Effectiveness of the
National Earthquake Hazards Reduction Program

A Report from the
Advisory Committee on Earthquake Hazards Reduction

September 11, 2017

Contents

Executive Summary

The Advisory Committee on Earthquake Hazards Reduction (ACEHR) provides a biennial assessment of the National Earthquake Hazards Reduction Program (NEHRP) as required by the committee charter and Public Law 108–360. ACEHR is charged with assessing the effectiveness of NEHRP in performing its statutory activities and any needed to revisions; the management, coordination, implementation, and activities of NEHRP; and trends and developments in the science and engineering of earthquake hazards reduction.

2017 marks the 40th anniversary of NEHRP's first authorization in 1977 (Public Law 95-124) and the Federal government's sustained investment in NEHRP over this time has fostered considerable progress in helping to achieve the Program's vision of "*a nation that is earthquake resilient in public safety, economic strength, and national security* (NEHRP 2008). We now have a nationwide earthquake monitoring network, hazard maps and loss estimation methodology; improved seismic design and construction techniques for buildings, critical infrastructure and lifeline systems; and heightened awareness and preparedness for earthquake hazards by states and communities at risk (Leith 2017).

Despite these advances and the absence of major, damaging earthquakes in recent years, the nation's earthquake risk continues to grow. This is due to significant population growth and urban development in earthquake-prone regions of the country; increased seismicity caused by oil and gas production and other industrial activity; the vulnerability of older building and infrastructure; and, the increased interdependency and interconnectedness of society and our economy (FEMA 2017). Half of the nation's population and $59 trillion in building-related assets are located in portions of 42 states that could experience damaging ground shaking levels within the next 50 years (Petersen et al. 2014).

A single, major earthquake in California, the Pacific Northwest, the western and central United States, or parts of the Atlantic seaboard could cause damages in excess of $100 to $150 billion (CREW 2013; Elnashai et al. 2008; Jones et al. 2008; Kircher et al. 2006; RMS 2008), far greater than those caused by Hurricane Sandy and even Hurricane Katrina. The consequences of a catastrophic event should be alarming to Federal leaders. When that time comes, Federal legislative and executive leadership will be under scrutiny and held accountable for national preparedness and overall progress in earthquake risk reduction.

NEHRP at a Crossroads

ACEHR is quite concerned that interest and support for NEHRP has waned in recent years, as other natural disasters and national priorities have necessitated attention and competition for limited resources. A confluence of forces has diminished the Program's impact and its ability to bring about coordinated action in addressing earthquake risks. We believe that a full-scale reinvigoration and renewal of the Program is necessary in order to address the nation's current risk reduction challenges as well as the research, engineering, and implementation needs that a major earthquake will inevitably present.

In particular, we have two immediate and overarching recommendations.

1. ACEHR urges Congressional reauthorization of the Earthquake Hazards Reduction Act and the National Earthquake Hazards Reduction Program (NEHRP).

The lack of reauthorization since 2004, and funding well below the original authorization levels as well as the $306.5 million of annual Program investment recommended by the National Research Council (NRC 2011), have weakened the Program's overall effectiveness. We believe there are significant programmatic needs as well as exciting developments in the science and engineering of earthquake hazards reduction that should be considered by Congress and the four NEHRP agencies in deciding annual budgets and Program priorities and plans. Budgetary mechanisms should also be required to clearly identify NEHRP funds and hold agencies accountable for using those funds for such purposes.

2. Commensurate with the NEHRP reauthorization, ACEHR calls for the immediate conduct of an assessment of the nation's earthquake risk reduction progress to date in order to guide future NEHRP direction and funding levels.

This assessment should address the extent to which the Federal government, states, localities, tribes, and the private sector are taking steps to address the seismic vulnerability of buildings, critical infrastructure and lifeline systems, and identify key remaining gaps. ACEHR recommended such an evaluation in its 2015 and 2016 reports, and would welcome involvement in developing its scope and approach.

NEHRP Programmatic and Agency-Specific Recommendations

ACEHR makes two key recommendations, directed to Director of the National Institute of Standards and Technology (NIST) who serves as the Director of the Interagency Coordinating Committee on Earthquake Hazards Reduction (referred to in this report as the "ICC")[1]. We believe both of these are essential for engaging Federal leadership and a stronger Program Secretariat for planning and coordinating NEHRP efforts.

ICC Recommendations

1. ACEHR calls upon the Director NIST Director, as Chair of the ICC, to revitalize the ICC as a mechanism for advancing NEHRP within the respective agencies.

2. ACEHR calls upon the NIST Director, as Chair of the ICC, to work with the ICC to ensure appropriate and coordinated Program budgets.

[1] Under Public Law 108-360, the ICC shall be chaired by the NIST Director and membership shall be composed of the directors of the Federal Emergency Management Agency (FEMA); the National Science Foundation (NSF); the United States Geological Survey (USGS); the Office of Science and Technology Policy (OSTP), and the Office of Management and Budget (OMB).

ACEHR commends the rapid appointment of a new NEHRP Director and the hard work of the Secretariat in coordinating and leading NEHRP efforts as well as a number of important cross-agency and collaborative initiatives. We offer three recommendations for improving the programmatic coordination and leadership of NEHRP.

NEHRP Secretariat Recommendations

1. ACEHR recommends that the NEHRP Secretariat lead the NEHRP agencies in the development of an updated Strategic Plan and implementation strategy necessary for NEHRP to fulfill its mission.

2. ACEHR recommends the NEHRP Secretariat, with the four NEHRP agencies, facilitate a workshop to advance the use of risk-based rating systems for the seismic performance of buildings in the U.S.

3. ACEHR recommends that the NEHRP Secretariat, with the four NEHRP agencies, develop a uniform policy regarding the dissemination of information on NEHRP research and implementation efforts.

ACEHR's other specific recommendations are for the four NEHRP agencies— the Federal Emergency Management Agency (FEMA), NIST, National Science Foundation (NSF), and U.S. Geological Survey (USGS).

FEMA Recommendations

1. ACEHR urges the Administration, and the leaders of FEMA and the Department of Homeland Security, to take action to provide FEMA's earthquake program with the resources needed to fully meet the agency's responsibilities as required by law. The persistent underfunding of FEMA jeopardizes the effectiveness of the entire Program.

2. ACEHR recommends that FEMA continue to make seismic building code development, adoption and enforcement a priority.

3. ACEHR continues to recommend that FEMA return to a directly-funded, state-based program for earthquake hazard mitigation, planning, education and preparedness efforts and to reconsider the current state grant matching formula.

4. If the decade-long trend of underfunding of FEMA earthquake-related activities persists, ACEHR recommends that FEMA review its areas of responsibility, prioritize those efforts that have maximum impact on seismic resilience, and identify efforts that must be discontinued in order to make meaningful and timely progress on the most crucial efforts.

NIST Recommendations

1. ACEHR recommends that NIST initiate development of nationally-applicable seismic performance objectives, assessment procedures, and design criteria for lifeline systems.

2. ACEHR recommends that NIST assess the seismic performance of buildings in the eastern and central United States that have been designed primarily for code-compliant wind loads.

3. ACEHR recommends that NIST develop a proof-of-concept initiative to use a building seismic rating system to evaluate the expected performance of a portfolio of building types.

NSF Recommendations

1. ACEHR recommends that NSF prepare a synthesis report that identifies how current NEHRP-related investments contribute to NEHRP strategic goals and plans.

2. ACEHR recommends that NSF work with the NEHRP Secretariat to devise a reporting and information-sharing approach that provides a better basis for coordinating NSF NEHRP-related activities with other NEHRP agency activities.

3. ACEHR recommends that NSF fund a workshop or other forum on past and future opportunities for multidisciplinary research initiatives to contribute to the success of NEHRP.

4. ACEHR recommends that NSF more fully engage NEHRP partner agencies and external organizations to anticipate and foster the translation of research accomplishments into demonstrable advances for earthquake resilience.

USGS Recommendations

1. ACEHR recommends that the USGS continue to use advisory panels and other community-based forums to target immediate and long-term needs and strategies to meet its obligations under NEHRP.

2. ACEHR recommends that the USGS continue the development and implementation of the Advanced National Seismic System (ANSS) and that it becomes a line-item in the USGS budget.

3. ACEHR recommends that the USGS continue to support and develop online products that address community needs for information about earthquake hazards.

4. ACEHR recommends that the USGS maintain its strong internal and external research programs, commensurate with the extraordinary developments in data acquisition, and which address critical knowledge gaps.

Introduction

The Advisory Committee on Earthquake Hazards Reduction (ACEHR) was established in 2004 as part of the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) (Public Law 108-360). ACEHR's members are non-Federal employees serving three-year terms from research and academic institutions, earthquake-related professions, and state and local governments. We are charged with assessing trends and developments in the science and engineering of earthquake hazards reduction; the effectiveness of NEHRP in performing its statutory activities and any need to revise NEHRP; and the management, coordination, implementation, and activities of NEHRP.

This report is provided to the Director of the National Institute of Standards and Technology (NIST) who serves as the Director of the Interagency Coordinating Committee on Earthquake Hazards Reduction (referred to in this report as the "ICC")[2]. Its recommendations are also directed to the NEHRP Secretariat and the four NEHRP agencies—the Federal Emergency Management Agency (FEMA), NIST, National Science Foundation (NSF), and U.S. Geological Survey (USGS).

The report is structured to reflect on the Program's achievements and challenges since its inception in 1977, new trends and developments in the science and engineering of earthquake hazards reduction, and concerns about the future of NEHRP. Two critical and overarching needs for NEHRP's future are then discussed, followed by a series of programmatic and agency-specific assessments and recommendations.

NEHRP Past and Future

2017 marks the 40th anniversary of NEHRP's first authorization in 1977 (Public Law 95-124). It is with great pride that we reflect upon the knowledge, tools, and practices in earthquake hazards reduction that the Federal government's sustained investment in NEHRP has fostered (Leith 2017), and the progress that has been made in achieving the NEHRP vision of *a nation that is earthquake resilient in public safety, economic strength, and national security* (NEHRP 2008).

Over the past 40 years, Federal investment in NEHRP has led to the development of the Advanced National Seismic System (ANSS), a National Seismic Hazard Model and resulting maps (Peterson et al. 2014), and a consistent nationwide earthquake loss estimation methodology Hazus®, among others. NEHRP activities have also been essential to improving the seismic design and construction of buildings, critical

[2] Under Public Law 108-360, the ICC shall be chaired by the NIST Director and membership shall be composed of the directors of the Federal Emergency Management Agency (FEMA); the National Science Foundation (NSF); the United States Geological Survey (USGS); the Office of Science and Technology Policy (OSTP), and the Office of Management and Budget (OMB).

infrastructure and lifeline systems, and raising awareness and preparedness across the country and the world. Today, because of NEHRP, there is a much greater understanding of the risk that earthquake hazards pose across the entire country and the need for public investments to focus on averting damage and human and economic losses.

Portions of 42 states and almost half of the U.S. population could experience a damaging earthquake within the next 50 years; 16 states, including California, Oregon, Washington, Alaska, Hawaii, Tennessee, and Missouri, are at very high risk (Petersen et al. 2014). The increased number of earthquakes caused by the injection of waste water generated by oil and gas production and other industrial activity—or induced seismicity—is causing added risk to buildings, critical infrastructure and lifeline systems, particularly in the central and eastern United States (Petersen et al. 2017).

A recent study led by FEMA estimates that the nationwide value of buildings and contents exposed to strong ground shaking hazards is approximately $59 trillion (FEMA, USGS and Pacific Disaster Center 2017). Ten states with the highest populations exposed to very strong ground shaking—California, Washington, Utah, Tennessee, Oregon, South Carolina, Nevada, Arkansas, Missouri, and Illinois—account for over 26% of the nation's total earthquake risk exposure. This study also estimates that the long-term value of earthquake losses to the general building stock in any single year is $6.1 billion, not including the value of projected loss of life and casualties.

The United States has experienced several devastating earthquakes, including the 1994 Northridge, California earthquake which resulted in $50 billion in losses and required Federal and state governments to provide $9 billion in disaster relief (both in 1995 dollars) (Petak and Elahi 2001). The absence of major damaging earthquakes in the last 20 years should not be a rationale for inaction. Rather, the seismic lull should be a reason for concern. A single, major earthquake in California, the Pacific Northwest, the western and central United States, or parts of the Atlantic seaboard could cause damages in excess of $100 to $150 billion (CREW 2013; Elnashai et al. 2008; Jones et al. 2008; Kircher et al. 2006; RMS 2008), far greater than those caused by Hurricanes Katrina and Sandy. In addition to unprecedented life loss and catastrophic damage to buildings, critical infrastructure and lifeline systems, the cascading social and economic consequences from such a major disaster could continue for decades. Furthermore, in an increasingly interconnected global economy, a major earthquake anywhere in the country would not only stress local resources, but also significantly impact other parts of the United States and the world.

The consequences of a catastrophic event should be alarming to Federal policymakers and relevant agency leaders. When the next major earthquake occurs:

- NEHRP will be under scrutiny by the Congress, the press and the public. Congressional hearings, press enquiries and many public events will all require the participation of NEHRP leaders.

- Agency and Administration leadership will be held accountable by Congress for their roles, or the lack there of, in supporting and enabling earthquake hazards reduction in the past.
- Although FEMA may lead response, other NEHRP agencies will be called upon, and have major post-disaster roles, especially in recovery.

NEHRP's Future in Question

Despite tremendous accomplishments, ACEHR is quite concerned that NEHRP is now at a crossroad. A confluence of forces has diminished the Program's impact to the point that it is arguably more a program in name than actuality. Without new concerted efforts to renew and revive NEHRP, as discussed further in this report, we believe the Program will continue to struggle to bring about coordinated action in addressing earthquake risks. Legitimate questions can and should be asked regarding NEHRP's future.

We believe that four sets of forces have diminished the viability of the Program:

1. The lack of reauthorization since 2004 (PL 108-360) and annual appropriations that fall far short of the original authorization levels and are only 30% of the $306.5 million annually recommended in the National Research Council report, "*National Earthquake Resilience: Research, Implementation, and Outreach* (NRC 2011) as necessary to implement the 2008 -2013 NEHRP Strategic Plan and to materially improve national earthquake resilience.
2. Financial commitments among the four NEHRP agencies are quite varied. NEHRP funding within the three agencies without line item appropriations (all but the USGS) has been vulnerable to competing priorities. For example, FEMA funding has been woefully short since the agency has been integrated into the Department of Homeland Security and the cutbacks, particularly FEMA's funding of state and local earthquake programs, has restricted NEHRP's effectiveness.
3. The dilution of critical earthquake risk reduction research and implementation needs within broader resilience and multi-hazards programs of some NEHRP agencies. While there are potential benefits from such integration, on balance, there is also a significant dissipation of earthquake-focused efforts.
4. Implementation of modern seismic building codes at state and local levels varies considerably across and within states, even in areas with high levels of seismic hazard. Notable gaps also remain in the earthquake engineering of critical infrastructure and lifeline systems and the seismic rehabilitation of existing buildings.

Like any crossroad, there are choices to be made. For NEHRP, the future potential pathways are: (1) renewal and reemphasis as a separate program; (2) folding earthquake risk reduction efforts into a broader national program around resilience; or, (3) muddling through as at present. ACEHR strongly endorses the first path as the most appropriate given the unique research needs for understanding seismic risks and their mitigation.

Overarching Needs

ACEHR calls upon Congress, the Administration, and the NEHRP agencies to provide the support and resources for a full-scale reinvigoration and renewal of NEHRP, which, in particular, has two overarching and immediate needs.

Overarching Need 1

ACEHR urges Congressional reauthorization of the Earthquake Hazards Reduction Act and National Earthquake Hazards Reduction Program (NEHRP).

NEHRP reauthorization is essential for the Program's long-term viability. Any reauthorization needs to address the shortfalls noted above and establish:

- Appropriations and budgetary mechanisms that clearly identify NEHRP funds and activities at agency and sub-agency levels, and also hold agencies accountable for using those funds for such purposes.
- An engaged agency leadership and a stronger Program Secretariat for planning and coordinating NEHRP efforts. This entails sufficient leadership and resources to guide development of strategic and management plans, fund and conduct special assessments relating to future Program directions, and authority to recommend changes in NEHRP budgets to meet pressing needs and fund cross-agency programs.

Any reauthorization needs to support the Program to reflect current needs to address seismic risks: renewed consideration of earthquake hazards in the central and eastern United States; greater attention to the vulnerability of existing buildings; renewed emphasis on the implementation and adoption of seismic provisions in building codes and standards for critical infrastructure and lifeline systems; and a recasting of the earthquake hazards reduction effort as one of building state and local resilience to earthquakes as well as other hazards.

Core technological interests of NEHRP also need to be updated to consider advances in remote sensing, computing and data archiving, and social networking. These include the ANSS, the formerly-funded George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network. An enhanced emphasis on community resilience will also require strengthened roles and collaboration among the NEHRP agencies and other Federal and non-governmental partners.

Overarching Need 2

Commensurate with the NEHRP reauthorization, ACEHR calls for the immediate conduct of an assessment of the nation's earthquake risk reduction progress to date in order to guide future NEHRP direction and funding levels.

This assessment was recommended in the 2015 ACEHR report and reiterated in ACEHR's 2016 interim reports. It should address the extent to which the Federal government, states, localities, tribes, and the private sector are taking steps to address the seismic vulnerability of buildings, critical infrastructure and lifeline systems.
It is not intended as an evaluation of individual programs or agencies. Rather, it is a crucial undertaking to assess progress in achieving seismic risk-reduction and identify key remaining gaps. It should be national in scope but with sufficient state, regional and local detail; consider multi-sector roles (government, private sector, nonprofit sectors); and focus on risk reduction for the built environment including lifelines and infrastructure. ACEHR has given considerable thought to the scope and approach of such an assessment and would welcome involvement in this endeavor.

Emerging Trends and New Developments in Science and Engineering

ACEHR is also charged with reviewing emerging trends and new developments in the science and engineering of earthquake hazards reduction. We believe that there are exciting opportunities that should be considered by Congress and the four NEHRP agencies in deciding annual budgets and Program priorities and plans. However, we are also deeply concerned that these opportunities for major advances in the nation's earthquake risk reduction cannot be realized without the full-scale reinvigoration and renewal of the Program as we have discussed.

Geosciences

The landscape for characterizing seismic hazard has changed dramatically since the inception of NEHRP 40 years ago. Today, geoscientists now understand that: earthquakes can jump from one fault segment to another creating even larger magnitude events; earthquakes (presumably induced) in areas of previously low seismicity can result in seismic hazards equivalent to the most seismically active areas in the U.S.; and, the consequences of a giant subduction zone earthquake in the Pacific Northwest and elsewhere along the Pacific rim can be extreme. New tools are available to map the rupture during an earthquake, provide alerts of shaking levels as an earthquake develops (earthquake early warning), and predict the occurrence of earthquakes in a mainshock-aftershock sequence so that the public can be informed about evolving short-term risk. Extensive archives of real ground motion data and the ability to numerically simulate strong motions from scenario earthquakes provide an important link between geosciences and earthquake engineering that wasn't available before now.

Engineering

The recent emergence of a market-based, private-sector-led of building seismic rating system provides an enormous opportunity for both the private and public sectors to invest in building resilience and to provide businesses and the public with the information to make more risk-informed choices about the buildings that they occupy. Major cities like Los Angeles and San Francisco are leading the public sector in the

adoption of regulations requiring the upgrade of seismically-vulnerable buildings, which in turn is providing new opportunities for communicating building risk and performance and motivating mitigation. The structural engineering profession is also engaging in the development of resilient design standards and other performance criteria for structures that do more than ensure life safety and prevent collapse, but rather will help to ensure that buildings can remain occupied and functional after the ground shaking stops. These trends are just some of the significant opportunities that NEHRP agencies can capitalize on in helping to improve the earthquake resilience of the nation's building stock.

The essential role of earthquake-resilient lifeline systems in supporting community-scale resilience is increasingly apparent. Ensuring that lifeline systems can provide critical services following an earthquake requires clearly-defined, performance objectives for a variety of geotechnical hazards, including ground shaking, surface fault rupture, liquefaction, landslides, and ground settlement. These spatially-diverse hazards must be quantified consistently, including treatment of uncertainty, to enable realistic assessments of lifeline system performance.

Social Sciences

In response to an increased understanding of social vulnerability to earthquakes and other disasters, there has been a shift in social science research toward emphasizing strengths, capacities, and individual and community resilience. Likewise, as risk communication research has advanced it has also continued to evolve in response to emergent technologies such as those used to forecast earthquakes. There remains a pressing need to build the research infrastructure to improve our social, behavioral, and economic understanding of: the societal roots of risk with an emphasis on the social, cultural, political, and economic practices that facilitate risk creation; barriers and facilitators for the diffusion of risk reduction practices among public and private entities; behavioral and economic incentives and other considerations for public and private sector decisions about improving resilience; and factors that contribute to vulnerabilities and variation in them with changing population patterns, urban development, infrastructure and building aging, and transportation patterns.

Finally, in order to fully assess community resilience to earthquakes, advances in computer modeling must include the performance of all community systems—geophysical, engineering and social systems—and their interactions. To be successful, such efforts also require the deliberate design and funding for collaborative, multidisciplinary research across the social sciences, engineering, and geosciences.

Program Management, Coordination and Implementation

Despite our overarching concerns, ACEHR commends the rapid appointment of a new NEHRP Director and the hard work of the Secretariat in coordinating and leading NEHRP efforts as well as a number of important cross-agency and collaborative initiatives within and between some of the NEHRP agencies. However, NEHRP continues to suffer from the lack of strong agency-level leadership for a coordinated program.

Interagency Coordinating Committee (ICC)

The ICC is intended to provide senior leadership for NEHRP. The membership by legislation is comprised of the Director of NIST as chair and Directors of FEMA, NSF, USGS, OSTP, and OMB. The ICC is charged with overseeing the planning, coordination and management of the Program. The day-to-day activities of the NEHRP program are coordinated and managed by the NEHRP Secretariat housed at NIST.

The ICC has met only once in at least the last three years. ACEHR is concerned that, as a result of this, much of NEHRP's senior leadership may not understand the challenges that the Program faces, particularly the financial problems resulting from budgetary and staffing shortfalls, as well as the responsibilities that they will have following a major, national, earthquake disaster.

ICC Recommendation 1

ACEHR calls upon the NIST Director, as Chair of the ICC, to revitalize the ICC as a mechanism for advancing NEHRP within the respective agencies.

In order for NEHRP to fulfill its mission, the leadership of the four agencies must have an understanding of and commitment to the basic tenet of NEHRP and be well-briefed on progress within their own agencies and links with partner agencies. Although we recognize the difficulty of scheduling meetings with the agency principals, it is critical that new Administration leaders understand the crucial value of NEHRP's mission to the nation's public safety and economic viability, and the potential implications of not performing or supporting their responsibilities when an earthquake occurs. Budget enhancements and other initiatives following an earthquake disaster, as has occurred in the past, require leadership and coordination among the NEHRP agencies and a champion within the Administration.

ICC Recommendation 2

ACEHR calls upon the NIST Director, as Chair of the ICC, to work with the ICC to ensure appropriate and coordinated Program budgets.

We fully endorse prior ACEHR recommendations asking the ICC to work with the four NEHRP agencies to carefully consider full funding at an estimated $306.5 million annually

for the first five years of implementation of the 18-task, 20-year program for achieving national earthquake resilience as called for by the National Research Council (NRC 2011). In particular, FEMA has significant reduced its earthquake budget in recent years, yet it is the primary agency tasked with the Program implementation of earthquake hazards reduction and mitigation programs and strategies. The other three NEHRP agencies—NIST, NSF and the USGS—are also well below the funding levels recommended by the NRC (2011) as necessary to meaningfully reduce the nation's vulnerability to earthquakes.

With funding at static or reduced levels, and coupled with inflation, these agencies have experienced attrition, non- or reduced-replacement of critical personnel, and a degradation of capacity over time. Workforce development is essential for NEHRP to remain vital. It is also critical to broaden opportunities for women, racial and ethnic minorities, and other underrepresented groups. At present, the scientific and emergency management communities in this nation are not reflective of the diverse people that compose our national fabric. Thus, attention should be dedicated to recruiting, mentoring, and retaining a workforce that is more reflective of the populations in earthquake-exposed communities across the nation.

NEHRP Secretariat

NEHRP Secretariat Recommendation 1

ACEHR recommends that the NEHRP Secretariat lead the NEHRP agencies in the development of an updated Strategic Plan and implementation strategy necessary for NEHRP to fulfill its mission.

Advancing implementation has always been a critical goal of NEHRP but has often been given a minimum of support. While we recognize the existing strategic plan has valuable initiatives that still need to be addressed, we believe that an updated NEHRP Strategic Plan and implementation strategy are needed to translate and integrate the more recent knowledge and advances in earthquake hazards reduction into implementation at all levels of government as well as within nonprofit and private organizations. Strategic planning is a process that takes time to complete and, thus, ACEHR encourages the NEHRP Secretariat to initiate work on a plan update now and to fold in the insights gained through the national implementation assessment—that we are also recommending as part of the NEHRP reauthorization—as they become available.

NEHRP Secretariat Recommendation 2

ACEHR recommends that the NEHRP Secretariat, with the four NEHRP agencies, facilitate a workshop to advance the use of risk-based rating systems for the seismic performance of buildings in the U.S.

The 2013 and 2015 ACEHR reports have recommended that a seismic building performance rating system be developed and implemented. ACEHR recognizes that no

single NEHRP agency currently has the resources to develop and implement such a system on its own, nor should it. However, the Federal government can help ensure nationwide consensus standards for a market-based, private-sector-led building rating system, which is essential for such a system to be successful. The workshop goals should include discussing the status of different available rating systems, identifying the advantages and disadvantages of existing building rating systems, and formulating a plan to advance the use of building ratings in practice. This workshop may also be a crucial step toward developing a national standard for a building seismic rating system, and should provide important input into ACEHR's recommendation that NIST develop a proof-of-concept initiative in applying a building seismic rating system to evaluate the expected performance of a portfolio of building types.

NEHRP Secretariat Recommendation 3

ACEHR recommends that the NEHRP Secretariat, with the four NEHRP agencies, develop a uniform policy regarding the dissemination of information on NEHRP research and implementation efforts.

The results of publicly-funded research and implementation efforts of the four NEHRP agencies are made available in a variety of printed and electronic reports. In addition to making these reports available to the public, webinars and seminars are often used to disseminate reports. ACEHR recommends that the NEHRP Secretariat, in collaboration with the four agencies, establish a uniform policy regarding the dissemination of information on NEHRP research and implementation efforts that helps to ensure that the information is readily-available to a broad audience. A key element of the policy should be guidance on appropriate pricing that would encourage small to medium groups to participate in webinars and seminars.

Program Effectiveness and Needs

In this section of our assessment, we focus on the specific activities of the four NEHRP agencies (in alphabetical order).

Federal Emergency Management Agency (FEMA)

FEMA is the NEHRP agency with primary responsibility for implementing earthquake hazards reduction and mitigation programs and strategies. These activities include: development of seismic provisions and the dissemination of guidelines about seismic building practices; supporting implementation activities at the state- and local-level; earthquake education and outreach; and promotion of earthquake preparedness.

Even with severely constrained resources, FEMA has made notable progress in the past two years on ACEHR's 2015 recommendations. The long-anticipated addition of a tsunami module into the Hazus® disaster loss estimation software has been completed. The new

policy for Federally-declared disasters allows FEMA's Public Assistance program to reimburse eligible states, localities, and non-profit organizations for the costs to rebuild to the latest, hazard-resistant, building code provisions, rather than to pre-existing code levels. FEMA also continues to actively support the adoption of model building codes with strong seismic design provisions in earthquake-vulnerable localities and states. It also sponsors an array of projects that help to transfer and implement important research results, promote use of building practices that enhance seismic resilience, and improve earthquake education and awareness.

FEMA Recommendation 1

ACEHR urges the Administration, and the leaders of FEMA and the Department of Homeland Security, to take action to provide FEMA's earthquake program with the resources needed to fully meet the agency's responsibilities, as required by law. The persistent underfunding of FEMA jeopardizes the effectiveness of the entire Program.

While FEMA continues to make noteworthy contributions to NEHRP, the agency's mitigation efforts remain on a persistent multi-year path of significant underfunding, typified by FEMA's request for only 30% of authorized budget for the current year. FEMA's earthquake-related activities are dramatically underfunded compared to the $6.1 billion in annualized seismic risk facing the nation (FEMA 2017). In order to improve the nation's building inventory and infrastructure before the next major earthquake strikes, FEMA's functions within NEHRP (i.e. develop guidelines and technical resources for seismic risk reduction, provide appropriate training support to communities, and fund for disaster mitigation projects) must be supported.

The lack of adequate resources also means many opportunities to advance seismic resilience initiatives are being missed or have made little progress. Examples of mission critical elements which are not being accomplished include:

- Critical technical documents that are not being updated and have been removed from publication for lack of support.
- Leadership in land use planning, which is a foundational way to mitigate risk in areas subject to multiple hazards and dramatically improve community resilience.
- Improving lifeline and infrastructure performance which is essential to community resiliency following an earthquake.

FEMA Recommendation 2

ACEHR recommends that FEMA continue to make seismic building code development, adoption, and enforcement a priority.

While all 50 states have adopted some form of building codes, many local jurisdictions have not adopted building codes. Furthermore, other jurisdictions amend out, reduce, or do not enforce the seismic provisions within the building codes. In addition, the seismic

provisions in building codes are under attack by special interests. When a state or community fails to adopt current building codes, the safety of our citizens and the economic sustainability and resilience of our communities is jeopardized. FEMA has a vital role in the code development and adoption process, advocates for maintaining strong seismic provisions, and uses its policies, guidance and programs to support code adoption efforts by local jurisdictions. Furthermore, ACEHR urges FEMA to support state and local government initiatives to address the risk presented by existing buildings.

FEMA Recommendation 3

ACEHR continues to recommend that FEMA return to a directly-funded, state-based program for earthquake hazard mitigation, planning, education and preparedness efforts and to reconsider the current state grant matching formula.

The steady decline in overall funding to state earthquake programs must be reversed, if the nation is to be adequately prepared for a major earthquake. We recommend that NEHRP reauthorization efforts by Congress ensure that the earthquake program is aligned with all the other state assistance programs by adopting a 25% matching formula.

FEMA Recommendation 4

If the decade-long trend of underfunding of FEMA earthquake-related activities persists, ACEHR recommends that FEMA review its areas of responsibility, prioritize those efforts that have maximum impact on seismic resilience, and identify efforts that must be discontinued in order to make meaningful and timely progress on the most crucial efforts.

Funding for FEMA's responsibilities under NEHRP has been roughly 30% of authorization levels for some time. If underfunding persists, ACEHR recommends that FEMA explore different avenues for obtaining additional resources, which might include linking FEMA earthquake activities with the efforts of other FEMA branches, and within other multi-hazard, risk, and threat-oriented activities and initiatives. Without additional resources, ACEHR recommends that FEMA direct available resources towards those mission-critical efforts deemed most cost-effective. It is also important to acknowledge that, in doing so, the overall effectiveness of the NEHRP mission is being jeopardized. ACEHR offers to be of assistance in setting mission-critical priorities and identifying potential, lower-priority efforts to defer. A few underfunded priority activities include:

- Re-establish program activity related to infrastructure and lifelines
- Expand cooperative partnerships and assistance with States, Territories and regional groups
- Expand program implementation and outreach activities on behalf of FEMA and the other NEHRP agencies
- Strengthen and extend FEMA efforts related to model building codes and national consensus standards

- Provide support to put efforts related to seismic design guidance and model codes and consensus standards provisions development for existing buildings on par with efforts for new buildings
- Review and update existing seismic guidance publications and products
- Develop new seismic technical guidance to address issues identified as a result of new research results, lessons learned from previous earthquakes, and enforcement of the current seismic building code provisions.

National Institute of Standards and Technology (NIST)

NIST is responsible for carrying out research and development to improve building codes and standards and practices for structures, critical infrastructure and lifeline systems. NIST activities include promoting the implementation and integration of NEHRP research into model codes and standards for buildings, cost-effective performance-based seismic engineering, and providing resources to practicing architects and engineers to enhance seismic design and construction. NIST also supports the efforts of national standard organizations in the development of seismic safety standards and best practices for critical infrastructure and lifeline systems. In addition, NIST works with NSF, FEMA, and USGS on planning for earthquake engineering research.

ACEHR commends NIST for continuing to move the NEHRP agenda forward in priority areas. The ACEHR 2015 biennial report made two recommendations to: (1) "improve the dissemination of NEHRP related information and products to the architectural and engineering professions", and (2) "continue and emphasize NEHRP-related research and development programs on critical infrastructure and lifeline systems, geotechnical engineering, non-structural elements, and residential and industrial structures that have seismic vulnerabilities." NIST worked toward accomplishing both of these recommendations in the past two years, among other things, through: (a) enhancing the disseminating information using numerous methods; (b) completing and publishing the study on the "Critical Assessment of Lifeline System Performance: Understanding Societal Needs in Disaster Recovery" (NIST GCR 16-917-39) (Applied Technology Council 2016); (c) obtaining approval to hire geotechnical engineers to work on NEHRP and other geotechnical-related projects; and, (d) completing and publishing the study on the "Seismic Analysis, Design, and Installation of Nonstructural Components and Systems—Background and Recommendations for Future Work" (NIST GCR 17-917-44) (Applied Technology Council 2017).

ACEHR encourages NIST to continue with the above-described efforts and to select priority topics outlined in the roadmaps for earthquake-resilient buildings (NIST GCR 13-917-23) (NIBS 2013) and lifelines (NIST GCR 14-917-33) (NEHRP Consultants Joint Venture 2014) and recommendations made in subsequent studies undertaken as a result of these roadmaps. ACEHR is also pleased that there was an approximately 25% increase in NIST funding levels for disaster resilience from Congress in FY2016. However, the above-

referenced roadmaps identify the need for about $10 million total per year for earthquake-related engineering efforts, and this gap still needs to be filled. NIST has a unique role in NEHRP as an agency where the in-house technical staff can undertake significant technical projects that make broad contributions to applied seismic engineering. Staff is needed to support technical initiatives for critical applied research in lifelines and existing building areas as outlined in the roadmaps.

NIST Recommendation 1

ACEHR recommends that NIST initiate development of nationally-applicable seismic performance objectives, assessment procedures and design criteria for lifeline systems.

The United States needs a consistent, nationwide framework of lifeline performance and restoration goals, and procedures for quantifying earthquake hazards in a uniform manner over spatially-distributed lifeline systems as described in NIST GCR 14-917-33 (NEHRP Consultants Joint Venture 2014) and NIST GCR 16-917-39 (Applied Technology Council 2016). There are synergistic opportunities to develop these goals with the implementation of the NIST Community Resilience Planning Guide (NIST 2015) and the American Society of Civil Engineers Infrastructure Resilience Division (IRD). The IRD is planning for the development of resilience-based infrastructure standards which NIST should consider in developing lifeline system performance and restoration goals. Recently developed methods to quantify ground motions and permanent ground deformations occurring during an earthquake (e.g., fault rupture, lateral spreading, landslides, settlement) must be also be incorporated into uncertainty estimates for any lifeline performance objectives.

NIST Recommendation 2

ACEHR recommends that NIST assess the seismic performance of buildings in the eastern and central United States that have been designed primarily for code-compliant wind loads.

This should be a multi-regional project to evaluate buildings that have been designed for wind loads in accordance with the International Building Code and/or available extreme wind criteria. NIST has identified Memphis, Boston and Charleston as potential study areas, and ACEHR encourages NIST to consider a fourth location in the central United States with induced seismicity risk. The deliverable for this project should be recommendations to institute regional specific design criteria to economically deliver both enhanced seismic and wind performance.

NIST Recommendation 3

ACEHR recommends that NIST develop a proof-of-concept initiative to use a building seismic rating system to evaluate the expected performance of a portfolio of building types.

This task is focused on demonstrating the viability of using an existing building rating system to quantify building seismic risk and expected performance for a range of building types. An additional goal of this task is for NIST to comparatively evaluate the effectiveness of the existing screening tools to identify and differentiate relative seismic risk among buildings. A deliverable of this task would be recommended improvements for the screening tools and a plan for possible outreach to the engineering community about the use of these tools. This is an important first step in developing objective information for building owners to evaluate and mitigate building seismic risk. It should be coordinated with ACEHR's recommendation to the NEHRP Secretariat and four NEHRP agencies to facilitate a workshop to advance the use of risk-based rating systems for the seismic performance of buildings in the U.S.

National Science Foundation (NSF)

NSF has NEHRP responsibilities that extend across three of the Foundation's Directorates in Engineering; Geosciences; and Social, Behavioral, and Economic Sciences. Supported activities include a broad spectrum of fundamental research of transformative intellectual merit with the potential for broader impacts, facility support, and data resources that are essential to the advancement of the goals of NEHRP.

Through Geosciences, NSF has supported the Global Seismographic Network (GSN) and basic research on earthquake sources that has fundamentally altered our understanding of how earthquakes nucleate and the strong ground motions that are produced, especially in subduction zones. In Engineering, NSF has supported research on the influence of earthquake ground shaking, ground deformations, tsunamis and other earthquake effects on the performance of buildings, civil infrastructure and lifelines, and long-term community recovery. The Social, Behavioral, and Economic Sciences have supported investigations that have transformed theoretical models of earthquake risk communication and have informed generations of work on public education, policy development, and early alert warnings.

NSF research initiatives and funding have provided the basis for guidelines for structural and infrastructure performance and model building codes, and technologies to simulate and mitigate effects of earthquakes on the built environment. They have also encouraged the development of social scientific theory and facilitated other contributions that have led to technology transfer of fundamental NSF research into practical outcomes. These impacts are predicated upon close coordination among the research activities of NSF, related activities of the USGS and NIST, and implementation efforts of other organizations.

ACEHR commends the persistence by NSF in pursuing the above efforts. However, we have been dissatisfied with NSF's response to repeated requests to (1) provide a strategic overview of its NEHRP activities and (2) build on inter-Divisional linkages and synergies

with programs in other NEHRP agencies along with related programs in other Federal and state agencies as well as private industry. Response to these requests from Director-level leadership at NSF is vital for the linkages essential for NEHRP's mission.

ACEHR recognizes that NSF does not have a dedicated NEHRP category or line-item budget for funding. Rather, research accomplishments reflect decisions within various NSF programs and directorates to fund program initiatives and unsolicited proposals that address NEHRP and other broadly-related hazards activities. This has three serious consequences:

- This process makes it difficult for other NEHRP agencies to coordinate their research and mission-related activities with NSF.
- It blurs the extent to which earthquake-specific research is being funded. This is reflected in the shift over time at NSF from funding earthquake-specific programs and facilities toward broader, all-hazards-related initiatives. The latter include major funding for PREVENTS – Prediction of and Resilience against Extreme Events and for NHERI – Natural Hazards Engineering Research Infrastructure.
- Other NEHRP agencies and the research community more generally have a hard time identifying the latest relevant findings from NSF funded research and activities once complete.

ACEHR's 2015 recommendations to NSF aimed at clarifying current and future programmatic funding commitments in general and specifically under NHERI, and recommended NSF develop mechanisms for documenting, reporting, and publicizing current NEHRP-related research and findings from it. NSF personnel have repeatedly stated that their funding approach prohibits specifying research contributions in advance, but by searching relevant, on-line, publicly-available NSF databases one can identify earthquake-related research funding and accomplishments. This response, however, misses the opportunity for NSF to demonstrate the value of multidisciplinary investigations and overlooks the challenges associated with being unable to coordinate research programs in advance or commit to earthquake-specific research in funding opportunities.

ACEHR makes the following recommendations in response to these challenges.

Demonstrating NSF Investments

NSF Recommendation 1

ACEHR recommends that NSF prepare a synthesis report that identifies how current NEHRP-related investments contribute to NEHRP strategic goals and plans.

This report should be guided and prepared at a high-enough level within the Foundation to acknowledge and merge NSF's contributions across Directorates, including initiatives

such as PREVENTS, NHERI, Southern California Earthquake Center (SCEC), EarthScope, National Geophysical Observatory for Geoscience (NGEO) and the Natural Hazards Center**.** The report should identify how, in thematic terms, each initiative advances earthquake-specific research needs and gaps with attention to the key scientific issues and questions being addressed as well as the broader impacts of these initiatives. The emphasis should be concise higher-level explanations and not simply listings of projects.

NSF Recommendation 2

ACEHR recommends that NSF work with the NEHRP Secretariat to devise a reporting and information-sharing approach that provides a better basis for coordinating NSF NEHRP-related activities with other NEHRP agency activities.

This process should, on an annual basis, identify specific contributions to the NEHRP strategic plan, opportunities for collaboration, and research gaps. This should be designed to inform annual budget and programmatic planning for the NEHRP Secretariat, rather than an after-the-fact summary of what was funded. In order to provide balanced reporting across NSF investments, representatives from the Engineering, Geosciences, and Social, Behavioral, and Economic Science Directorates should participate regularly in ACEHR meetings.

Engaging Internal and External Partnerships

ACEHR recommended in 2015 that NSF review lessons from multidisciplinary hazard-related initiatives to assess the quality of its cross-disciplinary participation. The NSF response to the earlier recommendation was that "NSF continues to review the accomplishments and continuing challenges of cross-disciplinary and multidisciplinary research" with a listing of such multidisciplinary initiatives. The response does not speak to lessons learned, identification of problems, or ways to enhance social science participation.

NSF Recommendation 3

ACEHR recommends that NSF fund a workshop or other forum on past and future opportunities for multidisciplinary research initiatives to contribute to the success of NEHRP.

This workshop or forum should explicitly address contributions of social science, engineering, and geoscience research to NEHRP-related initiatives. Consideration should be given to the scientific contributions, their degree of integration in funded projects, lessons learned about such activities, identification of problems, and ways to enhance social science participation. A primary issue is how fundamental social science advances concerning such things as behavioral economics, decision-making, social vulnerability, and implementation can be more fully incorporated for advancing the transformative

impact of major NEHRP-related research initiatives. While progress has been made in requiring that major research initiatives engage with social scientists, treatment of the social, behavioral, and economic sciences can be quite varied. Too often the "social sciences" are treated as a single discipline with one person from one discipline added to a team or project. This merely creates a veneer of multi-disciplinary involvement.

NSF Recommendation 4

ACEHR recommends that NSF more fully engage NEHRP partner agencies and external organizations to anticipate and foster the translation of research accomplishments into demonstrable advances for earthquake resilience.

Many of NSF's research accomplishments have been advanced through the efforts of national and international organizations. Some of these advances have been initiated by community organizations (e.g., Incorporated Research Institutions for Seismology (IRIS), UNAVCO, SCEC, Earthquake Engineering Research Institute (EERI), Applied Technology Council (ATC) and others) and some have been facilitated by interagency agreements. In particular, ACEHR commends NSF collaborations with (1) USGS in achieving significant advances in the observational and data resources that jointly support the ANSS, and (2) FEMA, NIST and USGS for efforts to disseminate knowledge and improve earthquake engineering practice through design guidelines, building codes and standards, and other technologies. The recommended engagement should (1) develop visionary research goals and challenges to advance the NEHRP mission in both the long- and short-term, and (2) work with national and international partners (both academic and governmental) to leverage investments across NSF Directorates to support collaboration and coordination of both research program and long-term investments in facilities and data collection and management.

Realizing the NSF Potential

As one of the nation's scientific leaders, NSF has the potential to not only fund transformative research activities, but to also further encourage and support the collaborative activities and technology transfer mechanism that will result in even more wide-reaching, broader impacts.

United States Geological Survey (USGS)

Under NEHRP, the USGS is responsible for conducting research and other activities necessary to characterize and identify earthquake hazards, assess earthquake risks, and monitor seismic activity.

ACEHR's 2015 report highlighted five areas of emphasis for the USGS:

1. Proactive acquisition of seismic data to address the uncertainty in ground motion scaling relations for the central and eastern US
2. Implementation of Earthquake Early Warning (EEW) for the Nations' West Coast
3. Development and communication of the risks posed by induced seismicity
4. Continued development of earthquake scenarios for high-risk urban area
5. Improved interaction with operators of critical infrastructure and lifeline systems on the use of near real-time data products.

ACEHR commends the USGS for the significant implementation progress that has been made in all these areas. Continued progress is hampered, however, by uncertainty in funding that also affects the Survey's ability to be responsive to new needs.

USGS Recommendation 1

ACEHR recommends that the USGS continue to use advisory panels and other community-based forums to target immediate and long-term needs and strategies to meet its obligations under NEHRP.

Guidance for implementing the goals of NEHRP is essential to ensure that opportunities are not missed, priorities are set, and implementation is accomplished within program constraints. Currently the USGS is advised by the NEHRP Scientific Earthquake Studies Advisory Committee (SESAC), the ANSS National Steering Committee, National Seismic Hazard Model Steering Committee, and the National Earthquake Prediction Evaluation Council, among others.

Some recently published reports and reports in progress that have resulted from community-based input on strategies and needs are:

- "Advanced National Seismic System – Status, development opportunities, and priorities for 2017-2027," U. S. Geological Survey Circular 1429 (USGS 2017)
- "USGS National Strong-Motion Project Strategic Plan: 2017-2022" (draft)
- "Leveraging Geodetic Data to Reduce Losses from Earthquakes," U. S. Geological Survey Open File Report (under review).

USGS Recommendation 2

ACEHR recommends that the USGS continue development and implementation of the Advanced National Seismic System (ANSS) and that it becomes a line-item in the USGS budget.

ACEHR is encouraged by the development and expansion of the ANSS which is essential to the development of an earthquake early warning (EEW) system for the U.S. West Coast (ShakeAlert) and other important products. EEW has great potential to save lives and reduce property damage and thus, merits sustained funding to design, implement and operate such a system. Funding from Congress, the State of California, philanthropy and other sources for the design and implementation of the ShakeAlert technology is

encouraging. ACEHR is concerned, however, that unless the USGS receives consistent funding for operation and maintenance of ANSS, it and products like EEW will not be sustainable in the long-term.

USGS Recommendation 3

ACEHR recommends that the USGS continue to support and develop online products that address community needs for information about earthquake hazards.

The USGS has many valuable online services to provide immediate earthquake notification to government agencies, researchers and the public that include ShakeMap, ShakeCast, "Did You Feel It?", and Prompt Assessment of Global Earthquakes for Response (PAGER). It is also vital that the USGS continue to provide online access to the National Seismic Hazard Model and accompanying maps and tools, all of which is essential to the engineering community and others working in earthquake resilience.

USGS Recommendation 4

ACEHR recommends that the USGS maintain its strong internal and external research programs, commensurate with the extraordinary developments in data acquisition, and which address critical knowledge gaps.

For example, increased seismicity in the central and eastern United States has provided a wealth of new data that is being used to examine fundamental questions on the scaling of earthquake strong ground motion, the rapid temporal increase in earthquake hazards, and the fundamental physics of this earthquake process that will enable better preparedness and risk reduction.

A strong research program also requires a trained, inquisitive workforce. ACEHR notes that with USGS funding at static levels, coupled with inflation, the agency's capability to sustain research is being continually degraded over time. This is evident in the attrition and non- or reduced-replacement of critical personnel.

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