Strategic Plan

for the

National Earthquake Hazards Reduction Program

Fiscal Years 2009–2013

October 2008


FEMA

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

USGS
science for a changing world

This Strategic Plan for the National Earthquake Hazards Reduction Program (NEHRP) is submitted to Congress by the Interagency Coordinating Committee (ICC) of NEHRP, as required by the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124, 42 U.S.C. 7701 *et. seq.*), as amended by Public Law 108-360.

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Executive Summary

This Strategic Plan for the National Earthquake Hazards Reduction Program (NEHRP) for Fiscal Years 2009–2013 is submitted to Congress by the Interagency Coordinating Committee (ICC) of NEHRP, as required by the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124, 42 U.S.C. 7701 *et. seq.*), as amended by Public Law 108-360.

The Plan outlines a cooperative program of earthquake monitoring, research, implementation, education, and outreach activities performed by the NEHRP agencies. These agencies are:

- the Federal Emergency Management Agency;
- the National Institute of Standards and Technology, the NEHRP lead agency;
- the National Science Foundation; and,
- the U.S. Geological Survey.

The continued success of NEHRP will emphasize the linked roles of the NEHRP agencies and their partners, based on a common vision and shared mission.

The NEHRP Vision is:

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

The NEHRP Mission is:

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

Accomplishing the NEHRP mission requires developing and applying knowledge based on research in the geological, engineering, and social sciences; educating leaders and the public; and assisting State, local, and private-sector leaders to develop standards, policies, and practices. The NEHRP agencies have established three overarching, long-term **Strategic Goals,** with 14 associated objectives, to support this mission:

Goal A: Improve understanding of earthquake processes and impacts.

Objective 1: Advance understanding of earthquake phenomena and generation processes.

Objective 2: Advance understanding of earthquake effects on the built environment.

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 4: Improve post-earthquake information acquisition and management.

Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.

Objective 5: Assess earthquake hazards for research and practical application.

Objective 6: Develop advanced loss estimation and risk assessment tools.

Objective 7: Develop tools that improve the seismic performance of buildings and other structures.

Objective 8: Develop tools that improve the seismic performance of critical infrastructure.

Goal C: Improve the earthquake resilience of communities nationwide.

Objective 9: Improve the accuracy, timeliness, and content of earthquake information products.

Objective 10: Develop comprehensive earthquake risk scenarios and risk assessments.

Objective 11: Support development of seismic standards and building codes and advocate their adoption and enforcement.

Objective 12: Promote the implementation of earthquake-resilient measures in professional practice and in private and public policies.

Objective 13: Increase public awareness of earthquake hazards and risks.

Objective 14: Develop the Nation's human resource base in earthquake safety fields.

The three goals honor congressional intent and result from the work of the NEHRP agencies in concert with the stakeholder community. For each goal, Chapter 3 outlines key objectives, implementation strategies, and anticipated outcomes that provide insight into the importance of each activity to the Nation. Several guiding principles, described in Chapter 2, served as the basis for developing the goals and objectives.

The Plan adds nine new cross-cutting **Strategic Priorities** that directly support the goals and augment other ongoing agency activities needed to satisfy them. The NEHRP agencies plan to emphasize these priorities during the Strategic Plan period. The priorities are:

- Fully implement the Advanced National Seismic System.
- Improve techniques for evaluating and rehabilitating existing buildings.

- Further develop Performance-Based Seismic Design.
- Increase consideration of socioeconomic issues related to hazard mitigation implementation.
- Develop a national post-earthquake information management system.
- Develop advanced earthquake risk mitigation technologies and practices.
- Develop guidelines for earthquake-resilient lifeline components and systems.
- Develop and conduct earthquake scenarios for effective earthquake risk reduction and response and recovery planning.
- Facilitate improved earthquake mitigation at State and local levels.

The Strategic Priorities were developed through a number of key activities in 2006 that highlighted gaps in the Program activities that were outlined in the previous Plan. Following these activities, the ICC identified the Strategic Priorities that deserve increased emphasis by the NEHRP agencies. Progress on these priorities will depend on available resources. The Strategic Priorities are described in Chapter 4.

These goals, objectives, and Strategic Priorities are consistent with and expand upon the "Grand Challenges for Disaster Reduction: Priority Interagency Earthquake Implementation Actions" identified by the Subcommittee on Disaster Reduction of the President's National Science and Technology Council.

This Plan provides a straightforward and executable strategy for NEHRP. Successful strategic planning and Program accomplishment must be consistent with existing policies, based on realistic assumptions, and responsive to changing conditions. The pace of Program accomplishment will depend on the resources that are available to the Program agencies during the 2009–2013 Plan period. This Plan is intended to guide relevant funding decisions by NEHRP agencies. Following the adoption of this Plan, the NEHRP agencies will jointly develop a Management Plan that details Strategic Plan implementation activities that are consistent with agency appropriations and funding priorities.

The NEHRP agencies will keep abreast of advancements in science and technology, and adjust short- and long-term developmental efforts accordingly. NEHRP will remain focused on the elements of this Strategic Plan, but will adapt to contingencies and opportunities that may arise. If a major earthquake occurs in the United States during the Plan period, NEHRP will initiate efforts to study the effects and impacts of that event, including successes, failures, and unforeseen problems that arose in mitigation, response, and recovery practices and policies, and adjust this Plan as needed.

The costs of earthquake loss reduction and post-earthquake recovery are shared by the public and private sectors. The role of NEHRP is to provide the public and private sectors with the scientific and engineering information, knowledge, and technologies needed to prepare for earthquakes and thus reduce the costs of losses and recovery. NEHRP will continue to develop partnerships with its

stakeholder community of earthquake professionals working in academia and in business, government, technical, professional, and codes-and-standards organizations that are involved with the earthquake risk reduction process, in fulfillment of its role.

A 2003 report[1] noted that "our ability to secure society against catastrophic earthquake losses depends on a strong and viable NEHRP." Properly supported and implemented, this Strategic Plan fulfills that need.

[1] Earthquake Engineering Research Institute, *Securing Society Against Catastrophic Earthquake Losses: A Research and Outreach Plan in Earthquake Engineering*, June 2003.

Chapter

1

Introduction

The Challenge

Earthquakes pose one of the greatest natural hazards in the United States, with potential for significant casualties and damage to buildings and infrastructure. According to a 2006 National Research Council (NRC) report,[2] 42 States have some degree of earthquake risk and 18 of those States have areas of high or very high seismicity. Over 75 million Americans live in urban areas with moderate to high earthquake risk (See Figure 1). The NRC report notes that the estimated value of structures in all States prone to earthquake damage is approximately $8.6 trillion (2003 dollars).[3]

Although damaging earthquakes occur infrequently in the United States, they strike without warning, with potentially catastrophic consequences. The 2006 NRC report notes that 33 people lost their lives in the 1994 Northridge, California, earthquake, with direct losses estimated at $45 billion to $55 billion. The 1995 earthquake in Kobe, Japan, with a built environment similar to that of the United States, caused more than 6,300 deaths, with estimated direct losses in excess of $120 billion. Both earthquakes were under magnitude 7 (M7). In the history of the United States, earthquakes M6.5 or greater have occurred in Alaska, California, South Carolina, the Intermountain West, the Central U.S., and New England. There is paleoseismic (geological) evidence, confirmed by historic records from Japan, that earthquakes as large as M9 have occurred in the distant past in the Pacific Northwest. Because few large magnitude earthquakes have struck the United States since it

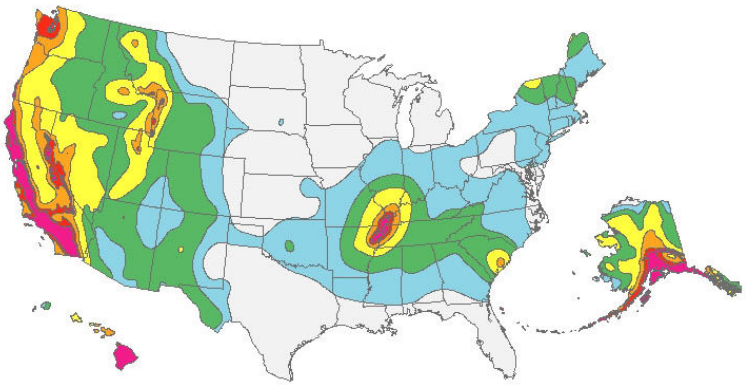

Figure 1. The U.S. Geological Survey (USGS) National Seismic Hazard Maps show 42 States with some degree of earthquake risk. The data from these maps are incorporated into seismic provisions of model building codes—one of the central ways that NEHRP translates knowledge into practice. Image courtesy of USGS.

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

[3] Based on the Consumer Price Index, the 2003 cost would translate to approximately $10.1 trillion in 2008 dollars.

became highly urbanized, contemporary American society tends to underestimate the true earthquake risk.

Given the urbanization that has occurred in the past century, NRC and the Earthquake Engineering Research Institute (EERI)[4] conclude in post-2000 reports that direct costs of losses in the built environment (buildings, lifelines, and other structures) and indirect economic costs (including business losses) in a future major earthquake that strikes a large urban area could easily exceed $100 billion, on the same scale as the losses suffered in Hurricane Katrina in 2005. The accompanying injuries and deaths would make this impact more severe. This estimate is all the more plausible when several issues that were raised in the EERI report, distilled in the following paragraphs, are considered:

- Growth in population, economies, and societal interconnectedness have led to significant increases in lives and infrastructure at risk and to ever larger areas affected by "local" disasters. For example, earthquake damage to a major West Coast container shipping port or to vital river crossings (bridges, pipelines) in mid-America would result in significant disruptions to the national economy, possibly weakening U.S. competitiveness in the world economy.
- Urbanization in most of the seismically active areas in the United States has led to greater potential damage in those areas.[5] Although detailed damage cost comparisons are not available, the consequences of urbanization are evident from a comparison of the 1971 San Fernando, California, and 1994 Northridge earthquakes, which were of similar magnitude. In 2007 dollars, San Fernando caused approximately $3 billion in losses and Northridge caused $45–$55 billion in losses. Although not all of this difference can be attributed to societal changes over time, increased urbanization leads to higher potential loss—more and more is at stake.
- Earthquake-related provisions in building codes used in the United States have primarily sought to protect the lives of building occupants, with the objective (but not a guarantee) of "life safety." Code-compliant buildings may protect their occupants in future earthquakes but are not required to be designed to limit economic loss. Similarly, damage to infrastructure lifelines, such as utilities, may not cause death or injury, but may result in significant economic losses and delayed recovery efforts.
- Earthquake hazards and their impacts are still not fully understood. Every new damaging earthquake provides new knowledge about their nature and how to guard against future losses. Large earthquakes have occurred in areas such as the Pacific Northwest and Central United States, but there is no firsthand experience in those areas with severe ground

[4] Earthquake Engineering Research Institute, *Securing Society Against Catastrophic Earthquake Losses: A Research and Outreach Plan in Earthquake Engineering*, June 2003.

[5] USGS Circular 1188, *An Assessment of Seismic Monitoring in the United States: Requirement for an Advanced National Seismic System*, identifies 26 U.S. urban areas at significant earthquake risk.

shaking and its impact on the built environment. In order to devise loss reduction strategies in regions that have not experienced large earthquakes in recent times, results from smaller earthquakes, and large earthquakes in other areas, must be extrapolated to estimate the risks. This leads to large uncertainties in damage and impact assessments, as well as in the public awareness of risk.

- Based on current rates of replacement for buildings and infrastructure, today's building stock, much of which does not comply with modern building codes, will continue in use for decades to come. The costs of current mitigation technologies for existing structures are often high and effective tools for making decisions about mitigation investments are limited, so widespread adoption of mitigation measures faces significant obstacles.

Meeting the Challenge

Earthquakes cannot be prevented, but their impacts on life, property, and the economy can be managed. Congress first authorized the National Earthquake Hazards Reduction Program (NEHRP) in 1977 (Public Law 95-124) to "reduce the risks of life and property from future earthquakes in the United States." Congress oversees NEHRP through a periodically recurring reauthorization process. The most recent reauthorization, Public Law 108-360, authorized NEHRP funding through fiscal year 2009, and mandated Program management, oversight, and reporting requirements (See Appendix C).

There are four NEHRP agencies: the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). These agencies have distinct but highly complementary missions. Coordination of the agencies' work in their mission areas provides synergies to address earthquake risk in the United States. The agencies' earthquake-related missions, which were outlined in the prior NEHRP strategic plan,[6] are summarized below. Their statutory responsibilities are presented in Appendix C.

- **FEMA** translates research and lessons learned from earthquakes into guidance, training, support for States and multistate consortia, and other program implementation activities. FEMA works with national model codes and standards groups; promotes better building code practices; assists States in developing mitigation, preparedness, and response plans; aids in the development of multistate groups; and supports comprehensive earthquake education and awareness. FEMA also develops and disseminates earthquake-resistant design guidance for new and existing buildings and lifelines and aids in the development of performance-based design guidelines and methods. FEMA applies earthquake hazards reduction measures, where applicable, to other natural and man-made hazards; provides preparedness, response, and mitigation recommendations to communities; and establishes

[6] Federal Emergency Management Agency, *Expanding and Using Knowledge to Reduce Earthquake Losses—The National Earthquake Hazards Reduction Program, Strategic Plan 2001–2005*, FEMA 383, 2003.

demonstration projects on earthquake hazard mitigation to link earthquake research and mitigation with emergency management programs.

- **NIST** serves as NEHRP lead agency and conducts applied research and development (R&D) in earthquake engineering to improve building codes and standards for new and existing buildings and infrastructure lifelines, advance seismic-resistant construction practices, develop measurement and prediction tools supporting performance-based standards, and evaluate advanced technologies. Consistent with its broader research mission, NIST research focuses on removing technical barriers, evaluating advanced technologies, and enabling innovation and competitiveness in the U.S. design and construction industry. As lead agency, NIST provides the overall direction, coordination, and support of NEHRP joint activities. The NIST Director chairs the Interagency Coordinating Committee. The NEHRP Director, a NIST employee, directs the NEHRP Secretariat, chairs the working-level Program Coordination Working Group, and serves as NEHRP point of contact with non-government groups and interests.
- **NSF** supports a broad range of basic research in geosciences; engineering; and social, behavioral, and economic sciences relevant to the understanding of the causes and impacts of earthquakes. NSF supports research into the causes and dynamics of earthquakes, plate tectonics, and crustal deformation as well as research on the seismic performance of geotechnical, structural, nonstructural, and infrastructure-lifeline systems. NSF also supports research on such social, behavioral, and economic phenomena as risk perception, mitigation decision making, incentive systems related to risk and mitigation, and factors that can promote community resilience. NSF supports advanced earthquake engineering research experimental facilities and cyberinfrastructure. NSF provides support for the education of new scientists and engineers, the integration of research and education, and outreach to professionals and the public.
- **USGS** conducts and supports targeted geoscience research investigations on earthquake causes and effects, produces national and regional seismic hazard maps and assessments, monitors and rapidly reports on earthquakes and their shaking intensities in the United States and abroad, works to improve public understanding of earthquake hazards, and coordinates post-earthquake reconnaissance carried out and supported by NEHRP agencies and other organizations.

The national investment in NEHRP through these agencies recognizes at least four important factors related to the costs of preparing for large-scale disasters. First and foremost, ensuring public safety is inherently a government responsibility. Second, absent appropriate incentives, private interests and corporations invest in preparedness and mitigation measures that they believe protect their economic well-being, not necessarily those that yield greatest societal well-being. Third, earthquake impacts and consequences can be felt at regional and national scales; they are not restricted to a local area of most severe shaking. As a result, post-earthquake performance is based on all infrastructure elements acting as a system, not simply as an aggregation of individual components. In today's economy, damaging earthquakes that strike in some areas of the country

will severely impact the national economy and, possibly, national security. Finally, there are few, if any, construction-related businesses that are large enough to possess the investment resources for research and development needed to address major national earthquake safety challenges.

The 1977 NEHRP authorization and subsequent reauthorizations have delineated agency roles, established Program priorities, and authorized Program funding levels. A cornerstone of NEHRP since its inception has been the partnership among the Program agencies to achieve progress and successes in earthquake risk reduction that would not be possible if the agencies worked in isolation. Although each Program agency has a unique mission and associated capabilities, full Program potential cannot be realized without significant agency interactions.

The costs of earthquake loss reduction and post-earthquake recovery are shared by the public and private sectors. The role of NEHRP is to provide the public and private sectors with the scientific and engineering information, knowledge, and technologies needed to prepare for earthquakes and thus reduce the costs of losses and recovery. NEHRP will continue to develop partnerships with its stakeholder community of earthquake professionals and with codes-and-standards organizations that are involved with the earthquake risk reduction process, in fulfillment of its role.

NEHRP Achievements

During the past 30 years, NEHRP has made dramatic strides toward improving earthquake awareness and preparedness in the United States. Some of the more significant advances are:

- **Earthquake processes**. Basic research and earthquake monitoring have significantly advanced the understanding of the geologic processes that cause earthquakes, the characteristics of earthquake faults, the nature of seismicity, and the propagation of seismic waves. This understanding has been incorporated into seismic hazard assessments, earthquake potential assessments, building codes and design criteria, rapid assessments of earthquake impacts, and scenarios for risk mitigation and response planning.
- **Earthquake hazard assessment.** Improvements in the National Seismic Hazard Maps have been developed through a scientifically defensible and repeatable process that involves peer input and review at regional and national levels by expert and user communities. Once based on six broad zones nationwide, they now are based on a grid of seismic hazard assessments at some 150,000 sites throughout the country. The new maps, first developed in 1996, are periodically updated and form the basis for the Design Ground Motion Maps used in the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, which serves as the basis for the seismic elements of model building codes.
- **Earthquake risk assessment.** Development of earthquake hazard- and risk-assessment techniques for use throughout the United States has improved awareness of earthquake impacts on communities. NEHRP funds have supported the development and continued

refinement of HAZUS-MH (Hazards U.S.-Multihazard), powerful risk assessment software that is used nationwide to address earthquake, flood, and hurricane wind hazards.

- **Earthquake safety in design and construction.** Earthquake safety in new buildings has been greatly improved through the adoption, in whole or in part, of earthquake-resistant national model building codes by State and local governments in all 50 States. Development of advanced earthquake engineering technologies for use in design and construction has greatly improved the cost-effectiveness of earthquake-resistant design and construction while giving options with predicted decision consequences. These techniques include new methods for reducing the seismic hazard of nonstructural components, base isolation methods for dissipating seismic energy in buildings, and performance-based design approaches.

- **Earthquake safety for existing buildings.** NEHRP-led research, development of engineering guidelines, and implementation activities associated with existing buildings have led to the first generation of consensus-based national standards for evaluating and rehabilitating existing buildings. This work provided the basis for two American Society of Civil Engineers (ASCE) standards documents: ASCE 31—*Seismic Evaluation of Existing Buildings*, and ASCE 41—*Seismic Rehabilitation of Existing Buildings*, both discussed later in this Plan. While great strides have been made since the 1980s, additional work is needed to improve the cost-effectiveness of measures associated with existing buildings (See Figure 2).

Figure 2. Damage to older, reinforced concrete building in the 1994 Northridge Earthquake. © 1994 by Peter W. Clark and Regents of the University of California.

- **Partnerships.** NEHRP has developed and sustained partnerships with State and local governments, professional groups, and multistate earthquake consortia to improve public awareness of the earthquake threat and support the development of sound earthquake mitigation policies.

- **Earthquake information.** There is now a greater body of earthquake-related information available to public- and private-sector officials and the general public. This comes through effective documentation, earthquake response exercises, learning-from-earthquake activities, publications on earthquake safety, training, education, and information on general earthquake phenomena and means to reduce their impact. Millions of earthquake preparedness handbooks have been delivered to at-risk populations, many translated from English into languages most easily understood by large sectors of the population. NEHRP now maintains a website (www.nehrp.gov) that provides information on the Program and

communicates regularly with the earthquake professional community through the monthly electronic newsletter, *Seismic Waves*.

- **Earthquake notification.** The USGS National Earthquake Information Center and regional networks, all elements of the Advanced National Seismic System (ANSS), now provide earthquake alerts within a few minutes after an earthquake on magnitude and location. When coupled with graphic *ShakeMaps* showing the distribution and severity of ground shaking, this information is essential to effective emergency response, infrastructure management, and recovery planning.
- **Training and education.** Thousands of graduates of U.S. colleges and universities have benefited from their experiences with NEHRP-supported research projects and training activities. Those graduates now form the nucleus of America's earthquake professional community.
- **Advanced data collection and research facilities.** NEHRP took the lead in developing ANSS and the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). Through these initiatives, NEES forms a national infrastructure for testing geotechnical, structural, and nonstructural systems, and ANSS will provide a comprehensive, nationwide system for monitoring seismicity and collecting data on earthquake shaking on the ground and in structures (See Figure 3). NEHRP also has participated in the development of the Global Seismographic Network to provide data on seismic events worldwide.

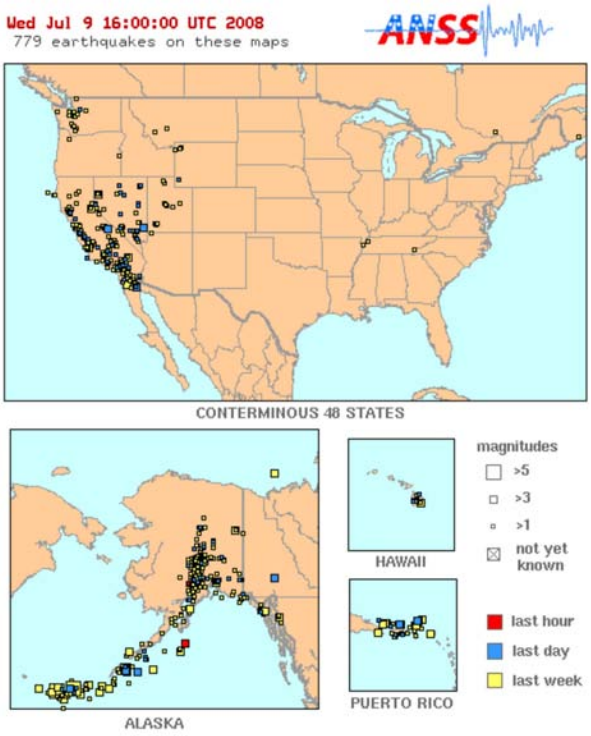

Figure 3. Locations of U.S. earthquakes recorded and reported by ANSS during a one-week period in July 2008. Image courtesy of USGS.

NEHRP Responsibilities and Focus

This Strategic Plan emphasizes pre-earthquake mitigation, not post-earthquake response. Nevertheless, NEHRP provides essential information and tools used in earthquake response. These include notifications of earthquake location and magnitude, estimates of the distribution and severity of ground shaking, and impact and loss assessments. In addition, FEMA is tasked by statute

with executing the National Response Framework (NRF), the successor to the National Response Plan, as one of its core missions, and both NIST and USGS provide emergency support functions under the NRF that are not required under NEHRP. USGS also has delegated responsibility under the Disaster Relief Act of 1974 (the Stafford Act) for notification of earthquake events.

The emphasis on pre-earthquake mitigation is consistent with observations made by the National Science and Technology Council in 2005,[7] when it noted that "a primary focus on response and recovery is an impractical and inefficient strategy for dealing with [natural disasters]. Instead, communities must break the cycle of destruction and recovery by enhancing their disaster resilience."

The ultimate value of NEHRP is in the protection of life and property during and after an earthquake. To achieve that end, the research and data collected under NEHRP must be used effectively; research and data collection need to result in successful practices and ultimately in earthquake safety nationwide.

[7] National Science and Technology Council, Committee on Environment and Natural Resources, *Grand Challenges for Disaster Reduction—A Report of the Subcommittee on Disaster Reduction*, June 2005.

Chapter

2

NEHRP Vision, Mission, and Strategic Planning Principles

This chapter presents an overview of the guiding principles used in the strategic planning process. The first step in developing this Plan involved defining the overall vision and mission for NEHRP. The vision and mission statements serve as the basis for Program direction and planning. These concepts were then expanded to more specific goals and objectives that lay out the structure, activities, and focus of the program over the next five years. Finally, strategic planning priorities and principles were used to provide a pragmatic context for the development of the Plan. The priorities are based on an appraisal of opportunities and critical needs across multiple objectives; while the planning principles are based on a realistic assessment of available resources, facilities, personnel, and cooperative opportunities. Combined, the vision and mission, goals and objectives, and strategic priorities and planning principles, form a logical foundation and framework for the strategic planning and direction of NEHRP.

Vision and Mission

The NEHRP Vision is:

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

The NEHRP Mission is:

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

Accomplishing the NEHRP mission requires developing and applying scientific and engineering knowledge; educating leaders and the public; and assisting State, local, and private-sector leaders to develop standards, policies, and practices. The NEHRP agencies have established three overarching, long-term **Strategic Goals,** with 14 associated objectives, to support this mission:

Goal A: Improve understanding of earthquake processes and impacts.

Objective 1: Advance understanding of earthquake phenomena and generation processes.

Objective 2: Advance understanding of earthquake effects on the built environment.

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 4: Improve post-earthquake information acquisition and management.

Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society-at-large.

Objective 5: Assess earthquake hazards for research and practical application.

Objective 6: Develop advanced loss estimation and risk assessment tools.

Objective 7: Develop tools to improve the seismic performance of buildings and other structures.

Objective 8: Develop tools to improve the seismic performance of critical infrastructure.

Goal C: Improve the earthquake resilience of communities nationwide.

Objective 9: Improve the accuracy, timeliness, and content of earthquake information products.

Objective 10: Develop comprehensive earthquake risk scenarios and risk assessments.

Objective 11: Support development of seismic standards and building codes and advocate their adoption and enforcement.

Objective 12: Promote the implementation of earthquake-resilient measures in professional practice and in private and public policies.

Objective 13: Increase public awareness of earthquake hazards and risks.

Objective 14: Develop the Nation's human resource base in earthquake safety fields.

Activities to attain the goals range from performing basic and applied research, to developing cost-effective risk reduction measures, to promoting the implementation of these measures in practice. Attaining the goals will increase community and regional earthquake resilience, improve life safety, reduce economic losses, and minimize security disruptions. Chapter 3 describes the three goals and associated objectives, with anticipated outcomes for each objective. Although the goals and objectives are presented individually, they are largely interconnected. All contribute collectively to accomplishing the NEHRP mission.

The Plan includes nine **Strategic Priorities** that directly support the goals and objectives. These Strategic Priorities were identified through a working-level analysis of the gaps in NEHRP activities that was directed by the Interagency Coordinating Committee (ICC). The priorities are

cross-cutting initiatives that would address these gaps. Following the gap analysis, the ICC identified and endorsed the Strategic Priorities as efforts that deserve increased emphasis by the NEHRP agencies, beyond their ongoing activities. These priorities are described in Chapter 4. The levels of added emphasis and progress will depend on available resources. The Strategic Priorities are:

- Fully implement the Advanced National Seismic System.
- Improve techniques for evaluating and rehabilitating existing buildings.
- Further develop Performance-Based Seismic Design.
- Increase consideration of socioeconomic issues related to hazard mitigation implementation.
- Develop a national post-earthquake information management system.
- Develop advanced earthquake risk mitigation technologies and practices.
- Develop guidelines for earthquake-resilient lifeline components and systems.
- Develop and conduct earthquake scenarios for effective earthquake risk reduction and response and recovery planning.
- Facilitate improved earthquake mitigation at State and local levels.

Strategic Planning Principles

Several guiding principles were followed in developing the Program goals, objectives, and anticipated outcomes. They are listed below.

Program Revision—Not Reinvention

In early 2006, NEHRP solicited stakeholder input on future Program direction. The input included many useful suggestions for Program improvements, while largely acknowledging that NEHRP's basic framework is sound. As a result, this Plan used the past achievements and current structure of NEHRP as a foundation from which to build a new NEHRP with forward-looking goals and priorities. This new Plan remains faithful to the NEHRP statutory requirement to focus on earthquake hazards (risk) reduction. Other entities will continue to address emergency response and recovery requirements in keeping with their responsibilities under the National Response Framework.

As an integral part of this approach, the Program must respond to change. Planning must be sufficiently broad and flexible to accommodate new ideas and technological innovations that may arise during the Plan period and accelerate progress toward the NEHRP vision. With the help of the newly formed external Advisory Committee on Earthquake Hazards Reduction,[8] the NEHRP

[8] See Appendix C.

agencies will regularly convene workshops and conduct forward-looking studies to identify technological opportunities or necessary paradigm shifts. New areas requiring attention or study may be revealed by investigations of the effects and impacts of recent earthquakes or relevant technological developments. When acted upon, recommendations and results of the workshops and studies will help to achieve the NEHRP vision.

Flexible and Realistic Plan Implementation

Successful strategic planning and Program accomplishment must be consistent with existing policies, based on realistic assumptions, and responsive to changing conditions. The pace of Program accomplishment will depend on the funding that is appropriated to the Program agencies during the 2009–2013 Plan period. Following the adoption of this Plan, the NEHRP agencies will jointly develop a Management Plan that details Strategic Plan implementation activities that are consistent with agency appropriations and priorities.

Coordination and Cooperation among the NEHRP Agencies

There is no single congressional appropriation for NEHRP, nor does the NEHRP Secretariat[9] control individual agency budgets, personnel, or activities. However, the NEHRP agencies have agreed on *unified Program planning, with coordinated budget preparation.* The coordination will be an iterative process. It will, for example, be necessary to reexamine Program activities as annual agency appropriations are signed into law; adjustments to proposed NEHRP commitments will be made, as appropriate. This new coordination measure will improve Program cost-effectiveness by expanding interagency synergy and cooperation in Program activities. This measure will also draw on the complementary strengths of the NEHRP agencies, providing a basis for them to work in concert, without duplicative efforts, toward common objectives and cost-effective impacts, thus achieving together more than they could individually.

Close Partnership with the Earthquake Professional Community

NEHRP strives to conduct its major initiatives in concert with the earthquake professional community, including the public and private sectors, and to develop a national consensus on important NEHRP products. Four examples of this partnership approach are the National Seismic Hazard Maps (produced by USGS), the HAZUS loss-estimation model, work on improving new construction as represented by the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (FEMA 450), and work on reducing the risk from existing buildings as represented by the *NEHRP Guidelines for Seismic Rehabilitation of Existing Buildings* (FEMA 273/356). In addition to being state-of-the-art technical guidance products, these products also serve as the entry point for new information into the Nation's consensus design standards. For new buildings, the consensus standard is the American Society of Civil Engineers (ASCE) *Minimum*

[9] See Appendix C.

Design Loads for Buildings and Other Structures (ASCE 7). For existing buildings, the consensus standards are ASCE's *Seismic Evaluation of Existing Buildings* (ASCE 31) and *Seismic Rehabilitation of Existing Buildings* (ASCE 41). These standards have been developed through consensus processes involving the Nation's leading earthquake professionals and their professional organizations. These products serve as the basis for earthquake-resistant provisions in national model building codes, such as those published by the International Code Council, that have been adopted in whole or in part in all 50 States. The NEHRP agencies work actively with national and international building codes and standards organizations to ensure that NEHRP-developed knowledge and technology are available for adoption. NEHRP agencies carefully monitor the progress of their products through the standardization process and adjust their future support activities to address problems and gaps in knowledge. This work will continue, as will open dialog with earthquake professionals through workshops, Internet interaction, and other approaches.

While NEHRP is a Federal program of coordinated efforts by the four Program agencies, most implementation efforts occur at the State and local levels—through activities such as building code adoption, zoning, and response and recovery planning. The States, the private sector, universities, and regional, voluntary, and professional organizations contribute very significantly to earthquake risk-reduction efforts and are frequent partners in NEHRP activities. Earthquake professionals in these organizations have much to offer NEHRP. This community of professionals has been highly supportive of NEHRP and continues to be indispensable to its effectiveness. The NEHRP agencies will sustain and enhance these partnerships and create new partnerships to accelerate the application of earthquake loss reduction in the United States.

Maximum Use of Research and Data Collection Facilities

The Plan proposes to take maximum advantage of new advanced research facility and data collection networks that have become partially or fully available in recent years, particularly the Advanced National Seismic System (ANSS), the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and the Global Seismographic Network (GSN).

USGS is deploying ANSS to integrate, modernize, and expand earthquake monitoring nationwide. The ANSS plan calls for the installation and maintenance of approximately 7,000 new seismic stations and sensors to measure ground and building response to seismic shaking. As of 2008, ANSS is about 10 percent complete in terms of instrument deployment. Despite the slow pace of instrumentation purchase and deployment, ANSS has made significant strides in integrating and standardizing seismic monitoring, data collection, and earthquake notification nationwide. Through ANSS, previously uncoordinated monitoring efforts around the Nation have been brought together in a single system. ANSS is currently developing coordinated national and regional data processing facilities for consistent and rapid notification of earthquake occurrence and impact while providing valuable data and products critical for research and emergency response.

NEES is a shared national network of 15 experimental facilities, collaborative tools, a centralized research data repository, and earthquake simulation software, all linked by *Internet2* connections. The National Science Foundation (NSF) developed NEES to improve our understanding of earthquakes and their effects on buildings, lifelines, and other structures and to develop design and construction techniques to reduce and mitigate the impacts of these effects. This pioneering design allows testing facilities and results to be shared among researchers and practitioners, both nationally and internationally (See Figure 4). NEES represents a dramatic stride forward in earthquake engineering research capability, coordination, and cooperation.

USGS and NSF jointly developed and support the GSN, which provides data from 140 seismic stations around the globe, providing worldwide data for earthquake notifications, tsunami warnings, earth science research, and nuclear test treaty verification. GSN station deployment was completed in 2007. The GSN has entered its long-term operational phase in which system maintenance and periodic upgrades will be required to maintain its state-of-the-art capabilities.

Figure 4. NEES shake table testing of a full-scale wood frame, residential building. © 2006 by Andre Filiatrault.

NEHRP recognizes that technical data on ground shaking from well-maintained earthquake monitoring networks such as ANSS and the GSN provide the quantitative foundation for developing earthquake resilience techniques and strategies.

Finally, NEHRP interests should take advantage, when appropriate, of NSF-supported activities such as the Incorporated Research Institutions for Seismology (IRIS) portable instrumentation facilities (IRIS/PASSCAL), the IRIS Data Management Center, and elements of the *EarthScope* program. Applicable EarthScope data resources include U.S. Array, the Plate Boundary Observatory, San Andreas Fault Observatory at Depth, and synthetic aperture radar and LIDAR imagery sources.

Multidisciplinary, All-Hazards Approach

This Plan is multidisciplinary in its approach, fostering interactions in applying multiple technical disciplines to solve earthquake hazard mitigation problems. For example, research and development in separate technical fields, such as structural and geotechnical engineering, will be linked to maximize Program effectiveness. Societal issues related to implementing engineering measures, and response and recovery activities, will not be ignored.

Recent disasters have shown clearly that social, policy, economic, and engineering issues faced by NEHRP have many parallels with and connections to other extreme events associated with different large-scale disasters. Indeed, NEHRP leaders examined issues associated with the Nation's response to Hurricane Katrina in formulating this Plan. Multi-hazard planning and engineering have become national priorities. In terms of specific engineering issues (e.g., structural design), cascading effects when infrastructure lifeline components fail, and societal response to both natural (e.g., wind, tsunami) and man-made (e.g., explosion) hazards, there are many opportunities for synergy among research and implementation activities associated with different hazards. NEHRP will strive to identify the areas of potential synergy with activities associated with other hazards, to improve the use of information gained from studies of other hazards in earthquake-related activities, and to determine where NEHRP advances can be of benefit to efforts to address issues related to other hazards. It is essential for NEHRP actions to include facilitating knowledge transfer from experiences with other natural hazard incidents and the Nation's response to them to earthquake preparedness. This approach includes examining ways that knowledge gained in NEHRP activities can be transferred to successful mitigation of other hazards.

Linkages with Broader and Related Federal Policies, Plans, and Priorities

NEHRP links to broader government planning and coordination activities. Foremost among these linkages is the multiagency Subcommittee on Disaster Reduction (SDR) of the National Science and Technology Council (NSTC). The SDR advises and assists the NSTC on policies, procedures, plans, issues, scientific developments, and research needs to facilitate and promote natural and technological disaster mitigation, preparedness, response, and recovery.[10] NEHRP is engaged in the activities of the SDR and interacts with the SDR on matters related to earthquake effects mitigation.

The SDR recently published *Grand Challenges for Disaster Reduction*, which delineates national priorities for creating and sustaining disaster-resilient communities,[11] considering various natural and technical hazards. These priorities and their links to NEHRP Strategic Goals are:

1. Provide hazard and disaster information where and when it is needed (NEHRP Strategic Goal C).
2. Understand the natural processes that produce hazards (NEHRP Strategic Goal A).
3. Develop hazard mitigation strategies and technologies (NEHRP Strategic Goals A, B, and C).
4. Recognize and reduce vulnerability of interdependent critical infrastructure (NEHRP Strategic Goals B and C).

[10] Charter of the Subcommittee on Disaster Reduction, Committee on Environment and Natural Resources, National Science and Technology Council, 2006.

[11] National Science and Technology Council, Committee on Environment and Natural Resources, *Grand Challenges for Disaster Reduction—A Report of the Subcommittee on Disaster Reduction*, June 2005.

5. Assess disaster resilience using standard methods (NEHRP Strategic Goal C).
6. Promote risk-wise behavior (NEHRP Strategic Goal C).

The recently published SDR Earthquake *Grand Challenge* implementation plan (www.sdr.gov/185820_Earthquake_FINAL.pdf) outlines priority science and technology implementation actions specific to earthquakes. The SDR implementation plan is consistent with and complements the statutory responsibilities of NEHRP, as well as this Strategic Plan.

Other Federal agencies and programs benefit from NEHRP activities, both through the application of new NEHRP-developed technologies and the adoption of model building code provisions. In general, NEHRP interacts with the other agencies through the Interagency Committee on Seismic Safety in Construction. Similarly, other Federal agencies often engage in agency-unique seismic research or application work that can complement or augment NEHRP work with their unique capabilities. The NEHRP agencies engage cooperatively with those efforts as opportunities arise (See Figure 5). Finally, other agencies are engaged in earthquake risk reduction activities that address specific needs such as those associated with transportation infrastructure, dams, nuclear power facilities, and other critical elements of the built environment. Where appropriate, NEHRP will cooperate with these agencies and apply relevant results from their program efforts to enrich NEHRP activities.

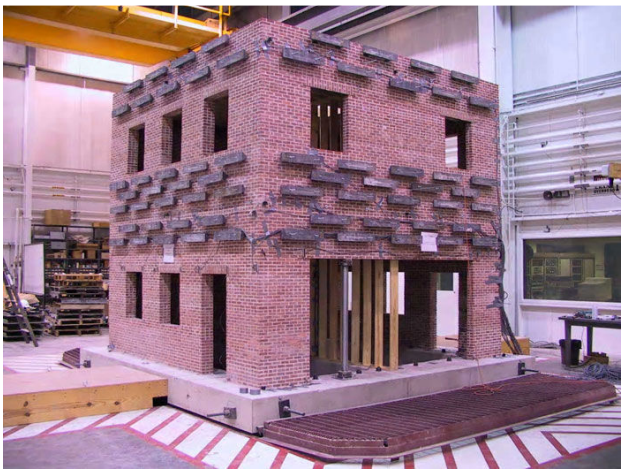

Figure 5. Cooperative test of a half-scale unreinforced brick building by the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) and the NSF-supported Mid-America Earthquake Center. Image courtesy of ERDC-CERL.

Increased International Cooperation

The results of NEHRP activities provide knowledge and tools that the United States can make available to assist other nations that have been unable to develop comprehensive earthquake research and mitigation activities. In contrast, some nations have had great success in earthquake research and mitigation, providing opportunities for NEHRP to develop mutually beneficial strategic partnerships. Some international partnerships already exist, at the agency level and at the broader NEHRP level. In all aspects of its research, implementation, and education efforts, NEHRP will strive to develop and continue appropriate international partnerships. Ongoing cooperative activities include participating in the U.S.-Japan Panel on Wind and Seismic Effects and the U.S.-Japan Panel on Earthquake Research; conducting joint workshops with the China Earthquake Administration; creating research partnerships with the Japanese National Research Institute for

Earth Science and Disaster Prevention; and performing seismic hazard assessments for Afghanistan. Details of these efforts are provided in the NEHRP Annual Report for FY 2007.

To coordinate the international aspects of the GSN, USGS, NSF, and IRIS will continue to work closely with the international Federation of Digital Seismic Networks to set data and meta-data standards for digitally recording seismic stations.

Service to the Public

Above all else, NEHRP exists to serve the Nation. In fulfilling the NEHRP mission of creating an earthquake-resilient nation, NEHRP will openly engage and serve the public. Many of NEHRP's efforts target the earthquake professional community, which in turn serves the public. In addition, direct public outreach, knowledge and technology transfer, and education and training are essential elements of NEHRP. These activities will be accomplished by providing general information on earthquake hazards, specific information on local and regional earthquake threats, practical information on earthquake mitigation, and notification of earthquake occurrences and their impacts. Examples of public engagement activities are homeowner's guides to earthquake safety, newspaper inserts describing the regional earthquake risk, publications on earthquake scenarios and estimated impacts, and web-based products showing the distribution and severity of earthquake shaking within minutes of an event. Finally, NEHRP leaders will strive to ensure that all aspects of the Program are transparent and always open to public reflection and feedback. Relevant information will be frequently posted on the Program website (www.nehrp.gov) and means for the public to communicate with NEHRP leaders will always be clear, open, and available.

Chapter

3

Goals and Objectives

This Strategic Plan is built upon three goals that serve as the foundation for the Program vision—a nation that is earthquake-resilient in public safety, economic strength, and national security. The goals are not independent. They are linked in ways that lead logically and ultimately to increased earthquake risk reduction nationwide. Each goal includes four or more objectives, each with implementation strategies and anticipated outcomes that provide insight into its importance to the Nation. The Strategic Priorities, those areas that have been determined by the Interagency Coordinating Committee to be appropriate for increased emphasis when resources are available, are described in Chapter 4. In this chapter, each objective description also lists the supporting Strategic Priority areas.

Goal A: Improve Understanding of Earthquake Processes and Impacts

The National Earthquake Hazards Reduction Program (NEHRP) will support basic research in the geosciences, engineering, and social sciences on earthquake phenomena, on earthquake impacts, and on means to reduce earthquake effects. The NEHRP agencies recognize that this research is essential to form the knowledge base from which targeted applied research and mitigation practices and policies can be developed. Research directions include earthquake generation and propagation processes; earthquake effects on soils, foundations, lifelines, and structures; new and innovative materials and systems that can be used for more cost-effective construction and retrofit; communication of earthquake dangers to populations at risk; economic and societal impacts of earthquake occurrence; and economic and societal impacts of adopting earthquake safety and mitigation measures. Goal A is the foundation for Goals B and C.

Objective 1: Advance understanding of earthquake phenomena and generation processes

NEHRP will support basic research to advance understanding of the fundamental physical processes of earthquakes. The problem is complex, requiring laboratory, seismic, geodetic, geologic, and remote sensing observations. These observations will be combined with new techniques to understand the physics of earthquakes and their impacts on the Earth's crust. NEHRP will support research on fault mechanics and rupture histories, tectonic plate motions and driving forces, strain rates and evolution, aseismic slip, fault interactions, and the processes of earthquake initiation, nucleation, and rupture. This effort requires knowledge of subsurface geology gained through

geophysical field investigations usually conducted as cooperative efforts involving NEHRP agencies, State geological surveys, and academic institutions. This knowledge will contribute to developing and improving physics-based models of earthquake processes for all regions of moderate to high seismicity. These models will include relevant descriptive aspects of subsurface geology: crustal structure, fault locations and extents, seismic wave velocities, and other relevant physical parameters. Once validated using historical data, such models can be used to project future seismicity and to show where crucial observational data and research are needed. For this effort, NEHRP will apply relevant geophysical data emerging from the Global Seismographic Network (GSN), the Advanced National Seismic System (ANSS), the National Science Foundation (NSF) *EarthScope* program, and other relevant technologies (See Figure 6). *Fully Implement ANSS* is a **NEHRP Strategic Priority**.

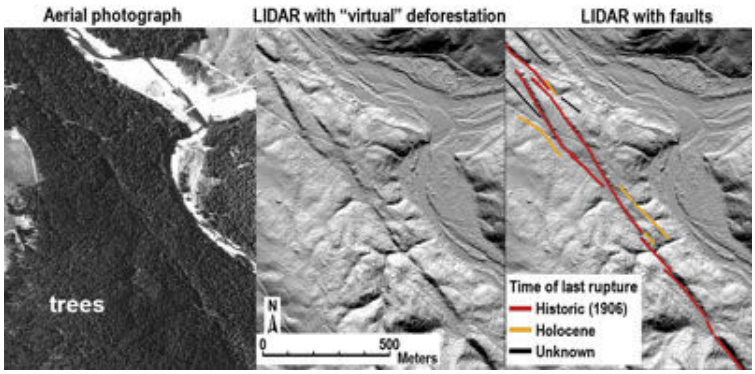

Figure 6. Use of LIDAR (Light direction and ranging) to map fault traces in areas of heavy vegetation. Image courtesy of USGS.

Outcome: Well-tested physical models of earthquake processes leading to improved earthquake characterizations, hazard forecasts, and predictions of earthquake occurrence and impacts, which can be used to prioritize and focus mitigation resources in areas of highest earthquake loss potential.

Objective 2: Advance understanding of earthquake effects on the built environment

NEHRP will support basic research to advance scientific and engineering knowledge of earthquake effects on the built environment. This research will contribute to developing cost-effective design methodologies and technologies for mitigating these effects on soils, lifelines, existing structures, and new construction. The experimental facilities of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) provide a major national resource for conducting basic geotechnical and structural earthquake engineering research (See Figure 7). Fundamental to understanding the seismic performance of the built environment are data on earthquake ground motion and its impact on structures, and data on soil-foundation interaction during earthquakes. NEHRP will support basic research that uses the NEES facilities to improve understanding of the dynamic behavior of near-surface soils; to produce high-resolution characterization of soil properties below and surrounding structures to determine site-specific amplification and attenuation of bedrock motions; and to develop cost-effective technologies to mitigate or reduce the impacts of ground failure. NEHRP will also support basic research on the seismic performance of slopes/retaining structures, engineered earth structures, municipal solid waste containment facilities, levees, dams, and port facilities.

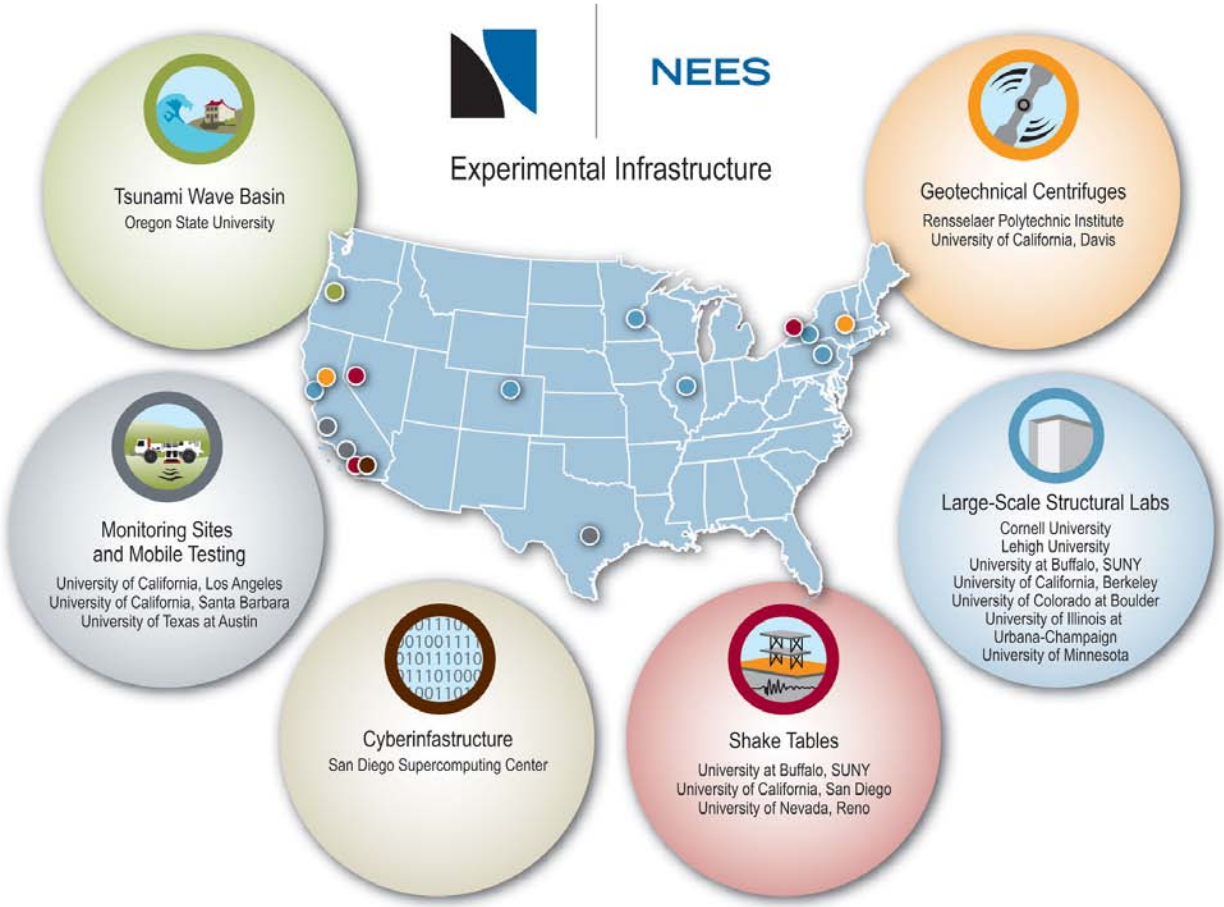

Figure 7. Key facilities in the NEES infrastructure. © 2008 by NEES Consortium, Inc.

The NEES facilities (See Figure 7) provide unique experimental capabilities to address the **NEHRP Strategic Priorities**, *Further Develop Performance-Based Seismic Design (PBSD)* and *Improve Techniques for Evaluating and Rehabilitating Existing Buildings*. These facilities will also contribute to the **NEHRP Strategic Priorities**, *Develop Advanced Earthquake Risk Mitigation Technologies and Practices*, and *Develop Earthquake-Resilient Lifeline Components and Systems*. NEHRP will support research that integrates experimentation and analysis to produce improved understanding of, and models for, the seismic performance of new and existing buildings, lifelines, and other structures; new design and construction technologies that minimize the effects of strong ground motion and permanent ground displacement due to fault rupture or soil failure on the built environment; new earthquake-resistant materials and structural configurations; and cost-effective retrofit technologies for the vast inventory of existing structures located in seismically active areas. New materials and improvements in construction techniques will improve cost-effectiveness in the U.S. construction industry and U.S. competitiveness in international markets.

Observations from past earthquakes have shown that significant economic loss, injuries, and deaths can result from damage to nonstructural components in buildings, even when the supporting

structural systems are not severely damaged. High occupancy and critical buildings, such as schools, offices, and acute care medical facilities, are particularly vulnerable to this threat. NEHRP will support research on innovative and cost-effective approaches for seismic protection of building contents, installed equipment, and nonstructural architectural systems.

ANSS provides data from geotechnical arrays, ground response stations, and structural response arrays that provide the "ground truth" input to understanding the performance of structures affected by strong shaking. This understanding is an essential component in accurately forecasting the performance of the built environment in future earthquakes. In addition, earthquake-induced ground failures such as landslides, liquefaction, and surface faulting are studied for their impacts on buildings and other structures.

Figure 8. Test of a half-scale model of a three-story parking garage on the shake table at the University of California (UC) San Diego's Englekirk Structural Engineering Center. The UC San Diego shake table is an element of the NEES infrastructure, the largest shake table in the United States, and the only outdoor shake table in the world. This study is supported by NSF, NEESinc, the Precast/Prestressed Concrete Institute, and the Charles Pankow Foundation.

Outcome: Improved site characterization methodologies for the built environment, together with cost-effective technologies, engineering practices, and design strategies for mitigating ground failure and improving the seismic performance of structural and nonstructural systems, with full consideration given to the level of seismic resilience needed.

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

NEHRP will support basic multidisciplinary research on mitigation of, response to, and recovery from earthquake hazards that integrates engineering, social, behavioral, public policy, and economic research by utilizing a framework to link science and engineering with research in the social sciences to support future studies. The framework will include studies needed to mitigate losses from future earthquakes, define the roles of the private and public sectors in helping to reduce earthquake losses (including issues related to cost-sharing for mitigation and recovery), and provide support to victims and communities that suffer earthquake damage. The framework consists of four elements: risk assessment, risk perception, risk communication, and risk management.

NEHRP will support basic research into the wide variety of factors related to the levels of risk and vulnerability faced by the Nation from earthquakes so that risks may be reduced, community resilience increased, and costs of damage lessened. These factors include the relationships among earthquakes, the performance of the built environment, and human institutions and behaviors. NEHRP will support multidisciplinary research on the many factors related to societal response and to decisions about adopting earthquake hazard mitigation practices and policies, as made by households, private businesses, corporations, and State and local governments. Emphasis will be placed on social and economic incentives that can facilitate the adoption of mitigation measures that recognize that individuals focus on short-term horizons and hence do not consider the long-run benefits of investing in earthquake mitigation measures. To develop mitigation programs that will achieve their desired effects, it is necessary to understand the goals and objectives of relevant interested parties, as well as the types of information they collect and use in making their decisions. This will include research on behavioral decision making related to low-probability, high-consequence events. NEHRP will support studies on communicating information on earthquake hazard and risk, and the uncertainties surrounding the risk, more effectively. NEHRP will also support research designed to effectively communicate the long-term benefits of investing in mitigation measures. In particular, it will support behavioral and economic research on designing effective public-private partnerships for encouraging and/or requiring those in earthquake prone areas to invest in cost-effective loss reduction measures.

NEHRP will support research on emergency preparedness and response by households, emergency management organizations, and communities, emphasizing organizational planning and innovation to improve response. NEHRP will also support research on those factors that impact the processes of physical, social, and economic recovery from earthquakes. This research will consider the recovery activities of individuals, businesses, communities, and geographic regions, including their vulnerable population segments and critical facilities and organizations. *Increase Consideration of Socioeconomic Issues Related to Hazard Mitigation Implementation* is a **NEHRP Strategic Priority**.

Outcome: Improved mitigation recommendations tailored to needs and disaster resilience through understanding social, behavioral, public policy, and economic factors governing adoption of risk reduction measures and improved recovery planning and practices.

Objective 4: Improve post-earthquake information acquisition and management

Comprehensive, accurate, and consistent information on the phenomena, damage, impacts, and societal responses observed in previous earthquakes are invaluable in planning for future events. NEHRP will lead a nationwide effort among professional, governmental, and academic institutions to systematically collect, share, and archive information on the effects of significant earthquakes. The data acquisition effort will include collection of information on the observed geological and seismological effects and the performance of structural, geotechnical, social, and emergency response systems following earthquakes. Relevant existing NEHRP activities, primarily *The Plan to Coordinate NEHRP Post-Earthquake Investigations* (USGS Circular 1242), will form the basis of

data collection efforts in future major earthquakes. The data acquisition effort must be done in a systematic and consistent manner so that data and results from one earthquake are comparable to those from another.

NEHRP will develop a Post-Earthquake Information Management System (PIMS) to assemble and manage relevant scientific, social behavior, engineering, casualty, economic loss, response, and recovery cost information for damaging earthquakes. Information will be stored, presented, and made available in a structured electronic data management system that will enable earthquake professionals, both practitioners and researchers, and the public to learn quickly from actual field experience. In conjunction with implementing PIMS, USGS Circular 1242 will be updated to reflect required new post-earthquake investigation procedures. The intent is to ensure that lessons learned in major earthquakes are not lost, failures are not repeated, and successes are exploited. The need to *Develop a National Post-Earthquake Information Management System* is a **NEHRP Strategic Priority**.

Outcome: A managed NEHRP-supported effort to collect, archive, maintain, and disseminate accurate post-earthquake investigation information, with emphasis on information relevant to the United States and its society and infrastructure. Information will be cataloged in the PIMS electronic data repository to maximize public accessibility and ease of use via the Internet. PIMS can also form the basis for a future expanded national information repository for post-event investigation data collected from other major natural hazards, such as floods, hurricanes, and tornadoes.

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

NEHRP will use the results of basic research (Goal A) to develop technologies, practices, procedures, tools, and standards for implementing cost-effective earthquake risk reduction measures. Products will include improved understanding of the levels of community resilience needed; relevant, cost-effective engineering analysis, design, and construction techniques; more accurate seismic maps and hazard assessments; advanced reference materials suitable for use by building code developers; support for hazard mitigation ordinances, programs, and incentives; and early warning of major earthquake activity. These products will be tested for their applicability and vetted with professional organizations for their acceptability. NEHRP will ensure that the products are widely distributed in easily accessed and implemented formats.

Objective 5: Assess earthquake hazards for research and practical application

NEHRP will produce computer-based models of expected ground shaking amplitudes for a variety of mitigation purposes. These models underlie NEHRP's National Seismic Hazard Maps that support national model building codes. These national hazard assessments are updated every

several years to incorporate results of new research and earthquake activity. The updates are closely coordinated with the earthquake professional community. NEHRP will also develop detailed hazard assessments and maps showing shaking intensities and areas of potential surface faulting and ground failure for key urban areas at risk (See Figure 9), as well as updated, time-dependent regional seismic hazard assessments when they are warranted. NEHRP will continue to improve these assessments by including new data and the results of research on the effects of regional deformation, local geology, fault interactions, ground failure and liquefaction susceptibilities, and quantitative estimates of uncertainties in the assessments.

NEHRP will support research on significant factors that contribute to the characteristics of ground shaking (amplitude, duration, and frequency content) in earthquakes. These factors include earthquake type, depth, and direction of fault rupture; attenuation along seismic wave paths; and local geology, topography, and soil conditions.

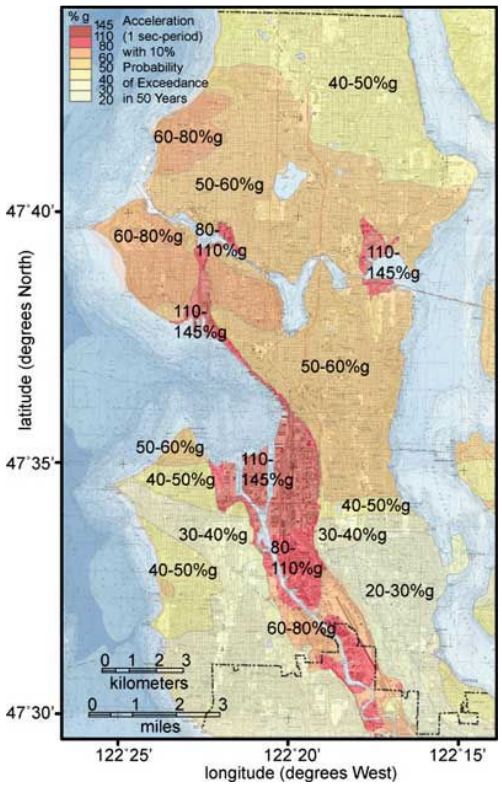

Figure 9. Detailed seismic hazard assessment for Seattle, WA. This information is being used in mitigation planning in the Puget Sound area. Image courtesy of USGS.

Outcome: Application of this knowledge to the building codes and standards development process, ultimately leading to improved building codes and mitigation actions based on advanced understanding and estimates of earthquake ground shaking and potential for surface faulting, liquefaction, and landslides over various geographic scales, time periods, and geologic settings.

Objective 6: Develop advanced loss estimation and risk assessment tools

NEHRP loss estimation and risk assessment tools will be used to support Federal, State, and local emergency management and response for the post-earthquake environment. Research using these tools will extend to recent preliminary findings regarding post-disaster loss estimates and impacts and emergency management support models.

NEHRP will continue to develop and improve modeling capabilities that quantify the benefits of earthquake risk mitigation measures relative to their costs. Communities will be able to use this modeling capability to maximize the impacts of their mitigation dollars. NEHRP will continue to build on and refine loss estimation tools, such as the nationally established HAZUS-MH and the

recently developed MAEviz (See Appendix A). NEHRP will develop loss estimation tools that can be applied in real time to support enhanced State and local response and speed Federal response.

In addition to improving these tools, NEHRP will work to expand the application of these tools at regional and local levels through the training of potential users and dissemination of results. In pursuit of this objective, NEHRP will apply relevant results from other programs and experiences gained in addressing other natural hazards.

Outcome: Application of state-of-the-art, cost-effective earthquake loss and risk modeling tools to support mitigation and preparedness measures and emergency response capabilities.

Objective 7: Develop tools to improve the seismic performance of buildings and other structures

NEHRP will support the development of new materials, structural systems, and techniques for rehabilitating existing structural systems that will improve the seismic resilience of buildings and other structures.

NEHRP will support research on the key aspects of next-generation PBSD criteria for new and existing buildings. Current model building codes are largely prescriptive in nature and founded principally on one objective: to prevent substantial loss of life. For conventional buildings, they do not guarantee complete safety of inhabitants, specific limits on damage, or continued functionality after strong shaking. By increasing design conservatism, selected provisions of building codes attempt to ensure that buildings classified as "essential" (e.g., hospitals and fire stations) will be able to serve their intended functions following earthquakes, but actual performance is not clearly defined. The codes often fail to support architecturally or functionally unique building designs, such as those found with tall buildings. NEHRP will work with the physical sciences, engineering, social sciences, and practitioner communities to define new PBSD parameters and methodologies so that buildings can be designed to specified, post-earthquake performance levels. *Further Develop PBSD* is a **NEHRP Strategic Priority**.

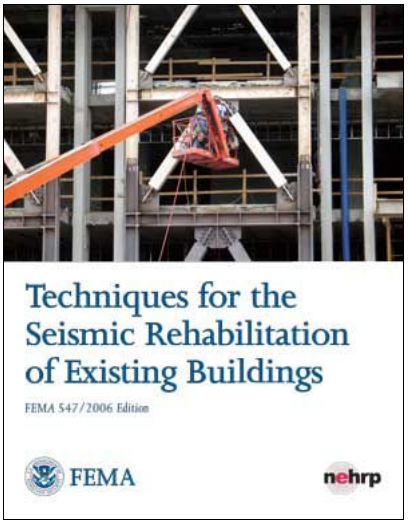

Figure 10. FEMA 547—this report, developed in partnership with NIST, documents techniques used by structural engineers to strengthen existing buildings. Image courtesy of FEMA.

Many older buildings present severe collapse hazards in large earthquakes. More research is needed to understand the special problems associated with evaluating and rehabilitating older buildings, as well as to develop the guidance needed to enable practitioners to put that knowledge to use so that only the truly dangerous older

buildings are identified. NEHRP will continue to support research on evaluating the earthquake safety and functionality of existing buildings, their cost-effective retrofit and rehabilitation, and translation of research results into effective guidance (See Figure 10). Research findings will help to reduce the conservatism in current national consensus procedures for existing buildings. NEHRP will also identify viable economic justifications that provide incentives to complete needed rehabilitation. These measures should reduce costs and encourage implementation of mitigation measures. *Improve Techniques for Evaluating and Rehabilitating Existing Buildings* is a **NEHRP Strategic Priority**.

NEHRP will continue to support developing and improving analysis procedures that define more accurately earthquake shaking and other effects on nonstructural elements. It will also support the development of new technologies that can be used to support or secure such elements in ways that will ensure occupant safety during earthquakes.

NEHRP will support expanded structural response monitoring of existing and new buildings and other structures in relatively high-hazard settings to obtain data that complement experimental testing and numerical analysis results. This monitoring will be accomplished through ANSS (Objective 9) and other associated monitoring systems that are placed in buildings. NEHRP will pursue development and deployment of systems of building motion sensors and associated wireless data communications that significantly reduce the cost of building monitoring. NEHRP will also support the development and use of response modification techniques that can provide cost-effective and dependable active or passive control of building response during earthquake shaking.

NEHRP will facilitate transferring knowledge gained in basic research projects (Objective 2) to practicing engineers, in ways that are readily understood and applicable, to increase the use of new technical innovations and tools in engineering practice, thus improving the cost-effectiveness of earthquake-resistant design and construction. Building structural systems (new and existing), nonstructural contents in buildings (See Figure 11), geostructures, lifelines, and non-building structures will be addressed. This will be accomplished through a combination of short-term and long-term applied research efforts, including combining numerical studies with experimental projects using the NEES facilities.

Figure 11. Nonstructural damage (fallen ceiling, partitions, piping, and ducts) to the basement of the Olive View Medical Treatment Building caused by the 1971 San Fernando earthquake in California.

ANSS will contribute to this objective by providing recordings of strong ground

shaking during earthquakes. ANSS will also provide recordings from instrumented structures showing their responses to strong ground shaking. This quantitative information is essential for advances in earthquake-resistant engineering design and construction practices.

As applicable, this work will incorporate the results and techniques developed for the mitigation of other natural and man-made hazards. *Develop Advanced Earthquake Risk Mitigation Technologies and Practices* is a **NEHRP Strategic Priority**.

Outcome: New cost-effective engineering design and construction practices for new and existing buildings and nonstructural building elements. With existing effective measures, these practices will be implemented by building designers, regulators, and the construction industry.

Objective 8: Develop tools to improve the seismic performance of critical infrastructure

NEHRP will use the results of basic research in earthquake-resistant design and construction to develop technologies and measures suitable for system-wide mitigation in new and existing infrastructure lifelines (See Appendix B) and critical facilities (e.g., facilities critical to public health, business continuity, or key economic or governmental functions). As part of this effort, NEHRP will coordinate with appropriate Department of Homeland Security (DHS) elements and initiatives including the *National Infrastructure Protection Plan—Addressing the Nation's Critical Infrastructure Elements and Key Resource Components*, and ongoing research work supported through the DHS Centers of Excellence. *Develop Earthquake-Resilient Lifeline Components and Systems* is a **NEHRP Strategic Priority**.

Figure 12. Model bridge tested at the University of Nevada, Reno, NEES facility. © 2007 by Mehdi Saiidi.

NEHRP will develop and promote the adoption and dissemination of industry and consensus standards, guidelines, and methodologies for reducing vulnerabilities of critical infrastructure systems. Improvements that can increase system survivability include decision-making tools, control systems, structural redundancy, system hardening, automated network assessment, shut-off systems, and dynamic correction and re-routing technologies. NEHRP will develop methodologies to help lifeline owners and operators identify potential earthquake risks and vulnerabilities and minimize their impacts through effective mitigation, thereby increasing system resiliency (See Figure 12).

Critical facilities such as ports and harbors, emergency operations centers, water treatment and distribution systems, and energy distribution systems are crucial to the public safety and economic health of the United States. NEHRP will develop new and improved technologies, mitigation measures, and guidelines to allow those involved in their design, construction, and operation to draw on the available research and experience, which will result in more resilient facilities.

NEHRP will develop partnerships with academic researchers, public- and private-sector professionals, owners, and operators to meet this objective.

Outcome: Increased safety, resilience, and post-earthquake functionality of infrastructure lifelines and critical systems in earthquakes.

Goal C: Improve the Earthquake Resilience of Communities Nationwide

NEHRP will integrate and assimilate the research and products developed under Goals A and B and promote their application. NEHRP will promote the implementation of efficient and effective earthquake safety practices and policies at all levels of government, within the private sector, and by the public. Activities include developing modeling tools to illustrate earthquake shaking patterns and impacts on the built environment that are of direct use to communities; assisting model building code development organizations; supporting State and local mitigation efforts; and fostering training, outreach, and education efforts for State and local leaders, the private sector, and the public. NEHRP will also use data provided by ANSS and the GSN to disseminate rapid and accurate information on earthquake impacts to emergency responders and affected communities. Improved earthquake resilience will also provide improved resilience against other natural (e.g., wind) and man-made (e.g., terrorist) hazards.

Objective 9: Improve the accuracy, timeliness, and content of earthquake information products

NEHRP will continue working toward timely completion of ANSS and for support of its operation and maintenance. ANSS is an effort to expand, integrate, and modernize earthquake monitoring and reporting in the United States. Its organizational structure is complete, integrating all regional and national earthquake monitoring activities into a coherent system with standard operating and reporting procedures. The ANSS National Earthquake Information Center (NEIC) and corresponding regional centers provide earthquake information, notifications, and impact assessments on a 24x7 basis. Despite the operational and organizational achievements of ANSS, the number of instruments

installed on the ground and in buildings in key urban areas provides only about 10 percent of the needed coverage.[12] *Fully Implement ANSS* is a **NEHRP Strategic Priority**.

NEHRP will expand its capability to assess earthquake impacts rapidly. NEHRP intends to produce *ShakeMaps*, based on real-time data and automatic data processing, for all large U.S. urban areas with moderate to high seismic risk. A *ShakeMap*, produced and distributed within minutes of an earthquake, is a quantitative, graphic depiction of the severity and distribution of ground shaking in an urban area. The new *Prompt Assessment of Global Earthquakes for Response* (PAGER) system couples *ShakeMaps* with population data to provide rapid estimates of population exposure to damage (See Figure 13).

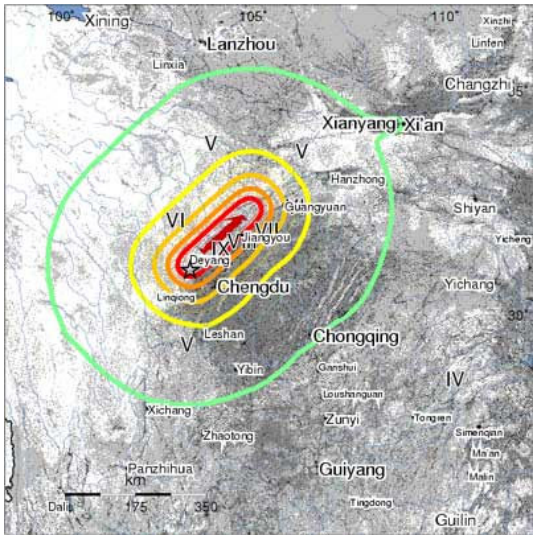

Figure 13. Earthquake damage area (intensity) estimated by the NEIC based on seismic wave analyses within a few hours of the magnitude 7.9 quake in China in May 2008. Star indicates earthquake epicenter. Early casualty estimates were based on this analysis. The total map area shown is approximately 1 million square kilometers. Image courtesy of USGS.

These ANSS products provide vital quantitative projections of an earthquake's impact to emergency response officials and the public. Managers of infrastructure lifelines, medical facilities, and business interests can also use *ShakeMaps* to estimate damage to specific facilities. Because the accuracy of *ShakeMaps* depends on the number and distribution of seismic instruments providing data for analysis, the successful realization of *ShakeMap* capabilities is directly linked to full ANSS implementation.

NEHRP will develop reliable automatic data processing techniques for rapid earthquake source characterization and notification. The 2004 Indian Ocean tsunami disaster exposed a critical need for rapidly and accurately characterizing extremely large earthquakes worldwide, a complex problem that challenges current limits of field instrumentation and automated data analysis procedures. NEHRP will further improve the rapidity and accuracy of information on magnitudes, locations, depths, and shaking intensities of extremely large earthquakes, using data from ANSS and the GSN, in close coordination with the National Oceanic and Atmospheric Administration Tsunami Warning Centers. The GSN will be operated at a high level of performance to support NEHRP's real-time monitoring mission and research data needs.

NEHRP will evaluate and test "earthquake early warning" systems, such as those that have been successfully deployed in Japan, Taiwan, Mexico, and other nations. Such systems can detect an

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

earthquake in progress and provide notice seconds to tens of seconds prior to actual ground shaking. Potential applications include safely stopping elevators, halting trains, monitoring critical systems, and alerting people to move to safer locations. Building on progress that has recently been made through research and development efforts in California, through the California Integrated Seismic Network (a part of ANSS) and the Southern California Earthquake Center, NEHRP seeks to identify which enhancements to the existing monitoring networks will be needed to support reliable earthquake warnings and to test warning systems that enhance public safety and contribute to loss reduction.

NEHRP will operate and maintain deformation monitoring networks (GPS, crustal strain, and fault creep) in selected high-hazard areas, and will incorporate data from these networks in earthquake monitoring products and analyses. In this effort NEHRP will work closely and cooperatively with the Plate Boundary Observatory and San Andreas Fault Observatories funded by NSF through the *EarthScope* program. Data from these networks and facilities are important for understanding the earthquake cycle, including pre- and post-seismic phenomena such as subsurface displacements, stress and strain changes, and aftershock sequences. Portable, readily deployable arrays of geophysical instruments can provide essential augmentation to fixed networks during post-earthquake studies. NEHRP will operate and maintain deformation monitoring networks in selected high-hazard areas and work cooperatively with other interests to augment these networks following significant earthquakes.

Outcome: A standardized, comprehensive, and modern seismic monitoring and data analysis system, providing high-quality data and information for accurate and timely notification on earthquakes and their impacts worldwide, as well as data for tsunami warning, earthquake hazard and loss assessments, and basic and applied research in seismology and engineering.

Objective 10: Develop comprehensive earthquake risk scenarios and risk assessments

NEHRP will promote the development of realistic earthquake scenarios for urban communities and regions that are at moderate or higher risk. These scenarios are based on assessments of earthquake hazards, detailed and accurate inventories (engineering descriptions of buildings and infrastructure), and standardized procedures to model earthquake impacts. Earthquake impact scenarios have been used recently in Salt Lake City, Seattle, San Francisco, and Los Angeles to communicate risk, increase public awareness, assist State and local governments in preparing for response, and initiate mitigation efforts. These scenarios will apply the HAZUS-MH risk assessment and loss estimation tool and products from all aspects of the NEHRP effort, including *ShakeMap*.

Scenarios highlight the earthquake vulnerabilities of any community or region, pointing to key mitigation strategies required to reduce those vulnerabilities and highlighting needed post-earthquake response and recovery measures. These vulnerabilities could include a class of buildings, such as unreinforced masonry, or specific vulnerabilities, such as essential facilities or critical infrastructure components. Community leaders, representing both government and private

interests, should be involved in funding, managing, and developing these scenarios, ensuring that results are accepted and actionable. *Develop and Conduct Earthquake Scenarios for Effective Earthquake Risk Reduction and Response and Recovery Planning* is a **NEHRP Strategic Priority**.

NEHRP will undertake multidisciplinary investigations to analyze the relative vulnerabilities of various population segments, critical facilities, and organizations. Public- and private-sector organizations will be analyzed. Means will be developed to identify the most at-risk components of national social, economic, and government systems. To help communities take cost-effective actions, NEHRP will develop economic models that define optimum strategies for applying limited funds for earthquake risk reduction. *Increase Consideration of Socioeconomic Issues Related to Hazard Mitigation Implementation* is a **NEHRP Strategic Priority**.

NEHRP will also take advantage of data collected following, and the knowledge gained as a result of, significant earthquakes to improve the quality of the input for these assessments and scenarios. Support for scenarios and risk assessment is directly tied to the **Strategic Priority** *Develop a National Post-Earthquake Information Management System.*

Outcome: Improved understanding of regional and community earthquake risks and greatest vulnerabilities through state-of-the-art impact scenarios will lead to the implementation of effective and efficient mitigation and emergency response, relief, and recovery planning measures.

Objective 11: Support development of seismic standards and building codes and advocate their adoption and enforcement

NEHRP will actively support the development, and advocate the adoption and enforcement, of earthquake-resistant design and construction provisions in national standards and model building codes for new and existing buildings. These model building codes provide engineering standards and guidelines that can be adopted in State and local building code statutes.

NEHRP will provide technical support and resources to professional groups and organizations (e.g., the Building Seismic Safety Council) that develop model building codes and the documents upon which the model codes are based in order to achieve transparent performance levels for all construction. This support culminates periodically in the issuance of the *NEHRP Recommended Provisions* (most recently FEMA 450), which are then made available to professional organizations (See Figure 14). Working with leading private sector practitioners and academic

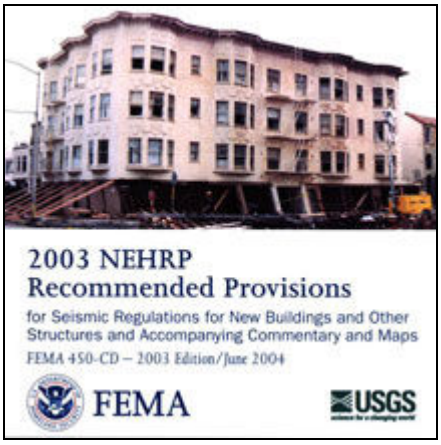

Figure 14. FEMA 450—2003 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. Image courtesy of FEMA.

researchers, NEHRP will ensure that relevant results of basic and applied research are developed to facilitate their practical application. NEHRP will support testing and validation of new design and construction techniques before they are proposed for building code adoption.

NEHRP will also support short-term, applied research projects that evaluate and demonstrate the need for and effectiveness of proposed code changes or innovations and assist in the transition of new research results into code revisions. NEHRP research will develop analytical and modeling tools for use by practicing engineers that enhance cost-effectiveness in the design process. This activity is tied directly to the **Strategic Priority** *Develop Advanced Earthquake Risk Mitigation Technologies and Practices.*

NEHRP will work in cooperation with the model building code community to improve the cost-effectiveness of building design requirements. National model building codes use both prescriptive and performance-based procedures for building design. Sustained efforts are needed to improve the existing prescriptive requirements and further develop the performance-based requirements. Efforts are also needed to make building performance expectations clear and easily understood, by both earthquake professionals and the public (See Objective 7).

NEHRP will also work to encourage and improve the acceptance and application of nationally recognized model building codes. Economic concerns and lack of understanding of the bases for new seismic code provisions can inhibit their adoption. NEHRP will study the bases of these concerns and identify means to address them, drawing on work carried out under Objective 3. NEHRP will also work cooperatively with the model building code community to address social, economic, and public policy influences on code application and to explore incentives that encourage local code adoption. Similarly, NEHRP will work to encourage the acceptance and application of seismic evaluation and design standards for lifelines.

Outcome: Improved, cost-effective earthquake safety through widespread adoption of the seismic provisions of building codes and design guidelines that are based on realistic hazard assessments, current results of engineering research and testing, and systematic review and evaluation by professional organizations.

Objective 12: Promote the implementation of earthquake-resilient measures in professional practice and in private and public policies

NEHRP will support comprehensive knowledge and technology transfer efforts. Working closely with private-sector, national model building code, and consensus standards organizations, NEHRP will prepare, maintain, and widely disseminate earthquake-resistant design guidance and related information on building codes, standards, and practices for new and existing buildings, structures, and lifelines. NEHRP will work closely with private-sector and national model building code organizations to develop improved means of knowledge transfer, including promoting the training of enforcement personnel.

NEHRP will promote the recognition of earthquake risks in corporate, financial, and business continuity planning, and in the insurance industry. This will be done in part through work with multistate earthquake consortia and similar groups.

NEHRP will work to promote earthquake mitigation at the State and local level, using various tools such as the existing Pre-Disaster Mitigation Grant Program and other assistance, to enable States and localities to develop mitigation, preparedness, and response plans. Mitigation grants and assistance have typically supported preparing inventories of existing buildings, conducting seismic safety inspections of critical structures and lifelines, updating construction and zoning codes, assisting communities in developing ordinances for community seismic safety, and increasing earthquake awareness and education. NEHRP will support the establishment and operation of State seismic safety commissions and committees, as well as multistate groups and consortia when earthquake mitigation and response planning efforts cross State boundaries. Finally, NEHRP will promote the training and professional development of all members of the building industry and the staffs of building regulatory agencies to ensure earthquake safety requirements are effectively applied and enforced. NEHRP will investigate the cost-effectiveness, impact, and acceptability of various incentives to increase public and private earthquake loss reduction actions. *Facilitate Improved Earthquake Mitigation at State and Local Levels* is a **NEHRP Strategic Priority**.

NEHRP will support the adoption of earthquake safety practices in Federal agencies through the Interagency Committee on Seismic Safety in Construction. Inventories of Federal agency buildings in the mid-1990s showed that the agencies owned more than 360,000 buildings and leased space in more than 50,000 additional buildings. In addition to providing safety for the occupants of these buildings, the Federal Government, as the largest single owner and lessor of buildings in the United States, can set a positive example for seismic safety that stimulates implementation efforts in State and local governments and the private sector.

NEHRP will promote broad dissemination of earthquake risk mitigation information, ensuring that research results and products (Objectives 5–9) are available to earthquake professionals and the public. Activities include expanding, enhancing, and advertising the NEHRP website (www.nehrp.gov) via links to NEHRP agencies and cooperating organizations and developing complementary means for disseminating earthquake hazards information and risk reduction products.

Outcome: Increased effectiveness of earthquake mitigation activities through the development and promotion of consistent and constructive risk mitigation policies and practices throughout all levels of government. Improved technology and knowledge transfer will ensure that appropriate earthquake professionals and the public adopt cost-effective knowledge and tools, reducing overall earthquake vulnerabilities for the Nation.

Objective 13: Increase public awareness of earthquake hazards and risks

NEHRP will support comprehensive earthquake public awareness programs, including the development and dissemination of materials to all appropriate audiences. It will support public access to locality-specific information that may assist the public in preparing for, responding to, and recovering from earthquakes. Working with local partners, NEHRP has distributed fact sheets, preparedness handbooks, scenario study results, and other materials to areas of the United States that are at risk. Individual NEHRP agency websites reach many on a daily basis.

To increase public awareness, NEHRP will strive to reach the widest audiences, of all national and ethnic backgrounds, in the most cost-effective manner. A variety of methods will be employed to reach audiences, including articles and presentations for professional, trade, and public groups; dissemination of information materials at public forums and conferences; cooperative efforts with other Federal, State, and local partners; and communications initiatives to increase public awareness of earthquake risk and measures that can be undertaken to reduce or eliminate its effects.

NEHRP is organizing and reviewing earthquake potential and prediction research through the National Earthquake Prediction Evaluation Council, in cooperation with the State-operated California Earthquake Prediction Evaluation Council (where geographically appropriate). NEHRP will enhance its support of peer reviews of earthquake potential assessments and predictions; provide consensus-based statements to the public on the meaning and importance of these assessments; and promote general public understanding of earthquake potential and prediction science and related issues.

Outcome: Increased public understanding of earthquake safety issues, including earthquake forecast statements.

Objective 14: Develop the Nation's human resource base in earthquake safety fields

NEHRP is committed to cultivating a world-class, broadly inclusive workforce with the technical knowledge in earth sciences and earthquake engineering to make our Nation more earthquake-resilient. NEHRP will support earth-sciences and earthquake-engineering education at all levels, including K-12, university-based, and informal learning for the public (See Figure 15). NEHRP will serve scientists, engineers, architects, builders, regulators, educators, students, and the public across the Nation, especially reaching out to groups underrepresented in earth sciences and earthquake engineering. NEHRP will also encourage research and education partnerships, nationally and internationally, to prepare students to become

Figure 15. Grade-schoolers learn about earthquakes during a visit to the National Earthquake Information Center. Image courtesy of USGS.

highly productive members of the global workforce in disaster reduction. NEHRP will support networks of research organizations, educational institutions, science centers, museums, professional societies, and small and large businesses to increase public awareness of earthquake hazards and community resiliency.

Outcome: Increased public awareness of the professional opportunities, challenges, and rewards of careers in fields related to earthquake safety.

Chapter

4

Strategic Priorities

This Strategic Plan is the first developed and approved by the National Earthquake Hazards Reduction Program (NEHRP) Interagency Coordinating Committee (ICC).[13] The Plan builds on concepts presented in the previous NEHRP Strategic Plan, *Expanding and Using Knowledge to Reduce Earthquake Losses, The National Earthquake Hazards Reduction Program Strategic Plan, 2001–2005* (FEMA 383), and sets a clear and comprehensive strategy to accomplish the NEHRP mission for fiscal years 2009–2013. The Plan draws upon several recently published documents and studies by others that make recommendations on future NEHRP directions.

To support the development of this Strategic Plan, the ICC oversaw a number of key actions in 2006 that identified gaps in the Program activities that were outlined in the previous Plan. These activities included an open forum for earthquake professionals at a major professional conference, a month-long web-based public comment period, an internal gap analysis of ongoing Program activities, and a review of Hurricane Katrina after-action reports. In addition, the Advisory Committee on Earthquake Hazards Reduction (See Appendix C) provided inputs to the ICC at a 2007 meeting.

Following these activities, the ICC identified nine Strategic Priorities (new thrust areas) that deserve increased emphasis by the NEHRP agencies, beyond their ongoing activities, contingent on available resources. The following list of the priorities presents them in the general order in which related Program goals and objectives are presented in Chapter 3. The listing is not in a ranked order of significance or criticality. Most of these Strategic Priorities will require coordinated multiagency, multidisciplinary activities.

Fully Implement the Advanced National Seismic System (ANSS)

In its 2006 report,[14] the National Research Council (NRC) described the benefits of fully implementing ANSS, a nationwide multipurpose network of free-field (in-ground) and in-structure seismic instrumentation. These instruments will provide the basic data on ground and building response in earthquakes that will be used in earthquake impact notification, deployment of response

[13] The ICC, established by Congress in P.L. 108-360, comprises the Directors of the Office of Science and Technology Policy, the Office of Management and Budget, FEMA, NSF, NIST, and USGS. See Appendix C.

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

resources, hazard assessments, and research. NRC concluded that "Full deployment of the ANSS offers the potential to substantially reduce earthquake losses and their consequences by providing critical information for land-use planning, building design, insurance, warnings, and emergency preparedness and response." In NRC's judgment, ANSS "would yield benefits amounting to several times the cost of improved seismic monitoring." This thrust area engages all NEHRP agencies in accelerating the ANSS deployment and making full use of the data that will be gathered by the system. This Strategic Priority supports **Objective 1** and **Objective 9**.

ANSS will provide essential data on strong earthquake shaking and its effects on buildings. This information impacts Goals A, B, and C. It will be used to understand better the generation of strong ground motions during earthquakes; improve models for predicting strong ground motions (including those used in model building codes); improve understanding of strong ground motion effects on buildings and lifeline systems; develop tools to improve the seismic performance of buildings, other structures, and lifelines; and improve the accuracy, timeliness, and content of earthquake information products.

Improve Techniques for Evaluating and Rehabilitating Existing Buildings

This Strategic Priority will engage NEHRP in basic and applied research and in knowledge-transfer activities with the earthquake professional community to develop and deploy cost-effective technologies for improving the earthquake resistance of existing buildings (See Figure 16). A 2003 NRC report[15] noted that "the economical retrofit of existing structures is perhaps the most important issue facing earthquake-prone communities today," and that "a new generation of retrofit technologies that cost less than existing, less effective techniques but preserve cultural and architectural resources and protect real estate investments from total loss is long overdue." This Strategic Priority supports **Objective 2** and **Objective 7**.

Figure 16. Laboratory testing of an older concrete column design. This type of damage is similar to that seen in Figure 2. © 2002 by Pacific Earthquake Engineering Research Center.

Further Develop Performance-Based Seismic Design (PBSD)

Existing national model building codes emphasize prescriptive seismic design procedures that seek to minimize loss of life but do not comprehensively address minimizing direct or indirect economic losses. PBSD

[15] National Research Council, *Preventing Earthquake Disasters—The Grand Challenge in Earthquake Engineering*, 2003.

focuses on what to achieve in building performance, providing a wider range of design options than prescriptive code-based procedures. It promises to bring greatly improved economy and functionality in seismic design. PBSD has been facilitated by the advent of sophisticated computational capabilities in the practicing engineering community. However, PBSD requires more detailed knowledge of how structures and nonstructural elements perform, as well as a clear understanding of what level of performance is needed to achieve desired resilience. Because the step-by-step building-code-based procedure is not used, PBSD also alters decision-making and liability processes to include more complete and complex analyses, additional consideration of risk levels, and more extensive consideration of cost-risk tradeoffs. This will require more extensive knowledge about social behavior, structural performance needed to support response and recovery, and investment decision making as described in the following Strategic Priority. Public Law 108-360 directed NEHRP to "support the development of performance-based seismic engineering tools, and work with appropriate groups to promote the consistent commercial application of such tools." This thrust will engage the NEHRP agencies in performing basic and applied research that supports PBSD development and in the knowledge-transfer activities needed to support implementation. This Strategic Priority supports **Objective 2** and **Objective 7**.

Increase Consideration of Socioeconomic Issues Related to Hazard Mitigation Implementation

A 2006 NRC report[16] discusses the numerous contributions that NEHRP has made to social sciences research related to natural disasters and provides an overview of continued social sciences research needs. The report highlights the need to integrate research on societal response, hazard vulnerability and mitigation, disaster preparedness, emergency response, and disaster recovery. The NEHRP agencies will seek to implement the NRC recommendations for future research. More importantly, they will work with State and local governments, practitioners, business owners, and insurers to improve disaster preparedness and hazard mitigation. Nowhere is this issue more significant than in the existing buildings area, another of the Strategic Priorities. This Strategic Priority supports **Objective 3**, **Objective 10**, and **Objective 12**.

Develop a National Post-Earthquake Information Management System

All of the referenced NRC reports mention the need for collecting, cataloging, preserving, and disseminating actual post-earthquake damage and effects observations. A 2007 NRC report[17] more broadly discusses the many issues related to improved use of information technology resources to collect and utilize disaster data. Field investigation data are virtually priceless in terms of "lessons learned" value as they provide full-scale performance data for real buildings and infrastructure systems. NEHRP will work with the earthquake professional community to improve post-

[16] National Research Council, *Facing Hazards and Disasters—Understanding Human Dimensions*, 2006.

[17] National Research Council, *Improving Disaster Management—The Role of IT in Mitigation, Preparedness, Response, and Recovery*, 2007.

earthquake reconnaissance and detailed and structured data collection; develop a national post-earthquake information management system; and stimulate the use of this information management system by researchers, practicing engineers, and government and business leaders. Included in this activity will be an update of USGS Circular 1242, *The Plan to Coordinate NEHRP Post-Earthquake Investigations*. This Strategic Priority supports **Objective 4**.

Develop Advanced Earthquake Risk Mitigation Technologies and Practices

NEHRP effectiveness has been limited by a lack of practical, effective mechanisms to transfer fundamental engineering and scientific knowledge gained from National Science Foundation-supported basic research into practical measures that can be implemented in model building codes, design tools, and construction standards. Such transfer will facilitate cost-effective design and construction of earthquake-safe structures. This need was highlighted in a 2003 Applied Technology Council report[18] as a "research-to-implementation gap." This Strategic Priority follows that report's recommendation to establish an applied research and development program that links basic research results to the practicing engineering professional. This Strategic Priority supports **Objective 7** and **Objective 11**.

Develop Earthquake-Resilient Lifeline Components and Systems

Through its impact on national model building codes, NEHRP has successfully introduced measures to significantly reduce immediate loss of life in buildings in future earthquakes. However, the 2003 NRC report[19] and the 2006 NRC report[20] emphasize the significant vulnerabilities of the Nation's infrastructure lifeline systems—transportation systems; ports; energy transmission and distribution systems; water and sewage systems; communications networks; and key industrial systems. These vulnerabilities are heightened because such systems often have complexities related to collocation and/or interdependencies that can lead to cascading failures, with local, regional, and national consequences. In addition, the systems typically extend over long distances, minimizing the chances of hazard mitigation through selecting safe sites, such as might be done for single structures. Disruptions to interconnected, networked systems have wide-reaching impacts, far beyond the collapse or damage of any individual structure. More resilient infrastructure lifelines will also enable more effective post-earthquake response and recovery. NEHRP will focus its efforts on critical lifeline components and systems that are not being addressed by other agencies or organizations, thus avoiding duplicative efforts and maximizing leveraging of resources. Increasing

[18] Applied Technology Council, *The Missing Piece: Improving Seismic Design and Construction Practices*, ATC-57, 2003.

[19] National Research Council, *Preventing Earthquake Disasters—The Grand Challenge in Earthquake Engineering*, 2003.

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

lifeline resilience will be highly multidisciplinary in nature; all NEHRP agencies will be engaged in this initiative. This Strategic Priority supports **Objective 8**.

Develop and Conduct Earthquake Scenarios for Effective Earthquake Risk Mitigation and Response and Recovery Planning

Earthquake scenarios are important tools for risk mitigation and disaster response and recovery, presenting a realistic picture of regional impacts of significant earthquakes likely to strike the Nation. Properly crafted scenarios help government, community, and business leaders, as well as the public, better understand earthquake consequences as they plan for the future. Examples of recent comprehensive scenarios include those for damaging earthquakes striking the Seattle[21] and San Francisco Bay[22] areas (See Figure 17). NEHRP will work with non-governmental partners and community leaders to develop a suite of consistently defined scenarios for the Nation's earthquake-prone urban areas. This Strategic Priority supports **Objective 10**.

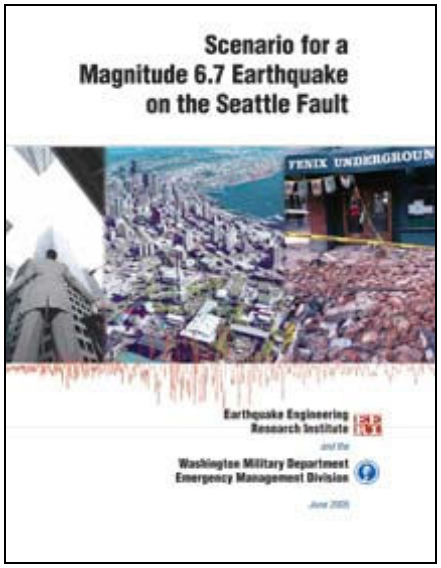

Figure 17. Cover from a Seattle scenario report. © 2005 by Earthquake Engineering Research Institute and Washington Military Department Emergency Management Division.

Facilitate Improved Earthquake Mitigation at State and Local Levels

The recent NEHRP reauthorization requires the Federal Emergency Management Agency (FEMA) to "operate a program of grants and technical assistance to enable States to develop preparedness and response plans, prepare inventories, conduct seismic safety inspections of critical structures and lifelines, update building and zoning codes and ordinances to enhance seismic safety, increase earthquake awareness and education, and encourage the development of multi-state groups for such purposes." FEMA has historically addressed this requirement by supporting multistate earthquake consortia and administering a program of State earthquake risk mitigation grants. Since 2003, all such grants have been consolidated into Department of Homeland Security grant programs, losing their targeted earthquake identity. Subject to availability of funding, NEHRP will endeavor to reestablish a dedicated State earthquake grant program. This Strategic Priority supports **Objective 12**.

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[21] Earthquake Engineering Research Institute and Washington Military Department Emergency Management Division, *Scenario for a Magnitude 6.7 Earthquake on the Seattle Fault*, 2005.

[22] Earthquake Engineering Research Institute, Earthquake Spectra, Vol. 22, No. S2, *When the Big One Strikes Again —Estimated Losses Due to a Repeat of the 1906 San Francisco Earthquake*, 2006.

Chapter

5

Summary

This document provides a straightforward, realistic, and executable Strategic Plan for the National Earthquake Hazards Reduction Program (NEHRP) during the period 2009–2013. It is based on what is needed and practical, and it presents the most efficient and effective uses of NEHRP resources to reduce future losses from earthquakes in the United States. The Plan is purposely based on a realistic and reasonable assessment of the anticipated constraints facing NEHRP over the Plan duration. This strategy has been studied and developed over a 12-month period by the NEHRP agencies, and has received attention and review at the highest levels of these agencies through the NEHRP Interagency Coordinating Committee (ICC). The pace of Program accomplishment, including addressing the nine new Strategic Priorities, will depend on the resources that are available to the Program agencies during the Plan period.

The planning principles, goals, objectives, and implementation strategies of this Plan will serve as formal guidelines for all NEHRP efforts. Starting with the fiscal year 2007 report published in March 2008, the NEHRP Annual Reports will follow the structure given in this Plan, reporting on activities under each goal and objective, as well as progress toward anticipated outcomes. This will provide a direct basis for the ICC, the Advisory Committee on Earthquake Hazards Reduction (ACEHR), and the earthquake professional community to measure Program success. A companion Management Plan that provides more detailed assessment criteria for Program accomplishment will be developed following the adoption of this Plan. Required by statute, this Management Plan will be produced jointly by the NEHRP agencies and will be consistent with their anticipated appropriations. Management Plan revisions that reflect accomplishments, needs, and available resources will be developed as needed.

During the Strategic Plan period, the NEHRP agencies will keep abreast of advancements in science and technology, adjusting both short- and long-term developmental efforts to take advantage of them. To support this, NEHRP will conduct workshops and other planning initiatives to highlight new technology breakthrough areas and their applications. These activities will be organized in consultation with ACEHR and in partnership with members of the earthquake professional community.

If a major earthquake occurs in the United States during the Plan period, NEHRP will initiate efforts to study the effects and impacts of that event. These studies will assess what worked, what failed, and what unforeseen problems arose in mitigation, response, and recovery practices and policies. Should this occur, this Plan may be overtaken by events and need significant revision.

NEHRP will continue to explore developing specific, effective partnerships with its stakeholder community—appropriate academic, industry, government, technical, professional, and codes and standards organizations that are intimately involved with the earthquake risk reduction process. Through these efforts, unanticipated but welcome opportunities may emerge that require timely response from NEHRP.

Thus, NEHRP will remain focused on the elements of this Plan but adaptable to contingencies and opportunities as they arise. In addition to reviewing annual accomplishments and progress, the ICC will review this Plan annually. With the advice of ACEHR, the ICC will determine what changes, if any, are needed to improve its applicability and effectiveness.

A 2003 report[23] noted that "our ability to secure society against catastrophic earthquake losses depends on a strong and viable NEHRP." Properly supported and implemented, this Strategic Plan fulfills that need.

[23] Earthquake Engineering Research Institute, *Securing Society Against Catastrophic Earthquake Losses: A Research and Outreach Plan in Earthquake Engineering*, June 2003.

Appendix

A

Abbreviations and Acronyms

ACEHR	Advisory Committee on Earthquake Hazards Reduction
ANSS	Advanced National Seismic System
DHS	Department of Homeland Security
EERI	Earthquake Engineering Research Institute
FEMA	Federal Emergency Management Agency
FY	Fiscal Year
GSN	Global Seismographic Network
HAZUS	Hazards U.S. (FEMA's Earthquake Loss Estimation Methodology)
ICC	NEHRP Interagency Coordinating Committee
ICSSC	Interagency Committee on Seismic Safety in Construction
IRIS	Incorporated Research Institutions for Seismology
MAEviz	Mid-America Earthquake Center seismic loss assessment system
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEHRP	National Earthquake Hazards Reduction Program
NEIC	USGS National Earthquake Information Center
NEPEC	National Earthquake Prediction Evaluation Council
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRF	National Response Framework
NSF	National Science Foundation
NSTC	National Science and Technology Council
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PAGER	Prompt Assessment of Global Earthquakes for Response
PBSD	Performance-Based Seismic Design
PBSE	Performance-Based Seismic Engineering
PCWG	NEHRP Program Coordination Working Group
PIMS	Post-Earthquake Information Management System
SDR	Subcommittee on Disaster Reduction
USGS	U.S. Geological Survey

Appendix

B

Glossary of Key Terms

Built Environment: The constructed (as opposed to natural) surroundings that support human activity, such as buildings, transportation systems, utilities, etc.

Critical Facility: Any facility whose loss would have a debilitating impact on security, economic activity, public health, or safety. Examples of such facilities include hospitals, police and fire stations, emergency operations centers, major airports, and major commercial or naval ports and harbors.

Critical Infrastructure: Assets, systems, and networks, whether physical or virtual, so vital to the United States that the incapacity or destruction of such assets, systems, or networks would have a debilitating impact on security, national economic security, public health or safety, or any combination of those matters.[24]

Disaster Resilience: The ability[25] of social units (e.g., organizations, communities) to mitigate risk, contain the effects of disasters, and carry out recovery activities in ways that minimize social disruption, while also minimizing the effects of future disasters. *Disaster resilience* may be characterized by reduced likelihood of damage to and failure of critical infrastructure, systems, and components; reduced injuries, lives lost, damage, and negative economic and social impacts; and reduced time required to restore a specific system or set of systems to normal or pre-disaster levels of functionality.[26] The National Infrastructure Protection Plan describes *resiliency* as the capability of an asset, system, or network to maintain its function or recover from a terrorist attack or any other incident.[27]

Earthquake Professional: Any professional who is involved with earthquake risk and hazard mitigation, or with response to earthquakes. Includes planners, designers (architects and engineers), builders, researchers, building code officials, and government employees (including legislators).

Hazard: The Department of Homeland Security (DHS)[28] defines *hazard* as "Something that is potentially dangerous or harmful, often the root cause of an unwanted outcome." Earthquake

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[24] Department of Homeland Security, *National Infrastructure Protection Plan*, 2006.

[25] http://mceer.buffalo.edu/research/resilience/Resilience_10-24-06.pdf.

[26] Ibid.

[27] Department of Homeland Security, *National Infrastructure Protection Plan*, 2006.

[28] Ibid.

hazards are potential threats to life and property caused by the effects of earthquakes on the surface of the earth: ground shaking and ground failure through liquefaction or fault breakage.

Infrastructure: DHS[29] defines *infrastructure* as "The framework of interdependent networks and systems comprising identifiable industries, institutions (including people and procedures), and distribution capabilities that provide a reliable flow of products and services essential to the defense and economic security of the United States, the smooth functioning of government at all levels, and society as a whole." The term *infrastructure* is used interchangeably with *civil infrastructure*, *municipal infrastructure*, and *public works*.

Lifelines: Lifelines are major elements of the Nation's infrastructure that are essential to community well-being and serve communities across all jurisdictions and locales.[30] Lifeline systems include, but are not necessarily limited to, drinking water and water treatment systems, transportation systems (highway, rail, airport, port, and harbor), energy (production, refining, storage, and distribution of oil, gas, and electric power), and communications.

Mitigation: DHS[31] defines *mitigation* as "Activities designed to reduce or eliminate risks to persons or property or to lessen the actual or potential effects or consequences of an incident." Mitigation measures are often developed in accordance with lessons learned from prior incidents. Measures may include zoning and building codes, floodplain buyouts, and analysis of hazard-related data to determine where it is safe to build or locate temporary facilities. Mitigation can include efforts to educate governments, businesses, and the public on measures they can take to reduce loss and injury.

Risk: Risk is the potential for loss or injury due to an adverse circumstance or hazard. In the earthquake context, estimates of national risk are based on three primary factors:[32] the inventory of structures, the potential damage and consequences extrapolated from past experience to current conditions, and the seismic hazard as determined from geological and seismological studies.

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[29] Department of Homeland Security, *National Infrastructure Protection Plan*, 2006.

[30] www.americanlifelinesalliance.org.

[31] Department of Homeland Security, *National Infrastructure Protection Plan*, 2006.

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

Appendix

C

NEHRP Today

Congressional Oversight and Mandates

Congress oversees the National Earthquake Hazards Reduction Program (NEHRP) through a reauthorization process it conducts every 2 to 5 years. The most recent reauthorization (Public Law 108-360, enacted in 2004) designated the National Institute of Standards and Technology (NIST) as the lead agency, authorized NEHRP funding through fiscal year 2009, and mandated management, oversight, and reporting requirements.

NEHRP Agency Statutory Responsibilities

By statute, the NEHRP partner agencies are the Federal Emergency Management Agency (FEMA), NIST, the National Science Foundation (NSF), and the U.S. Geological Survey (USGS). The agencies' Program roles draw upon agency mission strengths in a complementary and non-duplicative manner so that NEHRP effectiveness and efficiency are greater than would be accomplished by the agencies acting individually. Tables C.1–C.4 at the end of this appendix list the agencies' statutory (Public Law 108-360) responsibilities and cross-reference them with related goals and objectives in the Strategic Plan.

Program Leadership and Administration

The 2004 reauthorization established the Interagency Coordinating Committee (ICC) to "oversee the planning, management, and coordination" of NEHRP. ICC membership includes the Directors of FEMA, NIST, NSF, USGS, the Office of Science and Technology Policy, and the Office of Management and Budget. The NIST Director chairs the ICC, which meets approximately three times a year to coordinate agency policies and activities relevant to NEHRP, review progress, and address interagency issues that require resolution. As the Program lead agency, NIST staffs a NEHRP Secretariat that supports the ICC.

At the working level, the NEHRP Program Coordination Working Group (PCWG) supports the ICC. The PCWG is composed of representatives of the four NEHRP agencies and meets monthly to implement ICC policies and directives and coordinate NEHRP operational activities. The NEHRP Secretariat supports the PCWG and includes the NEHRP Director, who chairs the PCWG. The NEHRP Director reports to the Director of the NIST Building and Fire Research Laboratory.

Under the provisions of the recent reauthorization, the ICC is responsible for the following:

- A Strategic Plan;
- A detailed Management Plan to implement the Strategic Plan;
- A coordinated interagency budget for the Program; and,
- An annual report.

The legislation specifies that the annual report include the Program budget for each NEHRP agency for the current fiscal year; the proposed Program budget for each NEHRP agency in the next fiscal year; a description of Program activities and results for the previous year; a description of the extent to which the Program has incorporated the recommendations of the Advisory Committee on Earthquake Hazards Reduction (ACEHR); a description of activities and associated budgets for the current and coming fiscal years for those Program agency activities that are not included in the Program but contribute to it; and a description of activities and associated budgets for the current and coming fiscal years for the FEMA NEHRP-related grants program.

Advisory Committee on Earthquake Hazards Reduction

The 2004 reauthorization also directed the establishment of ACEHR to assess trends and developments in the science and engineering of earthquake hazards reduction; the effectiveness of the Program in carrying out its statutory activities; the need to revise the Program; and the management, coordination, implementation, and activities of the Program. ACEHR balances representation from research and academic institutions, industry standards development organizations, State and local governments, and financial communities who are qualified to give advice on earthquake hazards reduction. ACEHR is required to submit biannual reports of its assessments and recommendations for improving NEHRP and advancing the Program toward its goals. ACEHR, which is appointed by and reports to the NIST Director, is established under provisions of the Federal Advisory Committee Act (5 U.S.C. App.). The Designated Federal Official for ACEHR is located within the Office of the Director of the NIST Building and Fire Research Laboratory, and the NEHRP Secretariat supports ACEHR activities.

NEHRP Impact on the Built Environment

NEHRP functions as a pre-disaster research, planning, and implementation body, although individual NEHRP agencies have separate authorities, such as those under the National Response Framework and the Stafford Act. Much of what NEHRP performs is tied closely to design and construction practice in the United States.

Figure C.1 illustrates the role of NEHRP in impacting the built environment, a primary facet of Program activities. Although Figure C.1 does not represent all of what NEHRP accomplishes, it

provides insight into a significant portion of NEHRP's activities. In Figure C.1, NEHRP's activities and functions are seen as elements of a continuous process. Throughout this process, the four Program agencies interact with earthquake professionals in the private sector, in the national model building code organizations, in academia, and in State and local government.

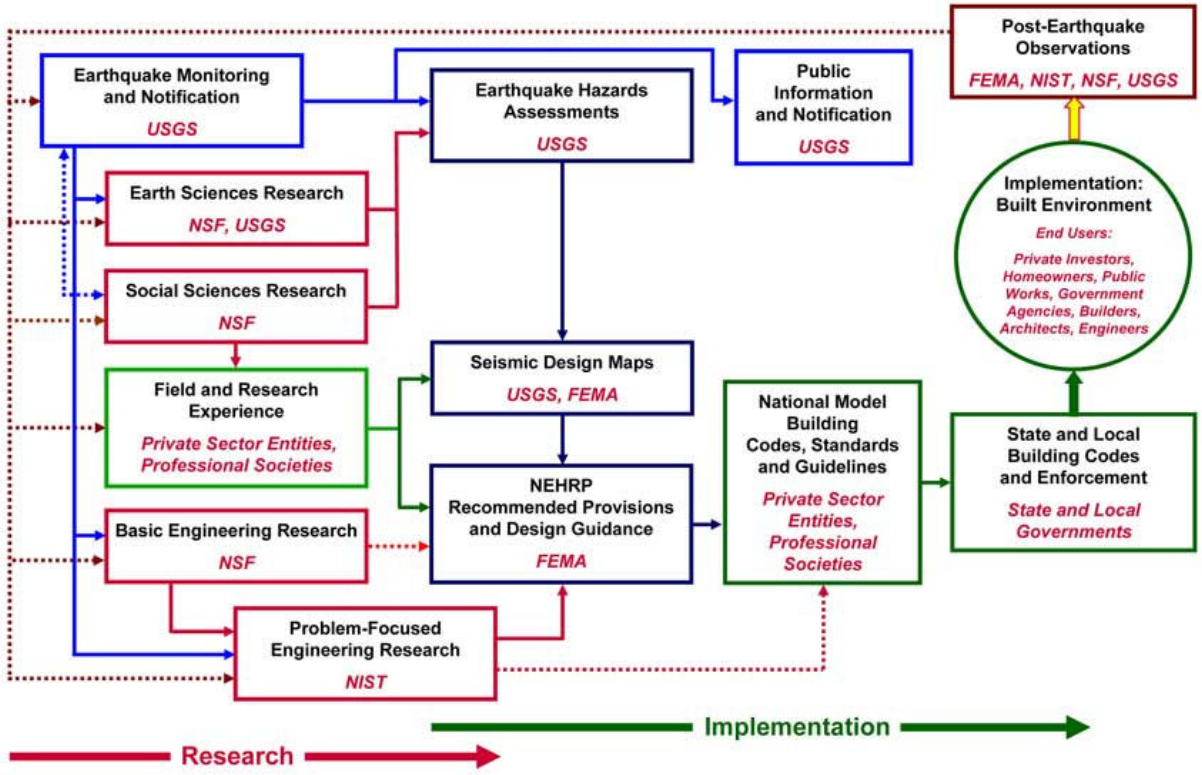

Figure C.1: NEHRP Impact on Building Design and Construction. Image courtesy of NIST.

Using the resources of the Advanced National Seismic System (ANSS), USGS monitors earthquake activity to notify those in affected areas and collect data to develop earthquake hazards assessments, which in turn are used to update national seismic design maps. ANSS also includes structural monitoring, the data from which are used to support engineering research at NSF and NIST.

NSF and USGS support geoscience research to develop better physics-based models of earthquake generation and propagation processes.

NSF supports basic research in the various engineering fields and in the social sciences, the results of which are used to develop a knowledge base of earthquake engineering and socioeconomic information on the issues that impact decision making for mitigation and response efforts. Some of the fundamental knowledge gained from these NSF-supported efforts is used directly by FEMA in its implementation activities, while NIST performs applied research and development that transitions some basic research results into FEMA's implementation activities, thus bridging the gap between basic research and implementation.

In addition to serving this bridging role, NIST is responsible for earthquake engineering research to improve building codes and standards for new and existing buildings and infrastructure lifelines; advance seismic-resistant construction practices; develop measurement and prediction tools supporting performance-based standards; and evaluate advanced technologies.

FEMA works with earthquake professionals, using experience gained in the field, to transition the knowledge from NEHRP research activities into recommended design provisions for model building codes and supplemental design guidance for those codes. FEMA then works with national model building code organizations and ultimately with State and local governments to ensure that the NEHRP-developed recommendations are considered in national model building codes. As the recommended provisions are put into practice, experience gained in actual earthquakes is fed back into the continuous NEHRP developmental process.

Table C.1: Federal Emergency Management Agency

Statutory Responsibility (P.L. 108-360)	Strategic Plan Goal	Strategic Plan Objective
Work closely with national standards and model building code organizations, in conjunction with NIST, to promote implementation of research results.	C	10, 11, 12
Promote better building practices within the building design and construction industry, including architects, engineers, contractors, builders, and inspectors.	B C	7 11, 12
Operate a program of grants and assistance to enable States to develop mitigation, preparedness, and response plans; prepare inventories and conduct seismic safety inspections of critical structures and lifelines; update building and zoning codes and ordinances to enhance seismic safety; increase earthquake awareness and education; and encourage the development of multistate groups for such purposes.	B C	8 10, 11 12, 13
Support the implementation of a comprehensive earthquake education and public awareness program, including development of materials and their wide dissemination to all appropriate audiences and support public access to locality-specific information that may assist the public in preparing for, mitigating against, responding to, and recovering from earthquakes and related disasters.	B C	6 13, 14
Assist NIST, other Federal agencies, and private-sector groups, in the preparation, maintenance, and wide dissemination of seismic-resistant design guidance and related information on building codes, standards, and practices for new and existing buildings, structures, and lifelines; and aid in the development of performance-based design guidelines and methodologies supporting model codes for buildings, structures, and lifelines that are cost-effective and affordable.	B C	7, 8 12
Develop, coordinate, and execute the National Response Plan when required following an earthquake, and support the development of specific State and local plans for each high-risk area to ensure the availability of adequate emergency medical resources, search and rescue personnel and equipment, and emergency broadcast capability.	C	10, 13
Develop approaches to combine measures for earthquake hazards reduction with measures for reduction of other natural and technological hazards, including performance-based design approaches.	B	6, 7
Provide preparedness, response, and mitigation recommendations to communities after an earthquake prediction has been made [by USGS].	C	12, 13
[May] enter into cooperative agreements or contracts with States and local jurisdictions and other Federal agencies to establish demonstration projects on earthquake hazard mitigation, to link earthquake research and mitigation efforts with emergency management programs, or to prepare educational materials for national distribution.	C	12, 13, 14

Table C.2: National Institute of Standards and Technology

Statutory Responsibility (P.L. 108-360)	Strategic Plan Goal	Strategic Plan Objective
Lead Agency Responsibilities		
Ensure that the Program includes the necessary steps to promote the implementation of earthquake hazard reduction measures by Federal, State, and local governments, national standards and model building code organizations, architects and engineers, and others with a role in planning and constructing buildings and lifelines.	C	11, 12
Support the development of performance-based seismic engineering tools, and work with appropriate groups to promote the application of such tools, through earthquake-related building codes, standards, and construction practices.	B	7, 8
Request the assistance of Federal agencies other than the Program agencies, as necessary, to assist in carrying out this [Program].	C	12
Work with FEMA, NSF, and USGS to develop a comprehensive plan for earthquake engineering research to effectively use existing testing facilities and laboratories (in existence at the time of the development of the plan), upgrade facilities and equipment as needed, and integrate new, innovative testing approaches to the research infrastructure in a systematic manner.	A	2
Agency Program Responsibilities		
Work closely with national standards and model building code organizations, in conjunction with FEMA, to promote the implementation of research results.	C	11
Promote better building practices among architects and engineers.	C	12
Work closely with national standards organizations to develop seismic safety standards and practices for new and existing lifelines.	B	8
Support the development and commercial application of cost-effective and affordable performance-based seismic engineering by providing technical support for seismic engineering practices and related building code, standards, and practices development.	B C	7 12
Work with FEMA, NSF, and USGS to develop a comprehensive plan for earthquake engineering research to effectively use existing testing facilities and laboratories (in existence at the time of the development of the plan), upgrade facilities and equipment as needed, and integrate new, innovative testing approaches to the research infrastructure in a systematic manner.	A	2

Table C.3: National Science Foundation

Statutory Responsibility (P.L. 108-360)	Strategic Plan Goal	Strategic Plan Objective
Encourage prompt dissemination of significant findings, sharing of data, samples, physical collections, and other supporting materials; and development of intellectual property so research results can be used by appropriate organizations to mitigate earthquake damage.	A C	1, 2, 3 12, 13
In addition to supporting individual investigators, support university research consortia and centers for research in geosciences and earthquake engineering.	A	1, 2, 3
Work closely with USGS to identify geographic regions of national concern that should be the focus of targeted solicitation for earthquake-related research proposals.	A	1
Support research that improves the safety and performance of buildings, structures, and lifeline systems using large-scale experimental and computation facilities of the George E. Brown, Jr. Network for Earthquake Engineering Simulation, and other institutions engaged in research and the implementation of NEHRP.	A	2
Emphasize, in earthquake engineering research, development of economically feasible methods to retrofit existing buildings and to protect lifelines to mitigate earthquake damage.	A	2, 3
Support research that studies the political, economic, and social factors that influence the implementation of hazard reduction measures.	A	3
Include, to the maximum extent practicable, diverse institutions, including the Historically Black Colleges and Universities, and those serving large proportions of Hispanics, Native Americans, Asian-Pacific Americans, and other underrepresented populations.	A	1, 2, 3
Develop, in conjunction with FEMA, NIST, and USGS, a comprehensive plan for earthquake engineering research to effectively use existing testing facilities and laboratories (in existence at the time of the development of the plan), upgrade facilities and equipment as needed, and integrate new, innovative testing approaches to the research infrastructure in a systematic manner.	A C	1, 2, 3 12, 13, 14

Table C.4: U.S. Geological Survey

Statutory Responsibility (P.L. 108-360)	Strategic Plan Goal	Strategic Plan Objective
Conduct a systematic assessment of the seismic risks in each region of the Nation prone to earthquakes, including, where appropriate, the establishment and operation of intensive monitoring projects on hazardous faults, seismic microzonation studies in urban and other developed areas where earthquake risk is determined to be significant, and engineering seismology studies.	A B	1 5, 6
Work with officials of State and local governments to ensure that they are knowledgeable about the specific seismic risks in their areas.	C	13
Develop standard procedures, in consultation with the Director of FEMA and the Director of NIST, for issuing earthquake predictions, including aftershock advisories.	C	9
Issue when necessary, and notify the Director of FEMA and the Director of NIST of, an earthquake prediction or other earthquake advisory, which may be evaluated by the National Earthquake Prediction Evaluation Council, which shall be exempt from the requirements of FACA when meeting for such purposes.	C	9
Operate, using the National Earthquake Information Center, a forum for the international exchange of earthquake information, which shall: • Promote the exchange of information on earthquake research and earthquake preparedness between the United States and other nations; • Maintain a library containing selected reports, research papers, and data produced through the Program; • Answer requests from other nations for information on U.S. earthquake research and earthquake preparedness programs; and, • Direct foreign requests to the agency involved in the Program which is best able to respond to the request.	A B	4 9
Operate a National Seismic System.	C	9
Support regional seismic networks, which shall complement the National Seismic Network.	C	9
Work with NSF, FEMA, and NIST to develop a comprehensive plan for earthquake engineering research to effectively use existing testing facilities and laboratories (in existence at the time of the development of the plan), upgrade facilities and equipment as needed, and integrate new, innovative testing approaches in the research infrastructure in a systematic manner.	A	2
Work with other Program agencies to coordinate Program activities with similar earthquake hazards reduction measures in other countries, to ensure that the Program benefits from relevant information and advances in those countries.	A	1
Maintain suitable seismic hazard maps in support of building codes for structures and lifelines, including additional maps needed for performance-based design approaches.	B	5