Advisory Committee on Earthquake Hazards Reduction
National Earthquake Hazards Reduction Program

May 4, 2010

The Honorable Patrick D. Gallagher
Director
National Institute of Standards and Technology
Building 101, Room A1134
100 Bureau Drive
Gaithersburg, MD 20899-1000

Reference: Annual Report of the Effectiveness of the NEHRP Advisory Committee on Earthquake Hazards Reduction (ACEHR)

Dear Dr. Gallagher:

We are pleased to transmit our 2010 Annual Report on the Effectiveness of the National Earthquake Hazards Reduction Program (NEHRP) to you and the Interagency Coordinating Committee (ICC), as required by our committee charter and Public Law 108–360. By statute, we are instructed to assess and report on the program's effectiveness in a variety of areas as well as suggest any revisions that are needed. This is our third annual report.

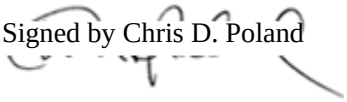
We are pleased with the progress the program is making in all areas and the collaborative working relationship that we have with you and the participating agencies and personnel. The 2009–2013 NEHRP strategic plan has outlined what needs to be done and the program is doing well to implement it within the funding constraints that exist.

This report is similar to the first report we submitted in 2008. It provides a complete overview of the program and includes an update on the trends and developments observed by committee members. We have chosen to organize our thinking around the 2009–2013 strategic plan and point out what advancements have been made, what changes are needed, and what opportunities are not being addressed due to the current funding constraints. We hope that this approach will allow the ICC to understand the consequences of maintaining current funding levels. We are very concerned about the lack of progress being made in securing the Nation from a seismic catastrophe.

It has again been our pleasure to serve as advisors to the program and we look forward to discussing the contents of our report with you. I would be honored to have the opportunity to meet with you and the ICC to present and discuss our findings and provide clarification as needed.

Sincerely,

Signed by Chris D. Poland



Chris D. Poland, PE, SE
Chair
Advisory Committee on Earthquake Hazards Reduction
National Earthquake Hazards Reduction Program

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Executive Summary

The Advisory Committee on Earthquake Hazards Reduction (ACEHR) of the National Earthquake Hazards Reduction Program (NEHRP) is deeply concerned about inevitable catastrophic earthquakes in the United States and their potential to cause severe economic losses (e.g., topping $100 billion) and prolonged human suffering. Despite being a strong nation, we are not well prepared. Entire regions will be seriously damaged and permanently impaired, and will take decades to recover. Large gaps exist between current and desired levels of seismic risk because much infrastructure was built long before we understood the underlying earthquake hazards and our communities were not constructed to recover from the resulting damage.

The 2010 earthquakes in Haiti (magnitude 7.0) and Chile (magnitude 8.8) are stark reminders of the value of earthquake preparedness and the importance of building codes. More than 200,000 people died in Haiti where building codes do not exist. In contrast, fewer than 1,000 deaths occurred in Chile where modern seismic building codes have existed since the 1960s. Where does the United States stand? Our communities in seismic regions that span 30 states have implemented seismic building codes to widely varying degrees and at widely varying times over the years. If an earthquake occurred today, we would expect many more deaths in communities that have only recently or have not yet adopted seismic building codes. And we would expect recovery to be slow in most communities due to low levels of resilience.

The activities carried out by NEHRP, such as shaping building codes, make a big difference. NEHRP activities can reduce earthquake casualties and shorten the time it takes for stricken communities to heal. The 2009–2013 NEHRP strategic plan stands as a comprehensive statement of what needs to be done in the near term to provide the information and tools needed for the Nation to build toward resilience. Unfortunately, given the slow pace at which NEHRP is currently able to implement its strategic plan, the Nation's vulnerability to earthquake hazards is steadily increasing and our Nation continues to head towards certain disaster. Human suffering will be intense, mega-losses will occur (from direct physical damage as well as from the cascading economic impacts of lifeline disruptions), and recoveries will be prolonged unless a more aggressive rate of plan implementation is enabled.

To protect society against catastrophic earthquake-induced losses, NEHRP must make lifelines a top priority. The American Society of Civil Engineers reports that more than $2 trillion needs to be invested in our Nation's aging infrastructure over the coming decades to support our high standard of living and economy. Ongoing investments in infrastructure should incorporate

seismic resilience. Modern nations depend on their lifelines—energy, transportation, water, and communications—both on a daily basis and in post-earthquake environments. The interruption of any of these lifeline services following an earthquake can produce severe economic losses, harm quality of life, and disrupt citizens' livelihoods. Furthermore, the complex interdependencies that exist among lifelines can generate many unforeseen and potentially catastrophic consequences that are likely to compound economic losses and hardships. Presently, the United States is at high risk, because there is no adequate effort to understand lifeline resilience and no development of performance-based design, construction, and renovation of lifeline systems. To achieve resilient lifeline services, the tasks outlined in the NEHRP strategic plan need to be implemented so that the investments needed at national, state, and local levels can be undertaken.

Leveraging the accomplishments of NEHRP requires immediate and universal access to the scientific information generated through those accomplishments. A national earthquake resource library is needed to preserve and disseminate the vast body of knowledge on earthquake science, engineering, social science, and preparedness. This library should include new field and analytical data collected after each major earthquake (which are in essence full-scale field tests of community resilience). Fundamental research findings are critical to advancing our knowledge. It is equally critical to transfer research findings into practice. Integrative research into the political, social, and economic circumstances that motivate society to achieve community resilience is needed to promote implementation of proven earthquake-resistant retrofit strategies.

The NEHRP strategic plan also needs to be expanded to make more effective use of the national resources focused on resilience. Over the past 5 years, the NEHRP Office, under the leadership of NIST, has made enormous progress. The office coordinates successfully with each of the participating NEHRP agencies—FEMA, NIST, NSF, and USGS—and has begun building an internal research team at NIST. Today, outreach beyond the NEHRP agencies would serve to accelerate progress toward needed levels of community earthquake resilience in the United States.

ACEHR's key recommendations are derived from areas within the strategic plan that are not being addressed and from recommendations made in ACEHR's 2008 report that need further attention.[1] They are listed below, and discussed in the body of the report.

Management, Coordination, and Implementation of NEHRP

- ***Recommendation 1***—The NEHRP Interagency Coordinating Committee should work to ensure that the amount of funding requested for NEHRP in the President's Budget each year is sufficient to permit full and timely implementation of the NEHRP strategic plan. At the present pace of plan implementation, the program will likely never meet its goals of providing the information and tools needed to achieve resilience nationwide.

[1] The recommendations made in ACEHR's 2008 report are listed within the executive summary of that report, which is attached as Appendix C.

- ***Recommendation 2***—The NEHRP Office should carry out its role of representing the NEHRP agencies with respect to external affairs. This includes facilitating enhanced coordination and collaboration between NEHRP and relevant non-NEHRP federal agencies and earthquake organizations. It ranges from taking advantage of the expertise and programs of the agencies that form the Interagency Committee on Seismic Safety in Construction to facilitating improved earthquake mitigation at the state level and in the private sector.

- ***Recommendation 3***—A national road map is needed for developing earthquake resilience of targeted lifelines that are critical to the Nation's security (e.g., in the energy, telecommunications, transportation, and water sectors) and community resilience. The NEHRP Office should focus on understanding and improving lifeline services during earthquakes to ensure delivery of critical resources and to support community resilience and restoration. This includes establishing performance objectives for lifelines under various seismic conditions, developing and promoting seismic guidelines for new and existing components and systems, and considering interdependencies and cascading effects.

- ***Recommendation 4***—A national earthquake resource electronic library is needed. This includes a post-earthquake information management database that houses data ranging from initial field reconnaissance to detailed investigative findings. It also includes information for the public and private sectors on earthquake mitigation and preparedness.

Federal Emergency Management Agency

- ***Recommendation 1***—Revitalize state earthquake programs and provide strong support and leadership to state commissions to characterize and mitigate unacceptable risk in communities, with targeted efforts on developing public policies, institutionalizing mitigation programs, and implementing pilot studies and scenarios. Leverage other relevant expertise and programs within the Department of Homeland Security to further the NEHRP strategic plan.

- ***Recommendation 2***—Develop and promote improved guidance to enhance emergency management capabilities in preparedness, response, and recovery at state and local levels. Include standards of preparedness for the private sector and guidance on providing post-disaster shelter and housing.

- ***Recommendation 3***—Develop and maintain improved guideline documents that will heighten the effectiveness and reduce the cost of seismic protection for new and existing buildings and lifelines, and applied socioeconomic policies for cost-effective mitigation. Promote their adoption and implementation among stakeholders, and measure the impact.

National Institute of Standards and Technology

- ***Recommendation 1***—Expand internal and external programs to effectively carry out the agency's roles in conducting applied research, in facilitating the implementation of cost-effective mitigation through codes and standards for the Nation's broad range of new and

existing lifelines, buildings, and industrial structures, and in transferring technology for use in actual mitigation.

- ***Recommendation* 2**—Build multidisciplinary expertise within NIST and foster relationships with other public agencies, private-sector entities, and consultants to accomplish and manage the applied research.

National Science Foundation

- ***Recommendation 1—***Commit to supporting future earthquake reconnaissance, coordination, and outreach efforts and needed additional studies for significant earthquakes occurring throughout the world; provide this support in close coordination with the NEHRP Office. Earthquakes are the primary feedback mechanism available to the earth science, earthquake engineering, and social science communities for understanding the responses of actual systems.

- ***Recommendation 2***—Assess large-scale experimental facilities throughout the United States, along with the equipment sites of the George E. Brown, Jr. Network for Earthquake Engineering Simulation, to determine how best to ensure that state-of-the-art experimental capabilities for earthquake engineering are available. Experimental facilities are essential to increasing the resilience of the United States by supporting the development of performance-based design provisions for new construction and assessment procedures for existing infrastructure.

U.S. Geological Survey

- ***Recommendation 1—***Ensure full implementation of the Advanced National Seismic System. Short of this goal as the first step, the Nation will not have a robust national seismic monitoring system to meet critical needs in the fields of emergency management, earthquake engineering, and earthquake science.

- ***Recommendation 2—***Ensure that USGS products are shaped to meet the needs of the engineering community so that products generated under the USGS National Seismic Hazard Mapping Project satisfy needs related to performance-based design.

- ***Recommendation 3—***Strive to convey important earthquake information to the public in an understandable manner, by working with social scientists and other earthquake professionals to enhance both the content and delivery of information. This pertains to communications about time-sensitive probabilities of large earthquakes (including instances of possible foreshocks), aftershock advisories, and authoritative interpretations of earthquake hazards in controversial areas such as the New Madrid region.

Call to Action

The NEHRP strategic plan recognizes that the traditional NEHRP goal of protecting lives needs to be expanded to improving resilience. It is critical for NEHRP to start addressing our aging infrastructure and to help steer the Nation toward security and resilience. Our problems will not be fixed overnight. Making progress will require long-term and dedicated efforts. However, the

consequences will be less severe if we start applying meaningful and effective efforts toward fully implementing the NEHRP strategic plan now. If we don't, the consequences could be catastrophic and entire communities may never recover.

ACEHR strongly urges that NEHRP focus on achieving community resilience, most importantly by supporting programs that implement earthquake risk-reduction measures, but also by supporting programs that advance our understanding of earthquake phenomena and that develop and evaluate cost-effective measures for strengthening resilience. Full and timely implementation of the 2009–2013 NEHRP strategic plan is the best next step.

Introduction

The National Earthquake Hazards Reduction Program, first authorized in 1977, is embodied in Public Law 108–360. It has grown to embrace an overarching vision of *a nation that is earthquake-resilient in public safety, economic strength, and national security,* and its mission *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.*

NEHRP is a highly successful program that for more than 30 years has uniquely contributed to improving earthquake awareness and preparedness in the United States and around the world. Through its four member agencies, it has significantly advanced our understanding of the earthquake process and related hazards and risks. This enhanced understanding has led to earthquake-safe design and construction techniques that when properly applied serve to secure communities against catastrophic failure. As with any emerging science and engineering technology, we are just beginning to understand how to best deal with the related hazards and risks. Today, there is a growing understanding that we need to expand our goals from safety to resilience.

The differing impacts of the recent earthquakes in Haiti and Chile starkly illustrate what NEHRP is trying to achieve in the United States and the benefits of understanding and preparedness. The difference in death tolls alone strongly validates a national commitment to earthquake risk reduction and disaster resilience.

Resilience—the Twenty-First-Century Goal for NEHRP

NEHRP has been committed since its inception to protecting lives through pre-event planning and mitigation of risks. Many program efforts, such as in seismic monitoring, seismic mapping, building code development, risk mitigation, and emergency preparedness have helped to provide a solid framework for community development and disaster planning. Yet, serious gaps exist and these are reflected in the current NEHRP strategic plan for 2009–2013. For example, the vast majority of the existing physical infrastructure was constructed to inadequate standards, well below current standards for new construction; even the new standards focus on life safety and are not sufficient to achieve resilience. Most buildings will suffer costly damage in a major earthquake, and critical lifelines (e.g., highways, ports, water supply systems, electricity grids, and telecommunications networks) will not provide their intended services for weeks or months after such an earthquake. The Nation lacks the information and tools needed to address these deficiencies and target the areas needing cost-effective and affordable rehabilitation.

There is a rapidly growing recognition that communities need more than the capacity to be self-sufficient for 72 hours following an earthquake or other disaster. They need to be able to quickly recover, that is, to be disaster resilient. Disaster-resilient communities must have credible response plans that recognize their inherent abilities to recover, and include places and plans for governing after a major disaster. Power, water, and communication networks need to resume operations shortly after a disaster. Residents need to be able to stay in their homes, travel to where they need to be, and resume fairly normal living routines within weeks, so they can restore

their community within a few years. Businesses need to understand and plan around the expected usefulness of their facilities and have plans for their restoration.

While the current national model building code has been adopted by some communities in every state and is effective for safeguarding life and protecting first responders, state and local adoption is neither universal nor comprehensive. There is an enormous diversity in the way codes are implemented that ranges from full attainment, to limited adoption, to areas that strip out disaster-resisting provisions, to communities that actually prohibit the application of building codes to homes. Building codes are of little use if they are not adopted by local jurisdictions and subsequently enforced by well-qualified building departments and their inspectors.

Furthermore, even if a U.S. city were constructed in *full compliance* with current building codes, a major earthquake would still cripple its ability to recover quickly because its buildings and lifelines have not been designed for post-disaster performance. They have only been designed to safeguard life, and, in some cases, support emergency response. Building to achieve resilience is at the heart of arresting the growth of vulnerability and striving toward resilience.

Every city is filled with older buildings and antiquated lifeline systems that were designed to earlier, now outdated, building codes or to no codes at all. There is always a subset of "killer" infrastructure that is extremely vulnerable to collapse, which would cause the deaths of many building occupants and users of transportation systems, and impede recovery for years. Many of our major urban centers are "catastrophes waiting to happen." Rehabilitating existing buildings is currently too expensive. New cost-effective and affordable solutions need to be developed that utilize new materials and technologies to reduce retrofit costs to affordable levels.

Resilience starts at the local level, with individuals, families, and businesses. Everyone in the country has a stake in creating resilience. Further, resilience of the built environment is only a part of the challenge. Resilience must also recognize and support the improvisational ability of communities to respond, and accommodate the socioeconomic and cultural aspects and needs of communities.

Resilient cities form resilient regions, which in turn build a resilient Nation. While the Nation can promote resilience through improved design codes and mitigation strategies, implementation and response must occur at the local level. The Nation cannot achieve resilience without motivating and supporting local measures that achieve resilience. Activities that would motivate and support such measures are outlined in the NEHRP strategic plan, but support for these activities is currently insufficient.

If national resilience is to be achieved, the Nation must enact legislation that empowers cities to build resilience neighborhood by neighborhood. State grants that support the identification and retrofit of "killer" buildings are required. Resources are needed to develop the human infrastructure for responding to and recovering from natural disasters. Understanding and planning for effective lifeline response after extreme events is a key part of developing community resilience. Building codes need to move towards performance-based earthquake engineering so that resilience, beyond "life safety," is the primary objective. The response of a "life safe" building in an earthquake may not result in deaths among its occupants, but the

building may be too badly damaged to be repaired or reused. True resilience would support rapid reuse of buildings and other components of infrastructure following earthquakes within the appropriate design envelope for a given region.

Many of the tools and procedures needed to create disaster-resilient cities exist and are continually being refined. Achieving resilience nationwide, however, will require a different approach than currently exists. The NEHRP strategic plan calls for modifications to current building codes, alignment of diverse lifeline systems around common performance objectives, and stimulation of strong community support for policies that foster resilience. Communities need to have access to the information and tools needed to mitigate deficient buildings and systems, and to design new buildings and systems to the performance levels needed.

Shifting to building codes focused on resilience and adopting new policies to strengthen communities are not possible without solid, unified support from all levels of government. The federal government should set performance standards that can be embedded in the design codes; be adamant that states adopt contemporary building codes and include provisions for rigorous enforcement; provide financial incentives to stimulate mitigation that benefits the Nation; and continue to support research that delivers new technologies that encourage cost-effective mitigation, response, and recovery. Through state and local governments, regions should identify the vulnerabilities of their lifeline systems and enact programs for their mitigation to the minimum levels needed to ensure resilience. Localities should expand their preparedness planning and develop mandatory programs that mitigate their built environment, as needed, to assure survival.

Preparation and Organization of This Report

The Advisory Committee on Earthquake Hazards Reduction was created during the 2004 NEHRP reauthorization and charged to oversee the program in four specific areas—new trends and developments, effectiveness, needed revisions, and management. By statute, ACEHR was formed of non-federal employees representing research and academic institutions, industry standards development organizations, state and local government, and financial communities across all related scientific, architectural, and engineering disciplines.

ACEHR was directed to report within 1 year of formation and at least once every 2 years thereafter, with due consideration given to the recommendations of the U.S. Geological Survey's Scientific Earthquake Studies Advisory Committee (SESAC). ACEHR first met in May 2007 and has since filed reports in May 2008 and May 2009. Since the last report, ACEHR has met face to face for 2-day sessions in November 2009 and March 2010. The committee also held two conference-call meetings to complete this report in January and April 2010. Summaries of all meetings and materials representing all reports and presentations made to the committee are available at www.NEHRP.gov.

Over the past year since the last report, the committee has requested and received briefings from the NEHRP Office and the four NEHRP agencies at each face-to-face meeting. The briefings and subsequent discussions were detailed, complete, and informative. The committee has appreciated the attention to detail shown by all presenters and their consideration of the recommendations that have been made. At the November meeting, the committee also received a briefing from the

White House Office of Resilience. Richard Reed, Special Assistant to the President for Homeland Security and Senior Director for Resilience Policy, discussed the resilience policies that the administration is currently developing and welcomed continuing dialogue with NEHRP. The paper developed by ACEHR in response to Reed's briefing is included as Appendix B. The committee also received and reviewed the NEHRP annual report for 2009. The meeting summaries adequately capture the information provided to the committee and the discussions that resulted in this report. ACEHR has not had the benefit of the recently commissioned National Research Council study that is now under way. That study may point to additional new directions.

This report is a brief synthesis of the committee's observations, conclusions, and recommendations related to the current status of NEHRP. It does not attempt to repeat information received by ACEHR on NEHRP activities to date. Those topics are adequately addressed in NEHRP's annual reports and strategic plans. It also does not attempt to outline the process used to develop the recommendations, as that is well noted in the meeting summaries. The committee represents a uniquely qualified cross section of the earthquake professions and the personal knowledge, experience, and vision of its members, combined with the information presented to ACEHR, form the basis for this report.

The report is organized around the task areas assigned to ACEHR by its authorizing legislation. The next section, entitled Program Effectiveness and Needs, is largely organized by NEHRP agency and focuses on past and current accomplishments, future plans, and modifications needed to address the goals of the 2009–2013 NEHRP strategic plan. Several prioritized recommendations are included for each agency that relate to augmenting agency activities beyond current efforts. An additional subsection, entitled Management, Coordination, and Implementation of NEHRP, provides complementary assessments of the NEHRP Office within NIST, the effectiveness of the Program Coordination Working Group (PCWG), and the intrinsic value of the Interagency Coordinating Committee (ICC), which is composed of the directors of the NEHRP agencies and the directors of the White House's Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP).

Appendix A, Trends and Developments in Science and Engineering, updates ACEHR's observations relating to eight disciplines that are highly relevant to NEHRP. These observations point to areas that are developing and trends that extend beyond the period addressed in NEHRP's current strategic plan. They are not exhaustive summaries of all work being undertaken in each discipline of the earthquake professions. Rather, they provide the NEHRP agencies with an overview of recent achievements that have been made and the issues and challenges facing the Nation, and include suggestions about where future strategic priorities should be focused. Appendix B contains ACEHR's White Paper on Achieving National Disaster Resilience, which the committee sent to the director of NIST in February 2010. Appendix C contains the executive summary from ACEHR's May 2008 report; the 2008 report was the committee's last full assessment of program effectiveness prior to this report.

Program Effectiveness and Needs

Management, Coordination, and Implementation of NEHRP

ACEHR provides four recommendations relating to the overall management, coordination, and implementation of NEHRP:

- ***Recommendation 1***—The ICC should work to ensure that the amount of funding requested for NEHRP in the President's Budget each year is sufficient to permit full and timely implementation of the NEHRP strategic plan. At the present pace of plan implementation, the program will likely never meet its goals of providing the information and tools needed to achieve resilience nationwide.

- ***Recommendation 2***—The NEHRP Office should carry out its role of representing the NEHRP agencies with respect to external affairs. This includes facilitating enhanced coordination and collaboration between NEHRP and relevant non-NEHRP federal agencies and earthquake organizations. It ranges from taking advantage of the expertise and programs of the agencies that form the Interagency Committee on Seismic Safety in Construction to facilitating improved earthquake mitigation at the state level and in the private sector.

- ***Recommendation 3***—A national road map is needed for developing earthquake resilience of targeted lifelines that are critical to the Nation's security (e.g., in the energy, telecommunications, transportation, and water sectors) and community resilience. The NEHRP Office should focus on understanding and improving lifeline services during earthquakes to ensure delivery of critical resources and to support community resilience and restoration. This includes establishing performance objectives for lifelines under various seismic conditions, developing and promoting seismic guidelines for new and existing components and systems, and considering interdependencies and cascading effects.

- ***Recommendation 4***—A national earthquake resource electronic library is needed. This includes a post-earthquake information management database that houses data ranging from initial field reconnaissance to detailed investigative findings. It also includes information for the public and private sectors on earthquake mitigation and preparedness.

After more than 25 years of good, individual progress by NEHRP agencies, the program now also benefits from NIST's strong, focused, and collaborative NEHRP Office, the effective PCWG, the ICC, and a high-level strategic plan that defines interagency collaboration and a common focus. The NEHRP Office maintains a current and informative Web site that serves to facilitate program management, coordination, and implementation. The 2009–2013 NEHRP strategic plan is proving to be a significant and useful document that not only sets direction but also serves to foster collaboration, consistency, and common vision in developing needed information and tools.

The expanded ICC is made up of the directors of NIST, FEMA, NSF, USGS, OMB, and OSTP. The desire of Congress to encourage a higher level of coordination and collaboration among the four NEHRP agencies, their budgeting processes, and the President's science initiatives was well received from the outset and resulted in the higher level of coordination and positive changes to NEHRP. The program benefitted from a highly effective and direct communication between ACEHR and the ICC, though that has not continued past the first 2 years. There remains, however, a steady stream of written reports and responses.

Program Funding Constraints

NEHRP's ability to implement its 2009–2013 strategic plan is being severely hampered by funding levels that in most cases are well below congressional authorizations. While this lower-than-authorized funding is understandable in the context of each agency and its department's priorities, the strategic plan does represent a compelling case for the level of research and application needed over the next 5 years and beyond to stimulate a measurable improvement in the Nation's resilience. We recognize that some strides have been made to increase funding, but ACEHR remains deeply concerned that NEHRP funding is well below the needed $330-million-per-year-level that was originally reported in the Earthquake Engineering Research Institute's report *Securing Society Against Catastrophic Earthquake Losses: A Research and Outreach Plan in Earthquake Engineering.* While we expect that the ongoing National Research Council study will update this estimate, there is no published evidence that refutes that amount.

NEHRP Agency Funding Levels

Enacted Agency NEHRP Budgets ($M)					
FY	FEMA	NIST	NSF	USGS	NEHRP Total
2005	14.7	0.9	53.1	58.4	127.1
2006	9.5	0.9	53.8	54.5	118.7
2007	7.2	1.7	54.2	55.4	118.5
2008	6.1	1.7	53.6	58.1	119.5
2009	9.1	4.1	55.0	61.2	129.4
2010	8.9	4.1	55.3	62.8	131.1

Requested Agency NEHRP Budgets ($M)					
FY	FEMA	NIST	NSF	USGS	NEHRP Total
2011	9.1	4.1	53.8	62.3	129.3

The lack of funding at authorized levels has impacted the activities of all the NEHRP agencies and seriously limited development of the information and tools needed to arrest the growth of the potential for catastrophic earthquake losses, let alone begin the long process of reducing those losses to acceptable levels. There should be no doubt that the Nation is facing multiple catastrophic earthquakes on the order of those seen recently in China, Italy, Haiti, and Chile. It will take decades of effort to secure this Nation against those levels of projected losses and that effort will gain traction only through the work embodied in NEHRP's strategic plan.

ACEHR recognizes that NEHRP funding is included in the budgets of the four participating agencies in different ways and is subject to congressional review and adjustment. ACEHR also recognizes that NEHRP funding is a small part of the budgets of the departments that contain the participating agencies, so small that it often does not appear among the line items included in the President's budget that is submitted to Congress. It is clear that funding decisions are made at the department and agency levels with little if any congressional oversight. ACEHR appreciates the need for balance in the budgets for each department and agency and their need to adhere to the President's priorities. The committee respectfully requests that the members of the ICC recognize the impact that their respective departmental and agency budgeting is having on implementing the strategic plan, advancing NEHRP, and preparing the Nation for an earthquake-induced catastrophe.

ACEHR appreciates that the ICC has chosen to continue the program, as authorized in 2004, during the current reauthorization process. We expect that the U.S. Senate will soon complete this process and urge the ICC to continue all program efforts without interruption during the process of accommodating the new program elements.

Expanding NEHRP Collaboration

ACEHR continues to believe that the effectiveness of NEHRP would be significantly enhanced if other federal agencies doing research and development in earthquake science and engineering were included in the program as we suggested in our 2009 report. We recognize that including additional agencies would entail more than simply extending invitations. It would require a measurable amount of administrative support that is not accommodated under the current leadership structure and administrative funding level.

The NEHRP vision is for a Nation that is earthquake-resilient in public safety, economic strength, and national security. The related mission is to develop, disseminate, and promote knowledge, tools, and practices through coordinated, multidisciplinary, interagency partnerships. While NEHRP's four participating agencies are making significant progress, there are other departments, agencies, and commissions that sponsor significant earthquake research in support of their individual missions that overlaps with that sponsored by NEHRP. These areas of overlap are often lost opportunities for integration and collaboration. This has not always been the case, however. The Interagency Committee on Seismic Safety in Construction (ICSSC) accomplished a lot through multiagency coordination in its early days.

To utilize fully the federal resources invested in earthquake hazards reduction, we suggest that either the ICSSC be reinvigorated and its charge expanded or an interagency working group (IWG) be formed consisting of other agencies that would work with the PCWG to assure maximum possible coordination and collaboration. In either case, at least the following agencies should be considered for membership along with any others that can contribute to NEHRP:

- Department of Energy
- Department of Homeland Security's Science and Technology Directorate, Office of Infrastructure Protection, and U.S. Coast Guard
- Department of Housing and Urban Development

- Department of Transportation's Research and Innovative Technology Administration
- Environmental Protection Agency
- National Oceanic and Atmospheric Administration
- U.S. Army Corps of Engineers
- U.S. Nuclear Regulatory Commission

NIST—Lead-Agency Responsibilities and the NEHRP Office

In the years before the 2004 NEHRP reauthorization, NIST's role within NEHRP was relatively minor and not fully realized because of a very low level of funding. Fiscal year (FY) 2005 brought a substantial change to NIST: it became the designated lead agency for NEHRP. Although NIST's direct budget for NEHRP has not been increased concomitantly with its responsibilities, the agency internally reallocated funds to establish the NEHRP Office and hire a program director. The NEHRP Office has also received valuable in-kind staff support from other NEHRP agencies.

The NEHRP Office has now been in place for nearly 5 years. NIST has taken seriously the assignment to lead the program by providing overall coordination, direction, and support of joint efforts consistent with congressional intent and centered upon objectives defined by the authorizing legislation. ACEHR appreciates the ongoing interest and support which are evident from the highest levels of the agency. The office of the NEHRP director is to be commended for its open approach to planning and leveraging resources by actively partnering with the earthquake professional community and by participating in regional consortia. NIST has fostered a strong level of interaction among the agencies participating in NEHRP. There has been notable outreach to interested stakeholders. The development process for the 2009–2013 NEHRP strategic plan is just one example of this successful interaction. The current work to develop a road map for earthquake engineering research will require continued strong leadership and sustained commitment to this collaborative philosophy.

In its 2008 report, ACEHR endorsed a transfer of responsibility for coordination of post-earthquake investigations to NIST. Several specific, related recommendations not included here were made in that report, which NIST should consider as they develop their coordination plan. ACEHR has identified the need for a post-earthquake information management system to collect and manage field data on earthquake impacts. Improving post-earthquake information acquisition and management has been identified as a critical objective in reaching the strategic goal of improving understanding of earthquake processes and impacts. A new NIST initiative, the Disaster-Resilient Buildings and Infrastructure Program, has been established that includes enhanced coordination of post-earthquake reconnaissance and database development and management. It will, however, be critical that this new program have sufficient dedicated staff and that it collaborate closely with the NEHRP Office to develop protocol that will provide guidance on data input, management, and access in order to ensure that the information that is gathered contributes to the goals and objectives of the NEHRP strategic plan.

During the past few years, the opportunities and responsibilities of the NEHRP Office have grown along with the development and implementation of NEHRP's strategic plans. The

expansion of NIST's research program and addition of five professional staff members who will be involved in the internal and $1–$2 million external research programs is to be commended, but the increased administrative burden this places on the NEHRP director is not insignificant. Any additional increases to such staff made to help ensure completion of the current strategic plan will require commensurate increases in the administrative staff.

Congress has assigned significant administrative responsibilities to NIST as the lead agency for NEHRP, including planning and coordinating the preparation of strategic plans aimed at ensuring that earthquake risk-reduction measures are implemented by households, businesses, and communities, by local, state, and federal governments, and by standards and code organizations, architects, engineers, and building owners; supporting the development of performance-based seismic engineering tools and their application; ensuring the incorporation of social science research in communicating risks; coordinating all federal post-earthquake investigations; and issuing recommendations for changes to model codes and reporting back to Congress on their implementation. The NEHRP Office shoulders these responsibilities, serves as secretariat to the ICC, and leads the PCWG. ACEHR believes that the office needs to be expanded to fulfill these obligations if the NEHRP strategic plan is to be fully implemented.

Federal Emergency Management Agency

ACEHR provides three recommendations for FEMA:

- ***Recommendation 1***—Revitalize state earthquake programs and provide strong support and leadership to state commissions to characterize and mitigate unacceptable risk in communities, with targeted efforts on developing public policies, institutionalizing mitigation programs, and implementing pilot studies and scenarios. Leverage other relevant expertise and programs within the Department of Homeland Security (DHS) to further the NEHRP strategic plan.

- ***Recommendation 2***—Develop and promote improved guidance to enhance emergency management capabilities in preparedness, response, and recovery at state and local levels. Include standards of preparedness for the private sector and guidance on providing post-disaster shelter and housing.

- ***Recommendation 3***—Develop and maintain improved guideline documents that will heighten the effectiveness and reduce the cost of seismic protection for new and existing buildings and lifelines, and applied socioeconomic policies for cost-effective mitigation. Promote their adoption and implementation among stakeholders, and measure the impact.

In addition to supporting FEMA and its programs, DHS maintains extensive and broad-based components outside of FEMA that are focused on understanding and responding to both man-made and natural hazards. Over the past 6 years, the department has been steadily refining processes and programs within these components to leverage what has been learned about preparing for and responding to man-made hazards for application to natural hazards. This has, in general, been done without consideration of or coordination with NEHRP. Both DHS and FEMA are making good progress toward their goals, though their respective activities appear to be proceeding somewhat in parallel and do not seem to be taking advantage of the other's

programs and accomplishments. Both sets of activities are needed, and each can make significant contributions to the other. Unfortunately, there appears to be a lack of communication and coordination that needs to be addressed so that federal efforts can be effectively leveraged to promote seismic risk-reduction capabilities at state and local levels.

For many years, FEMA played a leading role in promoting earthquake risk reduction and in transferring mitigation, preparedness, response, and recovery best practices to state and local government and the private sector. That pivotal role remains part of the current NEHRP strategic plan though it has been hampered by budget and staff reductions, lack of visibility of the Earthquake Program within FEMA, and an apparent diminished priority for the program within the agency. Nevertheless, the role of FEMA and its Earthquake Program within NEHRP remains vitally important to the program, as a transfer link between federal and state and local government agencies responsible for improving the Nation's resilience.

ACEHR recognizes and applauds FEMA's recent reestablishment of funding to state earthquake programs as a positive step toward restoring FEMA's role in providing incentives for state participation in earthquake risk reduction, but remains concerned about the continuing erosion of funding for support, technical assistance, and mitigation advocacy activities. FEMA funds allocated to NEHRP have declined significantly since 2002, and reached a low point in FY 2007. The loss of this support has greatly reduced the capabilities of an agency that has had many significant accomplishments, including developing (in cooperation with NEHRP partners USGS and NSF) HAZUS software that gives local and state planners the capability to develop loss scenarios for communities at risk and to rapidly determine the extent of damage after earthquakes; promoting implementation of the NEHRP Recommended Provisions in model seismic code provisions and in training and guidance to design and construction professionals; supporting collaboration among at-risk states to ensure that best practices are documented and promulgated; providing mitigation grants to states and communities; and facilitating the development of industry guidelines, standards, and codes for evaluating and mitigating existing buildings.

In previous years, FEMA had tremendous success working with states and communities, providing guidance and support for risk-reduction implementation projects and policies. This important work, however, has been seriously hampered in recent years by a lack of prioritization, support, and funding from DHS. FEMA's effectiveness has diminished as DHS, by reducing support for and the stature of the Earthquake Program, has constrained FEMA's capacity to support implementation of NEHRP's strategic plans.

Despite its declining budget, FEMA continues to be successful in developing and disseminating earthquake risk-reduction tools and disaster-resistant building codes. A noteworthy achievement is the successful development, through cooperative programs with the American Society of Civil Engineers (ASCE), of earthquake-resistant design standards for new construction, which are referenced in model building codes adopted by local governments and public agencies throughout the Nation. This success, particularly in the areas of lifelines and existing buildings, is now at risk as there is no funding available to maintain efforts and guidance documents.

FEMA's efforts to promote implementation of available earthquake risk-reduction tools have been less effective. The focus of these efforts has largely been on the adoption of seismic building codes by the public sector, including states and local agencies. However, not all communities have adopted the new building codes and, notably, some communities in the Nation's heartland continue to lag well behind in adoption of best construction practices and seismic codes appropriate to their risk. This lack of success can be tied to a perception that seismic code benefits are outweighed by their costs, a lack of understanding of the risk posed by earthquakes to a community's economy, or competition for limited resources in the current austere economic climate. There is a pressing need for continued intervention by FEMA in this environment focused on educating decision makers, design professionals, and the financial sector about the risks posed by earthquakes and the benefits of proactive mitigation to reduce those risks.

A number of FEMA's past, highly successful development efforts, including the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, have now been incorporated into national model building codes. Every large earthquake brings new lessons and opportunities to refine the seismic design standards to make them more applicable, achievable, and cost-effective. The NEHRP strategic plan calls for FEMA to maintain these essential tools through cooperative support for not-for-profit and private-sector organizations.

FEMA should also be lauded for its continued support of HAZUS loss-estimation software as a means of educating the public about the impacts of earthquakes, promoting mitigation, and rapidly assessing earthquake consequences; for initiating the QuakeSmart pilot program to promote public-private partnerships in preparedness; and for its promotion, under DHS, of private-sector preparedness (PS-Prep) through the development and adoption of preparedness standards.

Many critical tasks remain in the NEHRP strategic plan that can only be accomplished through the restoration of funding and staffing for FEMA's Earthquake Program. These efforts include developing local guidance and templates for post-disaster donations management, sheltering, and replacement housing services; integrating the risks posed by tsunamis into earthquake mitigation and preparedness efforts; assessing the feasibility of using social networking tools for pre- and post-disaster education, information gathering, and damage assessment; and enhancing HAZUS by including an infrastructure damage function to better simulate the interdependence of response and recovery operations and lifeline disruption.

National Institute of Standards and Technology

ACEHR provides two recommendations for the NIST research program:

- ***Recommendation 1***—Expand internal and external programs to effectively carry out the agency's roles in conducting applied research, in facilitating the implementation of cost-effective mitigation through codes and standards for the Nation's broad range of new and existing lifelines, buildings, and industrial structures, and in transferring technology for use in actual mitigation.

- ***Recommendation* 2**—Build multidisciplinary expertise within NIST and foster relationships with other public agencies, private-sector entities, and consultants to accomplish and manage the applied research.

In the years before the 2004 NEHRP reauthorization, NIST's research role within NEHRP was not fully realized because of a very low level of funding. Two increments in funding, in FY 2007 and FY 2009 (from the American Competitiveness Initiative), have brought a substantial change to the NEHRP research program at NIST. Both the internal and extramural research programs are off to a successful start. The new staff shows great promise and the proposed work will be evaluated in the future. If NIST is to accomplish its related goals under the NEHRP strategic plan, there is a need to plan for the future expansion of internal and external work to adequately address earthquake resilience over the broad range of new and existing buildings, lifelines, and industrial structures.

NIST has responsibility under the strategic plan for applied research and development in earthquake engineering focusing on improving standards and codes for new and existing buildings, infrastructure, lifelines, and construction practices, as well as on measurement and evaluation tools for testing new methods and technologies. The need for this work was documented in the report prepared by the Applied Technology Council entitled *The Missing Piece: Improving Seismic Design and Construction Practices*. As NEHRP's lead agency, NIST is also responsible for an overall program that will promote implementation of risk reduction measures, support the development of performance-based earthquake engineering, ensure the use of social science research, coordinate federal post-earthquake investigations, and make and track recommendations for changes in codes and standards of practice. Some of the research activities associated with these lead-agency responsibilities will also be carried out at NIST through internal and extramural programs.

External research projects began in the fall of 2008; a dozen have been funded to date, plus two more with American Reinvestment and Recovery Act (ARRA) funds. These projects have all been directed at the high-priority objectives identified in prior planning. Some projects have already published, and the results have been well received; for example, the first two technical briefs, which focused on the design of special moment resisting frames of reinforced concrete and structural steel, have won compliments from practicing engineers as well as university faculty. Projects supporting advancements in technical standards for structural design and for performance-based earthquake engineering demonstrate that NIST is managing its research program to cooperate and coordinate with the other NEHRP agencies.

The four professional researchers added to the NIST staff during the past year and a half have expertise in several key areas of structural engineering. The staff has been effective in defining and procuring NIST's external NEHRP research, and internal research projects on compatible high-priority topics have begun. While it is too early to measure the effectiveness of the internal research at NIST, it is not too early to plan for the future. Examples of statutory responsibilities and strategic plan tasks that have not been met because of a lack of funding include conducting applied research to enhance the effectiveness of seismic safety provisions in model building codes, promoting better building practices among architects and engineers, and working with

national standards developers to improve seismic safety standards for many types of new and existing lifelines.

In light of the substantial changes in the content and format of design standards and model building codes in recent years, the subject of how to most effectively regulate construction to achieve the goals of economical resilience is deserving of a series of coordinated projects, focused on questions such as the following:

- What manner of design and construction provisions are least or most likely to be correctly understood, implemented, or enforced?

- Will special purpose standards (for example, scope limited to a set of smaller building types) be efficient and effective, or simply be ignored in favor of general purpose standards?

- Have current model codes and standards unduly encumbered innovation that could lead to more economical or better resilience?

Some of this work may well fit better within the FEMA Earthquake Program, but the overall effort is clearly within the purview of NEHRP as a whole, and the economics program at NIST could be a key resource if financial support were made available.

The work to assist implementation of cost-effective measures for mitigation of seismic risk involves many technical disciplines, such as structural, geotechnical, and lifeline engineering, and has to be informed by research on communicating risk information and strategies for adopting mitigation policies, such as economic incentives, well-enforced regulations and standards, and insurance. NIST faces a challenge: it must develop sufficient expertise to both conduct the internal research and manage the external component of the research program. This broad competence is also necessary to carry out the mandate to promote cost-effective mitigation. Whether this competence is solely internal or a mix of permanent staff and contracted advisors and consultants should be carefully planned and properly financed. The planning must also take into account the recommendations from the review of national needs for earthquake resilience, currently under way at the National Research Council.

National Science Foundation

ACEHR provides two recommendations for NSF:

- ***Recommendation 1***— Commit to supporting future earthquake reconnaissance, coordination, and outreach efforts and needed additional studies for significant earthquakes occurring throughout the world; provide this support in close coordination with the NEHRP Office. Earthquakes are the primary feedback mechanism available to the earth science, earthquake engineering, and social science communities for understanding the responses of actual systems.

- ***Recommendation 2***—Assess large-scale experimental facilities throughout the United States, along with the equipment sites of the George E. Brown, Jr. Network for

Earthquake Engineering Simulation (NEES), to determine how best to ensure that state-of-the-art experimental capabilities for earthquake engineering are available. Experimental facilities are essential to increasing the resilience of the United States by supporting the development of performance-based design provisions for new construction and assessment procedures for existing infrastructure.

The NEHRP statutory responsibilities and strategic plan tasks assigned to NSF are distributed within the agency's Engineering and Geosciences Directorates. Social behavior and economic science research related to NEHRP is currently housed within the Engineering Directorate. In both Engineering and Geosciences, the research funded by NSF represents a combination of coordinated research programs and unsolicited proposals.

In the past, NEHRP benefited greatly from NSF-sponsored research including the multidisciplinary research programs within the Earthquake Engineering Research Centers and the Southern California Earthquake Center, which provided mechanisms for collaboration within the areas of social science, geosciences, and earthquake engineering. The foundations for many of the achievements identified by ACEHR in the areas of structural earthquake engineering, lifeline engineering, and earth science can be traced directly to these NSF-funded centers. ACEHR believes that such centers provide opportunities to engage broad stakeholder communities in the research mission and develop multiyear visions for increasing community resilience to earthquakes.

NSF has made a significant contribution to NEHRP through the development and operation of NEES and its associated research program. In addition to providing a mechanism for international collaboration, NEES plays a critical role in NEHRP by providing the facilities for large-scale testing of structural components and systems and the data used to calibrate numerical simulations, develop performance standards for new construction, and develop acceptance criteria for existing infrastructure. NEHRP's recent annual reports outline the significant accomplishments that have been made. The recent NSF grant award for NEES operations addresses oversight of the 14 experimental facilities, the network's shared cyber infrastructure, and education, outreach, and training associated with NEES for the second 5 years of operations.

ACEHR believes that state-of-the-art experimental facilities are essential for the development of performance-based design criteria and for achieving the vision of community resilience in the United States; and therefore, are critical to the continued success of NEHRP. Therefore, ACEHR encourages NSF to consider the viability of large-scale experimental facilities throughout the Nation as part of its post-2014 assessment of NEES.

Because damaging earthquakes are rare events, NEHRP and the earthquake engineering community have relied on NSF's support of post-earthquake reconnaissance to provide feedback regarding the actual performance of buildings, infrastructure, and emergency management and recovery efforts. Post-event field observations often lead to funded research projects to support more detailed investigations, and subsequent changes to practice in the United States. Consequently, ACEHR considers post-earthquake reconnaissance activities to be an essential component of efforts to improve community resilience following earthquakes that needs to be

supported by all NEHRP agencies in a collaborative and complete manner. Each agency's support needs to mirror their contribution to NEHRP and NSF has a significant role.

U.S. Geological Survey

ACEHR provides three principal recommendations for USGS**:**

- ***Recommendation 1***—Ensure full implementation of the Advanced National Seismic System (ANSS). Short of this goal as the first step, the Nation will not have a robust national seismic monitoring system to meet critical needs in the fields of emergency management, earthquake engineering, and earthquake science.

- ***Recommendation 2—***Ensure that USGS products are shaped to meet the needs of the engineering community so that products generated under the USGS National Seismic Hazard Mapping Project satisfy needs related to performance-based design.

- ***Recommendation 3—***Strive to convey important earthquake information to the public in an understandable manner, by working with social scientists and other earthquake professionals to enhance both the content and delivery of information. This pertains to communications about time-sensitive probabilities of large earthquakes (including instances of possible foreshocks), aftershock advisories, and authoritative interpretations of earthquake hazards in controversial areas such as the New Madrid region.

USGS is meeting its statutory NEHRP responsibilities in an effective way and is making good progress on achieving relevant objectives and strategic priorities in the NEHRP strategic plan for 2009–2013. It is doing this both through a host of active partnerships and through the professionalism of its own agency staff. Despite NEHRP-specific funding levels widely recognized to be persistently inadequate, USGS is ably accomplishing its first-order NEHRP tasks to (1) provide earthquake monitoring and notification, (2) assess seismic hazards, and (3) conduct research needed to reduce the risk from earthquake hazards nationwide.

Examples of NEHRP implementation activities being carried out by USGS are described in the August 2009 NEHRP annual report, the DOI Budget Justifications and Performance Information for Fiscal Year 2011, and a SESAC summary of its February 2009 meeting in Seattle, Washington. Many of these USGS activities were also described to ACEHR at its meetings in November 2009 and March 2010. The following recent and current USGS NEHRP activities are noteworthy and commendable:

- Use of $29.9 million in ARRA funds to upgrade seismic and geodetic monitoring networks and data processing centers—including $19.2 million for modernizing ANSS infrastructure.

- Expansion of Multi-Hazard Demonstration Projects (MHDPs) in California, the Pacific Northwest, and the Central States (a new MHDP to build resilience in Alaskan coastal communities is planned for FY 2011).

- Activities to improve hazard products and monitoring capabilities in the Pacific Northwest, together with collaborative scientific studies of episodic tremor and slip in the Cascadia subduction zone.

- Progress on developing an earthquake early warning system in California, which now under Phase II (2010–2012) is involving prototype development with test users to determine whether a statewide operational system is feasible in California.

- Release of the next-generation national seismic hazard maps, which are feeding into the building code process, together with the introduction of risk-targeted design maps aimed at achieving uniform risk in terms of a uniform probability across the country of building collapse in 50 years.

To its credit, USGS has successfully engaged diverse stakeholders, including seismologists, engineers, emergency managers, and other varied users of earthquake data and information. Many diverse groups are collaborating with USGS in developing ANSS, as well as in many other aspects of the agency's NEHRP mission. The effectiveness of these collaborations is enhanced by the openness and responsiveness of USGS to advisory groups such as SESAC, the ANSS National Steering Committee, regional ANSS advisory committees, and SCEC, among others.

One objective indicator of USGS effectiveness in relation to government performance criteria is the top rating given to ANSS in 2007, 2008, and 2009 by the Investment Review Board of DOI. Among 60 major information technology investments within DOI, ANSS ranks highest for business value to the mission of USGS and DOI and lowest for implementation and operational risk. That said, only a small fraction of the authorized and required funding for ANSS has been appropriated. Without additional sustained funding, beyond the one-time $19.2 million in ARRA funding, ANSS will not achieve its directive to build a robust national seismic monitoring system and the earthquake professions will miss opportunities to rapidly advance their understanding of the sources of earthquake damage. The NEHRP strategic plan and other reports clearly indicate that major advances in understanding are possible after the next major earthquake IF there are sufficient instrumental records available. At the current rate of ANSS development, these pace-setting records will likely not be available and once-in-a-lifetime opportunities will be lost.

There are other areas where ACEHR believes improvements—or a greater emphasis—can be made by USGS. To advance the goals and objectives of the NEHRP strategic plan for 2009–2013, we encourage more interactions with the earthquake engineering community. In particular, USGS should increase focused interactions with structural engineers so that products generated under the USGS National Seismic Hazard Mapping Project meet their needs related to performance-based design. Also, once efforts have been completed in September 2011 to make improvements to ANSS earthquake monitoring networks with ARRA funding, we urge renewed ANSS attention to the instrumentation of buildings and structures and to how the resulting information is characterized and delivered to meet engineering needs.

Another area deserving attention is how important earthquake information can be communicated to the public so that the information is easily and correctly understood. Near-real-time earthquake information products produced by USGS are a well-recognized success story—

recently highlighted by the rapid delivery of information following the Haiti and Chile earthquakes. However, these same two earthquakes provided examples of how "scientifically correct" statements of aftershock probabilities can be misunderstood, resulting in confusion among the public and inappropriate actions by public officials. Although both earthquakes occurred in foreign countries, the experience is relevant for anticipating similar situations following future large earthquakes in the United States.

Statements of earthquake hazard commonly need to be communicated to the public concerning the probability of a large earthquake in a particular area (for general public awareness and risk management), the probability that an earthquake may be a foreshock to a larger following event, and aftershock advisories. In each of these cases, clarity and "translation" of technical information for the lay person are important. General collaboration among earthquake scientists, engineers, and other earthquake professionals is desirable for planning these types of communications.

ACEHR believes that USGS, together with the earth science community, needs to be more aggressive in communicating to the public an authoritative interpretation of the earthquake hazard in the middle Mississippi Valley. Conflicting views about the seismic potential of the New Madrid seismic zone have confused the public and confounded progress in implementing building codes. For example, local jurisdictions in Tennessee (most notably Shelby County, in which Memphis is located), Arkansas, and Kentucky have adopted the International Building Code without seismic provisions. The Pacific Northwest is another area where USGS needs to promote an authoritative interpretation of the earthquake hazard. Public confusion there has apparently arisen from differing views of the probability of the next Cascadia megathrust earthquake.

Finally, we note that ACEHR is instructed under its charter to consider recommendations of the USGS SESAC in developing its own recommendations. We endorsed and included the latest available recommendations from SESAC to USGS in our 2008 report, and we look forward to receiving future recommendations from SESAC.

Appendix A
Trends and Developments in Science and Engineering

ACEHR is charged to report on new trends and developments related to NEHRP. Time constraints and the size of the committee do not permit this to be an exhaustive treatment of the topic, though the committee's unique composition does permit an expert-based overview. The presentation that follows is organized around the key disciplines that form the earthquake professions and should serve to provide a concise picture of the possible future. Included are both suggested refinements of tasks in the current NEHRP strategic plan and new tasks that should be added to future plans.

Social Science

This section addresses applied research developments in sociology, psychology, political science, economics, organizational management, public administration, public health, and land use planning that are related to seismic risk reduction. The social scientists involved in this work are increasingly shifting their research efforts from emergency response to hazard vulnerability, disaster recovery, and hazard mitigation, but still greater attention is needed in these areas to achieve NEHRP Strategic Plan Objective 3 (Advance understanding of the social, behavioral, and economic factors linked to implementing risk reduction and mitigation strategies in the public and private sectors), Objective 9 (Improve the accuracy, timeliness, and content of earthquake information products), and Objective 13 (Increase public awareness of earthquake hazards and risks).

Developments

NEHRP agencies have supported a significant amount of seismically relevant social science research. This research has primarily been supported by NSF funding, although USGS has supported some applied social science research in connection with seismic hazards at Parkfield and the San Francisco Bay area. NSF has also increased the level of interdisciplinary research through its Engineering Research Centers and through the recent involvement of its Social, Behavioral, and Economic Sciences Directorate in NEHRP-relevant research. In addition, FEMA has recently instituted the QuakeSmart program, which is similar to Project Impact but is more narrowly focused on businesses and has a significantly lower funding level.

As noted by the Committee on Disaster Research in the Social Sciences (2006), NEHRP funding has produced a significant understanding of household, business, and community responses during disasters. This research has resulted in well-substantiated principles for disaster response planning and design criteria for constructing warning messages. In addition, NEHRP research has produced a better understanding of households' and businesses' adoption of mitigation and preparedness actions, but the gains in prediction have been modest. Social scientists have increasingly recognized the diversity of households and businesses and, thus, the substantial variation in disaster impacts that these diverse social units experience. Social scientists have achieved a qualitative understanding of the processes by which communities adopt land use

regulations and building codes, but more research is needed before this knowledge produces practical results. Social science research has begun to validate the effectiveness of pre-impact disaster recovery planning but, here too, more research is needed.

Needs

Recent reports have identified a number of priorities for social science research relevant to seismic risk reduction (CDRSS, 2006; EERI, 2005; SDR, 2005). Six especially important issues and challenges are (a) hazard/vulnerability analysis, (b) hazard mitigation and emergency preparedness, (c) hazard awareness and public outreach, (d) inducements for household and business adoption of hazard risk reduction measures, (e) aftershock warnings, and (f) disaster response and recovery. In addition, there are some broader issues regarding NEHRP agency collaboration.

Hazard/Vulnerability Analysis

Past reports have emphasized the need to better understand the factors that affect or drive societal and community vulnerability to earthquake hazards (CDRSS, 2006; EERI, 2005; SDR, 2005), and this was also emphasized in the 2008 ACEHR report. An increasingly important focus of risk assessment research in the social sciences is on the social impacts of disasters. The major categories of social impacts are psychosocial, demographic, economic, and political effects. A major deficiency in much of the previous research on social impacts has been what might be labeled the *implicit proportionate effects assumption* that ignored the differential distribution of disaster impacts over population segments and economic sectors. In fact, more recent research has shown that some population segments (low education/income, ethnic minorities, female-headed households) and economic sectors (small businesses and those that are reliant on just-in-time processes) are affected more severely than others. Research is needed to better understand these differential impacts. Such research will support the development of compensatory programs designed to reduce the impact of disasters on these segments and sectors, to accelerate their recovery from disasters, and to reduce their long-term vulnerability.

Hazard Mitigation and Emergency Preparedness

Past reports have emphasized the need to better understand the factors that affect the adoption and implementation of hazard adjustments. Recent social science research has made progress in explaining household hazard-adjustment adoption by finding evidence that this process is influenced as much by people's perceptions of a hazard adjustment's attributes (e.g., effectiveness in protecting persons and property, utility for other purposes, and required time/effort, knowledge/skill, tools/equipment, and social cooperation) as by their risk perceptions. To date, there has been no evaluation of household emergency preparedness and hazard mitigation actions to assess their *actual* performance (as opposed to their perceived performance) with respect to these criteria. Such an assessment would allow emergency managers to promote the risk reduction measures that are most effective and also most likely to be adopted by households and businesses.

Hazard Awareness and Public Outreach

Recent reports have emphasized the need to develop a better understanding of risk communication. In past decades, federal, state, and local agencies have conducted a number of hazard awareness and public outreach programs, but few of these programs have been subjected

to systematic evaluation. Project Impact was canceled on the grounds that its effectiveness had not been demonstrated. This was literally true because no comprehensive program assessment had been attempted even though there was substantial anecdotal—and preliminary scientific—evidence of its effectiveness. Scientific evidence of its success might have thwarted efforts to cancel the program. FEMA has recently initiated the QuakeSmart program that targets businesses. This program appears to be quite promising in terms of its effects on hazard mitigation but its outcomes have not been systematically evaluated and an evaluation component does not seem to have been planned. This project is extremely relevant to social science research; FEMA program managers and social scientists would both benefit from collaboration on a systematic program evaluation. Systematic formative and summative evaluations of this and other hazard awareness and public outreach programs could provide valuable information about whether they need to be revised and, if so, what components need to be modified.

Inducements for Household, Business, and Local Government Adoption of Hazard Adjustments

Recent reports have emphasized the need to develop a better understanding of the role of economic incentives, standards, and regulations. Research in these areas is important because hazard adjustments generally require households, businesses, and local governments to make an immediate payment in exchange for an uncertain return. For example, the payoff for hazard insurance premiums is uncertain with respect to both time (When will an earthquake occur?) and amount (How much damage will it cause?). As a result of these uncertainties, households, businesses, and local governments lack the imminent deadline that typically motivates action during emergency response. The ambiguous planning horizon makes people unwilling to make appropriate levels of investment in risk reduction. This underinvestment in risk reduction raises the question of what inducements governments at various levels could offer to supplement risk communication in generating appropriate levels of investment. Specifically, how can local governments more effectively influence households and businesses, how can state governments more effectively influence local governments, and how can the federal government more effectively influence state governments? Research is needed to assess the effectiveness of regulations (building codes and land use plans) and incentive programs (federal disaster reimbursement policies, such as increases in the federal share of disaster response and recovery expenditures) at the point of actual *implementation*, not just jurisdictional *adoption.*

Aftershock Warnings

Warning is an important type of risk communication on which social scientists have conducted a substantial amount of research. Warning research has identified four critical topics that need to be addressed in constructing effective warnings—a description of the hazard, geographic areas and population segments at risk, recommended protective actions, and sources to contact for further information and assistance. Nonetheless, hazard assessment personnel often violate these warning message design criteria when communicating to public officials and risk-area residents. Thus, research is needed to identify the reasons why the warning message design criteria are not being used. Moreover, there are some situations in which risks need to be balanced against the benefits of certain actions such as entering buildings containing valuable supplies. In such cases, decision protocols need to be developed to support decision processes.

Disaster Response and Recovery

There is an increased recognition that government agencies could take much longer than the current expectation of 72 hours to reach all households and businesses after a major urban earthquake. Thus, further research is needed to assess what people can do, or can be trained to do, within the immediate emergency response period before trained professionals arrive. One specific need is for self-assessment (or perhaps Community Emergency Response Team assessment) of home safety to determine if continued occupancy is safe. In addition, there is a critical need for an assessment of temporary housing needs after a major urban earthquake. There have been only modest housing problems after disasters in which there were high vacancy levels, but problems were significant for vulnerable populations after the Loma Prieta earthquake and were quite severe for the entire population after Hurricane Katina. More needs to be known about the voluntary or forced mobility of different population segments after disasters and the actions that are needed at the local, state, and federal levels to prepare for post-disaster temporary housing.

Broader Issues Regarding NEHRP Agency Collaboration

NEHRP agencies have made significant achievements in the area of social science research but the level of achievement is unevenly distributed over these agencies; more coordination among them is desirable and feasible. Specifically, NEHRP should develop improved mechanisms for collaboration between NSF and the mission agencies (FEMA, NIST, and USGS) to link the mission agencies' social science research needs (especially program evaluations) with the social science research capabilities available through NSF. This would only be an extension of NSF's past efforts rather than a completely new activity because NSF has previously supported collaborative research with agencies such as the Department of Transportation and the National Oceanographic and Atmospheric Administration.

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Earth Science

This section addresses aspects of earthquake seismology, strong-motion seismology, and developments in associated programs relevant to NEHRP. The knowledge, tools, and practices in this arena overlap science and engineering—especially relating to design ground motions, where scientists and engineers work closely together. They also overlap science and emergency management.

Seismologists currently emphasize three basic approaches to meeting societal needs for earthquake loss reduction: (1) monitoring, analysis, and mapping of seismic hazards; (2)

predicting the severity of future ground shaking for design and scenario planning; and (3) rapid post-event alerting together with relevant information products. At the same time, there is vigorous research aimed at the following: integrating seismology, geology, geodesy, and fault mechanics to develop a comprehensive physics-based understanding of earthquake phenomena; achieving capabilities for earthquake *forecasting*, based on rigorous statistical studies of space-time patterns of earthquake occurrence; and developing reliable methods for providing *earthquake early warning* (real-time alerting once an earthquake is in progress and before energetic seismic waves arrive).

Developments

Achievements and developments in earth science relevant to NEHRP goals are highlighted, among other places, in the August 2009 NEHRP annual report for FY 2008; a summary of the February 2009 meeting of SESAC, which was provided to ACEHR at its November 2009 meeting; USGS Budget Justifications and Performance Information for FY 2011; NEHRP agency reports at ACEHR's November 2009 and March 2010 meetings; and NSF's EarthScope Science Plan for 2010–2020. Based on these summaries and ACEHR observations, the following are noteworthy:

ARRA Funding for ANSS and Other Seismic and Geodetic Monitoring Networks

A total of $29.9 million in ARRA funds, allocated to USGS, is being used to upgrade seismic and geodetic monitoring networks and data processing centers, including $19.2 million for modernizing ANSS infrastructure. Significantly, ARRA investments in ANSS for strong-motion monitoring (nonstructural) include (a) adding at least 135 NetQuakes accelerographs in urban areas, (b) upgrading analog and other outdated accelerographs at 50 USGS National Strong-Motion Project urban strong-motion stations, and (c) either adding (115) or upgrading (38) 153 free-field strong-motion monitors throughout the United States—for improved ShakeMap coverage and for near-fault strong-motion recording—at strategically selected broadband and short-period stations operated by ANSS regional partners.

Episodic Tremor and Slip

Episodic tremor and slip (ETS) is a remarkable, recently discovered geophysical phenomenon, operative in various subduction zones around the world, that involves non-volcanic tremor (which can be recorded seismically) and associated deep, episodic aseismic slip events (which can be measured with GPS observations). Deep episodic tremor has also been found beneath the San Andreas fault in central California. Collaborative studies of the Cascadia subduction zone in the Pacific Northwest, being carried out under both USGS-NEHRP and NSF-EarthScope programs, are yielding high-resolution data and abundant new insights relevant to understanding the loading of stress on the plate interface and to estimating ground motions expected in Seattle from a Cascadia megathrust earthquake like the February 2010 magnitude 8.8 earthquake in Chile.

Multi-Hazards Demonstration Projects

For a fifth year in 2011, the USGS Earthquake Hazards Program will continue its MHDP in southern California, building on the phenomenal success of the November 2008 Great Southern California Shakeout—the Nation's largest ever emergency response and public preparedness exercise, which involved more than 5.5 million participants. A rupture scenario for a magnitude

7.8 earthquake on the southern San Andreas fault and animated ground-motion maps were key elements of the exercise. In 2009 USGS began extending MHDP activities to the Pacific Northwest and to the middle Mississippi Valley of the central United States, ahead of the 200th anniversary of the large 1811–1812 earthquakes in the New Madrid seismic zone.

New Generation of National Seismic Hazard Maps

USGS, working in conjunction with earthquake engineers associated with the Building Seismic Safety Council (sponsored by FEMA), has produced a new generation of national seismic hazard maps for use in earthquake-resistant design of structures that are not strictly expressions of hazard, but integrate the fragility of common construction. Risk-targeted design maps derived from the new seismic hazard maps are feeding into the ASCE 7-10 standard in 2010 and the 2012 edition of the International Building Code. The motivation for producing the risk-targeted maps is that designing for uniform-hazard ground motions (e.g., 2% probability of exceedance in 50 years) does not result in uniform risk in the sense of uniform probability of collapse in 50 years.

Ground Motion Prediction Modeling, Seismic Hazard Analysis, and Design

An important development for ground motion prediction modeling, as well as for probabilistic seismic hazard analysis and earthquake engineering design, was the publication in 2008 of the Pacific Earthquake Engineering Research Center (PEER) Next Generation Attenuation (NGA) models for shallow crustal earthquakes in the western United States. Now, with funding from the U.S. Nuclear Regulatory Commission (USNRC) and in collaboration with USGS and national experts, PEER has started a follow-up project to develop Next Generation Attenuation relationships for the central and eastern United States (NGA-East). This project is part of a major thrust by the electric utility industry, the U.S. Department of Energy, and the USNRC to update probabilistic seismic hazard analyses throughout the Central and Eastern States for nuclear facilities. Under this collaboration, a comprehensive project being managed by the Electric Power Research Institute is under way (2008–2011) to update seismic source characterization throughout this region.

Earthquake Early Warning

In recent years, significant progress has been made outside of the United States in the development of earthquake early warning systems designed to provide alerts ahead of the arrival of strong shaking in heavily populated areas. Such systems are currently operational in five countries (Japan, Mexico, Turkey, Italy, and Romania) and are under development in six others (Taiwan, Iceland, Switzerland, Greece, Egypt, and the United States). In the United States, under USGS auspices, a 3-year algorithm-testing phase (2007–2009) was completed to develop a prototype statewide earthquake early warning system in California. A second phase (2010–2012) of user development has started, aimed at demonstrating whether an operational system is feasible in California.

Trends and Challenges

Social Networking and the Engagement of Young People

New media channels such as YouTube, podcasts, and Facebook were prominently used in the Great Southern California ShakeOut, and a lively 4-minute “Preparedness Now” video was prepared by the Pasadena Art Center College of Design. According to a report in *Newsweek*

magazine (March 15, 2010), three quarters of *millenials* (those 29 or younger, described as "the first truly digital generation") have created a personal profile on Facebook or some other social-networking site. The challenge: NEHRP participants who are *baby boomers* (those now 46 to 64) and *Gen Xers* (30 to 45) will need to recognize these new communication patterns among young people and find new approaches for engaging them in earthquake awareness and preparedness.

Large-Scale Earthquake Exercises and Lessons Learned

The November 2008 Great Southern California Shakeout has been heralded as a "flagship" model for other regional-scale earthquake exercises. Some of the lessons learned (see February 2009 SESAC report) emphasize the challenges of preparing for a future large earthquake in the United States—for example, the importance of providing real-time feeds to new digital map display screens at emergency operations centers as well as hard copies in the field where responders do not have computer access; increased interactions with utilities and first responders; improved earthquake monitoring systems; and broader use of ShakeCast and related products for rapidly distributing earthquake information.

Twitter-Based Earthquake Detection System

An innovative example of using social networking in NEHRP is USGS's Twitter Earthquake Detection (USGSted) project, which uses the Twitter platform to collect real-time earthquake-related messages. Twitter reports can come out of an epicentral area faster than existing earthquake detection and reporting systems, and such alerts can be valuable in sparsely instrumented regions. Another potential new tool for situational awareness is the use of accelerometers in smart phones to densify data on ground shaking in urban areas (a USGS-funded pilot project is under way). The challenge: Handling an abundance of data from non-traditional sources will require new ways to sort out intelligence and useful information from "noise."

Large Earthquakes and Earthquake Information Products

Data products provided in near-real time such as ShakeMap, ShakeCast, Prompt Assessment of Global Earthquakes for Response (PAGER), and Did You Feel It? have been greatly successful in serving user needs for rapid earthquake information and situational awareness. Combining earthquake information with Google™ mapping tools is also becoming commonplace. Research is under way to extend PAGER capabilities beyond population exposure to provide quantitative estimates of damage, fatalities, injuries, and displaced populations. (Note: Development of "Loss" PAGER is intended to supplement, not replace, HAZUS-MH.) The key challenge will be ensuring that, when the next large U.S. earthquake occurs, critical earthquake information products are successfully delivered—as the public fully expects.

EarthScope Contributions to Identifying and Assessing Earthquake Hazards

NSF's EarthScope program is a non-NEHRP (but related) activity that is making major contributions to understanding the geophysics, tectonics, and continental dynamics of North America, and providing high-resolution data sets together with new data processing and distribution capabilities. Seismic arrays (USArray, the Transportable Array), continuous GPS measurements (PBO), and satellite radar information on surface deformation (InSAR) are all contributing to identifying and assessing earthquake hazards. The challenge for NEHRP is to achieve, where feasible, greater coherence and synergy between NSF (fundamental research)

programs and USGS (applied research/mission) programs—particularly in NEHRP strategic planning for seismic and geodetic monitoring.

Demographics of the NEHRP Workforce

SESAC reports in April 2008 and February 2009 called attention to an aging workforce within USGS—a problem affecting other NEHRP agencies as well. Employees occupying half of the 147 permanent full-time-equivalent positions (FTEs) in the USGS Earthquake Hazards Team are currently retirement eligible; in 5 years, 60 percent will be eligible. Among the 129 permanent FTEs in the USGS Geologic Hazards Team, about 42 percent of team members have been hired within the last 6 to 7 years. In order to continue performing mission-critical tasks, the challenge is to maintain workforce capabilities in NEHRP through aggressive recruitment and training—and to manage budget levels that are eroding workforce strength.

Needs

Using the NEHRP strategic plan for 2009–2013 for guidance, ACEHR has identified at least four earth-science-related areas in which continued attention or increased emphasis by the NEHRP agencies is warranted:

Full Funding of ANSS

Full funding of ANSS continues to be a compelling NEHRP need. The ability of USGS and its regional partners to provide real-time earthquake data and products that enable rapid and efficient local, state, and federal response is dependent on the continued building of ANSS and on funding that can not only sustain operations but also build a system resilient enough to withstand disruptive impacts (disruption of seismic monitoring within Chile by the recent magnitude 8.8 earthquake is a case in point). Progress in engineering seismology is being hindered by the sparseness of strong-motion recording systems throughout the Nation, and more strong-motion instrumentation in buildings and structures is needed for improved engineering evaluation and design.

Meeting Needs of Earthquake Engineers for Performance-Based Design

In an earlier section, we noted the development of a new generation of national seismic hazard maps, including risk-targeted design maps. The basis for the new maps needs to be communicated across the earth science and engineering professions. Increased interactions are needed between USGS and structural engineers to meet needs related to performance-based design. Engineers, for example, need enhanced characterizations of ground shaking such as two- and three-dimensional characterizations of ground motion, liquefaction, and other forms of ground failure.

Clearer Communication of Important Earthquake Information to the Public

Objective 13 in the NEHRP strategic plan for 2009–2013 has the desired outcome of "Increased public understanding of earthquake safety issues, including earthquake forecast statements." ACEHR believes that greater attention needs to be paid to how important earthquake information is communicated to the public—with help from social scientists—so that the information is easily and correctly understood. Communicating the probability of a large earthquake in a particular area, the probability that an earthquake may be a foreshock to a larger following event, and aftershock advisories are all cases in which clear communication to the public is desirable.

More Aggressive Communication to the Public of Authoritative Interpretations of Earthquake Hazard in the Central United States and the Pacific Northwest

Conflicting views about the seismic potential of the New Madrid seismic zone have confused the public and confounded progress in implementing seismic building codes. USGS, together with its NEHRP partners and the earth science community, needs to be more aggressive in establishing a consensus view of the informed technical community about the earthquake hazard in the central United States and in communicating that view to the public as an authoritative interpretation. Similar efforts are needed to establish and communicate authoritative probability statements about the expectation for a Cascadia megathrust earthquake in the Pacific Northwest.

Geotechnical Earthquake Engineering

Geotechnical earthquake engineering is traditionally placed between the disciplines of earth science and structural engineering, although it interfaces with all earthquake-related disciplines given its breadth. As a result of the geotechnical engineering profession's placement and its size relative to earth science and structural engineering, its true impact on earthquake resilience can be underappreciated at times. However, advancements in earthquake resilience require incorporation of important geotechnical effects of earthquakes, such as surface fault rupture, seismic site effects, liquefaction, seismic instability, and soil-foundation-structure interaction. As the criticality of a multidisciplinary approach to addressing earthquake hazards (as well as other hazards) is recognized, geotechnical engineering as a natural linkage between disciplines can provide a critical path forward in increasing earthquake resilience.

Developments

The important effects of local ground conditions on earthquake ground motions are now widely appreciated and incorporated in the International Building Code (IBC). Liquefaction is also widely recognized as a critical hazard affecting safety and resilience, and liquefaction triggering procedures are fairly well established for many soils. Potential seismic slope-instability hazards are mapped by several state geologic surveys, and dam/waste regulatory agencies have established comprehensive evaluation procedures. Geotechnical engineers have led the development of quantitative, GIS-based documentation of the effects of earthquakes.

Needs

Significant challenges remain, however, in geotechnical earthquake engineering and related professions. Earthquake science and engineering should grow more interconnected and interdisciplinary. NEHRP can shepherd this emerging trend. Geotechnical engineering needs to be an integral part of multidisciplinary seismic research. Although NIST's establishment of an extramural applied-research program fills a critical gap between NSF-funded basic research and the implementation of earthquake risk-reduction measures, the NIST program should include the effective transfer of geotechnical engineering knowledge.

The broader goal of sustainability requires that earthquake resilience issues be addressed. For example, levee and flood protection system reliability, including their seismic performance, must

be addressed by the Nation. Resilience can be achieved through the use of innovative mitigation techniques, such as those for liquefaction.

Improved hazard maps for ground failure and methods for characterizing the magnitude and distribution of ground movements triggered by earthquakes are needed. Better methods are needed for predicting liquefaction impact on geographically distributed systems. The triggering of liquefaction or ground softening in silty and clayey soils requires greater understanding, and engineers require improved tools for evaluating the consequences of liquefaction. Robust analytical procedures have been developed for predicting ground deformation and characterizing structural response to ground movements. Research facilities, such as NEES, can be employed to clarify ground movement and soil-structure interaction for practical purposes. In particular, the profession lacks clear guidance on the potential impact of soil-structure interaction on building performance and of soil-water-structure interaction on earth dam and levee performance.

High-end computing coupled with enhanced visualization software is transforming the manner in which we evaluate seismic performance. Practicing engineers require critical assessments of these sophisticated computational tools to ensure that reliable results are produced. Realistic modeling of earth particles, interfaces, and discontinuities remains an important need. Supporting efforts need to continue toward characterization of geo-material properties and the uncertainty inherent in any seismic problem. Field and laboratory experiments are required to advance earthquake science and engineering through innovative site and material characterization technologies. The geotechnical information collected following earthquakes should be archived as well and made available to researchers, engineers, planners, and emergency responders. Incorporation of advanced technologies and imaging techniques, such as Light Detection and Ranging (LiDAR), in post-earthquake reconnaissance can strengthen the lessons that the profession can glean from future earthquakes.

Performance-based earthquake engineering requires consensus methods for selecting and scaling ground motions to represent the seismic hazard at a project site and quantitative data that translates calculated engineering responses into damage and then deaths, dollars, and downtime. Without full implementation of ANSS, the spatial variability of ground shaking due to local geology cannot be refined or utilized optimally in post-earthquake emergency response. Geotechnical structures, including downhole arrays, should be better instrumented. Improved models of ground shaking near faults and in the eastern and central United States are required. The seismic response of IBC 2006 Site F soils requires better characterization. Owners should be motivated to better understand the special nature and needs of their project and engage engineers to design for the desired level of performance according to a site-specific hazard assessment. While NEHRP should advance building codes, the program should also advance tools that move the profession toward true performance-based design.

Structural Earthquake Engineering

Recent developments in structural engineering include efforts to develop performance-based seismic engineering and methods to develop tools for health monitoring and rapid assessment of structural condition following earthquakes.

Performance-based engineering comprises two primary parts: (1) the development of practical and reliable means of predicting the probable behavior of buildings and structures in earthquakes and the effects of this behavior at the local, regional, and national levels; and (2) the development of design methodologies and technologies that can effectively control and limit earthquake damage and consequences in both new and existing structures.

Following earthquake disasters, local and regional agencies have a need to identify those buildings and structures that are safe for continued occupancy and for use as centers for recovery, as well as those structures damaged to an extent that renders them unsafe or otherwise unusable. In the past, assessment of structural condition could be conducted only through the efforts of individual engineers with the knowledge and skills to rapidly assess damage and make reliable judgments as to structural condition. In a large disaster, such as a major earthquake affecting a city like Charleston, Los Angeles, Memphis, Seattle, San Francisco, or Salt Lake City, thousands of buildings and lifeline structures will be affected. There are not enough sufficiently trained engineers or government officials to perform the needed assessments in a rapid manner. Failure to identify safe, useable, and unusable structures places citizens in affected regions at risk and hinders the ability of government to marshal the resources necessary to speed aid to the affected region. Tools for health monitoring and rapid assessment of a building's structural condition are an important development in addressing this issue.

Developments

The ability to predict before an earthquake occurs how individual buildings and structures, as well as entire portfolios of buildings and structures, will behave is essential to any program intended to increase the Nation's earthquake resilience. Without this capability, it is impossible to understand the risks or to effectively allocate resources to mitigate these risks. Twenty years ago, such performance assessments could be made only by a very few expert engineers who had the knowledge and judgment to effectively perform this task. These experts were far too few in number to permit consistent, widespread, and routine assessment of the risks.

The development and introduction of HAZUS over 10 years ago provided the capability to realistically assess earthquake risks at a community level, but did not provide engineers with the ability to reliably predict the likely performance of individual structures. Work undertaken at the three earthquake engineering research centers formerly supported by NSF began to provide engineers with the tools needed to reliably predict the performance of individual buildings and structures in terms of the likely damage and, more importantly, the human, economic, and societal losses resulting from this damage. This work has been extended by the FEMA-sponsored ATC-58 project, Development of Next-Generation Performance-Based Seismic Design Procedures for New and Existing Buildings. The first phase of this project is to develop a performance assessment methodology, which will be accompanied by the Performance Assessment Calculation Tool (PACT). The 75 percent draft of this phase is due to be completed

in 2010 with final project completion due in 2011. This methodology and accompanying calculation tool will be available for use by practicing professionals to assist in their design process and for use by academia for future research ideas and as a teaching tool.

Many other important projects have been developed by NEHRP agencies in the past 5 years that are providing structural engineers with a better understanding of the likely seismic performance of buildings and structures or are providing guidance for the proper seismic design of building systems or components. The following list highlights several of these efforts:

- FEMA developed and published *Quantification of Building Seismic Performance Factors* (FEMA P695) and, with support from the National Oceanic and Atmospheric Administration, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis* (FEMA P646).

- NIST inaugurated its ongoing series of NEHRP TechBriefs, produced through the NEHRP Consultants Joint Venture, by publishing *Seismic Design of Reinforced Concrete Special Moment Frames: A Guide for Practicing Engineers* and *Seismic Design of Steel Special Moment Frames: A Guide for Practicing Engineers.*

- NSF supported the operations of the George E. Brown, Jr. Network for Earthquake Engineering Simulation, as well as research projects utilizing the network's experimental facilities and cyberinfrastructure.

- USGS issued the next generation of its U.S. National Seismic Hazard Maps, which have been incorporated into the 2009 edition of the *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures* (FEMA P-750), into the ASCE/SEI 7-10 standard, *Minimum Design Loads for Buildings and Other Structures*, and into the 2012 edition of the International Building Code.

- USGS and NSF supported targeted and directed structural earthquake engineering research.

Once earthquake risks to society have been identified, it is essential that engineers have cost-effective construction technologies capable of limiting damage to acceptable levels if these risks are to be effectively controlled. Twenty years ago, seismic isolation and passive energy dissipation technologies were known and available but proved to be prohibitively expensive to implement in many structures. Structural engineering researchers have focused much attention in recent years on the development of alternative damage-resistant structural systems that are more economical to implement. Some noteworthy success has been achieved, including the development and adoption by building codes of buckling-restrained braced steel frames and precast-hybrid concrete frames, both damage-resistant systems. In addition, new methods of constructing traditional structural systems and components are becoming available, providing the capability to design and construct a more damage-resistant, resilient community. Perhaps equally important, researchers are also developing methods to reduce risk associated with a variety of nonstructural components and systems, including storage racks, ceiling systems, interior partitions, and electrical distribution and piping systems. This is particularly important because

most of the economic losses associated with recent U.S. earthquakes have resulted from nonstructural rather than structural damage.

Trends and Challenges

Over the past 10 years, the use of performance-based seismic engineering in the design of new buildings and rehabilitation of existing buildings has become more commonplace, especially for high-profile projects. Typically, however, the performance goals for the majority of these projects are based on the code-specified, life-safety level. This deterministic approach to performance, to date, has not been able to take advantage of the probabilistic approaches that are currently being developed through FEMA-sponsored research (e.g., the ATC-58 project Development of Next-Generation Performance-Based Seismic Design Procedures for New and Existing Buildings).

The use of performance-based seismic designs for new buildings has led to the adoption of "prescriptive" performance-based design requirements in jurisdictions such as San Francisco and Los Angeles, requirements that are intended to produce buildings that will respond, as a minimum, in a life-safe manner given design earthquake ground motions occurring at the site. In addition, the PEER-sponsored Tall Building Initiative, along with funding from the Pankow Foundation and California's Seismic Safety Commission, is preparing guidelines for the design of tall buildings using a performance-based seismic engineering approach.

ASCE-31 and ASCE-41 are the standards that are used in the seismic evaluation and rehabilitation of existing structures. The documents utilize discrete, deterministic performance goals for a variety of earthquake hazard levels. In general, these performance goals are similar to those associated with the design of new buildings.

With the development of the upcoming probabilistically based, performance-based seismic assessment and design procedures for new and existing structures, the metrics for designing new buildings and rehabilitating existing buildings for earthquake resistance will change and will allow for reliable means of predicting the probable behavior of buildings and structures in terms of repair costs, repair times, and casualties. With this new approach, goals for resilient structures, specified in terms of these metrics, will be able to be reliably formulated.

Needs

Substantial additional work is needed to enable effective implementation of the performance-based engineering procedures that are described in the NEHRP strategic plan and needed to achieve resilient structures. Significant needs include the following:

- Development of fragility and consequence functions for the many types of structural systems and nonstructural components found in buildings and structures so that the performance of new and existing buildings and structures, and the losses associated with their performance, can be accurately predicted.

- Development of reliable means of predicting structural collapse so that existing structures that are truly hazardous can be identified and so that new structures can be reliably designed to protect, as a minimum, life safety.

- Continued development of performance-based engineering tools that will enable engineers and other design professionals to reliably assess structural performance and design buildings and structures for improved performance.

- Development of quantifiable performance definitions and goals and an associated building rating system to support development of resilient communities.

- Development of practical and effective structural systems that can be used to minimize damage and loss in both new and existing structures that are focused on achieving resilient designs.

- Quality control and quality assurance in design and construction to achieve resilient structures.

- Development of tools that will enable the data generated by ANSS and privately owned health monitoring instruments in buildings to be instantaneously collected, processed, and interpreted to make rapid assessments on structural condition.

- Seismic monitoring of buildings.

- Education of the professional design community so that they can effectively use these new performance-based seismic engineering and health monitoring and assessment tools.

- Increased collaboration between the structural engineering and seismological communities regarding the likely earthquake hazards and earthquake ground motions affecting the design and construction of the built environment.

Building Codes and Quality Assurance

One of the most effective ways to improve earthquake safety is to ensure that buildings are constructed according to current national standards. A substantial majority of fatalities and injuries from earthquakes are due to the failure of buildings. A resistant building stock mitigates the initial damage, minimizes harm to people and property, speeds a community's recovery, and conserves resources. In 1999, FEMA Director James Lee Witt stated "When disaster strikes, no matter where or how, building codes, and local code officials, are America's first line of defense against tragedy...Communities that recognize the life-or-death consequences of building codes pick up the pieces and recover from disasters while communities that shirk those codes wallow in the damage for months and years."

Authority for regulating building construction remains with the states; therefore, such construction is regulated by state and local governments. There is no mandatory national building code, but there is an established mechanism for getting strengthening provisions into national model building codes, and these model codes can be adopted by states and localities. For almost a century, model building code development and adoption has been an effective

mechanism for transferring research into implementation and for enabling state and local entities to remain current in addressing specific hazards that are capable of producing disasters.

Developments

For the past four decades NEHRP has been working, along with the structural engineering community, within the model code system to improve seismic performance criteria for new buildings.

In the spring of 2000 the IBC and International Residential Code (IRC) were published by the International Code Council as a collaborative effort by the three leading model building code organizations in the United States. The NEHRP Recommended Provisions served as the basis for the seismic regulatory code language in the first editions of the IBC and IRC (I-Codes); this resulted from the participation of FEMA and USGS in the council's code development process.

The substantial advantages of a nationally consistent set of code requirements are clear. A single set of comprehensive codes allows for the conservation of industry resources and a uniform approach to the education of architects, engineers, trades workers, and construction code and fire prevention officials. It eliminates trade and design barriers stemming from contradictory regulations and promotes better constructed buildings through consistent inspections and improved regulatory administrative processes. The hope was that, through a unified code-development process, issues surrounding construction regulation would have a single forum for discussion, consideration, and resolution, which would facilitate more effective public-private partnerships at all levels of government.

Since the establishment of the IBC and IRC those codes have achieved dominance as the basis for construction regulation in the United States. The three founding model code organizations have consolidated, providing a strong advocacy base. NEHRP recommendations continue to be incorporated into the new editions of the I-Codes and the ASCE 7 structural reference standard. Furthermore, code training for all construction professionals has increased dramatically, and building inspector certifications are at an all-time high.

Trends and Challenges

Adoption and Enforcement

While the contemporary model building code has been adopted in every state to some extent, state and local adoption is neither universal nor comprehensive. There is enormous diversity in the way codes are adopted in the United States, from full attainment, to limited adoption, to marginal enforcement, to areas that strip out disaster-resisting provisions, to smaller communities that have no effective building code.

The best code in the world is of little use if it is not adopted and enforced by well-qualified inspectors. The most successful way to ensure that buildings are actually constructed according to the code and per their engineered plans is through the use of competent public officials with sufficient resources to do thorough and accurate inspections as well as skilled structural plan reviews.

Creating earthquake-resistant buildings is a long-term proposition. It is a wasted opportunity if we do not insist that all new buildings are constructed in ways to limit future damage and conserve resources. Code-compliant new buildings can be constructed at minimal additional expense while providing considerable enduring benefits.

Even when its incremental cost is extremely low, a major challenge facing earthquake-resistant construction in some areas is the resistance of local developers to any added expense for strengthening new buildings due to the short duration of developers' financial exposure. Understandably, a developer's goal is to turn over a project as quickly as possible for an appropriate financial gain. Unfortunately, there are those who will sacrifice the long-term benefit for the short-term profit in order to make projects feasible. Obviously, local elected officials support development because of its contribution to a community's economic well-being. Unfortunately, due to a lack of political will or inadequate understanding of the long-term risks involved, many local governments fail to embrace disaster-resisting regulations that can protect against future vulnerability and loss of the economic stimulants they are seeking.

Performance-Based Codes—The Next Generation

The intent of the IBC is "to establish the minimum requirements to safeguard the public health, safety and general welfare…and safety to life." While modern codes do a good job of saving lives and preserving certain essential facilities, they are not intended to ensure that most buildings will be usable after an earthquake. Many code-compliant buildings will save lives, but may not remain operational during repair or will need to be demolished after a large earthquake. These code limitations are beginning to be addressed through the valuable work being done in the area of performance-based design, which is discussed in the Structural Earthquake Engineering section of this appendix.

Needs

Quality Control

Because building codes are a state and local issue, there need to be powerful incentives for those who do not currently support a strong code and enforcement philosophy. Consider the following ideas:

- FEMA currently ties part of the recovery money for a federally declared disaster to preparedness and mitigation. The possibility of including building code compliance as a criterion for reimbursement should be investigated.

- An insurance program patterned after the National Flood Insurance Program (NFIP) could be effective. There are existing evaluation services available such as the Insurance Services Office (ISO) Building Code Effectiveness Grading Schedule (BCEGS) or the International Accreditation Service (IAS). Also, some insurance companies provide discounted rates to the private sector based on the ISO-BCEGS. This practice should be encouraged and expanded.

Migration of Basic Construction Requirements

A recent trend has been to move construction requirements from the text of building codes to multiple reference standards. Regrettably, the effort has moved some indispensable elements out

of the latest editions of the codes. The requirements are technically incorporated into the building code through reference standards that are used extensively by structural engineers for building design. However, certain basic details critical for seismic-resistant construction do not appear in the base code or customarily on the engineered drawings for smaller commercial and multi-family buildings. Construction inspectors generally keep a building code with them for ready reference, but many important requirements will not be found in the book they keep in their vehicle. When building inspectors are required to search numerous standards for basic requirements, the enforcement of these types of details becomes extremely cumbersome, less effective, or even overlooked. In addition, certification testing for building inspectors is based only on the building code because it is impractical to test to all of the various reference standards. Today it is possible to become a certified building inspector with no knowledge of basics like concrete reinforcement detailing or suspended ceiling bracing for areas of high seismic risk.

If the goal is to have buildings comply with seismic-resistant regulations, the last line of defense is the local inspector who ensures that the engineer's design and seismic-resisting elements are correctly incorporated into the actual construction. It is extremely important that inspectors have ready access to basic requirements which do not appear in the latest editions of building codes or building plans. Gaps need to be identified and prescriptive field inspection requirements need a home in the building codes.

Existing Structures

Existing buildings present additional challenges. Every community will have some older buildings that are not constructed to modern codes. It may not be practical to retrofit all existing structures in disaster-prone areas, but essential buildings and those that represent a substantial hazard must be analyzed and strengthened. There are a number of good standards available for voluntary strengthening of existing buildings. However, we must continue to search for ways to lower the cost and provide incentives if significant improvements are to be made. Tax credits like those offered to improve energy conservation should be considered to encourage improving seismic performance.

Lifeline Earthquake Engineering

Lifelines provide the networks for delivering resources and services necessary for the economic well-being and security of modern communities. They are frequently grouped into six principal systems: electric power, gas and liquid fuels, telecommunications, transportation, waste disposal, and water supply. Since Hurricane Katrina, there has been increasing attention given to regional systems of levees and floodwalls as important lifelines. Examples include work to evaluate and remediate the earthquake vulnerability of levees in the Sacramento River delta. Taken individually, or in aggregate, lifeline systems are essential for emergency response and restoration after an earthquake, and are indispensable for community resilience.

Developments

Lifelines have received increasing attention with respect to national security. For example, the National Infrastructure Protection Plan includes 18 different sectors of critical infrastructure that

include or are directly related to the lifeline systems traditionally studied under NEHRP. Emphasis has been placed on the development of high-performance computational models that simulate the regional response of complex networks. For example, the Great Southern California ShakeOut, which was the largest earthquake preparedness drill in U.S. history, examined the consequences of a magnitude 7.8 earthquake on the southern San Andreas fault through a variety of computational models. Earthquake impacts on water supplies, energy generation and delivery systems, and transportation networks were an important part of the exercise. Over half of the fatalities and a substantial part of the $210 billion in economic losses arising from the scenario earthquake resulted from fires that were exacerbated by lack of water in damaged water distribution systems.

A multiyear study has been undertaken by the National Infrastructure Simulation and Analysis Center under the DHS Office of Infrastructure Protection of the impact of a major earthquake in the New Madrid seismic zone. The study includes damage to lifeline systems and the interdependencies among various systems, with assessments of electric power outages, transportation network disruptions, and degradation of natural gas and petroleum/refined products supply systems. Complementing such regional studies are assessments of system-wide earthquake performance undertaken by water utility companies, including the East Bay Municipal Utility District, Los Angeles Department of Water and Power, and the San Francisco Public Utilities Commission, as a basis for planning and rehabilitation of their systems. These assessments have used advanced system simulations and seismic hazard characterization using the results of NEHRP-supported research and development programs.

Significant research in lifeline and geotechnical earthquake engineering has been accomplished at large-scale and centrifuge testing facilities. Examples include the large-scale and centrifuge experiments currently under way at NEES, as well as shake-table and full-scale tests carried out at various universities, including those supported by the NSF-supported earthquake engineering research centers. With NEES support, there has been consistent, systematic research to evaluate lifeline facilities at full scale to understand better and quantify the seismic performance of bridges and electrical components and the soil-structure interaction of underground pipelines.

Substantial emphasis has been placed on electric power systems by the American Recovery and Reinvestment Act, with $4.5 billion directed to development of the smart grid. At the same time, initiatives have been undertaken to enhance renewable energy through wind and solar contributions to the U.S. electric power system, with legislation passed in many states to achieve 20 percent of electric power through renewable energy within 10 to 20 years. The broad changes under way for U.S. electric power raise questions with respect to system resilience, particularly the effects of increasing reliance on renewable energy sources. There are significant opportunities for using the distributed intelligence of the smart grid to make better decisions about the locations of potential damage and the optimal restoration of post-earthquake power.

Trends and Challenges

Both the vulnerability assessments and analytical procedures developed for lifeline earthquake engineering are being applied to other hazards, including natural hazards and human threats. Studies of lifeline system response to the World Trade Center disaster emphasize the remarkable degree of interdependence that exists among lifeline systems. The investigation of lifeline

interdependencies has been a cornerstone of NEHRP-based research and modeling. Because of the cascading effects that can result from lifeline disruption, local lifeline damage can rapidly expand to have a regional, a national, and even an international impact. Examples include the disruption of the New York Stock Exchange due to the loss of telecommunications and electricity after the World Trade Center disaster and the impact of Hurricane Katrina on the U.S. petroleum and natural gas delivery infrastructure affecting the worldwide cost of both commodities.

Since Hurricane Katrina, there has been growing emphasis on developing hazard-resilient communities. NEHRP-supported programs have led the way to understanding and planning for the disruption of critical lifeline services and to providing important tools and modeling procedures for multi-hazard applications. Notable accomplishments include models for the economic and community consequences of earthquake damage and the integration of these models to predict indirect economic losses and community disruptions on a regional basis.

Because of the enormous national security implications of electric power systems, ports and harbors, oil and natural gas delivery systems, water supplies, and telecommunications, it is important to ensure that best practices are being implemented and that the vulnerabilities associated with the interdependencies among different lifeline systems are being corrected. Improving the resilience of lifeline services for both new and existing systems is essential for regional economic stability and the public good. The expert resources of the natural hazards professional community are available to identify performance goals, best practices, and standards, to define appropriate peer review procedures, and to develop specific mitigation practices that can be applied across the Nation.

It is surprising therefore that there is an absence of unified or even loosely coupled performance standards for lifelines. Clear expectations for emergency service and plans for the coordinated response of different lifeline systems are generally absent. Levels of vulnerability are unnecessarily high and the ability to recover from extreme events is much less effective than most communities recognize.

Needs

Substantial work is needed to address lifeline system preparedness, improve performance, and coordinate improvements to achieve enhanced community resilience and national security. Significant issues and areas of high priority include the following:

- A national workshop should be convened in the near future to obtain balanced and multidisciplinary advice from the lifelines community on the development of a coordinated approach to and roadmap for lifeline earthquake risk reduction. Short-, medium-, and long-term goals for the NEHRP and national lifeline programs should be developed. Performance standards should be addressed at the workshop, and the steps to an appropriate level of regulatory oversight should be explored. The workshop should address the multi-hazard aspects of lifeline performance and should result in a consensus on how NEHRP activities can advance multi-hazard resilience. NIST is the most appropriate host of such a workshop.

- NEHRP lost its only dedicated source of support for implementing lifeline risk reduction measures in practice when FEMA funding was terminated in 2007 for the American Lifelines Alliance. Support for implementation needs to be restored, with a new model for the collaborative setting of priorities and programmatic support for measures to mitigate lifeline earthquake hazards.

- Support should be sought for critical lifelines from governmental agencies not part of NEHRP, such as the Departments of Energy, Transportation, and Defense. There should be collaboration between NEHRP and the DHS Office of Infrastructure Protection to address earthquake hazards and the integration of NEHRP-supported technology and approaches into an all-hazards approach and broader definition of homeland security. Common lessons from earthquakes, hurricanes, floods, severe accidents, and human threats should be synthesized and general principles adopted for improving hazard-related lifeline component and system performance.

Disaster Preparedness, Response, and Recovery

NEHRP continues to be a uniting effort that provides concepts for planning, response, relief, recovery, and reconstruction in an all-hazards environment at local, state, and federal levels. NEHRP provides the backbone for learning lessons from disasters and integrating science into emergency management. There is a long and close collaborative relationship between USGS and FEMA in dealing with sudden-onset events, as well as those that are catastrophic. This relationship should continue and be expanded to include those agencies and programs that play a significant role in preparedness and response, particularly the National Oceanic and Atmospheric Administration's (NOAA) flood and tsunami programs and agencies that play a significant role in post-disaster sheltering, housing, and reconstruction.

Developments

Substantial new developments in disaster response, relief, recovery, and reconstruction are emerging and continue to be documented from the lessons learned from recent disasters, particularly Hurricane Katrina and the earthquakes in Haiti and Chile. Major NEHRP efforts include the regional catastrophic-response planning efforts in northern and southern California and in the New Madrid seismic zone, which are driven by ground motion models developed by USGS, estimated losses generated by HAZUS, and planning supported by FEMA. Earthquake scenarios based on the work of USGS and FEMA are being paired with regional catastrophic planning and exercise efforts supported by DHS and FEMA to identify response gaps and build organizational relationships between state and federal responders. Planning for response and recovery from earthquakes benefits many of the concepts and methodologies used to address other extreme events.

The expansion of the USGS multihazard demonstration project in southern California provides an excellent example of the efficacy of collaboration among preparedness and response players across hazards. Paired with a landmark social science research base study (funded by DHS), the southern California effort has been able to build, along with other such programs across the

country, public education and preparedness based on the latest social science findings on educational program effectiveness.

ShakeMap, ShakeCast, CISN Display, and other products affiliated with ANSS continue to make enhancements related to alerting, notification, and response and recovery planning that support national, state, and local emergency management capacities.

Continued development and implementation of performance-based building code design, and increasing recognition of the critical importance of nonstructural enhancements for building resilience and reducing damage and losses, will have a positive impact on community resilience and building performance. Technological developments related to earthquake early warning systems and parallel assessments of the societal implications of such technology offer promise for assessing and communicating threats and risks to the public.

Key determinants of a community's capacity to respond and recover from disasters are the preparedness and resilience of individuals, organizations, businesses, and infrastructure. From its inception, NEHRP has been a leader in promoting preparedness, community resilience, and partnerships with the private sector. NEHRP needs to continue in this role by advocating for DHS/FEMA Private Sector Preparedness and other outreach and partnership activities, and for standards in these sectors against which to gauge capacity.

A critical element of NEHRP is the continuous gathering of knowledge and improvements to practice through the multidisciplinary Learning from Earthquakes (LFE) program. LFE provides a model for the continuous improvement of engineering and emergency management practice that should be broadened to address the multihazard environment.

Needs

Additional work is required to enable effective implementation of planning for disaster response, relief, recovery, and reconstruction, including the following:

- Complete the development of catastrophic and disaster planning scenarios in major urban areas prone to earthquakes based on ground motion mapping from USGS.

- Enhance the HAZUS loss-estimation tools developed by FEMA to address tsunami inundation (USGS, NSF, and NOAA); improve building inventory data (FEMA); update fragility functions (NSF, NIST, FEMA); and integrate ShakeMap and ShakeCast into a fully automated loss-estimation tool.

- Continue to support assessment of the technological and societal factors related to earthquake early-warning methodologies.

- Undertake research to better understand the vulnerability of communities, particularly the impacts of disasters on fragile populations and the roles of non-governmental organization (NGO) service providers and volunteers (individuals, NGOs, and the corporate sector) in post-disaster response, relief, and recovery.

- Continue the collaboration between USGS and NOAA in enhancing the regional seismic networks, and coordinate timely tsunami warnings with earthquake warnings in collaboration with NOAA.

- Undertake comprehensive assessments of community relief, recovery, and reconstruction efforts to inform and expedite post-disaster recovery planning.

- Continue the assessment of post-disaster housing by exploring innovative technologies for construction and integration of interim housing into community restoration, reconstruction, and social and economic recovery.

Appendix B

White Paper on Achieving National Disaster Resilience

Advisory Committee on Earthquake Hazards Reduction
National Earthquake Hazards Reduction Program

February 3, 2010

The Honorable Patrick D. Gallagher
Director
National Institute of Standards and Technology
Building 101, Room A1134
100 Bureau Drive
Gaithersburg, MD 20899-1000

Reference: White Paper on Achieving National Disaster Resilience (Attached)

Dear Dr. Gallagher:

As you know, Richard A. Reed, Special Assistant to the President for Homeland Security and Senior Director for Resilience Policy, met with us at our last Advisory Committee on Earthquake Hazards Reduction (ACEHR) meeting on November 19, 2009. His comments regarding his activities aimed at achieving national disaster resilience were both encouraging and challenging. His offer to continue a dialog with the NEHRP agencies about national earthquake resilience was generous and not to be overlooked.

Since our committee represents a unique gathering of the nation's expert earthquake professionals, we believe we have the ability to gather our thoughts and offer succinct information that will be useful at the nation's highest level for setting policy directions. Through a committee-wide writing process, we have developed a brief white paper highlighting our opinions regarding earthquake resilience that we believe would be beneficial to the continuing NEHRP dialog with the White House that Mr. Reed suggested.

We appreciate the opportunity to serve as your advisory committee, and look forward to continuing this discussion.

Very Truly Yours,

Chris D. Poland, PE, SE
Chairman
Advisory Committee on Earthquake Hazards Reduction

Achieving National Disaster Resilience through Local, Regional, and National Activities

A White Paper
Advisory Committee on Earthquake Hazards Reduction
National Earthquake Hazards Reduction Program

Terrorist attacks, earthquakes, and other natural hazards pose a serious threat to our society at the national, regional, and local levels. These events threaten our people, our physical infrastructure, our economy, and our national security.

The National Earthquake Hazard Reduction Program (NEHRP) has been committed since its inception in 1977 to protecting lives through pre-event planning and mitigation of risks. Many tools, such as seismic monitoring and mapping, building code development, risk mitigation, and emergency preparedness provide a solid framework for community development and disaster planning. Yet, serious gaps exist. For example, the vast majority of the existing physical infrastructure was constructed to inadequate standards, well below current standards for new construction; even the new standards focus on life safety and are not sufficient to achieve resilience. Most buildings will suffer costly damage in a major earthquake, and critical lifelines (*e.g.*, highways, ports, water supply systems, electricity grids, and telecommunications networks) will not provide their intended services immediately after such an earthquake.

Disaster-resilient communities must have credible response plans that include places and abilities to govern after a major disaster. Power, water, and communication networks need to resume operations shortly after a disaster. Residents need to be able to stay in their homes, travel to where they need to be, and resume fairly normal living routines within weeks, so they can restore their community within a few years.

The NEHRP Advisory Committee on Earthquake Hazards Reduction (ACEHR) participated in a discussion regarding disaster resilience with the White House Senior Director for Resilience Policy at the committee's November 23, 2009 meeting at the National Science Foundation in Arlington, VA. Consistent with that discussion, the ACEHR provides this white paper to summarize briefly the committee members' views about earthquake disaster resilience: current conditions, needs for fundamental changes, and recommendations for future actions.

Current Status of the Nation with Regard to Disaster Resilience

While the contemporary national model building code has been adopted by some communities in every state and is effective for safeguarding life and protecting first responders, state and local adoption is neither universal nor comprehensive. There is an enormous diversity in the way codes are implemented that ranges from full attainment, to limited adoption, to areas that strip out disaster-resisting provisions, to communities that actually prohibit the application of building codes to homes. Building codes are of little use if they are not adopted and enforced by well-qualified building departments and their inspectors.

Furthermore, a major earthquake striking a U.S. city that was constructed in *full compliance* with current building codes would cripple the city's ability to recover quickly, because its buildings and lifeline systems have not been designed for post-disaster performance. They have only been designed to safeguard life, and, in some cases, support emergency response.

Significantly, there is no such thing as a fully modern code-compliant city, because every city is filled with older buildings and antiquated lifeline systems that were designed to earlier, now outdated, building codes or no codes at all. There is always a subset of "killer" infrastructure that is extremely vulnerable to collapse, which would cause the deaths of many building occupants and users of transportation systems, while impeding recovery for years.

Change Is Needed

Resilience starts at the local level, with individuals, families, and businesses. Everyone in the country has a stake in creating resilience. Further, resilience of the built environment is only a part of the challenge. Resilience must also encompass the socioeconomic and cultural aspects and needs of communities.

Resilient cities form resilient regions, which in turn build a resilient Nation. While the Nation can promote resilience through improved design codes and mitigation strategies, implementation and response must occur at the local level. The Nation cannot achieve resilience without motivating and supporting local measures that achieve resilience. Support for such activities is currently lacking.

If national resilience is to be achieved, the Nation must enact legislation that empowers cities to build resilience neighborhood by neighborhood. State grants that support the identification and retrofit of "killer" buildings are required. Resources are needed to develop the human infrastructure for responding to and recovering from natural hazards. Understanding and planning for effective lifeline response after extreme events is a key part of developing community resilience. Building codes need to move towards performance-based earthquake engineering so that resilience, beyond "life safety," is the primary objective[1].

Many of the tools and procedures needed to create disaster-resilient cities exist and are continually being refined. Achieving resilience nationwide, however, will require a different approach than currently exists. Modifications to current building codes, alignment of diverse lifeline systems around common performance objectives, and strong community support for adopting policies that foster resilience are needed. Deficient buildings and systems need to be mitigated, and new buildings and systems need to be designed to the performance levels needed.

Shifting to building codes focused on resilience and adopting new policies to strengthen communities are not possible without solid, unified support from all levels of government. The federal government should set performance standards that can be embedded in the design codes; be adamant that states adopt contemporary building codes and include provisions for rigorous enforcement; provide financial incentives to stimulate mitigation that benefits the Nation; and continue to support research that delivers new technologies that encourage cost-effective mitigation, response, and recovery. Through state and local governments, regions should identify the vulnerabilities of their lifeline systems and enact programs for their mitigation to the minimum levels of need to ensure resilience. Localities should expand their preparedness planning and develop mandatory programs that mitigate their built environment, as needed, to assure survival.

[1] The response of a "life safe" building in an earthquake may not result in deaths to its occupants, but the building may be too badly damaged to be repaired or reused. True resilience would support rapid reuse of buildings and other components of infrastructure following earthquakes within the anticipated design envelope for a given region.

Recommended Actions to be Taken at the Federal Level

The federal government must play a central role in promoting resilience, giving visibility to the multi-dimensional and multi-sector aspects of the challenge, and encouraging the various sectors to join the resilience movement.

Key NEHRP-specific earthquake resilience actions that are required immediately include (listed in order of decreasing priority):

1. Support state and local governments and the private sector by providing increased and targeted incentives to adopt and enforce resilience-focused building codes, fix "killer" buildings, and develop more effective mitigation, response, and recovery programs. Some programs exist, such as the FEMA State Hazard Mitigation Grants, but they are too small and need to be funded at meaningful levels.

2. Promote and incentivize resilient and reliable lifeline services during extreme events to deliver critical resources and support community restoration.

3. Establish a policy that provides adequate funding of programs that implement knowledge in all hazard areas through national codes, standards, training, education, guidance materials, and technical and continuing education. The National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA) have the responsibility to transfer research into practice, but they are critically underfunded for this work. The required level of funding is comparable to that supporting fundamental NEHRP research if we are to put into practice the knowledge we have gained over the past several decades.

4. Foster cross-agency communication, collaboration, and coordination on community resilient programs.

5. Have independent agencies conduct two studies, validated by OMB and CBO, to determine the costs and benefits of investing in resilience. The first study should focus on private sector investments in facilities mitigation. The second study should focus on both public and private sector investment in critical infrastructure and lifelines. These studies would provide private sector companies with the bottom line justification needed to make investments in long-term resilience.

Key earthquake resilience actions that apply more broadly than the NEHRP agencies alone but are also required immediately include:

1. Require federal agencies with disaster-response missions to interact in a coherent and consistent way with individual states. In the long term, effective local resilience depends on enabling individuals and educators under state and local programs.

2. Estimate the cost to strengthen the federal infrastructure and develop a plan to address those areas of greatest vulnerability to ensure that government functions are resilient[2] — that they function effectively after a major disaster, with minimal disruption, so that the impact on government operations is not itself a contribution to the problem.

[2] The ACEHR is aware that Executive Order 12941 required the federal agencies to estimate such costs for their existing building earthquake risks but is unaware that such an estimate has ever been developed and released.

The ACEHR members appreciate the opportunity to comment on how the Nation should be guided towards improved security and resilience. We encourage a continuing dialog among the NEHRP agencies and the White House Director of Resilience Policy as a means of implementing the recommendations we have outlined to achieve the NEHRP strategic vision of *"A nation that is earthquake-resilient in public safety, economic strength, and national security."* We must address earthquakes and other hazards now to become a resilient Nation.

Appendix C

Executive Summary
From ACEHR's May 2008 Report on NEHRP Effectiveness

Executive Summary

The Advisory Committee on Earthquake Hazards Reduction (ACEHR) is deeply concerned about the withering of appropriated funds for the National Earthquake Hazards Reduction Program (NEHRP). At $100 to $125 million per year, NEHRP funding has been essentially flat or below inflation levels for the past 30 years**.** Appropriations have been well below authorized levels. In 2004, Congress reacted to the Nation's need and significantly increased the authorization for NEHRP. Rather than strengthening NEHRP with investments linked to authorized levels, however, the reverse has been the case. For the past 5 years, NEHRP funding for FEMA's implementation programs to help safeguard states and communities has been substantially reduced, resulting in serious negative consequences with a dramatic increase in risk.

Despite reduced funding, ACEHR finds that NEHRP has achieved significant improvements, notably in its restructuring and broader collaborative efforts, since the 2004 reauthorization. NEHRP is committed to, and has made progress toward, becoming a fully effective, collaborative, and focused program to protect the Nation against unacceptable risks from seismic hazards.

NIST, as the newly designated lead agency for NEHRP, has formed a NEHRP office with a highly regarded NEHRP director. Each of the other participating agencies—FEMA, NSF, and the USGS—has a significant role in NEHRP, with the active participation of each agency's director. The agency directors serve on the newly expanded Interagency Coordinating Committee (ICC), which now includes the Directors of the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB).

NEHRP is responsible for ensuring earthquake risk reduction opportunities are made available to vulnerable communities. This responsibility ranges from conducting basic research to transferring research results into cost-effective mitigation. The overall success of NEHRP is highly dependent on legislative and administrative support for increased funding.

To protect society against catastrophic earthquake-induced losses, NEHRP must become a well recognized national priority. Risk reduction actions must be taken at the national, state, and local levels. First and foremost, the state grant programs through FEMA must be fully funded. Currently, there is a lack of financial support to state grant programs for assisting communities, residents, and businesses in understanding their risk, sponsoring pilot projects to illustrate cost-effective mitigation, and developing effective response plans to facilitate the immediate and long-term recovery process in the aftermath of a severe earthquake.

Earth science, engineering, and social science fundamental research is critical to advancing our knowledge and should be fully supported. It is equally critical to transfer research findings into practice. Without integrative research into the political, social, and economic circumstances that motivate society to achieve community resilience, implementation of proven earthquake resistant retrofit strategies will fall short. Sufficient attention is not being paid to the development of national standards for lifelines and existing buildings that will provide a resilient built environment. Strong motion recording equipment must be installed rapidly through full funding of the Advanced National Seismic System (ANSS) before the next major earthquake strikes.

Through ANSS, the USGS provides critical information for emergency response, earthquake engineering, and a better understanding of the physics of earthquakes.

Key recommendations of the ACEHR are listed below by agency:

FEMA

- ***Recommendation 1***: Revitalize state earthquake programs and support pilot studies to characterize and mitigate unacceptable risk in communities.
- ***Recommendation 2***: Fund FEMA at the authorized level and assure funding is dedicated to earthquake risk reduction.
- ***Recommendation 3****:* Continue to develop and maintain guideline documents that will improve the effectiveness and reduce the cost of seismic protection for lifelines, existing buildings, new buildings, and applied socioeconomic policies for cost-effective mitigation. Promote their adoption and implementation to stakeholders.

NIST

- ***Recommendation 1*****:** NIST must secure the funding to effectively carry out its role as the lead agency for NEHRP and its role in applied research and assistance in implementation of cost-effective mitigation through codes and standards.
- ***Recommendation 2*****:** NIST must plan for the development of multidisciplinary expertise within its own staff and foster relationships with other public agencies and private-sector entities to accomplish the coordinated research to effectively fulfill its obligations.

NSF

- ***Recommendation 1****:* NSF should enhance its support for multidisciplinary research related to NEHRP, which can be used as a model for reducing risks associated with other natural and human-induced hazards. In particular, there is an opportunity for the Engineering and Geosciences Directorates to partner with the Social, Behavioral, and Economic Sciences Directorate to understand the social and economic factors that promote mitigation measures.
- ***Recommendation 2*****:** NSF should enhance its support for curiosity-driven basic research, which has been the foundation of many important technical discoveries. Basic research sponsored by NSF educates the next generation of engineers and scientists engaged in earthquake risk reduction. Such support is thus a means of expanding the workforce in earthquake engineering and science.
- ***Recommendation 3*****:** NSF should solicit support from other federal agencies to leverage the NSF investments in the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) to address critical research needs for the civil infrastructure. To date, research support for NEES has not matched the levels needed by the earthquake community to reduce earthquake risks significantly.

USGS

- ***Recommendation 1*****:** Fully fund ANSS at the level authorized in the current NEHRP legislation. The USGS must make a commitment to work through the Department of the Interior (DOI) and OMB to ensure that this objective is met.

- ***Recommendation 2*:** Proceed with multihazard demonstration projects, such as the project being carried out in southern California that was initially funded by Congress in Fiscal Year (FY) 2007. The demonstration projects should expand the multihazard scope to include other high-risk areas as part of this effort.
- ***Recommendation 3*:** Enhance the interaction of the USGS with its NEHRP partners in earthquake engineering (NIST and NSF), earth science (NSF), and earthquake preparedness (FEMA). The noteworthy level of coordination in some geographic areas, such as California, and in some project areas, such as the National Seismic Hazard Mapping project, should be extended to other geographic and project areas.

Management, Coordination, and Implementation

- ***Recommendation*:** Consistent with the change in the leadership of NEHRP, ACEHR recommends that USGS delegate post-earthquake investigation leadership to NIST, including the organization and deployment of reconnaissance teams and sponsoring the publication of discipline-oriented interactive media that archive collected data.

The United States invests more than $1 trillion each year in new construction. It is now well recognized that the condition of our infrastructure is in crisis, with more than $2 trillion required over the coming decades to reconstruct and support a vibrant country and economy. The Nation depends on its lifelines—power, surface transportation, water, waste water, and communication—on a daily basis, and certainly after a natural disaster. The failure of any of these lifelines following an earthquake can have severe economic impacts on businesses and residents in the affected areas. Further, complex interrelationships of lifelines will produce many unforeseen and potentially catastrophic consequences that will likely significantly increase damage and economic losses. Consequently, the Nation is at high risk because there is no nationally sponsored effort to direct the system-wide consideration of these resources and development of appropriate design, construction, and renovation standards and programs. Moreover, a small percentage of existing buildings will kill people in the next major earthquake. These buildings must be identified and mitigated. Because these actions require more than engineering, we need to better understand the economic and political means to mitigate high risk buildings that have great societal importance.

Each dollar spent on NEHRP can save up to 10 times that amount in avoided losses**.** ACEHR urgently recommends refocusing NEHRP on achieving community resilience by fully funding implementation programs, followed by support for programs that advance our understanding and for programs to develop and evaluate cost-effective measures to achieve resilience against earthquakes.