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Hearing

Review of the National Earthquake Hazards Reduction Program
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U.S. House of Representatives Committee on Science, Space, and Technology
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Testimony by

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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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