exchange and collaboration among earthquake engineering researchers, educators, students, practitioners, and stakeholders. Accessed via the NEES website at nees.org, NEEShub is powered by HUBzero software developed at Purdue University.

NEEShub features the NEES data repository a curated, centralized repository used to store and share data and research results. When launched in 2009, NEEScomm prioritized a strong partnership with the NEES sites and targeted what had been a seriously deficient central data repository and cyberinfrastructure for collaboration. Since the first release of the NEEShub "cloud" platform 4 years ago, the community has actively responded to user-focused cyberinfrastructure improvements with a pace of file and directory creation that has increased exponentially. Today, the NEES-curated central repository of research data features a vastly populated repository of NEES research data and showcases over 2.5 M data files and folders that engineers can search, sort, download, and manipulate. NEEShub also stores and shares a variety of other earthquake engineering resources, including publications, databases (4), computational models, simulation software, educational materials, and data management and visualization tools.

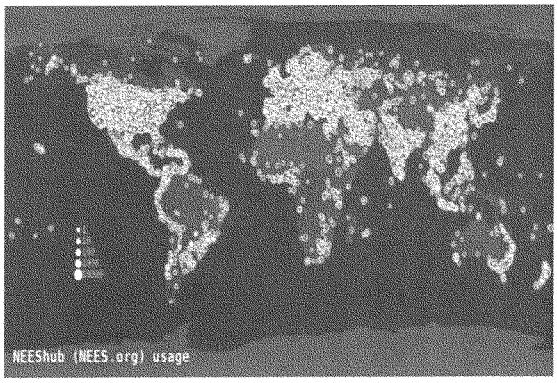


Figure 1. Usage of the NEEShub between 8/2010 to 3/2014

Since the first release of NEEShub in August 2010, researchers, students and practicing engineers from more than 200 countries have performed 1,428,026 web and 47,998 tool sessions (Figure 1). The arrival of the NEEShub has ushered in a new collaborative capability with vastly improved IT resources for research and development in earthquake engineering.

Nation's level of Earthquake Preparation and Resiliency

The current state of preparedness is much enhanced by advances made in the past decades, in large part supported through NEHRP funded research and implementation, but more must be done to protect our communities. Continued attention is required because of the growth of our cities and industrial centers, the new focus on resilience and the dependency of resilience on the performance of older, vulnerable construction. Advances in knowledge and information technologies can improve the rapid and efficient adoption of practices and technologies that improve resilience of communities by reducing damage after the event and by accelerating the pace of recovery, and these should be exploited.

Coordination between Federal, State and Local stakeholders for Earthquake Emergency Preparation

NEHRP, through its basic research and implementation agencies at NSF, NIST, and FEMA, is ideally positioned to provide proof of concept for emerging technologies as well as the evidence needed to sustain their implementation. Led by a State agency, each Emergency Function is designed to bring together discipline-specific stakeholders to collaborate and function within the four phases of emergency management: mitigation, preparedness, response, and recovery. State agencies, local governments and others must be prepared to respond to emergencies that might occur within their areas of responsibility within the first 72 hours of the event; and, must be able to assess whether their capabilities are sufficient to respond effectively. The Emergency Services functions of each State should be coordinated as far as possible with the comparable functions of its political subdivisions, of the federal government, of other states, and of private agencies of every type so the most effective use may be made of all manpower, resources, and facilities for dealing with an emergency. In instances where interstate cooperation needs to be promoted, the federal government should take the lead in fostering the collaboration for the benefit of the affected citizens.

Recommendations for Research and Development Measures in Earthquake Preparation and Mitigation, for the NEHRP Program

The importance of earthquake preparation and mitigation cannot be overemphasized. Addressing a challenge of this magnitude calls for a coordinated (agency and community-based) approach in the development of an effective research agenda to properly address it. There is precedent for this action, the Advisory Committee on Earthquake Hazards Reduction National Earthquake Hazards Reduction Program in its June 2012 Report (ACEHR12) (5) to the Director of the National Institute of Standards and Technology, the lead agency of the Interagency Coordinating Committee (ICC) assessed and reported on the NEHRP program effectiveness. ACEHR12 provides a series of key recommendations/initiatives for research and development measures that should serve as a roadmap for the future.

Maintaining a balanced program supporting research in the earth science, engineering, and social science areas is important. In achieving resilience of communities against earthquakes and tsunamis, engineering related research is of the highest priority as it directly impacts the mitigation of the extent of damage to built-environment and can reduce the time needed for recovery. Research that can efficiently identify older vulnerable construction and ways to mitigate the risk to people, community and businesses should be of the highest priority followed by research on new methods of construction and improved materials and technologies focused in the reduction of damage from these events. In the next level of importance is the support for research on impacts of earthquakes at the regional scale, especially as it relates to the ability of a community to re-establish its footing as a viable community; and, the support of implementation programs that will encourage cities to undertake studies and develop plans for resilience.

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NEES

GEORGE E. BROWN, JR. NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION

2004-2014
A DECADE OF EARTHQUAKE ENGINEERING RESEARCH

Photo opposite: Education, Outreach, and Training event at the NEES at Buffalo site.

Julio Ramirez
NEES Chief Officer
and NEEScomm Center Director

A Decade of Earthquake Engineering Research

In November 1998, the National Science Board approved construction of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) with funds totalling $82 million from the National Science Foundation (NSF) Major Research Equipment and Facilities Construction appropriation.

Construction occurred during the period 2000-2004. As part of its contribution to the National Earthquake Hazards Reduction Program, the NSF funded NEES operations as well as many of the research projects that were conducted in NEES facilities.

In the ten years since officially opening its doors in 2004, NEES has provided a vibrant collaboratory consisting of unique experimental facilities and a cyberinfrastructure as its collaboration platform, NEEShub, representing hundreds of millions of dollars of investment. The NEES collaboratory has served tens of thousands of users from over 210 nations.

In 2009, Purdue University replaced NEES Consortium, Inc. (NEESinc) as manager of the network of 14 advanced laboratories and its supporting cyberinfrastructure. The NEES Community and Communications Center (NEEScomm) was established in West Lafayette, IN.

Participating universities included: University of California, Berkeley; University at Buffalo, State University of New York; Cornell University; University of California, Davis; University of Illinois, Urbana-Champaign; Lehigh University; University of California, Los Angeles; University of Minnesota; University of Nevada, Reno; Oregon State University; Rensselaer Polytechnic Institute; University of California, San Diego; University of California, Santa Barbara; University of Texas at Austin.

Each of these university-based laboratories enabled researchers to explore a different aspect of the complex way that soils and structures behave in response to earthquakes and tsunamis. The laboratories were available not just to researchers at the universities where they are located, but to investigators throughout the United States who were awarded grants through NSF's annual NEES Research (NEESR) Program and other NSF programs. In fact, researchers located at colleges or universities remote from the NEES sites have led 80% of NEESR projects. The laboratories have also been used for research conducted or funded by other federal, state, and local agencies, by private industry, and by international researchers under the partnerships that NEES has cultivated with research facilities and agencies in Japan, Taiwan, Canada, and China.

In July 2010, NEEScomm released the first version of the NEEShub, the collaboration platform for NEES researchers. Linking the NEES experimental facilities to each other, to NEEScomm, and to off-site users, this unique cyberinrastructure has enabled researchers participating on-site or remotely to collect, view, process, and store data from NEES experiments at the NEES-curated central repository, also known as the Project Warehouse. Using the NEES cyberinfrastructure, researchers conduct numerical simulation studies and perform hybrid (combined experimental and numerical) testing involving one or more NEES equipment sites.

At the heart of this system is NEEShub, a platform designed to facilitate information exchange and collaboration among earthquake engineering researchers, educators, students, practitioners, and stakeholders. Accessed via the NEES website, NEEShub is powered by HUBzero software developed at Purdue University.

Earthquakes and tsunamis can be devastating not only to the infrastructure of a society, but also to families, the community, and people's sense of security. To reduce the impact of these events, and to save lives, the NEES network originated as a national research infrastructure to enable innovation in earthquake and tsunami loss reduction, to create an educated workforce in hazard mitigation, and to conduct broad outreach and lifelong learning activities.

This mission for NEES aligns with the larger plan from the National Earthquake Hazards Reduction Program for earthquake and tsunami risk reduction. Research at NEES facilities has contributed to the advancement of understanding of seismic phenomena, such as the characteristics and effects of tsunamis and the potential for soil liquefaction. It has also strengthened our knowledge of how the built environment responds to earthquakes. NEES investigators have studied the responses of a variety of structures, from reinforced concrete columns used in buildings and bridges to wind turbines and port container cranes.

NEES projects have validated the improved seismic performance of bridge piers made with innovative polymer materials; of base-isolated designs for steel structures; of reinforced masonry shear-wall structures; and of retrofit techniques for nonductile, reinforced concrete frames with infill walls. New design methods have been developed for mid-rise wood-framed buildings, metal building systems, precast concrete floors, and reinforced concrete wall systems. NEES research has also produced new simulation tools and fragility data for nonstructural building systems.

The impact of the NEES network has been felt on the development of future earthquake engineering researchers as well as practicing engineers. The network has supported the efforts of educators to build the workforce necessary to discover and implement research findings. NEES students learn earthquake engineering through involvement in research projects, undergraduates through NEES' annual Research Experiences for Undergraduates program, and graduate students by directly working with NEES investigators. In a recent survey, NEEScomm found that at least 559 graduate students, including 191 PhD candidates, have been trained through participation in NEES research.

Many of the projects conducted in the NEES laboratories have prompted, or laid the groundwork for, improvements in building codes, evaluation and design guidelines, and construction practices, enhancing societal resilience to earthquakes and tsunamis.

Many of those receiving PhDs now hold faculty positions at major research universities worldwide.

The community of NEES researchers, educators, and students encompasses a large group of universities, industry partners, and research institutions in the United States and abroad. This publication is meant as a sample of the breadth of the impact of the activities of researchers, students, educators, and practitioners collaborating in NEES. Already, more than 4,000 citations of NEES work bear testimony to the efforts of the NEES community. To date, more than 400 multi-year, multi-investigator projects have been completed or are in progress at NEES sites. These projects have produced a wealth of valuable experimental data and continue to produce transformational research and outcomes that impact engineering practice from analytical models to design guidelines and codes.

We invite you to explore some of the outcomes and impacts of a decade of earthquake engineering research and to try to envision the future impacts that these works may have yet to achieve.

Julio Ramirez
NEES Chief Officer and NEEScomm Center Director

PREFACE

"The most important step in the progress of every science is the measurement of quantities. Those whose curiosity is satisfied with observing what happens have occasionally done service by directing the attention of others to the phenomena they have seen; but it is to those who endeavor to find out how much there is of anything that we owe all the great advances in our knowledge."

--James Clerk Maxwell, Scottish Physicist, 19th Century

As was elegantly stated by James Clerk Maxwell, experimentation and accompanying data sets have always been essential in research for the validation of models and theories, the identification of structural performance, and the improvement and development of systems and components.

A less obvious but perhaps more important reason for the growing significance of scientific data is the evolving multi-disciplinary nature of research. Advances in one discipline become critical for research in another area, and data are the mechanism to make those linkages quantitatively. Society benefits from an improved understanding of the performance of the built environment, which enables a better quality of life. Specifically, advances in earthquake engineering secure economies, protect human lives, and contribute to the resilience and sustainability of our communities.

For the past decade, the double focus of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) has been simulation – physical, numerical and hybrid – and preservation of the resulting data.

This publication provides a window into the vibrant collaborative milieu in which dedicated researchers, educators, and professional staff endeavored to produce and preserve high-impact research. Review boards consisting of researchers and practicing engineers examined information about the hundreds of research projects conducted over the past ten years. After careful evaluation, the review boards selected the projects now presented in each section. We wish to express our deepest appreciation for the dedicated work of the members of the review boards, listed on the next page.

It is also our great pleasure to specially recognize the Principal Investigators who contributed to the project descriptions included in the publication. Each project description received approval by the corresponding project PI.

It is important to note that, for a given investigation, it typically takes years for impacts to be felt. As the advances in earthquake engineering continue, the influence of the entire NEES community will be recognized for decades to come, and undoubtedly, other, ongoing NEES projects will join the numbers of those described in these pages.

EDITORIAL

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Editor and Writer: Marti LaChance
Graphic Designer: Lynn Holland
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Dr. Julio A. Ramirez
Professor of Civil Engineering
NEES Chief Officer and NEEScomm Center Director
George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES)
207 S. Martin Jischke Drive #301
Purdue University, West Lafayette IN 47907, USA
E-mail: ramirez@purdue.edu
Tel: 765 430-7853

Fellow of the American Concrete Institute (FACI), Dr. Julio A. Ramirez is a Professor of Civil Engineering at Purdue University, West Lafayette IN. Dr. Ramirez is a consulting member of the American Concrete Institute (ACI) 318 Building Code Committee; and a voting member of Joint Committee ACI-ASCE 445, Shear and Torsion; and ACI-ASCE Committee 408, Bond and Development of Reinforcement. Dr. Ramirez is presently committed to two major projects: (a) a NEES Research (NEESR)- Grand Challenge research study aimed at identifying collapse triggers in non-ductile reinforced concrete buildings subjected to seismic actions, (b) center director for the George E. Brown Jr. Network for Earthquake Engineering Simulation NEES Operations wards for the period of 2010-2014. Prof. Ramirez currently serves as the Chief Officer of the National Science Foundation funded George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES) and Director of the NEEScomm Center headquarters of NEES Operations in Discovery Park of Purdue University.

Dr. Ramirez has served as an Associate Editor for the Committee on Concrete and Masonry Structures (CCMS) Division of the American Society of Civil Engineers (ASCE) Structural Journal and has also served as referee of technical articles for the ACI Structural Journal, ASCE Structural Journal, ASCE Computing in Civil Engineering, ASCE Transportation, and the Prestressed Concrete Institute Journals. He has been a member of several National Cooperative Highway Research Program (NCHRP) research panels. He has served in NSF proposal review panels for several directorates. He has received the 2000 Delmar Bloem Award and the 2006 Joe W. Kelly Award of the American Concrete Institute.

Chairman BUCSHON. Thank you very much.

I recognize Dr. Savage for five minutes for his testimony.

TESTIMONY OF DR. WILLIAM U. SAVAGE, CONSULTING SEISMOLOGIST, WILLIAM SAVAGE CONSULTING, LLC

Dr. SAVAGE. Thank you, Chairman Bucshon, Ranking Member Lipinski, and Members of the Subcommittee.

I am speaking to you today on behalf of the Seismological Society of America, a scientific organization devoted to the advancement of seismology and the understanding of earthquakes for the benefit of society. I also am speaking specifically about lifelines and my experience there devolves from 15 years working for Pacific Gas and Electric Company in San Francisco in the late '80s until 2000.

My written testimony addresses four pertinent questions that I was asked. Although there is not time this morning to cover all four, I would like to discuss the question asked about my views on the Nation's level of earthquake preparation and resiliency regarding lifelines, particularly the urban utility systems for electric power, natural gas, potable water, and wastewater. These systems are the underpinning of our modern society.

To get to the essential point, I personally think that we actually do not know how resilient our urban utilities systems are in terms of their operability to deliver customer service after the next strong earthquake. Utility personnel may have opinions one way or another but they generally do not have a strong objective basis for a definitive statement.

In my written testimony I briefly discussed four guideline documents prepared by FEMA's American Lifelines Alliance that use currently available information to provide guidance for conducting such assessments for the four types of urban utility systems. The guidance calls for systematic and quantitative consideration of the two key aspects of each assessment: first, specification of the local and regional earthquake hazards, both ground shaking and ground failures; and secondly, estimation of the expected performance of the utility system components given the hazard and the impact of the expected performance on customers.

The American Lifelines Alliance guidelines can only go so far in giving a rigorous answer to questions about what would happen if this or that earthquake occurred. The next stage of lifeline resiliency assessment is calling for development of more refined hazard characterizations using advances in geotechnical and seismological modeling to estimate ground motions and ground failures. The U.S. Geological Survey is already engaged in research that is leading to such advances.

Performance modeling of pipelines, substation equipment, overhead transmission structures, et cetera, is also advancing with NSF and NIST exploring research in these areas. Operating utilities and related professional organizations are evaluating the benefits of such advances and are likely to help fund them. These advances are necessary to achieve a high level of confidence in understanding the earthquake performance of lifeline components and thus the resiliency of utility operations. One of the mechanisms to pursue this goal is a reauthorized NEHRP program. Authorization

of this valuable program provides continuity and stability for the NEHRP agencies.

In closing, I should point out the obvious. There are two ways to find out if a utility lifeline is resilient to earthquakes. The first way is to invest in improved hazard characterizations and performance models for lifelines and plan to mitigate the unacceptable risks. The second way is to just wait and see what happens in the next damaging earthquake.

Thank you for the opportunity to speak before you and I would be happy to answer any questions you may have.

[The prepared statement of Dr. Savage follows:]

Testimony of William U. (Woody) Savage, PhD
Member of the Board of Directors of the Seismological Society of America (SSA)
Co-Chair of the SSA Government Relations Committee
Manager of William Savage Consulting, LLC

Before the House Science, Space, and Technology Committee
Subcommittee on Research and Technology

Chairman Buschon, Ranking Member Lipinski, and members of the Subcommittee, thank you for inviting me to testify on earthquake hazards as they relate to lifelines, in particular electric power and other utility systems. Today I am speaking on behalf of the Seismological Society of America, which is the largest and most respected professional society of seismologists and experts in related fields in the world.

During my professional career I have had the opportunity to gain extensive experience and insight into the physical and operational impacts of strong earthquakes on utility operations and facilities. I have had the opportunity to work with the agencies that comprise the National Earthquake Hazards Reduction Program (NEHRP) and see the benefits of strong interagency cooperation and collaboration amongst the community of seismologists. An authorized and appropriated NEHRP is fundamental to an earthquake-resilient nation.

In the following testimony, I'll draw on that experience in briefly covering the following points:

- Managing earthquake risk exposure of electric power systems
- Status of the nation's level of lifeline earthquake preparedness and resiliency
- Recommendations for research and development measures in mitigating earthquake hazards for electric and gas utilities
- Conclusions

1. Managing Earthquake Risk for Electric Power Utilities

I started working in the Geosciences Department at Pacific Gas and Electric Company (PG&E) in February 1986 as the lead seismologist on the Diablo Canyon Long-Term Seismic Program, a Nuclear Regulatory Commission license requirement. In early July of that year, a strong earthquake (magnitude 6.1) occurred very close to a major Southern California Edison (SCE) high-voltage transmission substation near North Palm Springs, CA. The substation equipment (circuit breakers, switches, etc.) was damaged extensively and shut down the Pacific Coast Intertie (the electric transmission system between Southern California and the Pacific Northwest). A senior executive at PG&E, upon being briefed about the North Palm Springs earthquake and its disruptive effect on power transmission in

California, asked the Civil and Electrical Engineering and Geosciences Departments a key question: "Could this happen to PG&E?"

This simple question led to a simple answer, "YES," for many of PG&E's high-voltage substations, particularly those in the San Francisco Bay Area, the heart of PG&E's service territory. My counterpart in the Civil Engineering Department and I joined with a senior electric engineer and developed a map for the greater Bay Area showing locations of active faults and substations that had the same types of high-voltage substation equipment that had failed in the SCE substation. Based on this information, a plan was developed to systematically replace the vulnerable equipment with more expensive, seismically resistant breakers and switches. This "Breaker Replacement Program" was budgeted and began to be implemented over multiple years.

Unfortunately, the next large earthquake to strike California occurred in the southern San Francisco Bay Area, the M6.9 Loma Prieta earthquake of October 17, 1989. Although the Breaker Replacement Program was not yet completed, it was deemed a success, as the substations with replaced breakers could be restored quickly, while the substations with extensive damage had to wait weeks for replacement breakers to be obtained and installed.

PG&E's experience in recovering from a severe urban earthquake provided an opportunity for specialists in transmission reliability from PG&E, SCE and the Los Angeles Department of Water and Power to develop an ongoing discussion of how to manage earthquake risk for our respective utilities. During this period, the next severe California earthquake occurred in Southern California, the January 17, 1994, M 6.7 Northridge earthquake. This event caused extensive damage to the electric transmission and distribution systems in the heart of Southern California and also damaged natural gas transmission lines. The occasional discussions among the West Coast electric utilities prior to the Northridge event self-organized into an ad-hoc "Inter-Utility Seismic Working Group", which I chaired. The Working Group developed gas and electric subgroups, and added Southwest Gas and Southern California Gas, San Diego Gas and Electric companies and Bonneville Power Administration and BC Hydro. We met semi-regularly (either face-to-face or by telephone) to discuss specific issues regarding the seismic performance of electric and gas system components. The open exchange of technical information was welcomed by all the individuals involved. What seemed to facilitate this openness was the lack of substantial involvement by senior management.

California's Seismic Safety Commission identified the California Public Utilities Commission as the lead agency having oversight responsibility for the seismic safety of the regulated utilities. In 1993 the Seismic Safety Commission outlined a seismic safety program to improve the earthquake performance of the electric power and natural gas utilities. They directed the utilities to develop and adopt a comprehensive policy on acceptable levels of earthquake risk with long-term priorities and schedules for the reduction of unacceptable hazards. The Inter-Utility

Working Group took on the responsibility for preparing this policy statement. The version published in 1995[1] is as follows:

Each California gas and electric utility system shall withstand earthquakes to provide reasonable protection of life, to limit damage to property, and to provide for resumption of utility system functions in a reasonable and timely manner. An acceptable level of earthquake risk is the residual risk that remains when this policy has been implemented.

It is the goal of this policy that each utility satisfy its responsibilities to protect the public and to provide reliable customer service in the face of possible earthquake effects. Although compliance with this policy will provide reasonable public safety and customer service, it will not prevent all loss of life, property damage, or loss of utility function.

Each utility is responsible for its own compliance with this policy by preparing and carrying out a long-term seismic safety implementation plan. It should be based on the current understanding of earthquake hazards and risk, and the current technical capabilities and practices of the industry."

PG&E established a formal Seismic Risk Management Program in 1994 in accordance with this policy statement.

2. American Lifelines Alliance

I was involved in the formation of the American Lifelines Alliance, which was established by FEMA in 1998 and was terminated due to lack of funding in 2006.

The American Lifelines Alliance (ALA) was a public-private partnership funded by the Federal Emergency Management Agency (FEMA) of the Department of Homeland Security (DHS) and managed by the Multihazard Mitigation Council of the National Institute of Building Sciences (NIBS). The goal of ALA was to reduce risks to lifelines – the essential utility and transportation systems that serve communities across all jurisdictions and locales – from all hazards. To do so, it facilitated the development, dissemination, and implementation of planning, design, construction, rehabilitation and risk-management guidance and encourages use of this information to improve the performance and reliability of new and existing critical infrastructure. The ALA's key stakeholders were lifeline operators and the communities they serve, standards development organizations, and engineering and risk-management professionals. The ALA provided a forum to address current industry and community needs and formed a unique partnership to work across lifelines systems. ALA products were intended to be incorporated in national

[1] Technical Council on Lifeline Earthquake Engineering (TCLEE) Monograph No. 6, Michael J. O'Rourke (editor), *American Society of Civil Engineers*

consensus standards documents as well as disseminated to key industry stakeholders through relevant associations and industry publications.

During its active existence, ALA partners included FEMA, NIBS, the Federal Highway Administration, PG&E, ROHN Industries, USGS, and the Bureau of Reclamation.

The funding support originally planned for ALA by FEMA waned substantially during the organization's life, and ended up severely curtailing its effectiveness. However, one of the last projects that ALA was able to complete was the preparation and publication of guidelines for utility performance assessment. There are four guidelines, covering electric power systems, oil and natural gas pipeline systems, water systems, and wastewater systems. Each guideline consists of a guidelines document and a commentary document. Because of the untimely closure of ALA, it was not possible to carry out full implementations of the guidelines as demonstration projects. Individuals who have expressed an interest in doing performance assessments have obtained copies of the guidelines, but to my knowledge there has not yet been a full implementation of any of the guidelines.

Interested persons may go to the web site AmericanLifelinesAlliance.com (please note: it is a .com site, not .org) to review the assessment guidelines and other ALA products and resources.

3. Status of Current Utility Lifeline Earthquake Preparedness and Resiliency

It's my opinion that, as a nation, we don't actually know how earthquake-prepared or earthquake-vulnerable our lifeline utilities are. The utilities that have suffered relatively recent natural hazard events know, but the ones that do not have recent experience, either directly or vicariously (e.g., to a neighbor utility), probably do not know. They won't know their state of preparation/vulnerability until they do a formal assessment along the lines as prescribed in the ALA documents, or suffer a severe earthquake. Many aspects of vulnerability have to do with the adequacy of anchorage and bracing, falling of adjacent non-critical components, etc. Even a walk-through by an earthquake-savvy utility person who is expert on the modes of earthquake damage and operational failure of electric power systems could provide some useful information.

4. Coordination between federal, state, and local stakeholders for earthquake emergency preparation and mitigation

I am not a particularly good commentator on this subject, as my ongoing involvement in these matters are fairly sub-regional, not national. What I have observed is that the preparation for future earthquakes and management of earthquake risk has not recovered the priority that it had prior to the terrorist attacks in 2001. The ALA project was a struggle for FEMA to sustain, for example. I

think that the more seismically exposed regions (Pacific Northwest and California) in particular have made progress at local levels, but the more moderate-hazard urban areas seem to not have been able to sustain programs given lower ability for cooperation at the national level. For lifelines, I'm pleased to see the current NIST efforts to develop the Community Disaster Resilience Program with efforts to promote such activities rather widely around the country. Particularly with regard to utility lifelines, their internal organizational commitment to safety and reliability can help build wider local and regional support for assessing current levels of preparedness and promoting mitigation. Our nation has a strong track record of pulling together for response and recovery from major natural hazard events, but the better approach is assessing exposure and programmatically improving resilience in advance of the next earthquake.

4. Recommendations for Research and Development Measures in Mitigating Earthquake Hazards for Utilities

PG&E established a successful user-directed research program with the Pacific Earthquake Engineering Research Center (PEER) at UC Berkeley that has lasted 20 years. During the several years that I managed PG&E's side of that program, many useful results were obtained that could be directly and immediately applied by PG&E, such as shake-table testing of various types of high-voltage substation components. In my view, the PEER Lifelines Project has directly benefitted the funding entities (initially PG&E and later including California Department of Transportation) for more than two decades. This applied-research model has an advantage over principle-investigator-directed research in that when users put their own money into research, they legitimately own, and feel motivated to use, the results.

5. Conclusions

The NEHRP agencies have important contributions to make in the arena of utility lifeline earthquake preparedness and resiliency. NIST and NSF both support contributions of new knowledge relevant to lifeline performance in the face of earthquake risks. In particular, USGS has taken extraordinary steps to provide earthquake hazard data that are quite valuable in the real-time assessment of earthquake hazards for emergency response. Their internal research support of USGS experts and their external support of non-USGS earthquake hazard specialists are directly used for the updating of national hazard maps, providing emergency responders with critical data, and providing the basis for earthquake preparedness by all elements of our society.

The ALA project initiated by FEMA was well-envisioned and was managed as well as could be done in a difficult governmental time and setting. Re-establishing a lifelines partnership would provide a setting for engaging lifeline organizations to

promote and conduct rigorous earthquake performance assessments; it is necessary to understand the problem before it can be fixed. We do not have to wait for the next damaging earthquake to identify seismic vulnerabilities and mitigate them.

Thank you again for this opportunity to provide testimony on these important subjects to the Subcommittee members. I hope this information and my perspectives are useful as you proceed with your deliberations.

July 2014

Narrative Biography – William U. (Woody) Savage

Currently, I am Manager of William Savage Consulting, LLC and provide professional services as a consulting seismologist. In addition, I am an Adjunct Professor in the Department of Geoscience and Department of Civil and Environmental Engineering and Construction at the University of Nevada, Las Vegas. I also have an Emeritus Geophysicist position with the U.S. Geological Survey.

Prior to this, from 2001 to 2010, I was employed by the U.S. Geological Survey at the USGS research office in Menlo Park, CA, and subsequently the Yucca Mountain Project office in Las Vegas, NV. From 1986-2001 I was a senior seismologist with Pacific Gas & Electric, and I started my career with Woodward-Clyde Consultants as a senior seismologist from 1974-1986.

My educational background includes attending the University of Oregon Honors College (BA in Physics) and the University of Nevada, Reno, where I received MS and PhD degrees in Geophysics

In my 40-year career, I have worked on seismic hazard assessments for major dams, nuclear power plants, nuclear waste storage, and electric power and natural gas transmission facilities, involving both data collection/analysis and independent in-house and/or regulatory review.

During this period I have had numerous productive and highly valued interactions with personnel from all four NEHRP agencies and greatly respect the skills and dedication of their employees and management, and value the programs that they are carrying out regarding earthquake hazards (USGS), earthquake engineering (NSF), and earthquake risk reduction (FEMA and NIST).

I am a Board Member of the Seismological Society of America and Co-Chair of the Society's Government Relations Committee. I have also been an active, long-term member of the American Association for the Advancement of Science, American Geophysical Union, American Society of Civil Engineers, Consortium of Organizations for Strong-Motion Observation Systems, and Earthquake Engineering Research Institute.

Chairman BUCSHON. Yeah, hopefully we can use the former in that to figure this out.

I now recognize Mr. Monken for five minutes for his testimony.

TESTIMONY OF MR. JONATHON MONKEN, DIRECTOR AND HOMELAND SECURITY ADVISOR, ILLINOIS EMERGENCY MANAGEMENT AGENCY

Mr. MONKEN. Thank you very much, Chairman Bucshon, Ranking Member Lipinski. I very much appreciate the opportunity to be here to speak with all of you and represent the Illinois Emergency Management Agency, Governor Quinn, and the State of Illinois to discuss this incredibly important program of the National Earthquake Hazards Reduction Program.

So it is a critical asset not just in our ability to work with the earthquake hazard but all hazards because it is really about that collaborative nature that the program is really founded under.

My biggest concern right now with the program overall is that the collaborative nature in which it was founded to execute is something that we have kind of strayed from over the course of the past few years. And there is a variety of different reasons why that has happened, but right now, it comes at a time when the risk of this particular hazard, we are gaining a better understanding of it and we are certainly seeing both increased frequency of seismic activity and we are getting a better understanding of the severity of the potential threat. And that was mentioned earlier with the USGS's release of their updated earthquake hazard maps and some of the statistics that we see just from the last few years.

So taken in context in Illinois and the central United States, that area of the country on average from 1981 to 2011 saw an average of 20 earthquakes per year. In the last three years we have seen a quintuple increase in the frequency of earthquakes to the tune of 100 earthquakes per year. So this in another itself is certainly concerning but it also highlights the importance of what we are talking about here.

Now, it is a little-known fact that the most powerful earthquake in the continental United States in history actually happened in the central United States in 1811 and 1812 when a 7.7 magnitude earthquake struck and two aftershocks. If a comparable magnitude earthquake struck today in the same area, it would cause economic damage to the total of about $300 billion. Put into context, Hurricane Katrina, the most expensive U.S. disaster in history to date, was $106 billion.

So there is a lot of progress that we can make in a lot of things that we have seen to make progress in this area in the emergency management community. A specific example is the CAPSTONE–14 exercise conducted in June of this year when we had an opportunity for 2,500 personnel in 20 States to participate in this four-day event. We beta-tested the first-ever multistate common operating picture sharing more than 13,000 real-time status updates of critical data from 440 counties and seven impacted states. Additionally, we launched the first National Resource Database with more than 500 mission-ready packaged asset deploying from 18 different states across the country. The tools and processes created for this exercise have fundamentally changed the way we plan for, re-

spond to, and recover from disasters of all types. Additionally, we developed awareness campaigns such as the Great U.S. ShakeOut with millions of people participating across the country. We also improved school safety drills and created public service announcements to educate those in areas of the country where the threat still remains a relative unknown.

Despite these successes, these efforts also served to identify gaps in our systems and capabilities, as well as the inherent weaknesses in our critical infrastructure and life-support systems. The problem in front of us now is, because of these issues, right now the track of NEHRP really threatens to not only lose some of the lessons that we have learned in recent years but really take us back to a time that predates the existence of the program.

Some of these problems began with the expiration of the NEHRP authorization of 2009, as has been discussed extensively today, and the lack of reauthorization since then. This program absolutely deserves to be a legislative priority and balance should be restored in terms of how the program is governed and funded. While emergency management plays a significant role in earthquake preparation response and mitigation, only 1 of the 15 Members of the NEHRP Advisory Committee actually comes from the emergency management profession.

From a funding perspective, emergency management is also grossly underrepresented, receiving less than seven percent of all funds allocated for this particular threat. To make matters worse, the state-level earthquake program managers are rapidly disappearing due to a decision by the Federal Emergency Management Agency pulling all state funding in Federal Fiscal Year 2013.

The need for coordination between all levels of government has never been greater, and yet the program continues to lag behind at the federal level because of FEMA's NEHRP office being buried and fragmented within the agency. This disjointed approach makes it even more important for the earthquake consortia located throughout the State that perform that multistate coordination effort. Language related to consortia absolutely needs to be restored as part of the authorization recognizing these entities as critical in the process of multistate coordination for these particular threats and along regional lines.

The most important change in research and development measures is a better integration of the components of the program. NEHRP was designed to be a hazard reduction program, not just hazard research and to conduct more targeted risk assessments based on joint evaluations from program participants. These assessments should be focused on more detailed impact analysis and sectors of critical infrastructure such as road and bridge networks, rail systems, potable and wastewater systems, voice and data communications in the national power grid to use the limited resources that we have on the most important projects first.

I appreciate the time here today and I look forward to any questions that you might have.

[The prepared statement of Mr. Monken follows:]

MR. JONATHON MONKEN

Director & Homeland Security Advisor, Illinois Emergency Management Agency

STATEMENT FOR THE RECORD
On behalf of the
Illinois Emergency Management Agency

Submitted to the House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
United States House of Representatives

A Review of the National Earthquake Hazards Reduction Program

July 29, 2014

Thank you Chairman Buschon, Ranking Member Lipinksi, and distinguished members of the subcommittee for holding this hearing today.

I am pleased to have the opportunity to testify today on behalf of the Illinois State Emergency Management Agency and Governor Quinn on an issue of paramount importance to the people of Illinois. The National Earthquake Hazards Reduction Program (NEHRP) remains a critical asset in our fight against the myriad hazards facing our state and region.

Background

The Earthquake Hazards Reduction Authorization Act authorizes appropriations for carrying out the Earthquake Hazards Reduction Act of 1977. The program provides funding for the National Science Foundation, the Federal Emergency Management Agency, the U.S. Geological Survey (USGS), and the National Institute of Science and Technology.

In addition to NEHRP's scientific and research-driven efforts, the program provides assistance enabling states to develop preparedness and response plans and increase earthquake awareness. A primary objective of NEHRP is providing outreach and public education. Other key NEHRP objectives include development of cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large; providing guidance and recommendations on codes and ordinances to enhance seismic safety; and improving earthquake resilience of communities nationwide.

The overarching functional purpose of NEHRP is to bring together the partner agencies to promote knowledge of and institute practices for the risk reduction of earthquakes. According to the NEHRP website, the program accomplishes these goals "through coordinated, multi-disciplinary, interagency partnership among the NEHRP agencies and their stakeholders – that improve the Nation's earthquake resilience in public safety, economic strength, and national security." Unfortunately, while this sentiment is noble, in recent years the program has wandered from the stated intent and started focusing on research more than actionable activities. This move from the intent of the program comes at a time when the risk and consequences of a major earthquake in this nation are more present than ever.

Understanding the Hazard

This discussion regarding NEHRP is quite timely, especially given the ongoing threat of earthquakes across the country. Two weeks ago the U.S. Geological Survey (USGS) released an update to the National Seismic Hazard Maps along with updated statistics on earthquake activity in all regions of the country. In the central United States where Illinois is located, the number of earthquakes annually has quintupled from 2011-2013 with an average of one hundred tremors per year, up from a 30-year average of 20 per year from 1981-2011. This spike in seismic activity serves as a reminder of the NEHRP program's value to the nation and the challenge of preparing for a natural disaster of proportions never seen in U.S. history.

Illinois specifically is at risk from two major seismic zones, the Wabash Valley Seismic Zone and the New Madrid Seismic Zone (NMSZ). The Wabash Valley Zone is located between southeastern Illinois and southwestern Indiana. The NMSZ is located in the Central Mississippi Valley and includes portions of the states of Alabama, Arkansas, Illinois, Indiana, Kentucky, Missouri, Mississippi, and Tennessee.

During any 50-year time span, there is a 25 percent to 40 percent chance of a magnitude 6.0 or greater earthquake in this seismic zone. Since 1974, the year network monitoring of seismic activity began, more than 3,000 earthquakes have been recorded in the NMSZ. Fortunately, none of these earthquakes exceeded a magnitude of 5.0, and most occurred without our noticing. The largest earthquake in recent years occurred on the Wabash Valley Seismic Zone. This earthquake registered a magnitude of 5.4 and occurred in Mt. Carmel, Illinois on April 18, 2008.

The most powerful earthquakes ever to occur in the continental United States took place in the NMSZ during the winter of 1811-1812. When put into context, an earthquake today in the NMSZ of similar magnitude to the quakes of 1811-1812 would result in an economic impact of nearly $300 billion. That is 300 percent larger than the most costly American disaster ever; Hurricane Katrina.

Actionable Progress

Given the nature of this threat, the state emergency management agencies in the central United States continue working extensively on catastrophic planning and conducted two of the largest homeland security exercises ever in 2011 and 2014. The lessons gleaned from these efforts have produced national best practices in the areas of resource management, response protocols, information sharing and whole community integration of an unprecedented scale. The tools and processes created for these exercises have fundamentally changed the way we plan for, respond to, and recover from disasters of all types. Additionally we have developed awareness campaigns such as the Great U.S. Shakeout, with millions of people participating across the country. We have also improved school safety drills and offering public service announcements to educate those in areas of the country where this threat remains a relative unknown.

The enormity of the task in front of the emergency management community to respond a disaster of this magnitude were demonstrated during the recent Capstone 14 exercise when more than 2,500 personnel in 20 states participated in the four-day event. We beta tested the first ever multi-state common operating picture sharing more than 13,000 real-time status updates of critical data from 440 counties in 7 impacted states. Additionally, we launched the first national resource database with more than 500 mission ready packaged assets deploying from 18 states.

Despite the successes, these efforts also serve to identify the gaps in our systems and capabilities, as well as inherent weaknesses in our critical infrastructure and life support systems. These discoveries bring great uncertainty to whether we are adequately prepared as a nation for the earthquake threat. Far too many structural vulnerabilities compromise our resilience, and NEHRP is potentially on a track which will not only see us lose the valuable gains we have made, but regress to a time that predates the establishment of the program.

Issues, Challenges, and Recommendations

The problems begin with the expiration of the NEHRP authorization in 2009 and the lack of reauthorization since then. This program deserves to be a legislative priority, and balance should be restored to how the program is governed and funded. While emergency management plays a significant

role in earthquake preparation, response, and mitigation, only one of the 15 members of the NEHRP Advisory Committee on Earthquake Hazards Reduction (ACEHR) panel comes from our profession. From a funding perspective, emergency management is also grossly underrepresented receiving less than 7 percent of the funds allocated for this threat. To make matters worse, the state-level earthquake program managers are rapidly disappearing due to a decision by the Federal Emergency Management Agency (FEMA) pulling all state funding in Fiscal Year 2013. To help address all these issues, the following recommendations should be considered:

1. **Enhance Coordination.** The need for coordination between all levels of government has never been greater, and yet the program continues to lag behind at the federal level because FEMA's NEHRP office is buried and fragmented within the agency. While the hurricane program benefits from its presence in the Office of Response and Recovery, the earthquake program is currently housed in the Mitigation Division, with no major emphasis on response or preparedness activities. This leads to grant guidance which omits the eligibility of response and preparedness activities in direct contradiction to the original program guidance.

   To correct this, program emphasis should be balanced and the program placed under the control of an SES level National Earthquake Program Manager within FEMA similar to the hurricane program. This will allow them to equally draw upon the various FEMA Divisions and functions. This disjointed approach at the federal level also leads to the increased importance of an already vital asset, the earthquake consortiums. These entities are the most effective and indispensable means of multi-state collaboration because they are focused on the unique nature of the threat in each region of the country.

2. **Support for Regional Consortiums.** Illinois is a member of the Central United State Earthquake Consortium (CUSEC) one of three such organizations representing a total of 43 states and territories which has a seismic risk. CUSEC, like the other two consortia, was formed with NEHRP funding support from the Federal Emergency Management Agency. CUSEC's primary mission working with its 18 member and associate states is, "... the reduction of deaths, injuries, property damage, and economic losses resulting from earthquakes in the Central United States."

   FEMA should continue to fund and rely upon the earthquake consortia to foster multi-state coordination, regional earthquake planning and exercise initiatives, increase public awareness, and leverage new technologies in emergency management. Many consortia-led initiatives have become national models, programs, and improvements in emergency management. Also, 75 percent of respondents to a July 2014 national survey of at-risk states and territories indicated states rated their partnership with the FEMA NEHRP consortia as "effective" or "highly effective." Language related to consortia needs to be restored as part of reauthorization.

3. **Balancing Research and Implementation.** NEHRP currently lacks a balanced program of engineering, science and research, and emergency management as originally intended by Congress. The most important change in research and development measures is a better integration of the components of the program. NEHRP was designed to be a hazard reduction

program, not just hazard research. The information being collected and analyzed should be leveraged to conduct more targeted risk assessments based on joint evaluations from program participants. These assessments should be focused on more detailed impact analysis on sectors of critical infrastructure such as road and bridge networks, rail systems, potable and wastewater systems, voice and data communications, and the national power grid. The importance of this interdependent infrastructure cannot be overstated; in the case of the power grid a New Madrid Earthquake could cause a power loss to more than a third of the U.S. population and result in an outage in the hardest hit areas that could last up to six months. The best way to combat these issues is through empowering those responsible for hardening and protecting these systems with the knowledge needed to be efficient in their efforts. This approach will greatly aid the planning process and guide mitigation efforts to help prioritize an endless list of needs and vulnerabilities to help us maximize the limited resources available. The inevitable conclusion of these efforts is saving countless lives when this terrible disaster hits.

Conclusion

As you can see through this testimony, NEHRP is a worthwhile and valuable program. As with most national programs, however, opportunities remain for us to continually support those responsible for managing the potentially horrific consequences of these hazards. Scientists, researchers, and emergency managers cannot operate in a vacuum independent of one another. Only through robust coordination can we properly prepare for, mitigate against, respond to, and recover from the impacts of a major earthquake.

The emergency management community stands ready to work with our partners in this effort, but we must have the continued partnership with our friends in Congress to push this program to the next level of success. I owe it to the citizens of Illinois to ensure this program is robust and effective in saving lives and protecting property. I appreciate you taking the time to hold this hearing and help me as I continue to ensure the safety of millions of Illinois residents and look forward to any questions you may have.

JONATHON MONKEN

Jonathon Monken was appointed by Governor Pat Quinn as Director of the Illinois Emergency Management Agency (IEMA) on February 14, 2011. As director, Mr. Monken oversees Illinois' disaster preparedness and response, nuclear safety and homeland security programs, as well as the agency's 225+ employees and a budget of more than $425 million. In this capacity, he also serves as the Illinois Homeland Security Advisor to the Governor.

At IEMA, Mr. Monken has directed the response and recovery effort to nearly 100 Illinois counties declared State disaster areas which included the statewide response to the 2011 blizzard, the record floods in 2011 and 2013 and the devastating tornados that struck Harrisburg and Ridgeway in 2012 and the statewide tornado outbreak on November 17th of 2013.

Mr. Monken is Chairman of the Central United States Earthquake Consortium (CUSEC), a partnership of the eight states affected by the New Madrid Seismic Zone. He serves as the National Emergency Management Association (NEMA) Vice-President for FEMA Region V and the Vice-Chair of the NEMA Homeland Security Committee. Mr. Monken serves on the Board of Directors for the National Information Sharing Consortium (NISC) and is a member of the Governors Homeland Security Advisors Council.

Prior to becoming IEMA director, Monken served for two years as Acting Director of the Illinois State Police, an agency with a staff of 3,400 sworn and civilian personnel and an annual budget of approximately $428 million. Jonathon also possesses a distinguished military career having served one tour of duty in Kosovo and two combat tours in Iraq between January 2003 and December 2006. While serving with the United States Army, Major Monken was awarded the Bronze Star Medal and the Army Commendation Medal with "V" Device for valor in combat.

Monken graduated from the United States Military Academy at West Point, where his military class rank placed him in the top 1% of his class. He also holds an MBA from Northwestern University's Kellogg School of Management.

Jonathon enjoys being active in his community and is a proud member of American Legion Post #1922 and Springfield Mid-Town Club of Rotary International.

He lives in Springfield with his wife Jennifer and their sons Jack, Luke and Zach.

Chairman BUCSHON. Thank you very much.

I now recognize Dr. Whittaker for his testimony.

TESTIMONY OF DR. ANDREW S. WHITTAKER, PROFESSOR AND CHAIR, DIRECTOR MCEER; DEPARTMENT OF CIVIL, STRUCTURAL AND ENVIRONMENTAL ENGINEERING, UNIVERSITY AT BUFFALO, STATE UNIVERSITY OF NEW YORK

Dr. WHITTAKER. Chairman Bucshon, Ranking Member Lipinski, and other Members of the committee, good morning.

My name is Andrew Whittaker and I am delighted to appear before you this morning. I am an academic structural engineer employed as a Professor of Civil Engineering in the Department of Civil, Structural, and Environmental Engineering at the University at Buffalo and I serve as the Director of the earthquake-focused center known by the acronym MCEER.

Your letter of invitation asked me to respond to four specific items in my written testimony and I talk to only one of the four today for reasons of time. And the question is what are your recommendations for research and development measures in earthquake preparation and mitigation?

The United States Geological Survey is building the Advanced National Seismic System, as identified previously by Dr. Applegate. Information from the instruments in the System will permit refinement in the mapping of the earthquake hazards, the development of improved ground motion prediction equations, and a much better understanding of how clusters of buildings respond to earthquakes. Importantly, the successful and complete deployment of the Advanced National Seismic System by the USGS will enable the Earthquake Early Warning System that was identified previously. ANSS is not being deployed at the speed originally envisioned and I recommend that ANSS be completed as quickly as possible and that its maintenance and use be adequately funded.

Second, the National Science Foundation has operated the NEES collaboratory since 2004. As Professor Ramirez noted, the equipment sites within the collaboratory offer unique physical testing capabilities ranging from geotechnical centrifuges to earthquake simulators to a tsunami wave basin. University at Buffalo is home to one of these NEES equipment sites. Professor Ramirez identified the benefits of NEES that have found their way into our building standards and building codes already. The NEES collaboratory will end in September 2014 to be replaced by a smaller number of equipment sites with an expanded treatment of hazards. It is unclear what the impact on seismic risk reduction and earthquake resilience will be, but the momentum we have gained over the past decade will certainly be lost unless the National Science Foundation's support for earthquake engineering research is maintained at current levels or increased.

Five subject areas deserving of future NEHRP resources are identified in my written testimony and these cut across the 18 elements of the National Research Council roadmap. I will focus here on three of the five. First, lifelines. Lifelines such as water, gas,

and oil pipelines, power transmission systems, and rail lines and highways and bridges provide the core of resilience. Their failure or part thereof has led to significant cascading financial losses in past earthquakes and their unavailability after an earthquake dramatically slows response and recovery. The interdependency of lifelines and the regional and national economic and social impacts of their loss in the event of a major earthquake are not understood. Lifelines should be a focus of NEHRP because they substantially affect earthquake resilience and in my opinion have received far too little attention to date.

Progress has been made in the domain of performance-based earthquake engineering through NSF funding, NEES research, and the FEMA-funded ATC–58 project. Additional work is needed to refine the tools and calculation procedures, address other types of buildings and structural systems, to better consider the effects of soil structure interaction, and to extend the products to non-building structures.

Technology transfer and earthquake engineering has traditionally been accomplished by the promulgation of codes, standards, and guidelines. NEHRP has made many significant contributions to the standards, codes, and guidelines, and these efforts must be continued. In the past six years, NIST has sponsored the preparation of technical briefs that transform basic and applied research into practical guidance for design professionals, enabling them to fully leverage federal investments in NSF and USGS, and this activity must also continue.

FEMA plays a critical role in implementing risk mitigation measures developed by its NEHRP agency partners and others, and I recommend that support for FEMA be substantially strengthened to enable effective implementation, which is the key to achieving resilience.

In closing, continued support at NEHRP is vital because the risk our nation faces measured here in terms of economic loss, business interruption, dislocation of social fabric, and casualties grows by the day because mission-critical infrastructure, property, and population density are increasing in locations affected by earthquakes. Our nation will not become earthquake-resilient if the NEHRP agency partnership with the earthquake professional community is ended.

Thank you for the opportunity to testify today.

[The prepared statement of Dr. Whittaker follows:]

July 25, 2014

Hearing

Review of the National Earthquake Hazards Reduction Program
Subcommittee on Research and Technology
U.S. House of Representatives Committee on Science, Space, and Technology
2321 Rayburn House Office Building
Washington, DC 20515
July 29, 2014

Testimony by

Andrew Whittaker, PhD, SE
Professor and Chair
Director, MCEER
Department of Civil, Structural and Environmental Engineering
University at Buffalo
State University of New York
Buffalo, NY 14260

TESTIMONY

Chairman Buschon, Ranking Member Lipinski, and other Members of the Committee,

Good morning. My name is Andrew Whittaker. I am delighted to appear before you this morning as you review the National Earthquake Hazards Reduction Program.

I am an academic structural engineer employed as a Professor of Civil Engineering in the Department of Civil, Structural and Environmental Engineering at the University at Buffalo. I serve as the Chair of the Department, direct the earthquake-focused center MCEER that is headquartered in the Department, and consult to industry and government on the earthquake and blast engineering of buildings, bridges, and energy- and defense-related infrastructure. I am registered civil engineer and structural engineer in the State of California. My business is educating the next generation of professional engineers and teachers; developing knowledge, tools and technology to better engineer structures to efficiently and cost-effectively resist the effects of earthquakes and other hazards; and transferring research products into professional practice through committee service and related activities. The National Earthquake Hazards Reduction Program (NEHRP) and its products affect nearly every aspect of my professional life.

I am also a member of, or engaged with, a number of organizations that are keenly interested in the continued success of NEHRP. I identify these organizations because my testimony is informed by my engagement with each over the past two decades. However, the opinions I express below are my own and do not represent the position of any of these organizations.

- American Society of Civil Engineers, www.asce.org
- American Concrete Institute, www.concrete.org
- Consortium of Universities for Research in Earthquake Engineering, www.curee.org

- Earthquake Engineering Research Institute, www.eeri.org
- NEEScomm, www.nees.org
- Southern California Earthquake Center, www.scec.org

Introduction

The National Earthquake Hazards Reduction Program (NEHRP) has served as the organizing framework for earthquake risk mitigation in the United States since 1977, supporting research and development, and disseminating tools, technology and information to reduce the seismic risk faced by our nation. NEHRP supports risk reduction through seismic monitoring and hazard mapping, research in geotechnical and structural engineering, development of tools and technology that can be implemented in the field by design professionals, development of codes, standards and guidelines, and work on risk mitigation and emergency preparedness. NEHRP has indirectly trained three generations of engineers and scientists who have contributed significantly to seismic risk mitigation in the United States. Continued support of NEHRP is vital because the risk our nation faces, measured here in terms of economic loss, business interruption, dislocation of social fabric, and casualties grows by the day because mission-critical infrastructure, property and population density are increasing in locations affected by earthquakes.

NEHRP is administered through four government agencies, with the National Institute of Standards and Technology (NIST) as the lead agency and the Federal Emergency Management Agency (FEMA), National Science Foundation (NSF), and U.S. Geological Survey (USGS), as the other partnering agencies. The roles of the agencies are clearly defined. Dr. Jack Hayes of NIST has provided strong and capable leadership to NEHRP since 2006.

Tools, technologies, products and policy developed with NEHRP funding have and are being used to reduce risk from earthquakes and other natural and man-made hazards, including windstorms, hurricanes, floods and terrorist actions; see EERI (2008). Key contributions include loss assessment methodologies (e.g., the FEMA-funded ATC-58 project on performance based earthquake engineering (FEMA 2013)), technology to cost-effectively harden structures, and development of emergency response procedures. Effective risk mitigation involves the multidisciplinary engagement of physical and social scientists, engineers, and planners, and NEHRP has enabled this culture, which could be expanded to address other natural and man-made hazards.

The United States is at the forefront of earthquake risk reduction because of NEHRP. Many countries use NEHRP products, including seismic hazard mapping tools and procedures, numerical models and computer codes for design, and building codes and standards, to construct structures that are resistant to the effects of severe earthquake shaking. These actions bring great credit and prestige to our nation.

Your letter of invitation asked me to respond to four specific items in my testimony, and each is addressed below.

1. Please discuss your work on the National Research Council's National Earthquake Resilience Report. Please discuss your research related to the engineering of buildings in relationship to earthquake hazards. Please also discuss any work you have conducted or

participated in related to the formation of building codes in relation to earthquake research. Please provide information on MCEER.

National Research Council report: The National Research Council (NRC) report on *National Earthquake Resilience* was published in 2011. It presents the opinions of the NRC ad-hoc Committee on Earthquake Resilience—Research, Implementation and Outreach, formed under the NRC Division on Earth and Life Studies. The ad-hoc committee was assembled at the request of NIST and comprised 13 experts, representing the disciplines involved in earthquake science, engineering and risk reduction. The committee was tasked with developing a roadmap for research, technology and information transfer, and implementation, with the goal of making our nation more resilient to the effects of earthquakes. We used the NEHRP Strategic Plan for 2009-2013 (NIST 2008a) and the Earthquake Engineering Research Institute (EERI) report *Securing Society Against Earthquake Losses—A Research and Outreach Plan in Earthquake Engineering* (EERI 2003) as a starting point for our deliberations. I served as the academic structural engineer on the committee. The NRC report framed the NIST-requested roadmap using 18 elements or tasks. I drafted text and developed cost estimates for four tasks: Task 12, Physics based simulations of earthquake damage and loss; Task 13, Techniques for evaluation and retrofit of existing buildings; Task 14, Performance-based earthquake engineering of buildings; and Task 16, Next-generation sustainable materials, components and systems.

Research: My current research related to the engineering of buildings to resist earthquake effects is broad in scope and includes a) the characterization and representation of earthquake ground motion for the design of buildings, b) soil-structure and structure-soil-structure interaction, c) seismic base isolation systems, d) seismic energy dissipation systems, and e) reinforced concrete and steel-plate concrete composite walls. Past research related to the earthquake engineering of buildings includes framing systems in structural steel and non-structural components and systems.

Development of codes and standards: I have been involved in the development of earthquake-related building codes since the late 1980s, starting with the writing of guidelines and standards for the implementation of seismic dampers and seismic base isolators in buildings for the Structural Engineers Association of Northern California. Since then, I have contributed to a significant number of earthquake-related codes and standards, including the Building Seismic Safety Council *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (since 1990); American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Seismic Isolation Design* (since 2009); American Society of Civil Engineers (ASCE) Standard 7 *Minimum Design Loads for Buildings and Other Structures* (since 2000); ASCE Standard 4 *Seismic Analysis of Safety-related Nuclear Structures* (since 2006); ASCE Standard 43 *Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities* (since 2006); and ACI Standard 349 *Code Requirements for Nuclear Safety-Related Concrete Structures* (since 2001). Contributions to guidelines and reports that have or will inform building codes include ATC 19 *Seismic Response Modification Factors* (serving as project director); ATC 34 *Study of R Factors and Other Critical Code Issues* (serving as project director); ATC 33 *Seismic Rehabilitation of Buildings* (serving as a member of the analysis and new technologies teams), which formed the basis of ASCE Standard 41; FEMA P-58, *Seismic Performance Assessment of Buildings* (serving as the leader of the structural performance products team in the ATC-58 project); and ATC 82 *Selection and Scaling of*

Earthquake Ground Motions for Response-History Analysis (serving as project director), which underpin procedures to be deployed in ASCE 7-16. Other contributions are listed in the CV submitted with this testimony.

MCEER: MCEER is a center of excellence dedicated to the discovery and development of new knowledge, tools and technologies that equip communities to become more disaster resilient in the face of earthquakes and other extreme events. MCEER accomplishes this goal through multidisciplinary, multi-hazard research. Headquartered at the University at Buffalo, The State University of New York, MCEER was originally established by the National Science Foundation in 1986, as the first National Center for Earthquake Engineering Research (NCEER). In 1998, it became known as the Multidisciplinary Center for Earthquake Engineering Research (MCEER), from which its current name, MCEER, evolved. MCEER's mission has expanded from its original focus on earthquake engineering to address the impacts of a variety of natural and man-made hazards on critical infrastructure and facilities. Several federal agencies, the State of New York, foreign governments and private industry support MCEER.

2. What is your perspective on the nation's level of earthquake preparation and resiliency?

The NRC report on *National Earthquake Resilience* defines a disaster-resilient nation as

> "... one in which its communities, through mitigation and pre-disaster preparation, develop the adaptive capacity to maintain important community functions and recover quickly when major disasters occur."

I believe our nation is not prepared for the effects of a major earthquake in a large urban area, in part because the effects of a major earthquake, economic and social, will be felt far from its epicenter. Consider for example the Ports of Los Angeles and Long Beach through which approximately 40% of our nation's imports flow, with a total trade value of approximately $400 billion USD, and generating approximately 1.5 million jobs in California alone (California Chamber of Commerce 2014). An earthquake damaging the lifeline infrastructure in and around these ports could devastate the local and regional economies, substantially harm the state economy, and have a significant impact on our nation. Lifelines are at the core of resilience. We do not understand the vulnerability of our lifelines, their interdependencies, and the cascading effects of lifeline failures, regionally and nationally, and so we can neither judge nor characterize our resilience. (NIST has contracted with the Applied Technology Council to develop a research and implementation roadmap for achieving earthquake-resilient lifelines. The forthcoming report should provide clear guidance on what must be accomplished.)

At the community level, preparedness varies by geographic region, with cities in coastal California being better prepared than those where earthquakes are rare, noting that construction practice has traditionally focused on life safety, which contributes to, but does not ensure resilience.

3. How do you view the coordination between federal, state and local stakeholders for earthquake emergency preparation and mitigation?

My knowledge of the coordination between federal, state and local stakeholders in earthquake risk mitigation and earthquake preparedness is limited because I do not practice in these domains.

However, in states prone to frequent earthquakes, such as California, the coordination will be vastly better than on the east coast, where earthquakes are rare (but likely damaging in the event of a moderate magnitude earthquake) and may not be a point of regular discussion between local, state and federal emergency response officials. Stakeholders participating in exercises such as ShakeOut (http://www.shakeout.org) will have a better sense of emergency preparation and the roles of local, state and federal officials than those that do not.

Communities across the United States are vulnerable to the effects of earthquakes, with some at far higher risk than others. In many communities, the threats from hurricanes, floods and fires are much greater than those from earthquakes. There is an opportunity to apply and adapt the lessons learned from the ShakeOut exercises to other hazards in communities across the United States, enabling them to prepare, albeit indirectly, to deal with the effects of an earthquake.

Earthquake risk mitigation is difficult to both fund and to legislate. Risk will be mitigated as the built environment is replaced over time and new structures and lifelines are built to modern standards. I am not aware of a coordinated plan, at either the state or national level, to mitigate structures and lifelines that are vulnerable to earthquakes, in part because much of this construction is privately owned.

4. What are your recommendations for research and development measures in earthquake preparation and mitigation?

Earthquake preparation and mitigation is a multidisciplinary endeavor, requiring contributions from earth scientists and seismologists, geotechnical and structural engineers, social scientists and planners. The framework of a robust research and development program must enable effective transformation of basic research products into applied research products, applied research products into practice, and the effective integration of the products across the disciplines involved in earthquake mitigation and preparation.

The United States Geological Survey is building the Advanced National Seismic System (ANSS) to collect earthquake data from across the United States, with a focus on urban areas at high risk. Information from these instruments will permit refinements in the mapping of earthquake hazard, improved ground motion prediction equations, and enable a much better understanding of how clusters of buildings in dense urban regions interact with the soil and rock below. Another focus of ANSS is capturing the response of structures in strong earthquakes, which will facilitate improvements in their structural engineering, and in the longer term, to codes and standards. ANSS data will also be key to the successful deployment by the USGS of an earthquake early warning system, which would contribute significantly to resilience on the west coast of the United States. ANSS is not being deployed at the speed originally envisioned and its possible benefits are therefore not being maximized. I recommend that ANSS be completed as quickly as possible and its maintenance and use be adequately funded.

Since 2004, NSF has operated the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) collaboratory: 14 equipment sites spread across the United States, with the largest of the sites at the University at Buffalo. The equipment sites offer unique testing capabilities, ranging from geotechnical centrifuges, to earthquake simulators, to a tsunami wave basin. NEES equipment has permitted the evaluation of components of critical facilities and

lifelines at a much larger scale than previously possibly. Research products from NSF-funded NEES research have impacted the analysis, design and construction of buildings, bridges, lifelines and mission-critical infrastructure but much more could have been accomplished had the planned research funds been made available, which would have a) supported large-scale multidisciplinary projects to tackle some of the nation's grand challenges, and b) better enabled the verification and validation of numerical simulation tools. ACEHR (2008) recommended that other federal agencies utilize the NEES equipment sites and infrastructure, but additional support was not forthcoming. The NEES collaboratory will end in September 2014, to be replaced by a smaller number of equipment sites with an expanded treatment of hazards. It is unclear what the impact will be on seismic risk reduction and earthquake resilience, but momentum gained over the past decade will certainly be lost unless NSF support for earthquake engineering research is maintained at current levels or increased.

The NRC report identifies 18 elements or tasks in its roadmap for national earthquake resilience. Each is important. Five subject areas deserving of future NEHRP resources are identified below. They cut across, albeit at differing angles, the 18 elements of the NRC roadmap.

Lifelines: Lifelines, such as water, gas and oil pipelines, power transmission systems, and rail lines and highways and bridges provide the skeleton for our communities. Their failure, or part thereof, has led to significant cascading financial losses in past earthquakes, and their unavailability after an earthquake dramatically slows response and recovery. The interdependency of lifelines, and the regional and national economic and social impacts of their loss, in the event of a major earthquake are not understood. The American Lifelines Alliance was supported by FEMA through 2007 but not since. Lifelines should be a focus of NEHRP because they substantially affect earthquake resilience and have received far too little attention to date. ACEHR (2008) recommended a stronger NEHRP focus on lifelines from all four NEHRP agencies.

Performance-based earthquake engineering: Substantial progress has been achieved in the domain of performance-based earthquake engineering through NEES research, the NSF-funded Pacific Earthquake Engineering Research Center, and the recently completed, FEMA-funded ATC-58 project (FEMA 2013). The profession can now assess the likely loss (economic, business interruption, and casualties) to a new or existing building in either a specific earthquake or over a period of time. The ATC-58 products, which are available at www.fema.gov as a three-volume publication, FEMA P-58 (FEMA 2013), provide the information and software needed to calculate losses. Much additional research and development is needed to refine the tools and calculation procedures, address other types of buildings and structural systems, better consider the effects of soil-structure interaction, and extend the products to non-building structures, including lifelines, bridges and industrial facilities.

Hardening vulnerable buildings against earthquakes: Non-ductile reinforced concrete buildings represent a significant fraction of the nation's building inventory, and as a class of buildings presents the greatest challenge we face in terms of reducing and managing earthquake risk. Although work is well underway to catalog these buildings in regions of high seismic hazard, much more is needed in regions of low to moderate hazard to fully understand the risk to the nation. Physics-based numerical modeling tools, building on

the empirical models developed to date, should be verified and validated using NEES-type infrastructure and large-scale testing.

Seismic protective systems: Base isolation and supplemental damping systems are relatively mature technologies that have been deployed to seismically protect high-value and/or mission-critical structures such as buildings, bridges, nuclear power plants, on-shore gasification facilities, and off-shore oil and gas platforms. Significant progress was made with NSF funding at MCEER through 2007 to develop tools, technologies and computer software for implementing seismic isolation and damping systems, and to develop codes and standards to facilitate their use and regulation. Further research and development is warranted to develop isolators and dampers for protection of high-value components of structures.

Technology transfer: Technology transfer in earthquake engineering has traditionally been accomplished by the promulgation of codes, standards and guidelines. NEHRP has made many significant contributions and these must be continued. In the past six years NIST has sponsored the preparation of technical briefs (e.g., NIST 2008b) that transform basic and applied research into practical guidance for design professionals, enabling them to fully leverage recent federal investments in NSF and USGS, and this activity must also continue. ACEHR (2013) identifies the critical role played by FEMA in implementing risk mitigation measures developed by its NEHRP-agency partners and others, and recommends that support for FEMA be substantially strengthened, which is a position I strongly endorse.

Closing remarks

NEHRP has provided the framework for seismic risk reduction in the United States and supports the nation's goal for disaster-resilient communities as laid out in Presidential Policy Directive 8 (White House 2011). NEHRP supports research and the development of practical tools and technologies for use by design professionals in their daily practice of engineering the built environment. NEHRP transforms applied research from the United States and abroad into manuals and technical briefs for a broad constituency, ranging from design professionals (e.g. FEMA 2013) working on large structures to homeowners (e.g. FEMA 2011) interested in mitigating their personal earthquake risk. NEHRP products, including tools, technology and policy have and can be used to address, in part, other natural hazards and man-made hazards that threaten our communities.

The nation's continued support of NEHRP, through reauthorization, is vital if we are to become disaster-resilient nation. Our nation will not become earthquake resilient if the NEHRP-agency partnership with the earthquake professional community is ended.

Thank you for the opportunity to testify today.

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Dr. Whittaker is Professor and Chair in the Department of Civil, Structural, and Environmental Engineering at the University at Buffalo (UB) and the Director of MCEER. He is a licensed Civil Engineer and Structural Engineer in the State of California. He served for 7 years as President of the Consortium of Universities for Research in Earthquake Engineering (CUREE), which is a not-for-profit corporation in the United States. In 2010-2011 he served on a National Research Council committee to develop a 20-year research agenda for earthquake engineering research in the United States as the only academic structural/geotechnical engineer on the committee. Dr. Whittaker served as a member of the Board of Directors for the Earthquake Engineering Research Institute (EERI) from 2008-2010, as a member of the Board of Directors for the World Seismic Safety Initiative (WSSI) from 2008-2010, and currently serves on the Advisory Committee of the Southern California Earthquake Center. He contributes to the development and revision of codes and standards for the American Society of Civil Engineers, the American Concrete Institute, and the American Association of State Highway and Transportation Officials on topics related to earthquake and blast engineering of buildings, bridges and nuclear energy structures.

Dr. Whittaker's research interests include seismic behavior of low aspect ratio walls of conventional and composite (SC) construction; blast engineering of buildings and infrastructure; modular SC construction for nuclear energy structures; seismic protective systems; advanced seismic probabilistic risk assessment; performance-based earthquake engineering; and seismic hazard analysis.

Dr. Whittaker provides consulting, peer-review and expert-witness services to private companies, local, state, and federal government agencies in the United States, South America, Europe, United Kingdom, Australia, and Asia. A focus of his consulting work is the application of performance-based seismic design and advanced blast engineering to tall and ultra-tall buildings, long-span bridges, and power-related and mission-critical infrastructure.

Chairman BUCSHON. Thank you very much for your testimony and thank all the witnesses. And be assured that your written testimony is critical to the committee even though we don't have a large number of Members here today. Your both spoken and written testimony is critical when we try to reauthorize these programs. So I wanted you to know that.

Also, I thank Mr. Monken because this past winter I had two family Members stuck on I–57 for about 12 hours when you had that big snowstorm. But—I don't know if you were there then but—and your agency was very responsive trying to find out the status of my family. It was about ten below zero and there were accidents on 57 and people were stuck for a long time, so thank you. And I will take that personal privilege to thank your agency at this point.

Mr. MONKEN. You are very welcome, sir.

Chairman BUCSHON. And I am going to remind the Members that the committee rules limit questioning to five minutes.

The Chair at this point will recognize himself for five minutes. And I will direct this to Dr. Ramirez.

And I say this a little tongue-in-cheek, are all the major problems in earthquake engineering solved and should we now focus on solving problems in response and recovery?

Dr. RAMIREZ. Thank you, Chairman, for the question.

To improve the resilience of our society, it is important not only to facilitate the road to recovery but also to limit the amount of damage that occurs after an event. And here is where mitigation plays a critical role not only in identifying the vulnerable infrastructure, assessing it properly, and then putting in place measures to upgrade its performance. Work is very much needed in that area and should be continued.

Chairman BUCSHON. And Purdue has—also to you, Dr. Ramirez, Purdue has pledged to increase the number of engineers graduated. How do undergraduate and graduate engineering students participate in the research funded by the National Science Foundation grant to Purdue and NEES, and how does that contribution to their success—how does that contribute to their success post-graduation?

Dr. RAMIREZ. Thank you. The contribution is essential in the development of the conduct of the research. They do it at various levels. One of the most successful programs in NEES is the research experience for undergraduates. Since the program was instituted about eight years or so ago, close to 700 undergraduates have benefited from this experience. Of those, fully half of them have continued to do research as graduate students in the earthquake engineering field. Furthermore, in these last two years, graduates from the REU program have been now graduate students mentoring current REU students.

The graduate students are the blood of the research that is conducted throughout NEES, fully including Ph.D.s and masters. Over 1,200 of them have gotten their degrees through Purdue. Of the Ph.D. students, 75 percent of them have gone into academia and are now many of them researchers in NEES as well.

Chairman BUCSHON. Thank you very much.

And this would be for all witnesses. What is the greatest weakness in the current approach to earthquake mitigation? Anyone want to tackle the question?

Mr. Monken.

Mr. MONKEN. So, first off, I was in the emergency operations center all night. I didn't sleep until everyone made it out at about 5:00 a.m.——

Chairman BUCSHON. You remember that, right?

Mr. MONKEN. Every—absolutely. January 6 I will not forget.

Chairman BUCSHON. Yeah.

Mr. MONKEN. I think for—when it comes to mitigation the hard part is the size of the elephant is enormous and trying to prioritize those efforts is where we run into significant issues. There is not enough funding in the world and there aren't enough programs in the world to address them all. And I think the untapped potential that exists with the Members of the NEHRP really comes down to a more targeted approach of risk assessment as we go through and identify the projects that are most critical. So when we look at those lifeline sources, that was articulated well by many of the witnesses here today, starting with some of those systems to be able to try and address some of the systemic weaknesses that exist within the systems I think will have the most significant impact in terms of loss of life and property. So that prioritization I think in mitigation is the biggest shortfall that we had today to make sure that we are making the best use of limited assets.

Chairman BUCSHON. How do we do that? How do we make that happen?

Mr. MONKEN. I think with a greater integration when we look at things like the exercises that we conduct and a better integration with the private sector. So the last exercise we conducted was extremely valuable because we had 45 companies running parallel exercises simultaneously to give us a better and more detailed understanding of that 85 percent of all critical infrastructure that resides within the private sector. So they can help us prioritize some of their efforts and we can do a better assessment holistically if we see that better cross-section of the research community embedded within the exercise programs of emergency management as well.

Chairman BUCSHON. Anyone else have any comments?

Dr. Savage.

Dr. SAVAGE. I think the uncertainty in the NEHRP organizations based on the lack of authorization of the program is a tremendous threat, and I think that action that you all are looking at is probably in the near term the most important thing that can be done.

Chairman BUCSHON. Thank you. Dr. Whittaker, you have——

Dr. WHITTAKER. Just a short comment. You asked what is the greatest weakness in risk mitigation? I would say not knowing our exposure. And in my written testimony I have an example of the ports of L.A. and Long Beach through which 40 percent of our nation's imports flow. The loss of those ports would have a catastrophic financial impact on our nation, not just Southern California but the impact would stretch all the way across the country. We just don't yet know what those impacts would be. We don't know the interdependency of the lifelines, and until we do, it will be difficult to develop cost-effective mitigation strategies.

Chairman BUCSHON. Thank you.

I now recognize Mr. Lipinski.

Mr. LIPINSKI. Thank you, I want to start off by thanking Dr. Ramirez for emphasizing the need for more training for more engineers in our country. We certainly need more engineers in our nation and we need more engineers in Congress also I think.

Director Monken, I want to also thank you for your service to our nation and your service now to the State of Illinois. Obviously from what Chairman Bucshon was—the story he relayed, you are doing a good job there in some very tough times.

One question I wanted to ask Director Monken, how is the—how is your work with the federal government? Is there more that the federal government can be doing, in terms of coordinating with States? Is there anything that you would recommend?

Mr. MONKEN. Yeah, I think there is a couple issues that are out there right now. One is that the National Earthquake Program is not treated similarly to other catastrophic hazards, specifically hurricane is an example. So the National Earthquake Program does not have a dedicated program manager; there is not an SES-level individual at FEMA dedicated to the earthquake program. It is currently housed in Mitigation, which is not obviously an unimportant component of what we are talking about. It is hugely important. However, it does not give—because of its presence in Mitigation, it doesn't give it full access to the capacity of FEMA as the hurricane program has in the response and recovery division in terms of access to funding, additional resources, things like that.

And then as I mentioned in my testimony, the removal of funding directly to States to fund earthquake program managers at the state level being pulled in Fiscal Year 2013 has really created a situation now where we have very, very limited engagement. Right now, there are more FEMA regions that don't have an earthquake program manager than FEMA regions that do, and that is a huge problem because that is the point of coordination for emergency management nationally and it also underscores the importance of these consortia, the three earthquake consortia located throughout the United States that are region-specific. And they perform an incredible task of that state-to-state coordination and yet have not seen any changes in their funding or programmatic or policy-level support in the past 20 years. So the lack of emphasis on some of those grassroots coordinating programs I think has had a detrimental effect.

Mr. LIPINSKI. And one other question I wanted to ask, as you notice a theme here, I am an engineer. I am also a social scientist. I have always asked about the social science aspects of—any issue that we are dealing with and the research and how you deal with the human element.

So let me start with Director Monken. What kind of work do you do to try to ensure that people of the State of Illinois understand the risks from earthquakes? Is this a—do you find this to be a big problem? I know most people are going to think more about tornadoes than they do about earthquakes, but how does all of that come together? And what you do in terms of trying to make people aware of the risk and also to prepare them—so that they know what to do in case there is a major earthquake?

Mr. MONKEN. Yes, sir. It is a great question and I think it is accurately highlighted as a significant issue. We have had 11 declared disasters in Illinois in the last five years, none of which were earthquakes, so that is really where a lot of the emphasis happened. But I think some of the public awareness campaigns that we have done, the areas where we have had specific success is certainly within schools and that is where Chairman Bucshon was right on. Elementary school students, these are the folks that actually retain this information for the rest of their lives. Adults have made up their minds for all intents and purposes. In trying to reach out to students and educate them on those threats, there is the educational component that exists with it and that extends through the development and training of engineers at all levels. All those levels of understanding are important.

We also saw that our PSAs were actually generated by high school and college students in the States, so we actually put it to them to come up with public awareness campaigns, videos, and radio bits that were much more effective in actually reaching their peers instead of a government person like myself trying to relate to a 12-year-old and telling them why this is important. Have another one of their fellow students communicate that message to them.

And the ShakeOut grew from just a handful of a few thousand people the first year to the annual competition between Illinois and Indiana to see who can get more people to participate and over 10 million people participating nationally last year, those are successes that really need to be reinforced.

Mr. LIPINSKI. Thank you, and I appreciate all of the witnesses' comments on NEHRP, and again I emphasize that hopefully we will get reauthorization done. And I think all of your comments have—are very helpful to us as we work to move that forward.

So I yield back.

Chairman BUCSHON. Thank you.

I recognize Mr. Hultgren.

Mr. HULTGREN. Thank you, Chairman. Thank you so much, panel, for being here. I think this is really important for us to be able to hear how NEHRP affects practitioners, especially those at the state and local level, really on the ground, so I really thank you. And I especially want to thank Director Monken. So good to have you here. I appreciate your service to our country and to our State, and please say hi to your family back in St. Charles as well.

Mr. MONKEN. Yes, sir. Will do.

Mr. HULTGREN. I am glad you are here.

Director Monken, I wanted to address a couple questions to you first if I could. First, does NEHRP program—does the program produce actionable data for the emergency management community? If so, what types of data are produced, shared, and utilized, and how are technical guidance, behavior research, and other information produced by NEHRP agencies shared with local stakeholders?

Mr. MONKEN. So the answer is yes and no. So there is actually an incredible amount of information and data that is generated from the entities that are represented here as witnesses today and many other folks who are not, but the hard part is turning infor-

mation into intelligence, and the difference is whether or not it is actionable. And we have gotten a good partnership with U.S. Geological Survey. We had been able to use some of there what they call the PAGER program where people can actually report ground shake from their mobile phones to give us a clear picture of what is happening and to what extent the ground is shaking. Those things are all very, very important.

What we want to do is tie it together in a more practical sense and have a more collaborative outreach between emergency management to make sure that those efforts are as integrated as possible to make sure that the time being spent on research is targeted to the areas with greatest impact in terms of lives and property saved and really trying to make sure that it is more of a user-defined system.

So some of the information-sharing that we pilot-tested during the exercises here was unprecedented. Four hundred and forty counties in seven States have never shared data in any way, shape, or form in any disaster in U.S. history. I can't overstate the importance of that. But the research community absolutely needs to be integrated into that process to make sure that the models that are being generated and research are being compared and utilized to effectively execute the exercise.

Mr. HULTGREN. Is there an openness you think for that, first of all recognizing that the successes of the pilot program but then seeing potential hurdles and dealing with those hurdles? Is there an openness there? I guess how can we help?

Mr. MONKEN. Yes, sir. Well, certainly the reauthorization of the program is hugely important and some of the changes I mentioned at FEMA I think would go a long way to making sure we are doing that, and then supporting the consortia because that is—CUSEC, the Central United States Earthquake Consortium that Illinois and Indiana are part of, was actually the organization that ran that exercise. It wasn't a federally led effort. So reinforcing that type of success is absolutely important.

But I think it is fertile ground. Everybody wants the same thing when it comes down to it. The hard part is making sure, as I mentioned, the NEHRP Advisory Council out of 15 people only has one emergency manager on it. It is very difficult to understand local and state impact when they are not represented on that group that is consulting on how we should be guiding the program. So that is hugely important.

But I think it is fertile ground to do it and I think the folks that are doing the research, they want that input; they want that interplay because it only makes their research more targeted and more effective just like we want access to that information to build our exercises around and then ultimately compare that to a real-world event.

Mr. HULTGREN. Dr. Monken, I wondered if you could address—quickly, we touched on this a little bit—but if you could talk a little bit more about the state of research and development for hazard mitigation tools and products. These activities must meet the needs of state and local officials who must prepare their communities for disaster and help them respond. How well do NEHRP activities meet state and local needs and how could efforts be better aligned?

We kind of touched on that already, but what are the lessons that can be drawn from the resilience demonstrated in responding to a moderate earthquake and in preparing for a great one?

Mr. MONKEN. So I think the issues that we have seen that we have run into is in large part some of the state and local mitigation programs are very compartmentalized. So each of the programs or proposals are analyzed individually. So as we go through the FEMA process for spending mitigation dollars, each program is evaluated on its own merits without a great deal of consideration for the interconnectivity with corresponding projects in the same area of impact within the same scope of the hazard.

So I think that component needs to be brought to bear in more detail, not to mention the fact that in many cases if it is the private sector that benefits specifically from it, so if it is a utility company that has a mitigation project they want to do, that is not something that we do within the federal mitigation program. So how do we coordinate their efforts to make sure that we don't build, as we like to say, cylinders of excellence or these individual silos that are—that have these pockets of competency that aren't really tied into the interconnectivity of these lifeline systems that are out there?

So that is where the private sector outreach comes into play. So utility companies alone, there are 3,000 utility providers in the country, and trying to tie those folks together is difficult but they are willing participants to do it. And I think some of the issues are really known. If an earthquake like this hit the central United States, power would be out for 6 to 9 months, not days or weeks.

Mr. HULTGREN. Yeah. Well, my time is coming to a close. Thank you again, all of you, for being here. I appreciate your input on this important program.

Thank you. I yield back.

Chairman BUCSHON. Thank you.

At this point I will thank all the witnesses for your valuable testimony. Like I said, your written testimony—your spoken testimony is very important to the committee and for the Members for their questions.

The Members of the committee may have additional questions for you and we will ask you to respond in writing. The record will remain open for two weeks for additional comments and written questions from Members.

At this point the witnesses are excused and the hearing is adjourned.

[Whereupon, at 11:49 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Pramod P. Khargonekar

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Earthquake Hazards Reduction Program"

Dr. Pramrod P. Khargonekar, Assistant Director, Directorate of Engineering, National Science Foundation

Questions submitted by Rep. Larry Bucshon, Chairman, Subcommittee on Research and Technology

1. Following-up on my question during the hearing, please provide a list of the research and development being supported through NHERP related to lifelines in a seismic event.

National Science Foundation Support for Impacts of Seismic Events on Lifelines in the National Earthquake Hazards Reduction Program

The *National Earthquake Hazards Reduction Program (NEHRP) Strategic Plan for Fiscal Years 2009-2013* (Reference 1) addresses earthquake mitigation of critical infrastructure lifelines through the Plan's following strategic priorities and goals/objectives:

- One of the nine Strategic Priorities: "Develop guidelines for earthquake-resilient lifeline components and systems."
- Goal A, Objective 2: Advance understanding of earthquake effects on the built environment: "NEHRP will support basic research to advance scientific and engineering knowledge of earthquake effects on the built environment. This research will contribute to developing cost-effective design methodologies and technologies for mitigating these effects on soils, lifelines, existing structures, and new construction."
- Goal B, Objective 8: Develop tools to improve the seismic performance of critical infrastructure: "NEHRP will use the results of basic research in earthquake-resistant design and construction to develop technologies and measures suitable for system-wide mitigation in new and existing infrastructure lifelines… and critical facilities (e.g., facilities critical to public health, business continuity, or key economic or governmental functions)."

The NEHRP Strategic Plan, published in 2008, links infrastructure lifelines to critical infrastructure as defined by the Department of Homeland Security's *National Infrastructure Protection Plan*, 2006 (Reference 2). This critical infrastructure includes communications, energy, transportation, and water and wastewater systems.

NSF supports research on earthquake effects on lifelines through special program solicitations, core research programs, rapid response research (RAPID) grants, and the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) lifelines facility at Cornell University supported during fiscal years 2005 - 2014 under the NSF NEES operations umbrella award 0927178 to Purdue University. The attachment provides a list of active NSF awards that include a research focus on the impacts of seismic events on lifelines and recently expired NSF RAPID

awards of short duration that investigated the impacts on lifelines of major seismic events during 2010 - 2011 in Haiti, Chile, Japan, and New Zealand.

Special Solicitations

As FY 2013 and FY 2015 activities, NSF program solicitations 12-610 and 14-581, Interdisciplinary Research in Hazards and Disasters (Hazards SEES)., are a joint activity among the Directorates for Geosciences (GEO); Computer and Information Science and Engineering (CISE); Engineering (ENG); Mathematical and Physical Sciences (MPS); Social, Behavioral and Economic Sciences (SBE); and the Office of Integrative and International Affairs (OIIA). Below is a synopsis of this solicitation:

"The overarching goal of Hazards SEES is to catalyze well-integrated interdisciplinary research efforts in hazards-related science and engineering in order to improve the understanding of natural hazards and technological hazards linked to natural phenomena, mitigate their effects, and to better prepare for, respond to, and recover from disasters. The goal is to effectively prevent hazards from becoming disasters. Hazards SEES aims to make investments in strongly interdisciplinary research that will reduce the impact of such hazards, enhance the safety of society, and contribute to sustainability. The Hazards SEES program is a multi-directorate program that seeks to: (1) advance understanding of the fundamental processes associated with specific natural hazards and technological hazards linked to natural phenomena, and their interactions; (2) better understand the causes, interdependences, impacts and cumulative effects of these hazards on individuals, the natural and built environment, and society as a whole; and (3) improve capabilities for forecasting or predicting hazards, mitigating their effects, and enhancing the capacity to respond to and recover from resultant disasters.

Hazards SEES seeks research projects that will productively cross the boundaries of the atmospheric and geospace, earth, and ocean sciences; computer and information science; cyberinfrastructure; engineering; mathematics and statistics; and social, economic, and behavioral sciences. Successful proposals will integrate across these multiple disciplines to promote research that advances new paradigms that contribute to creating a society resilient to hazards. Hazards SEES intends to transform hazards and disaster research by fostering the development of interdisciplinary research that allows for appropriately targeted data collection, integration, and management; modeling (including predictive models for real-time decision making); visualization and simulation; data analytics and data-driven discovery; real-time sensing; cross-cutting knowledge development; and synthesis of applicable models and theory. Proposals must demonstrate the inclusion of the appropriate expertise to address the research questions, hypotheses, and problems being posed. Hazards SEES research projects should be designed around one or more locations, identifiable hazards, and/or themes. Furthermore, Hazards SEES research should train the next generation of scientists for interdisciplinary hazards and disaster research."

As an FY 2014 activity, NSF supported program solicitation NSF 14-524, Resilient Interdependent Infrastructure Processes and Systems (RIPS), through the Directorates for CISE, ENG, and SBE. The anticipated funding amount is $15,000,000 and up to 20 awards will be made. Awards will be made by end of FY 2014. Below is a synopsis of this solicitation:

"Critical infrastructures are the mainstay of our nation's economy, security and health. These infrastructures are interdependent. For example, the electrical power system depends on the delivery of fuels to power generating stations through transportation services, the production of those fuels depends in turn on the use of electrical power, and those fuels are needed by the transportation services.

The goals of the **Resilient Interdependent Infrastructure Processes and Systems** (RIPS) solicitation are (1) to foster an interdisciplinary research community that discovers new knowledge for the design and operation of infrastructures as processes and services (2) to enhance the understanding and design of interdependent critical infrastructure systems (ICIs) and processes that provide essential goods and services despite disruptions and failures from any cause, natural, technological, or malicious, and (3) to create the knowledge for innovation in ICIs to advance society with new goods and services. The objectives of this solicitation are:

- Create theoretical frameworks and multidisciplinary computational models of interdependent infrastructure systems, processes and services, capable of analytical prediction of complex behaviors, in response to system and policy changes.
- Synthesize new approaches to increase resilience, interoperations, performance, and readiness in ICIs.
- Understand organizational, social, psychological, legal, political and economic obstacles to improving ICI's, and identifying strategies for overcoming those obstacles.

The RIPS solicitation seeks proposals with transformative ideas that will ensure ICIs services are effective, efficient, dependable, adaptable, resilient, safe, and secure. Successful proposals are expected to study multiple infrastructures focusing on them as interdependent systems that deliver services, enabling a new interdisciplinary paradigm in infrastructure research...Projects supported under this solicitation may undertake the collection of new data or use existing curated data depending on the category of award, and must recognize that a primary objective is integrative predictive modeling that can use the data to validate the models and which can be integrated into decision making."

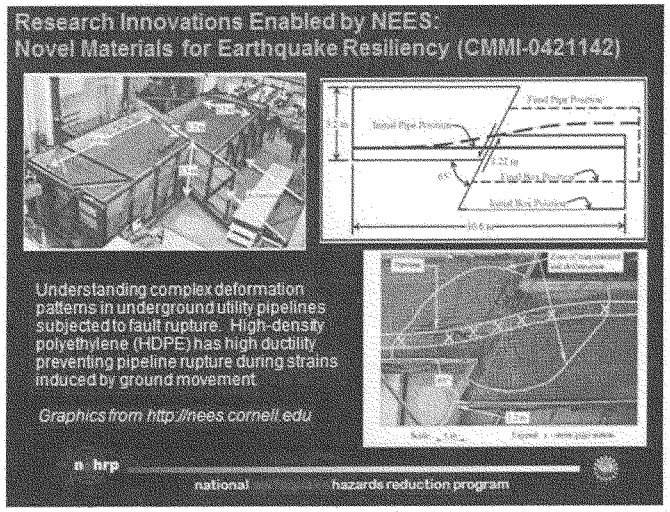
NSF Core Research Programs

Research on earthquake mitigation for lifelines has been supported from the following core research programs in the ENG Directorate, Division of Civil, Mechanical, and Manufacturing Innovation:

- Geotechnical Engineering (GTE)
- Hazard Mitigation and Structural Engineering (HMSE)
- George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Research (NEESR)
- Infrastructure Management and Extreme Events (IMEE)

NEES Lifelines Facility at Cornell University, Ithaca, New York, supported under NEES Operations Umbrella Award 0927178 to Purdue University, West Lafayette, Indiana

Located in Cornell University's Department of Civil Engineering, this facility has enabled large-scale testing to study the effects of large differential ground deformation on buried pipeline and conduit performance. The slide below show a test at the Cornell lifelines facility investigating the seismic capacity of high-density polyethylene (HDPE) pipelines used in water utility distribution systems.



References:

1. *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009-2013*, October 2008, http://www.nehrp.gov/pdf/strategic_plan_2008.pdf
2. Department of Homeland Security, *National Infrastructure Protection Plan*, 2006. http://www.chemicalsecurity.com/index/NationalStrategy/NationalInfrastructureProtectionPlan(2006).pdf. Note: The most recent version is dated 2013.

NSF Award	Research Award Title	Institution	Location		Investment
1441224	Collaborative Research: RIPS Type 2: Quantifying Disaster Resilience of Critical Infrastructure-based Societal Systems with Emergent Behavior and Dynamic Interdependencies	University of Maryland College Park	College Park	Maryland	$1,452,773
1441209	Collaborative Research: RIPS Type 2: Quantifying Disaster Resilience of Critical Infrastructure-based Societal Systems with Emergent Behavior and Dynamic Interdependencies	Johns Hopkins University	Baltimore	Maryland	$1,047,227
1437003	Three-Dimensional Isolation System for Building Resilience to Earthquake Hazard	University of Nevada, Reno	Reno	Nevada	$359,132
1436058	Collaborative Research: Optimal Design of Smart Damping for Structural Systems to Mitigate the Impacts of Natural Hazards	Clarkson University	Potsdam	New York	$68,885
1436018	Collaborative Research: Optimal Design of Smart Damping for Structural Systems to Mitigate the Impacts of Natural Hazards	University of Southern California	Los Angeles	California	$206,107
1435494	Evaluation of Earthquake-Induced Liquefaction Damage Potential to Infrastructure	Virginia Polytechnic Institute and State University	Blacksburg	Virginia	$255,316
1414903	EAPSI: Quantifying the Effect of Centralization on the Resilience of the Regional Healthcare System in the 2010-11 Canterbury Earthquake Sequence	Johns Hopkins University	Baltimore	Maryland	$5,070
1408486	Collaborative Research: An Intelligent Restoration System for a Self-healing Smart Grid	South Dakota State University	Brookings	South Dakota	$209,999
1408141	Collaborative Research: An Intelligent Restoration System for a Self-healing Smart Grid (IRS-SG)	Clemson University	Clemson	South Carolina	$170,000
1360664	Spider Orb-Web Inspired Cognitive, Fault-Tolerant Fiber	Clemson University	Clemson	South Carolina	$264,123
	Optic Sensor Network for SHM under Harsh Conditions				
1360041	Collaborative Research: Optimization of Remote Sensing Networks for Time-sensitive Detection of Fine Scale Damage to Critical Infrastructure	University of New Mexico	Albuquerque	New Mexico	$172,233
1361222	Collaborative Research: Optimization of Remote Sensing Networks for Time-sensitive Detection of Fine Scale Damage to	San Diego State University	San Diego	California	$365,320

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Responses by Mr. Roy E. Wright

HONORABLE STEVEN M. PALAZZO

QUESTIONS FOR RESEARCH & TECH SUBCOMMITTEE HEARING
JULY 29, 2014

HEARING ON: REVIEW OF THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM
QUESTION FOR MR. WRIGHT

Question: I'm concerned about FEMA's role in the NEHRP. As the agency tasked with mitigation, response, preparedness and recovery, the budget for FEMA in NEHRP is only $7.8M compared to $52.2M for NSF and $59M for USGS. From what I understand, with that tiny amount FEMA is assisting other agencies in developing modeling tools and building codes.

Response: FEMA acts as the implementation arm of the four-agency National Earthquake Hazards Reduction Program (NEHRP) that also includes U.S. Geological Survey (USGS), the National Science Foundation (NSF), and the U.S. Department of Commerce's National Institute of Standards and Technology (NIST). In this capacity, FEMA helps to translate research into practice and create guidance and other tools for designers, contractors, regulators, decision-makers and the public related to earthquake hazard reduction.

FEMA works in a highly collaborative manner and relies on its agency partners, regional consortia and numerous private sector groups to leverage its resources to help educate the Nation about earthquake hazard reduction and to work collectively to reduce that risk. As part of those efforts, we sometimes share resources with our partner agencies, as they do with us, and as our expertise and skills dictate. Examples of cooperative work include NIST-related earthquake hazard engineering on topics like performance-based seismic design and USGS-related work on seismic hazard maps and their Prompt Assessment of Global Earthquakes for Response (PAGER) earthquake alert notices. FEMA also relies on a group of cooperative partnerships with regional earthquake consortia that support FEMA with their expertise and existing relationships to accomplish our goals. Additionally, FEMA cooperates on NEHRP with other Federal agencies, including the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Energy (DOE), related to hazard mitigation tools and building codes. NIST and FEMA share responsibilities for performance-based design and building codes.

Question: Historically FEMA provided direct funding to states for carrying out earthquake preparedness activities. In 2012 this funding amounted approx. $2.5M that enabled states to maintain a core program. However in FY 13 FEMA stopped directly funding state earthquake program activities, contrary to Congressional language.

Response: FEMA has the responsibility of supporting the effective implementation of earthquake risk reduction, which includes assisting States and Territories to support local

seismic planning, educational campaigns, building code adoption, seismic inventory, and other mitigation activities.

In FY 2012 FEMA's legal interpretation of 44 CFR 361.4 clarified that the Cooperative Agreements that FEMA was carrying out with the high earthquake hazards States/Territories, needed to meet applicable regulatory requirements. This interpretation led to the enforcement of a 50% cost matching requirement (cash only) for the program. As a result of this enforcement, 15 of the 33 participating states and territories could not meet all or part of their matching requirements. The inability to meet the cost share match prevented many states and territories from receiving funding.

Before the FY 2013 Cooperative Agreements were issued, FEMA conducted a review of NEHRP responsibilities related to our regional, state and local partners to determine the most effective way to meet them. Based on the review, the difficulties with the matching requirement, and the forecasted efficiencies, FEMA decided to align resources with the Earthquake Consortia and other partner organizations for a national, regional, and multi-state approach and discontinue direct State assistance.

FEMA's Earthquake Consortia and Program Partner Organizations Programs provide nationwide support for activities such as:

- Earthquake awareness and education
- Multi-state coordination in emergency management, state geology departments, State seismic commissions, etc.
- Earthquake mitigation through building codes and land use,
- Training and workshops
- Publications
- Policy development
- Partnerships with private and local, state, Tribal, Federal governments, and universities
- Shake Out exercises
- Disaster-safety education
- Training for earthquake experts, emergency managers, other local officials and the private sector
- Creating partnerships across multiple sectors
- Building code development and adoption
- Mitigation outreach and awareness
- Earthquake science and engineering
- Social science, economic, political, cultural research
- Seismic engineering research
- Fostering relationships with research institutions and universities
- Creation of software, databases, visualizations useful for earth scientists, engineers, government agencies, news media, teachers, students, and the general public.

Question: Do you think the FEMA National Earthquake Hazard Response Program could benefit from a more balanced approach that includes response, preparedness and recovery, as compared to a program that focuses primarily on mitigation and standards?

Response: The FEMA branch responsible for activities under the National Earthquake Hazards Reduction Program (NEHRP) is housed within the Federal Insurance and Mitigation Administration (FIMA). The reason for this organizational structure is that most of FEMA's responsibilities under the NEHRP focus on mitigating future losses and were therefore more appropriately under FIMA. Under the NEHRP, FEMA is the agency most responsible for translating research results into practice and it is meeting that responsibility that results in the majority of the program activities and products that aid in the reduction of future earthquake losses.

This role in implementing the program has and continues to involve the development of a wide variety of products for various stakeholders. Many of these products are mitigation based, such as the *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*. However, there are many products that cover preparedness, recovery, and response as well. These include preparedness tools, such as:

- The annual Shake Out preparedness drill, which is primarily support by FEMA
- Seismic Considerations for Communities at Risk (FEMA Publication No. 83)
- Promoting Seismic Safety: Guidance for Advocates (FEMA 474)
- Earthquake Safety Checklist (FEMA B-526)
- Earthquake Safety Activities for Children and Teachers (FEMA 527)
- Home Hazard Hunt (FEMA 528)
- Earthquake Safety Guide for Home Owners (FEMA 530)
- Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)
- Guidelines for Design of Structures for Vertical Evacuation from Tsunamis (FEMA P646)
- Earthquake Publications for Businesses (QuakeSmart Toolkit, FEMA P-811)

For response and recovery, these products include:

- Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings (FEMA 306 – Basic Procedures Manual and 307 – Technical Resources)
- The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings (FEMA 308)
- Recommended Post-earthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings (FEMA 352)

While NEHRP products and personnel support mitigation, preparedness, response and recovery, not all of FEMA's earthquake-related activities take place in FIMA or in the branch responsible for the program. FEMA is a multi-hazard agency, and every component is responsible for addressing all hazards, including earthquake. For example, in the last three years, FEMA's National Exercise Program has simulated earthquake-

related exercises with several states, including an exercise with all of the states in the New Madrid Seismic Zone in recognition of the 200 year anniversary of the largest earthquakes to strike the continental United States. In addition, under Protection and National Preparedness, FEMA recently sponsored a PrepareAthon! that focused on earthquake hazard reduction and released several new earthquake preparedness products. The NEHRP is also the principal supporter of the annual "Shake Out" earthquake preparedness drill with over 20 million participants. Finally, the FEMA Office of Response and Recovery is currently responding to a presidentially declared earthquake disaster in Napa and Solano Counties, California and will be working with the State of California to help them recover.

FEMA earthquake-related responsibilities do not reside in the single office that is responsible for NEHRP; we address the earthquake risk as part of our multi-hazard mission in every area that FEMA is involved in.

Question: If you agree, what would that type of program entail, and how would FEMA implement such a program?

Response: FEMA does not agree that a new program is needed. The activities listed above demonstrate how FEMA is undertaking significant and relevant earthquake-related activities in all areas of emergency management. While we are always looking for ways to improve how we coordinate our NEHRP and earthquake-related activities, we believe that the existing program is the best way for FEMA to meet its program responsibilities.

Question: If mitigation, response, preparedness and recovery are not priorities, and other NEHRP agencies are not responsible for those tasks, can you justify the budget that FEMA, NIST, USGS and NSF are currently getting, when no agency is working on those priorities?

Response: FEMA's mission is to support our citizens and first responders to ensure that as a Nation we work together to build, sustain, and improve our capability to prepare for, protect against, respond to, recover from, and mitigate hazards. FEMA's strategic plan outlines strategic priorities to institutionalize key improvements while building Agency capacity and strengthening national capabilities for disaster preparedness. Addressing the earthquake risk to our country requires coordinated work across mitigation, response, recovery and preparedness—and each of these aspects is a priority for FEMA.

In response to recent questions for the record, (QFR 1042945), FEMA highlighted the agency's contributions to earthquake preparedness. These contributions extend from the National Exercise Program's conducting extensive earthquake-related exercises with several states, to Protection and National Preparedness's sponsoring an event focused on earthquake hazards as part of America's PrepareAthon!. Several new earthquake preparedness products were also released at the America's PrepareAthon! event. In addition, FEMA's Office of Response and Recovery recently responded to the

presidentially declared disaster in Napa and Solano Counties, California and continues to work with the State of California to help speed recovery in the impacted areas. These activities are all in addition to the work of the NEHRP, which is managed within FEMA's Risk Reduction Division of the Federal Insurance and Mitigation Administration (FIMA).

FEMA's multi-hazard mission addresses earthquake risks within each of the five mission areas of the National Preparedness Goal: Prevention, Protection, Mitigation, Response, and Recovery.

Question: FEMA focuses primarily on mitigation, but needs to balance priorities more evenly. Do you think that the NEHRP as a whole, which currently focuses solely on science, needs to focus more on emergency management?

Response: FEMA believes that the work conducted under the National Earthquake Hazards Reduction Program (NEHRP), in conjunction with the earthquake-related work underway throughout the entire agency, is well balanced and effective. As part of these efforts, FEMA invests substantially in fulfilling our emergency management responsibilities. Support for our whole community of stakeholders including the emergency management community is the top priority for the agency and includes support for training, equipment, exercises and every other component of the emergency management process. For example, over the past 10 years there have been three major regional or national level exercises based on earthquake events, all of which provided opportunities for local emergency managers to learn and test their capabilities. FEMA also acts as the lead agency within NEHRP on all program implementation and outreach activity translating the science and research conducted by the National Science Foundation, the National Institute of Standards and Technology, and the U.S. Geological Survey into a wide array of products including training materials and programs, partnership development, and support for regional, State and local partners. NEHRP mitigation work is closely tied to the much larger, agency-wide focus on emergency management and creates a strong and coordinated set of programs, activities and resources that maximizes our efforts and effectiveness related to earthquake hazards.

The National Preparedness Goal organizes FEMA's core capabilities into five mission areas: Prevention, Protection, Mitigation, Response, and Recovery. Each capability is addressed by particular provisions of the Stafford Act. Earthquake risk is addressed within each of the five mission areas of FEMA. NEHRP, acting in concert with all five mission areas of FEMA achieves the goal of reducing risk nationally and creating more resilient communities. The resources committed to FEMA's NEHRP activities represent a small fraction of what the agency commits to the earthquake peril and to emergency management.

Responses by Dr. Julio A. Ramirez

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Earthquake Hazards Reduction Program"

Dr. Julio A. Ramirez, Professor of Civil Engineering, NEES Chief Officer and NEEScomm Center Director, George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES)

Questions submitted by Rep. Larry Bucshon, Chairman, Subcommittee on Research and Technology

1. What developments related to civil or structural engineering, utilities, and emergency management, including materials, methods, and standards would make our infrastructure safer in the future? What technologies, tools, or strategies are on the horizon that will help to ensure that the next generation of critical infrastructure is more robust than existing designs? Are there particular areas in engineering, or throughout the scientific enterprise more broadly, where additional research could support existing earthquake response and mitigation efforts?

   Maintaining a balanced program supporting research in the earth science, engineering, and social science areas is important. In achieving resilience of communities against earthquakes and tsunamis, engineering related research is of the highest priority as it directly impacts the mitigation of the extent of damage to built-environment and can reduce the time needed for recovery.

   Research that can efficiently identify older vulnerable construction, from buildings and bridges to lifelines, and ways to mitigate the risk to people, community and businesses should be of the highest priority followed by research on new methods of construction and improved materials and technologies focused in the reduction of damage from these events.

   The current state of preparedness is much enhanced by advances made in the past decades, in large part supported through NEHRP funded research and implementation, but more must be done to protect our communities. Continued attention is required because of the growth of our cities and industrial centers, the new focus on resilience and the dependency of resilience on the performance of older, vulnerable construction.

   Advances in knowledge and information technologies can multiply the value of research data and improve the efficiency of the work of researchers more efficient. Investment is critically needed and offers high pay-off in this area. A clear example that supports this statement can be found in the area of earthquake risk mitigation. Linking the NEES experimental facilities to each other, to NEEScomm headquarters of NEES operations, and to off-site users is the NEES cyberinfrastructure. This unique system of information technology resources enables researchers participating at NEES laboratories or remotely to collect, view, process, and store data from NEES experiments, to conduct numerical simulation studies, and to perform hybrid (combined experimental and numerical) testing involving one or more NEES equipment sites increasing research efficiency. At the heart of this system is NEEShub, a platform designed

to facilitate information exchange and collaboration among earthquake engineering researchers, educators, students, practitioners, and stakeholders. NEEShub features the NEES data repository a curated, centralized repository used to store and share data and research results. Since the first release of the NEEShub "cloud" platform 4 years ago, the community has actively responded to user-focused cyberinfrastructure improvements with a pace of file and directory creation that has increased exponentially. Today, the NEES-curated central repository of research data features a vastly populated repository of NEES research data and showcases over 2.5 M data files and folders that engineers can search, sort, download, and manipulate. NEEShub also stores and shares a variety of other earthquake engineering resources, including publications, databases (4), computational models, simulation software, educational materials, and data management and visualization tools. Since the first release of NEEShub in August 2010, researchers, students and practicing engineers from more than 200 countries have performed 1,428,026 web and 47,998 tool sessions (Figure 1). The arrival of the NEEShub has ushered in a new collaborative capability with vastly improved IT resources for research and development in earthquake engineering. Investment in information technology is also warranted to improve the rapid and efficient adoption of practices and technologies that enhance resilience of communities by reducing damage after the event and by accelerating the pace of recovery, and these should be exploited.

In the next level of importance is the support for research on impacts of earthquakes at the regional scale, especially as it relates to the ability of a community to re-establish its footing as a viable community; and, the support of implementation programs that will encourage cities to undertake studies and develop plans for resilience.

Many of the world's global challenges, such as the mitigation of earthquake risk, can be best met with a strong presence engineers working in well-integrated teams with social scientists and other experts, yet the number of U.S. engineering students is declining. Continued investment in preparing the next generation of leaders in the field of earthquake engineering and science should remain of the highest priority to the nation.

2. How should we measure national earthquake resilience, and how do we know if we are becoming more earthquake resilient? What activities are critical for advancing resilience, and what are the enabling technologies for an earthquake resilient nation?

The National Research Council of the National Academies in the 2011 Report -National Earthquake Resilience -provided a working definition for "national earthquake resilience".

A disaster-resilient nation is one in which its communities, through mitigation and pre-disaster preparation, develop the adaptive capacity to maintain important community functions and recover quickly when a major disaster occurs.

Because the concept of resilience is specific to the context of the specific community and its goals, it can be expected that no single measure will be able to capture it sufficiently. No one resilience indicator can suit all purposes, and different measurements may be appropriate in different cases. Resilience requires awareness of earthquake risk, knowing what to do in response to that risk, and doing it.

The current state of preparedness is much enhanced by advances made in the past decades, in large part supported through NEHRP funded research and implementation, but more must be done to protect our communities. Continued attention is required because of the growth of our cities and industrial centers, the new focus on resilience and the dependency of resilience on the performance of older, vulnerable construction. Finally, as indicated in the response to the first question, advances in knowledge and information technologies can improve the rapid and efficient adoption of practices and technologies that improve resilience of communities by reducing damage after the event and by accelerating the pace of recovery, and these should be exploited.

Responses by Dr. William U. Savage

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Earthquake Hazards Reduction Program"

Dr. William U. Savage, Consulting Seismologist, William Savage Consulting, LLC

Questions submitted by Rep. Larry Bucshon, Chairman, Subcommittee on Research and Technology

1. What developments related to civil or structural engineering, utilities, and emergency management, including materials, methods, and standards would make our infrastructure safer in the future? What technologies, tools, or strategies are on the horizon that will help to ensure that the next generation of critical infrastructure is more robust than existing designs? Are there particular areas in engineering, or through the scientific enterprise more broadly, where additional research could support existing earthquake response and mitigation efforts?

   Response: An additional key question might be "What regulatory and financial changes are needed to establish secure and stable long-term relationships between and among lifeline organizations and their customers/users (both in the private and public sectors) to assure a mutually satisfactory economic balance that systematically reaches a stable condition of earthquake resilience?" A fundamental aspect of addressing these questions is that they all involve well-guided and sustained efforts in resolving engineering, science, and public policy problems and issues.

   The National Institute of Standards and Technology, as a NEHRP agency, has taken a leading role in developing an interdisciplinary, integrated approach to addressing the above questions through establishing a program called "Community Disaster Resilience" (http://www.nist.gov/el/building_materials/resilience/index.cfm). This program has the potential to draw on the broad national resource of expertise to examine the science and engineering progress needed in improving resilience as well as exploring and framing the operational aspects of resilience, such as performance standards and guidelines applied at the community level. By choosing to work at the community level across the nation, I think the public and private sectors can find common ground and cooperate to achieve community resilience.

2. How should we measure national earthquake resilience, and how do we know if we are becoming more earthquake resilient? What activities are critical for advancing resilience, and what are the enabling technologies

   Response: In my testimony regarding lifeline resiliency, I noted that it is necessary to develop and apply detailed computer models of lifeline systems (electric power transmission is the one I'm most familiar with) and study their performance under

various earthquake hazard scenarios to evaluate resilience. I expect that, in general, more elaborate models will be needed to assess earthquake resilience at the community to regional level. The FEMA earthquake loss assessment computer program called HAZUS is an example of such an analysis tool that focuses on financial losses. As the Community Disaster Resilience project develops, I would expect that improved analysis tools will be developed and tested to support the evaluation of proposed standards for building and infrastructure resilience in terms of local models of earthquake hazards, with results that predict the level of operability of various elements of a community exposed to a variety of earthquake hazards. As a footnote, implementing earthquake early warning, as developed by USGS and its partners, adds another means to increase the resiliency of regions exposed to strong earthquakes by enabling actions to limit or avoid damage and injuries by taking preplanned actions before the shaking arrives.

3. Dr. Hayes noted in his testimony that "maintaining the serviceability of lifeline systems is critical to societal resilience." What research and development is being supported by related industries with regard to lifelines in a seismic event? What more needs to be done?

   Response:

   Beginning with the 1971 San Fernando Valley earthquake and continuing through the Loma Prieta (1989) and Northridge (1994) earthquakes, the regional West Coast electric utilities (including Southern California Edison and San Diego Gas and Electric, Pacific Gas and Electric in central and northern California, and Bonneville Power Administration and BC Hydro in the northwest) have cooperated in working with high-voltage transmission equipment providers to understand the seismic vulnerabilities of existing substation components and develop equipment using revised designs and stronger bushing materials. Similar utility-driven cooperative research has been done to improve water and natural gas transmission and distribution components to reduce future earthquake damage. Ongoing cooperative research has also been carried out to develop and qualify automatic shut-off devices for natural gas lines and potable water lines to improve safety and service reliability in areas prone to ground failure and structural damage.

   Regarding what more needs to be done, an important planning and implementation document is being developed by NIST, entitled *Earthquake-Resilient Lifelines: NEHRP Research, Development, and Implementation Roadmap.* I understand that the release of the Roadmap is imminent, and it should serve as an essential integrative plan to cover all utility and transportation system lifelines in terms of seismic performance improvements as needed to meet resilience goals. The details of this report and its implementation should enable addressing in an organized way the needs for additional research and development that can most directly lead to improved resilient performance of the nation's lifelines.

Responses by Mr. Jonathon Monken

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Earthquake Hazards Reduction Program"

Mr. Jonathon Monken, Director and Homeland Security Advisor, Illinois Emergency Management Agency

Questions submitted by Rep. Larry Bucshon, Chairman, Subcommittee on Research and Technology

1. What developments related to civil or structural engineering, utilities, and emergency management, including materials, methods, and standards would make our infrastructure safer in the future? What technologies, tools, or strategies are on the horizon that will help to ensure that the next generation of critical infrastructure is more robust than existing designs? Are there particular areas in engineering, or throughout the scientific enterprise more broadly, where additional research could support existing earthquake response and mitigation efforts?

Virtual Business Emergency Operations Center
The Illinois Emergency Management Agency (IEMA) has led several private sector workshops and planning efforts to improve public/private disaster response communications and coordination. Because of this, IEMA has worked with Argonne National Laboratory to create an internet-based Virtual Business Emergency Operations Center (vBEOC) "app" for the private sector.

The vBEOC allows for public and private sector partners to share real-time, critical information before, during, or after disasters. It aggregates multiple data sources into dynamically configurable, situational awareness dashboards that include information about infrastructure such as road closures, utility service status, ongoing response actions, weather, and more.

During the June 2014 CAPSTONE-14 multi-state exercise, more than 40 private sector businesses used vBEOC to test interoperability and communications between themselves and State Emergency Management Agencies.

Multi-State Common Operating Picture (COP)
CUSEC Member States (Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee) have worked tirelessly to improve information sharing capabilities using Geographic Information Systems (GIS). During the 2011 National Level Exercise (NLE11), 74 layers of information were shared between the CUSEC Member States and six Federal agencies. Today, *these same States and agencies are able to share more than 1,500 data layers* to display a variety of "Essential Elements of Information"(EEIs).

EEIs are critical pieces of information that aid decision makers during emergency response. During the CAPSTONE-14, these EEIs will be used to display (on a regional basis) the status

of a variety of critical resources, transportation and infrastructure networks, and operations information.

Much of the progress since NLE11 is due to a strong partnership between the CUSEC Member States and the U.S. Dept. of Homeland Security's Science & Technology Directorate (DHS S&T).

For CAPSTONE-14, the CUSEC Member States' created many new processes and technological capabilities. Highlights and key outputs of this include:

- Development of regional data publication guidance, which details requirements for identifying EEIs.
- Creation and sharing of more than 1,500 data layers
- Sharing models and technologies such as the ArcGIS suite and WebEOC.
- Developing a model for the usage and integration of existing systems (WebEOC fusion, ArcGIS Online, and consumer applications and GIS viewers)
- Development and training a new resource sharing system, the Mutual Aid Support System, and development of Mission Ready Packages and related data models for interstate mutual aid.
- Development of a nationally applicable post-disaster building inspection Mission Ready Packages

2. How should we measure national earthquake resilience, and how do we know if we are becoming more earthquake resilient? What activities are critical for advancing resilience, and what are the enabling technologies for an earthquake resilient nation?

   Continuing to improve adoption and enforcement of modern building codes which incorporate seismic design is a cornerstone of risk reduction. To achieve an understanding of resiliency, you first have to understand your vulnerability. By using tools such as the USGS National Seismic Hazard Maps, FEMA's ROVER building inventory and assessment software, and FEMA's HAZUS loss estimation software, we can identify areas most at risk to earthquakes and other disasters. Once this is achieved tools such as GIS can be leveraged to begin the risk reduction planning process.

Responses by Dr. Andrew S. Whittaker

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Earthquake Hazards Reduction Program"

Dr. Andrew S. Whittaker, Professor, Chair, and Director of MCEER, University at Buffalo, State University of New York

Questions submitted by Rep. Larry Bucshon, Chairman, Subcommittee on Research and Technology

1. What developments related to civil or structural engineering, utilities, and emergency management, including materials, methods, and standards would make our infrastructure safer in the future? What technologies, tools, or strategies are on the horizon that will help to ensure that the next generation of critical infrastructure is more robust than existing designs? Are there particular areas in engineering, or throughout the scientific enterprise more broadly, where additional research could support existing earthquake response and mitigation efforts?

   Modern buildings, bridges, lifelines and other infrastructure, are safer and less vulnerable to damage in earthquakes than those designed and built a few decades ago. Improvements in the design and construction of buildings, through basic and applied research, technology transfer and updating of standards (codes) have been made possible by NEHRP funding. Improvements in the design and construction of lifelines have lagged those in buildings.

   New materials, such as high performance concrete and steel, composites and elastomers will enable the construction of cost-effective, high-performance resilient structures. Performance-based earthquake engineering tools and techniques will enable engineers to target specific levels of earthquake performance, which is one key to achieving local, regional and national resilience. Tools and techniques have been developed with funding from the NEHRP agencies since the mid 1990s but they are necessarily focused on individual components of the built environment and are unproven. The widespread use of the current tools and techniques, their verification and validation for a broad range of buildings, bridges and infrastructure, and their extension to lifelines and communities (aggregates of components) represent real opportunities for improving our resilience in the near and long terms.

   Standards (codes) of practice focus on minimum acceptable levels of performance, where the goal is generally set at providing life safety to each new component of the built environment, with no consideration of resilience. In the long term, the replacement of archaic structures with modern, code-compliant structures will improve the robustness of the built environment and improve community, regional and national resilience. NEHRP has played a leadership role in the improvement and updating of earthquake-related standards since the early 1980s and this must continue.

   Improved numerical and analysis tools, once verified and validated, will enable the performance-based engineering of an earthquake-resilient built environment. The NEESR

program, funded by the National Science Foundation, has provided valuable physical datasets that are being used to improve numerical tools for a limited number of component types and structures. Much remains to be done with the existing data and a much broader set of component types and structures should be studied in a coordinated manner, with priorities established on the basis of likely contributions to community, regional and national resilience.

Protective technologies such as seismic base isolation and damping systems have been developed in the past 20 years with support from the NEHRP agencies. These technologies are being implemented in mission-critical structures (e.g., hospitals, emergency operation centers, on-shore and off-shore energy facilities) for which post-earthquake functionality is vital. The scope of available protective systems should be expanded to enable cost-effective implementation across a broader range of structures, and parts thereof, thereby enabling the construction of next-generation facilities that are more robust than those at present.

One subject area that is deserving of more attention in the future is the interface between geotechnics and structures. Our understanding of the behavior of the interface between soil and structure during earthquake shaking lags far behind our knowledge of the behavior of soil and structure. Basic and applied research, involving physical simulations and numerical modeling, is needed to advance practice, improve codes and standards, improve performance and eliminate conservatisms and cost. These studies would also contribute significantly to our understanding of the earthquake response of lifelines because they are typically constructed on or near the surface of the earth.

2. How should we measure national earthquake resilience, and how do we know if we are becoming more earthquake resilient? What activities are critical for advancing resilience, and what are the enabling technologies for an earthquake resilient nation?

   A nation that is resilient to earthquakes is one with resilient communities and redundant and robust lifelines. In the absence of large magnitude earthquakes striking our major urban regions, the only viable strategy for measuring resilience is through earthquake scenarios. The scenarios involve modeling fault rupture at depth, propagation of the seismic waves across the region of interest, calculations of damage to buildings, bridges, infrastructure, and lifelines, and predictions of loss (e.g., casualties, financial loss). Executing earthquake scenarios before and after *virtual* improvements are made to the built environment, in the region of interest, and then comparing losses is a viable, non-destructive means by which to measure changes in resilience. Importantly, earthquake scenarios enable thoughtful decision-making, whereby precious federal resources can be allocated to maximize improvements in local, regional and national resilience.

   To advance, we must be able to measure changes in, and cost-effectively improve, our resilience. To do so, we must verify and validate the science, engineering and economic tools and techniques used to a) propagate seismic waves to the near surface of the earth, b) calculate the consequent response of, and damage to, the built environment, and c) characterize the damage in terms of meaningful resilience parameters, which could include casualties (life loss and injuries), financial loss (locally, regionally and nationally) and social dislocation (e.g., housing loss). A national commitment to fund basic and applied research in these areas is key to advancing resilience. Understanding the interdependency of our lifelines,

which link communities and business across our nation, is a critical need. Significant progress has been made in the past decade and this momentum must be maintained.

Appendix II

Additional Material for the Record

STATEMENT SUBMITTED BY SUBCOMMITTEE
RANKING MEMBER DANIEL LIPINSKI

OPENING STATEMENT

Ranking Member Dan Lipinski (D-IL)
Subcommittee on Research & Technology
Committee on Science, Space, and Technology

Subcommittee on Research & Technology Hearing
"A Review of the National Earthquake Hazards Reduction Program"

July 29, 2014

Thank you Chairman Bucshon for holding this hearing on reviewing the National Earthquake Hazards Reduction Program or NEHRP. I want to thank the witnesses on both panels for being here today. I look forward to hearing your testimony.

When we think of earthquake risks in the United States, we tend to think about the West coast where some of the most powerful earthquakes have occurred. Indeed, Americans living in California and western Washington State face the highest risk from earthquakes. But Americans in most states have a reasonable chance of experiencing ground shaking in the next 50 years from an earthquake that would be damaging.

Illinois has earthquake risks because it is affected by the New Madrid Seismic Zone, where large earthquakes occurred in the early 1800s. These earthquakes—which measured from 7.5 to 7.7 on the Richter scale—remain the most powerful earthquakes to hit the United States east of the Rocky Mountains. There are reports that the earthquakes were felt as far away as Washington, D.C., produced huge waves on the Mississippi River, caused structural damage, and led to the formation of new lakes. Although the death toll is unknown, it is not believed to be high because the area was sparsely populated. But that is no longer the case. Today, more than 15 million people live in the area.

In 2011, on the two hundredth anniversary of the New Madrid earthquakes, the federal government simulated what would happen if another large earthquake hit this region. And the results of the simulation were striking. Around 100,000 people could die, over 7 million people could be displaced from their homes, and the direct economic losses alone could total almost $300 billion. Of additional concern since the Fukushima disaster, 15 nuclear power plants are located in the New Madrid Seismic Zone.

We must reauthorize NEHRP so we can continue to address the large challenges that remain: retrofitting existing structures, improving the performance of critical infrastructure, and encouraging the adoption of mitigation measures by households, businesses, and communities. Additionally, we must ensure that social science research remains a key part of the NEHRP program. Understanding how people—including state and local officials, business owners, and individuals—make decisions and respond to warnings is essential to designing effective strategies to prepare for, respond to, and recover from a disaster.

Thank you again, Mr. Chairman, for holding this important hearing. I look forward to all of the witness testimony and the Q&A, and I thank you all for being here today. I yield back the balance of my time.

LETTERS SUBMITTED BY SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
CHAIRMAN LARRY BUCSHON

ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

101 Constitution Avenue, NW, Suite 375 East
Washington, DC 20001-2179
(800) 548.ASCE(2723) toll free (202) 789.7850
(202) 789.7859 fax w www.ASCE.org

July 28, 2014

The Honorable Larry Bucshon
Chairman, Subcommittee on Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

The Honorable Daniel Lipinski
Ranking Member, Subcommittee on Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Bucshon and Ranking Member Lipinski:

On behalf of the American Society of Civil Engineers (ASCE), I want thank you for your leadership and commitment to the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) and for scheduling the July 29th hearing on the program. I also wish to commend you for inviting Dr. Andrew Whittaker, M.ASCE and Dr. Julio A. Ramirez, P.E., M.ASCE to testify. Both are ASCE members, preeminent experts in earthquake engineering, and well versed in the operations of NEHRP. I believe that the Committee will be well informed by their testimony.

I urge you to carefully consider the earthquake-related risks the nation faces and to give full consideration to the swift reauthorization of NEHRP. The program has a proven record, going back to its founding in 1977, of making Americans safer. Through NEHRP, the federal government has engaged in seismic monitoring, mapping, research, testing, engineering and related reference materials for building code development, mitigation, and emergency preparedness. NEHRP has served as the backbone for protecting U.S. citizens, their property and the national economy from the devastating effects of large earthquakes. Although NEHRP is well known for its research programs, it is also the source for hundreds of new technologies, maps, design techniques, and standards that are used by design professionals every day to mitigate risks and save lives, protect property, and reduce adverse economic impacts.

ASCE and other stakeholders in the earthquake community have been working with the Science Committee staff on this important issue. We stand united in our opinion that the federal government's most effective tool in mitigating the potentially devastating impact of earthquakes is a robust NEHRP.

Once again, I want to thank you for holding this important hearing. We look forward to working with you and members of the Committee staff to ensure the continuation of this critical program. If ASCE can be of more assistance, please do not hesitate to contact Martin Hight, the American Society of Civil Engineers' Senior Manager of Government Relations at 202-789-7843 (mhight@asce.org).

Sincerely,

Randall (Randy) S. Over, P.E., F.ASCE
President

cc. The Honorable Lamar Smith, Chairman, Committee on Science, Space and Technology
The Honorable Eddie Bernice Johnson, Ranking Member, Committee on Science, Space and Technology

July 28, 2014

The Honorable Larry Bucshon
Chairman, Subcommittee on Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

The Honorable Daniel Lipinski
Ranking Member, Subcommittee on Research and Technology
Committee on Science, Space and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Bucshon and Ranking Member Lipinski:

On behalf of the BuildStrong Coalition, a group of national business and consumer organizations, corporations and emergency management officials dedicated to promoting stronger building codes, I want thank you for your leadership and commitment to the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) and for scheduling the July 29th hearing on the program. I also wish to commend you for inviting Dr. Andrew Whittaker, M.ASCE and Dr. Julio A. Ramirez, P.E., M.ASCE from the ASCE to testify. ASCE is a member of the BuildStrong Coalition and represents preeminent experts in earthquake engineering, and well versed in the operations of NEHRP. I believe that the Committee will be well informed by their testimony.

I urge you to carefully consider the earthquake-related risks the nation faces and to give full consideration to the swift reauthorization of NEHRP. The program has a proven record, going back to its founding in 1977, of making Americans safer. Through NEHRP, the federal government has engaged in seismic monitoring, mapping, research, testing, engineering and related reference materials for building code development, mitigation, and emergency preparedness. Although NEHRP is well known for its research programs, it is also the source for hundreds of new technologies, maps, design techniques, and standards that are used by design professionals every day to mitigate risks and save lives, protect property, and reduce adverse economic impacts.

The BuildStrong Coalition supports a multifaceted incentive based approach to mitigation. To that end, BuildStrong has endorsed a suite of legislation that serves to educate and incentivize states, communities, businesses, and consumers to build stronger, safer, and smarter:

- *The Safe Building Code Incentive Act of 2013 (H.R. 1878 & S. 924)* – Introduced by Rep. Mario Diaz-Balart (R-FL-25) and Sen. Robert Menendez (D-NJ), this bipartisan bill provides additional disaster relief assistance to states that adopt and enforce strong building codes.

- *The Disaster Savings Account Act of 2013 (H.R. 3989 & S. 1991)* – Introduced by Rep. Dennis Ross (R-FL-15), Sen. James Inhofe (R-OK) and Sen. Mark Begich (D-AK), this bipartisan bill provides a $5,000

tax deduction for money deposited into a savings account to offset disaster mitigation costs.

- *The Disaster Savings and Resilient Construction Act of 2013 (H.R. 2241)* –Introduced by Rep. Mario Diaz-Balart, this bill provides tax credits to homeowners and contractors who utilize modern building science when constructing and/or renovating homes and buildings.

Earlier this spring, the BuildStrong Coalition sponsored its Second Annual National Thought Leaders Forum with the Congressional Fire Services Institute (CFSI) to discuss these bills and other aspects of disaster mitigation. Several leaders from Congress who are actively involved in disaster mitigation issues spoke at the forum, including Rep. Mario Diaz Balart (R-FL), U.S. Sen. Mark Begich (D-AK), U.S. Rep. Lou Barletta (R-PA), U.S. Rep. Randy Neugebauer (R-TX), U.S. Rep. Dennis Ross (R-FL), U.S. Rep. Ed Perlmutter (D-CO), and U.S. Rep. Elizabeth Etsy (D-CT). We also launched an advertising campaign that coincided with the start of hurricane season that appeared in newspapers on Capitol Hill.

Thank you once again for holding this important hearing. I look forward to continuing our work together to strengthen our communities against natural disasters.

Sincerely,

Jimi Grande
Chairman
BuildStrong Coalition

LETTER SUBMITTED BY MR. JAY BERGER, EXECUTIVE DIRECTOR, EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

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August 12, 2014

U.S. House Committee on Science, Space and Technology
Subcommittee on Research and Technology

Re: Reauthorization of the National Earthquake Hazards Reduction Program (NEHRP)

Dear Chairman Bucshon and Ranking Member Lipinski:

The Earthquake Engineering Research Institute (EERI) is a national technical society dedicated to reducing the risks of earthquakes to communities throughout the United States and the world. Comprised of thousands of engineers, geoscientists, architects, planners, public officials, and social scientists, EERI represents every earthquake discipline, including researchers, practitioners, educators, government officials, and building code regulators.

EERI's objective is to reduce earthquake risk by (1) advancing the science and practice of earthquake engineering, (2) improving understanding of the impact of earthquakes on the physical, social, economic, political, and cultural environment, and (3) advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes.

We are extremely pleased that the Committee is now considering reauthorization of the National Earthquake Hazards Reduction Program (NEHRP).

Earthquakes have the power to devastate communities. They strike without warning, destroying buildings and infrastructure, and killing and injuring residents. Over 75 million Americans live in urban areas with moderate to high earthquake risk. The estimated value of structures in all States prone to earthquake damage is over $8.6 trillion[1].

The National Earthquake Hazards Reduction Program (NEHRP) is a critical and effective program that reduces the risk from earthquakes for communities throughout the United States. It is imperative that Congress reauthorize NEHRP, and provide adequate appropriation levels to support the work needed to make communities earthquake-resilient.

In the decades since it was created, NEHRP has been an effective way to reduce the nation's earthquake risk, but much work remains to be done. As our cities grow larger, denser, and more complex, the impacts from potential earthquakes also grow. NEHRP improves the Nation's earthquake resilience by coordinating and supporting the work of key federal agencies that work on earthquake-related issues (FEMA, NIST, NSF and

[1] *Strategic Plan for the National Earthquake Hazards Reduction Program, Fiscal Years 2009 to 2013*, 2008.

499 14TH Street, Suite 220, Oakland, California 94612-1934
☎ (510) 451-0905 FAX (510) 451-5411 eeri@eeri.org http://www.eeri.org
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USGS), focusing their efforts on the activities our nation needs most to improve its earthquake resilience. NEHRP activities emphasize pre-event planning and mitigation to reduce the amount of damage that inevitable future earthquakes will cause. As defined in Public Law 108-360, each agency has a unique and critical role to play in the development of new technologies, tools for earthquake professionals, and implementation activities to assist states regions and local jurisdictions become resilient.

The Earthquake Engineering Research Institute (EERI) strongly supports NEHRP reauthorization and believes that the following authorization levels are required for an effective program that meets the requirements in the public law.

Agency	Recent appropriation level	NRC Report Recommended Addition[2]	Earthquake Early Warning Addition[3]	Needed Appropriation
FEMA	$9.1 million	$24.0 million	$0 million	**$33.1 million**
NIST	$4.1 million	$5.0 million	$0 million	**$9.1 million**
NSF	$55.3 million	$5.9 million	$0 million	**$61.2 million**
USGS	$62.8 million	$0 million	$16.1 million	**$78.9 million**

These figures are based on the analysis of the National Research Council (NRC) in its 2011 report on NEHRP, *National Earthquake Resilience: Research, Implementation, and Outreach*. The NRC report identified 18 tasks needed to realize the NEHRP Strategic Plan. In recognition that funding for the full implementation is years off due to budget constraints, the Advisory Council on Earthquake Hazards Reduction (ACEHR), the NEHRP oversight body, identified 5 of the 18 tasks specified in the NRC report for focused attention by NEHRP:

- Socioeconomic Research on Hazard Mitigation and Recovery: $3 million (M)/year for NSF
- Observatory Network on Community Resilience and Vulnerability: $2.9M/year for NSF
- Guidelines for Earthquake Resilient Lifeline Systems: $5M/year for NIST
- Knowledge, Tools, and Technology Transfer to/from the Private Sector: $8.4M/year for FEMA
- Earthquake Resilient Community and Regional Demonstration Projects: $15.6M/year for FEMA

These figures also incorporate the recent USGS goal of implementing an Earthquake Early Warning System, which can alert residents, emergency officials, lifeline providers, and automated systems immediately after an earthquake has occurred but before strong shaking has reached a community (this can provide as much as tens of seconds of

[2] *National Earthquake Resilience: Research, Implementation, and Outreach*, 2011
[3] Given et al., *Technical Implementation Plan for the ShakeAlert Production System—An Earthquake Early Warning System for the West Coast of the United States*, 2014

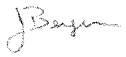
warning time). The USGS estimates the implementation of a functional and reliable Earthquake Early Warning system will require an additional $16.1 million per year[3].

In recent years, NEHRP appropriation levels have averaged approximately 50% of authorization levels and have generally matched the requests in the President's Budget each year. Congress has expressed an interest in bringing authorization levels closer to appropriation levels in the future. We agree that authorization levels should reflect the needed appropriation levels, but we must point out that the requested appropriation levels have not been sufficient to complete the tasks defined in Public Law 108-360. The Congress should recognize the consequences that reduced spending levels have on core NEHRP functions – negative impacts that will likely be most acute at a time of great crisis.

The recent calamitous earthquakes in Japan, New Zealand, and Chile—all modern, well-engineered societies whose buildings and lifelines are similar to ours—demonstrate how wide-reaching the effects of earthquakes can be. Even several years on, these communities continue to struggle to rebuild their homes and businesses, restart their economies, and resume a normal life. We face the same potential in the United States, and without proper funding for each of the four NEHRP agencies, our nation's ability to prepare, respond and recover will continue to erode from an already unacceptably low level.

Thankfully, the US has not experienced a large and devastating earthquake in the past couple of decades. However, we know that large earthquakes are in our future. When the next major earthquake strikes a US city, loss of life could be significant, the cost of response and recovery will be very high, and the repercussions will be felt throughout the national economy. NEHRP reauthorization is a key part of building the needed national resilience.

Thank you very much for this opportunity to express our views. The Earthquake Engineering Research Institute looks forward to working with you and members of the Committee staff to create more disaster-resilient communities. If EERI can be of more assistance, please do not hesitate to contact Jay Berger, EERI Executive Director at 510-451-0905 (jberger@eeri.org) or Keith Nelson, EERI Governmental Relations at 202-809-2190 (knelson@lobbyit.com).



Jay Berger
Executive Director