

Annual Report
of the
National Earthquake Hazards Reduction Program

To accompany the President's Budget Request to Congress
for Fiscal Year 2008

March 2007



FEMA

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



USGS
science for a changing world

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This annual report on 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.

The members of the ICC are:

Dr. William Jeffrey, Chair of the ICC
Director
National Institute of Standards and Technology

Dr. John H. Marburger, III
Director
Office of Science and Technology Policy
Executive Office of the President

Mr. R. David Paulison
Director/Under Secretary
Federal Emergency Management Agency

Dr. Arden L. Bement, Jr.
Director
National Science Foundation

Mr. Rob Portman
Director
Office of Management and Budget

Dr. Mark Myers
Director
U.S. Geological Survey

Preface

Earthquakes represent the largest single potential source for casualties and damage from a natural hazard in the United States. Although damaging earthquakes occur infrequently, they strike without warning, resulting in catastrophic consequences. "When the Big One Strikes Again," a regional scenario developed for last year's Quake '06 conference, projects that the 1906 San Francisco Earthquake, if it would occur today, would affect nearly 10 million residents within a 19 county area and would cost between $90 and $120 billion to repair or replace more than 90,000 damaged buildings and their contents. Depending upon when the earthquake occurs—day or night—building collapses would cause 800 to 3,400 deaths.

Although earthquakes cannot be prevented, their impact on life and property can be managed to a large degree. The National Earthquake Hazards Reduction Program (NEHRP), which is authorized by the Earthquake Hazards Reduction Act of 1977 (Public Law 95-124), as amended, seeks to mitigate earthquake losses in the United States through both basic and directed research and implementation activities in the fields of earthquake science and engineering.

For 30 years, NEHRP has reduced the vulnerability of the people and property of the United States through the following:

- Improvement in the understanding of the processes that generate earthquakes.
- Improvement in the understanding of the effects of earthquakes in terms of ground shaking and ground failure, building shaking and damage, and on the general infrastructure and economic fabric of the United States.
- Development of earthquake hazards and risk assessments and earthquake resistant building codes and practices.
- Implementation of earthquake risk reduction measures through the adoption of building codes, land use practices, and earthquake response exercises at all levels of government and in the private sectors.

This report to Congress describes the achievements of the NEHRP agencies and their partners in Fiscal Year (FY) 2005 and FY 2006 in mitigating earthquake losses nationwide.

Disclaimer: Certain trade names or company products are mentioned in the text to specify adequately the experimental procedure and equipment used. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the equipment is the best available for the purpose.

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Executive Summary

This annual report on the National Earthquake Hazards Reduction Program (NEHRP) is submitted by the Interagency Coordinating Committee (ICC) of NEHRP in compliance with Public Law 108-360. As specified in the legislation, this report provides the enacted budget from Fiscal Year (FY) 2007 and the proposed budget from FY 2008 and describes program activities during FY 2005 and FY 2006.

The NEHRP ICC is composed of the directors of the 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), as well as the directors of the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB). The ICC is chaired by the Director of NIST.

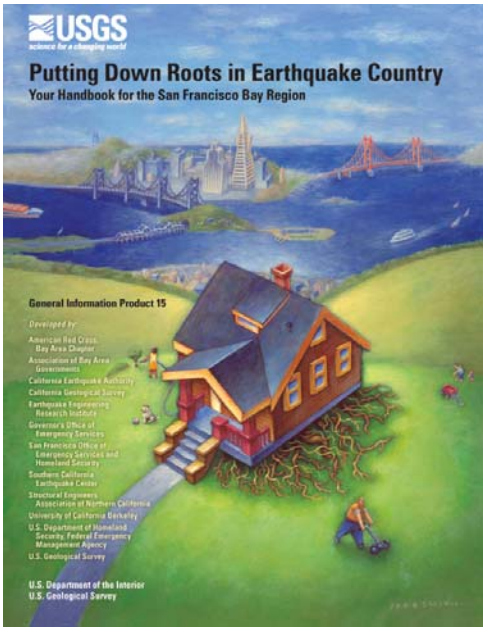
This report provides budget information for NEHRP. Total agency-identified funding for NEHRP purposes in FY 2005 and FY 2006 was $127.1 million and $118.7 million, respectively. Enacted funding for FY 2007 and requested funding for FY 2008 is $121.0 million and $127.7 million, respectively.

FY 2005 and FY 2006 were a period of transition, response, and advancement for NEHRP. Highlights of some of the activities described in this report are summarized below:

NEHRP Leadership. NIST assumed leadership of the NEHRP in 2005. Since that time, NIST has moved aggressively to establish a NEHRP Secretariat, the leadership functions of the ICC, and the operational functions of the Program Coordination Working Group (PCWG). The Secretariat, the ICC, and the PCWG are now well established and effectively working in concert. NEHRP also is well advanced in establishing the Advisory Committee on Earthquake Hazards Reduction (ACEHR), which is being formed under the Federal Advisory Committee Act. The ACEHR charter has been approved, members have been selected, and the Committee will hold its first meeting in 2007.

Sumatra Earthquake and Tsunami Response. The NEHRP agencies actively responded to the December 2004 Sumatra earthquake and Indian Ocean tsunami. This response consisted of the initial monitoring and reporting of the event, support for national and international groups involved in the immediate humanitarian relief and subsequent recovery efforts, data collection and research on the event and its impacts, and active participation in U.S.-sponsored efforts to improve tsunami monitoring and education in the Indian Ocean region. NEHRP agencies also participated in the subsequent President's Tsunami Warning Initiative that has resulted in substantial improvements to national and global earthquake monitoring and notification capabilities. These include new monitoring stations and enhanced communications for the Global Seismographic Network (GSN) and establishment of round-the-clock on-site operations and modernized computer systems at the USGS National Earthquake Information Center (NEIC).

San Francisco Earthquake Centennial. For 2 years, NEHRP agencies worked with other earthquake safety stakeholders to plan and develop a week-long commemoration of the 1906 San Francisco earthquake. This event, conducted in April 2006 in San Francisco, increased public awareness of the earthquake threat and promoted earthquake preparedness and earthquake safety policies. NEHRP carried out several studies focused on improving the scientific understanding of earthquake effects in the San Francisco Bay region. Based on this work, a realistic scenario was developed to study the potential impact of a repeat of the San Francisco earthquake, forming the foundation of earthquake preparedness planning. The Conference also stimulated the compilation and distribution of an updated Bay Area version of *Putting Down Roots in Earthquake Country*. This 16 page earthquake preparedness handbook was delivered to millions of households.



The cover of Putting Down Roots in Earthquake Country (Source: U.S. Geological Survey).

Earthquake Engineering Facilities. In September 2004, NSF completed the 5 year construction phase of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). NEES consists of 15 experimental facilities located at academic institutions nationwide. These facilities are all connected with a cyberinfrastructure that allows experiments and data to be shared nationally and internationally. The NEES facilities are now being used in extensive and unique tests of engineering and construction practices. In November 2006, a full-scale, wood-frame house, with typical construction and furnishings, was tested in a simulated earthquake at the University at Buffalo, The State University of New York.

Performance-Based Seismic Design (PBSD). The goal of PBSD is to develop practical assessment and design criteria that enable building owners and regulators to select desired performance and/or reliability levels for new construction or for upgrades of existing buildings that differ from the current building code-based life safety level. This project has significant potential for reducing earthquake losses. Led by FEMA, NEHRP continues to support this multi-year effort to develop PBSD guidelines for new and existing buildings. A Program Plan for Development of Next-Generation Performance-Based Seismic Design Guidelines was recently published by FEMA and a Characterization of Seismic Performance for Buildings will be published in 2007.

Progress in Building Codes and Standards. In 2004, NEHRP agencies, led by FEMA, began a 5 year effort to revise the *NEHRP Recommended Provisions (Provisions)*. This update features several significant changes that have been recommended or endorsed by the engineering community. FEMA continues to support the Building Seismic Safety Council (BSSC), which also submits changes or improvements developed under the

Provisions as proposed code changes for the International Building Code (IBC) and other code-making bodies. The BSSC was successful with several proposed code changes for the 2006 update cycle of the IBC. In 2006, the American Society of Civil Engineers (ASCE) finalized a new national consensus standard for the seismic rehabilitation of existing buildings, based primarily on NEHRP studies. The completion of this standard culminates a 20 year NEHRP-wide effort led by FEMA. ASCE 41-06 is scheduled for publication in 2007.

Cost-Benefit Analyses. During FY 2005 and FY 2006, independent studies supported the cost-benefit justification for NEHRP activities. The first of these, a FEMA-sponsored study, *National Hazard Mitigation Saves Lives* by the Multihazard Mitigation Council of the National Institute of Building Sciences, concludes that every disaster mitigation dollar spent by FEMA provides the Nation an average of $4 savings in future post-disaster relief and in increased tax revenue. The second study, *Improved Seismic Monitoring – Improved Decision Making* by the National Research Council of the National Academy of Sciences, concludes that improved seismic monitoring by the USGS would allow mitigation actions—based on improved information and consequent reduction of uncertainty—to yield benefits amounting to several times the cost of the enhancements.

The accomplishments described in this report show that the NEHRP agencies and their partners, working in collaboration and individually, have made significant progress toward earthquake loss-reduction nationwide. NEHRP continues an active role in providing national leadership in understanding and reporting on earthquakes and their effects, in developing effective, earthquake-resistant engineering, design, and construction practices, and in implementing these practices nationwide.

Chapter 1

Introduction

Congress first authorized the National Earthquake Hazards Reduction Program (NEHRP) in 1977, with the goal of reducing losses from earthquakes nationwide. Congress has reauthorized NEHRP numerous times since then, most recently in 2004 (Public Law 108-360). This legislation formally established the Interagency Coordinating Committee (ICC) for NEHRP and directed that "The ICC shall transmit, at the time of the President's budget request to Congress, an annual report to the Committee on Science and the Committee on Resources of the House of Representatives, and the Committee on Commerce, Science, and Transportation of the Senate."

Public Law 108-360 transferred NEHRP planning and coordination responsibilities from the Federal Emergency Management Agency (FEMA) to the National Institute of Standards and Technology (NIST), effective in 2005. Because of the resources required for NIST to establish the new NEHRP Secretariat, an annual report was not prepared for Fiscal Year (FY) 2006. Commencing in FY 2006, NIST has redirected internal funds to support the creation and sustenance of the Secretariat, and the other three NEHRP agencies have provided cost-share funds and support to the Secretariat. This document, the NEHRP Annual Report for FY 2007, provides program budgets for FY 2007 and proposed program budgets for FY 2008. It also describes program activities in FY 2005 and FY 2006, as prescribed in Public Law 108-360.

Four agencies carry out the greater part of the work of NEHRP. These agencies and their primary responsibilities are:

FEDERAL EMERGENCY MANAGEMENT AGENCY

- Translates results of research and technology development into effective earthquake loss reduction measures at state and local levels of government.
- Prepares technical guidance aimed at improving the seismic safety of new and existing buildings and lifelines, and prepares and disseminates information about building codes and practices.
- Supports public-private partnerships to develop disaster-resilient communities, helps state and local government decision-makers by providing estimates of potential losses due to earthquake hazards.
- Develops earthquake risk-reduction tools and measures.
- Develops and supports public education to increase awareness of earthquake loss reduction measures.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

- Serves as lead agency for NEHRP.
- Conducts problem-focused research and development in earthquake engineering to improve building codes and standards for both new and existing construction and to advance seismic practices for structures and lifelines.
- Removes technical barriers, evaluates advanced technologies, and develops measurement and prediction tools underpinning performance standards needed by the U.S. design and construction industry.

NATIONAL SCIENCE FOUNDATION

- Supports research covering geoscience, engineering, economic, and social aspects and impacts of earthquakes.
- Supports research into causes and dynamics of earthquakes, plate tectonics, and crustal deformation.
- Supports research on geotechnical, structural, nonstructural, and lifeline systems and advanced earthquake engineering research experimental facilities and cyberinfrastructure.
- Supports research on the social, behavioral, and economic aspects of earthquake hazard mitigation.
- Supports education of new scientists and engineers, integration of research and education, and outreach to professionals and the general public.

U.S. GEOLOGICAL SURVEY

- Conducts earthquake monitoring and maintains data analysis and earthquake notification facilities.
- Conducts and supports targeted basic and applied earth science investigations that increase knowledge about earthquake processes and effects.
- Produces national and regional assessments of seismic hazards.
- Coordinates NEHRP post-earthquake reconnaissance investigations.
- Supports external research through grants and cooperative agreements and works with partners and stakeholders to transfer earthquake-related products into practice.

REGIONAL CONSORTIA AND OTHER NEHRP PARTNERS

The NEHRP agencies, individually and collectively, support and work with a number of regional consortia. The multi-state regional organizations are:

- Cascadia Region Earthquake Workgroup
- Central United States Earthquake Consortium
- Northeast States Emergency Consortium
- Western States Seismic Policy Council

The NEHRP agencies also support many other organizations involved in earthquake risk reduction activities, such as engineering-based professional organizations, private-sector groups, universities, building-code organizations, and earthquake research centers and research facilities funded by the National Science Foundation.

ADVISORY COMMITTEE ON EARTHQUAKE HAZARDS REDUCTION

Public Law 108-360 requires the ICC to develop a Strategic Plan that "establishes goals and priorities for program activities…." The legislation also authorizes the establishment of an Advisory Committee on Earthquake Hazards Reduction (ACEHR). This Committee is charged with assessing trends and developments in the science and engineering of earthquake hazards reduction; the effectiveness of NEHRP; the need to revise NEHRP; and the management, coordination, and implementation of NEHRP.

The ICC will ask the ACEHR to review and comment on new NEHRP strategic planning documents as they are developed. At the time of submission of this annual report, the ACEHR is in the process of being formed; thus, the ICC is not prepared to publish a new Strategic Plan for NEHRP before this report is released. For practical purposes, NEHRP continues to function under the existing Strategic Plan: *Expanding and Using Knowledge to Reduce Earthquake Losses: The National Earthquake Hazards Reduction Program Strategic Plan 2001 – 2005* (FEMA 383). A revised Strategic Plan will be published in 2007.

This report focuses on NEHRP activities and accomplishments in FY 2005 and FY 2006 and on NEHRP budgets for FY 2007 and FY 2008. As mentioned above, NEHRP has existed since its initial authorization in 1977. In April 2006, in conjunction with the 100th Anniversary 1906 San Francisco Earthquake Conference, the Applied Technology Council and *Engineering News-Record* magazine recognized NEHRP as one of ten Top Seismic Products and Programs of the 20th Century. This national recognition attests to NEHRP's long-term impact.

Approach, Structure, and Features of this Report

Chapter 2

This report follows the requirements established for it in Public Law 108-360. It is brief, straightforward, and informative on National Earthquake Hazards Reduction Program (NEHRP) activities and budgets. It is assumed the reader is aware of the threats earthquakes pose to the public safety, economy, and security of the United States and why action is needed to address these threats. As a result, the report does not present background information on the causes and impacts of earthquakes.

Public Law 108-360 specifies that the annual report shall consist of the following elements:

- Budget for program activities during the current fiscal year (FY 2007);
- Proposed budget for program activities for the next fiscal year (FY 2008);
- Description of program results and activities for the previous fiscal years (FY 2005 and FY 2006);
- Implementation of the recommendations of the Advisory Committee on Earthquake Hazards Reduction;
- Description and budgets (current and proposed) for activities that are carried out by NEHRP agencies and contribute to NEHRP goals, but are not included in the program by statute; and
- Description and budgets (current and proposed) related to grants to states for earthquake mitigation and preparedness.

During the reporting period covered by this report, NEHRP structured its work under the goals defined in the current NEHRP Strategic Plan. These strategic goals are:

- Goal A. Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation.
- Goal B. Improve techniques to reduce vulnerability of facilities and systems.
- Goal C. Improve seismic hazards and risk assessment methods.
- Goal D. Improve understanding of earthquakes and their effects.

In this report, each of these goals is associated with a single congressionally-defined "program activity." All NEHRP accomplishments and proposed budgets are related to the "program activities" through these goals.

The "program activities" addressed in this report are those defined in Public Law 108-360 as:

- Develop effective measures, *i.e.*, practices and policies, for earthquake hazards reduction (Strategic Plan Goals B and C);
- Promote the adoption of earthquake hazard reduction measures by federal, state, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with a role in planning and constructing buildings, structures, and lifelines (Strategic Plan Goal A);
- Improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines, through interdisciplinary research that involves engineering, natural sciences, and social and economic sciences (Strategic Plan Goal D); and
- Develop, operate, and maintain the Advanced National Seismic System, the George E. Brown, Jr. Network for Earthquake Engineering Simulation, and the Global Seismographic Network.

Chapter 3

NEHRP in Evolution

In FY 2005 and FY 2006, the National Earthquake Hazards Reduction Program (NEHRP) was in transition, as the responsibility for planning and coordination passed from the Federal Emergency Management Agency (FEMA) to the National Institute of Standards and Technology (NIST). In addition to shifting NEHRP leadership responsibilities, Public Law 108-360 formally established the Interagency Coordinating Committee (ICC) and the Advisory Committee on Earthquake Hazards Reduction (ACEHR). During the past 2 years, NIST has acted aggressively to meet new responsibilities and requirements associated with NEHRP leadership. These actions are summarized below.

NEHRP Secretariat. In early 2006, NIST hired a full-time government employee as NEHRP Director and head of the office of the NEHRP Secretariat. This individual is a qualified engineer with experience in earthquake research, design, and construction practices, and in the management of complex programs and organizations. The office of the NEHRP Secretariat is charged with providing overall program management and coordination for NEHRP, strengthening program effectiveness by facilitating implementation of earthquake risk mitigation measures, ensuring that NEHRP statutory and reporting requirements are met, supporting the development and implementation of NEHRP strategic and management plans and coordinated interagency budgets, and building and maintaining effective liaison with NEHRP program agencies, industry stakeholders, academia, state and local government, and the general public. In FY 2006, NIST committed itself to supporting the Secretariat internally by redirecting research funds to start and maintain the Secretariat. The other NEHRP agencies assist the Secretariat either through direct partial financial support or in-kind personnel support. In September 2006, NIST established a contractual arrangement to provide support to the Secretariat for document preparation and publishing, meeting arrangements, and general logistical assistance.

Interagency Coordinating Committee. The ICC is a statutory body consisting of the Directors of the four NEHRP agencies and the Directors of the White House Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB). By statute, the NIST Director serves as the ICC Chair. The ICC oversees NEHRP planning, management, and coordination; prepares strategic and management plans; and develops a coordinated interagency budget for the program. The ICC met in April, July, and October 2006. Topics addressed at ICC meetings have included: applicable lessons learned from the Katrina experience, a "gap-analysis" of NEHRP needs based on current projects and activities for use in strategic planning, adoption of common rules and formats for budget reporting, identification and prioritization of candidate areas for increased program priority, and the multiplier effects of agency activities through the synergy provided by NEHRP.

Advisory Committee on Earthquake Hazards Reduction. The ACEHR is a statutory body. In 2006, the NEHRP Secretariat made significant progress in establishing this Committee. On July 25, 2006, a notice was published in the Federal Register soliciting

nominations for membership on the Committee. Throughout the year, the Secretariat has worked with professional organizations to ensure that they were aware of the opportunity to nominate members. The earthquake professional community responded very positively by nominating over 85 individuals as potential ACEHR members. By October 2006, a recommended membership list was prepared by the Program Coordination Working Group (PCWG), reviewed by the ICC, and forwarded to the ICC Chair for final approval. As of December 2006, the appointments of the nominees were being reviewed and processed in accordance with established Federal Advisory Committee Act and Executive Branch procedures. It is anticipated that the ACEHR will hold its first meeting in 2007. Future annual reports will describe ACEHR activities, recommendations, and actions on recommendations.

Program Coordination Working Group. NIST has established the PCWG, which is composed of the working-level program managers from each of the NEHRP agencies. The PCWG meets approximately once a month to coordinate agency activities, review reporting and planning documents, discuss problems and opportunities, and exchange relevant information. The PCWG members are responsible for keeping their agencies' Directors apprised of significant activities, and the Secretariat informs working-level counterparts at OSTP and OMB of these activities.

Program Budget for FY 2007

In this and the following section, the Fiscal Year (FY) 2007 and proposed FY 2008 program budgets are organized by National Earthquake Hazards Reduction Program (NEHRP) "Program Activities," as defined in Public Law 108-360, Section 103(a)(2). To follow these definitions of program activities in a direct, accountable manner, the current NEHRP Strategic Plan (FEMA 383) goals and the efforts and projects associated with them are assigned to single congressionally-defined program activities. In ongoing efforts to update the Strategic Plan, the NEHRP agencies intend to realign the Plan with the statutory program activities more clearly, facilitating the review of both program plans and program accomplishments in future reports.

Table 1. NEHRP 2007 Enacted Budget Listed by Statutory Program Activity

Statutory "Program Activity"	Funds Allocated to Activity ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	Total
1. Develop effective measures for earthquake hazards reduction.[3]	3.5	0.9		29.6	**34.0**
2. Promote the adoption of earthquake hazards reduction measures.[4]	2.0	0.3		3.5	**5.8**
3. Improve the understanding of earthquakes and their effects.[5]	3.6	0.5	30.0	10.4	**44.5**
4. Develop and operate ANSS (USGS), NEES (NSF), and GSN (USGS & NSF).					
ANSS				8.0	**8.0**
NEES			21.3		**21.3**
GSN			3.5	3.9	**7.4**
Total	9.1	1.7	54.8	55.4	**121.0**

Notes on Table 1:

1 Budgets are rounded to the nearest $0.1 million (M). The NIST, NSF, and USGS budgets represent those agencies' allocations for NEHRP activities from their FY 2007 Continuing Resolution (CR) budgets.

2 FEMA FY 2007 budget is an estimated allocation from DHS appropriation, which covers program activities but excludes S&E and State Grants administrated by FEMA National Preparedness Directorate.

3 The budget amounts reported for Program Activity 1 are the agencies' amounts allocated toward Strategic Plan Goals B & C, less any funds allocated for ANSS, NEES, and GSN.

4 The budget amounts reported for Program Activity 2 are the agencies' amounts allocated toward Strategic Plan Goal A, less any funds allocated for ANSS, NEES, and GSN.

5 The budget amounts reported for Program Activity 3 are the agencies' amounts allocated toward Strategic Plan Goal D, less any funds allocated for ANSS, NEES, and GSN.

Program Budget for FY 2008

This section is organized by National Earthquake Hazards Reduction Program (NEHRP) "Program Activities," as defined in Public Law 108-360, Section 103(a)(2). See Section 4 above for further explanation.

Table 2. NEHRP 2008 Requested Budget Listed by Statutory Program Activity

Statutory "Program Activity"	Funds Allocated to Activity ($M)[1]				
	FEMA[2]	NIST	NSF	USGS	Total
1. Develop effective measures for earthquake hazards reduction.[3]	3.5	4.0		30.3	**37.8**
2. Promote the adoption of earthquake hazards reduction measures.[4]	2.0	0.5		3.6	**6.1**
3. Improve the understanding of earthquakes and their effects.[5]	3.6	1.9	30.0	10.6	**46.1**
4. Develop and operate ANSS (USGS), NEES (NSF), and GSN (USGS & NSF).					
ANSS				8.0	**8.0**
NEES			22.2		**22.2**
GSN			3.5	4.0	**7.5**
Total	9.1	6.4	55.7	56.5	**127.7**

Notes on Table 2:

1 Budgets are rounded to the nearest $0.1 million (M).

2 FEMA FY 2008 budget is an estimated allocation from DHS appropriation, which covers program activities but excludes S&E and State Grants administrated by FEMA National Preparedness Directorate.

3 The budget amounts reported for Program Activity 1 are the agencies' amounts allocated toward Strategic Plan Goals B & C, less any funds allocated for ANSS, NEES, and GSN.

4 The budget amounts reported for Program Activity 2 are the agencies' amounts allocated toward Strategic Plan Goal A, less any funds allocated for ANSS, NEES, and GSN.

5 The budget amounts reported for Program Activity 3 are the agencies' amounts allocated toward Strategic Plan Goal D, less any funds allocated for ANSS, NEES, and GSN.

Activities and Results for FY 2005 and FY 2006

Chapter 6

This section is organized by National Earthquake Hazards Reduction Program (NEHRP) "Program Activities," as defined in Public Law 108-360, Section 103(a)(2), and shows how the NEHRP agencies are supporting the goals of the current NEHRP Strategic Plan through their activities. As noted above, the NEHRP agencies support many organizations involved in earthquake risk reduction activities. The activities of these organizations also are described below.

6.1. PROGRAM ACTIVITY: DEVELOP EFFECTIVE MEASURES FOR EARTHQUAKE HAZARDS REDUCTION

This program activity is supported by Goals B and C of the current NEHRP Strategic Plan. These goals, their objectives, and significant agency activities supporting them are described below. It should be noted that not all NEHRP agencies are equally involved in work under each goal.

Strategic Plan Goal B: Improve techniques to reduce seismic vulnerability of facilities and systems

Program objectives under Goal B are:

- Facilitate technology transfer among standards organizations, state and local officials, and private-sector professionals.
- Improve earthquake loss-reduction knowledge and the quality of practice.
- Support efforts to improve seismic standards and codes and improve design and construction practices for buildings and lifelines.

Important program and agency accomplishments during Fiscal Year (FY) 2005 and FY 2006 are described below for the Federal Emergency Management Agency (FEMA) and the National Institute of Standards and Technology (NIST).

FEDERAL EMERGENCY MANAGEMENT AGENCY

Performance-Based Seismic Design Project. The Performance-Based Seismic Design (PBSD) project is a multi-year effort to develop PBSD guidelines for new and existing buildings. The project goal is to develop practical assessment and design criteria that enable building owners and regulators to select desired performance levels for new construction or for upgrades of existing buildings that differ from the current building code-based life safety level.

The initial development contract for the project with the Applied Technology Council (ATC), an organization which develops engineering resources for use in mitigating the effects of natural and other hazards on the built environment, is almost complete. An updated and prioritized PBSD program plan was recently published as FEMA 445, *Program Plan for Development of Next-Generation Performance-Based Seismic Design Guidelines.* With its partners, FEMA is completing

FEMA 446, *Characterization of Seismic Performance for Buildings*, which will be published in 2007. FEMA 446 describes risk, as defined by user communities, and how PBSD could be quantified using different definitions of risk.

FEMA entered a new 5 year contract with ATC to develop the PBSD Performance Assessment Calculation Tool (PACT) and associated guidance. The PACT will be used to evaluate the performance of new and existing structures by applying standard methods of structural analysis, coupled with structural reliability/loss estimation methods. In the final phase of the project, the PACT will be used as the basis for developing the PBSD guidelines. Additional information on the PBSD project may be found at http://www.atcouncil.org/atc-58.shtml.

NEHRP Recommended Provisions for New Buildings. The *NEHRP Recommended Provisions (Provisions)* is the primary resource document for the Nation's building standards and model building codes. Current project work focuses on completing the update process for the next edition of the *Provisions* and related *Commentary*. The project work includes the U.S. Geological Survey (USGS) for the development of seismic hazard mapping; NIST practitioners; and researchers funded by the National Science Foundation (NSF) for basic research input.



Hilo, HI, November 13, 2006 – The FEMA coordinated mitigation inspection team, along with a U.S. Army Corps of Engineers structural engineer, checks the Hilo Fire Station for structural failures after a recent series of earthquakes (Photo credit: FEMA).

In 2004, FEMA began a 5 year effort for the next update of the *Provisions*. This update features several significant changes that have been recommended or endorsed by the practitioner community. The model building codes have adopted by reference significant portions of the seismic chapters of the American Society of Civil Engineers (ASCE)-7 minimum design loads standard, which relies heavily on the *Provisions* for much of this material. As a result, the *Provisions* now serve as a research-to-practice resource document. Attention is now turning toward the *Provisions Commentary* so that it can better serve as a training and educational product.

FEMA recently published FEMA 351, *NEHRP Recommended Provisions Design Examples* in CD format. A series of electronic training modules in PowerPoint that target different audiences will be completed in FY 2007.

Support for Seismic New and Existing Building Codes and Standards. FEMA supports the Building Seismic Safety Council (BSSC) Code Resource Support Committee (CRSC), a group of experts who submit changes or improvements developed under the *Provisions* as proposed code changes

for the International Building Code (IBC), the International Residential Code (IRC), and the National Fire Protection Association (NFPA) 5000 Building Code. The CRSC was successful with several proposed code changes for the 2006 update cycle of the IBC and the IRC. The CRSC was also involved in the most recent update of the NFPA 5000 Building Code and had a representative on the revision to the NFPA 255 Manufactured Housing Installation Committee, which was successful in adding seismic requirements to that standard.

FEMA provided training and testimony for the adoption of state-wide building codes in South Carolina and Tennessee and worked with the International Code Council (ICC) to develop code training materials, including the seismic design edition of the popular ICC *CodeMaster* series. FEMA also completed a seismic design edition of a *CodeMaster* for the IRC. The CRSC is currently updating national seismic design maps for the model codes based on the 2007 USGS seismic hazard maps.

In 2006, ASCE completed its balloting of the formal consensus process for ASCE 41-06, *Seismic Rehabilitation of Existing Buildings*. This new national performance-based consensus standard is based on FEMA 356, *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*. The completion of this standard culminates a 20 year NEHRP-wide effort led by FEMA. ASCE 41-06 is scheduled for publication in 2007.

Seismic Design Considerations for Storage Racks in Public Retail Facilities. Seismic safety of steel pallet storage racks located in publicly accessible areas was raised during the development of the 2003 *NEHRP Recommended Provisions*. The State of Washington requested guidance on the issue because a store fatality caused by the collapse of a pallet raised concerns over how racks would perform in earthquakes. FEMA 460, *Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public*, September 2005, contains the best retail industry practices, as well as the recommendations of a panel of distinguished experts in the storage rack and earthquake engineering fields.

Home Builders Guide for Seismic Resistant Construction. FEMA completed the updated FEMA 232, *Home Builders Guide for Seismic Resistant Design and Construction*. FEMA 232 includes the latest changes to the IRC and the results of the Consortium of Universities for Research in Earthquake Engineering (CUREE)/Caltech Wood Frame Buildings Project, which was led by the California Institute of Technology, the prime contractor to the California Governor's Office of Emergency Services (OES). FEMA 232 also presents a series of "better-than-code" recommendations, a series of actions that go beyond minimum code requirements that have been shown to improve home performance in earthquakes and increase chances of post-earthquake habitability.

Blast Benefits of Seismic Design. FEMA continued to work on this project, which is to identify and quantify the blast resistance benefits obtained through seismic design. Because both are horizontal loads with relatively strong loads impacting over a short time frame, there are considerable similarities. The work is being done by the U.S. Army Corps of Engineers (USACE) Construction Engineering Research Laboratory (CERL). The first phase was to evaluate the Murrah Building because this is a known building, blast, and result. The project modeled seismic upgrades and then exposed them to a similar blast and resulting progressive collapse using USACE modeling. Two exterior seismic upgrades, as well as the use of the current ACI-318 standard, all resulted in no progressive collapse beyond the initial blast damage. The results of the work were completed and



D'Iberville, Miss., December 6, 2005 - FEMA representatives explain mitigation techniques at a local home improvement store. FEMA encourages residents of Mississippi to rebuild smarter and stronger (Photo credit: FEMA).

published as FEMA 439A at the end of 2005. Work is underway on the next phase of this project, which is the analysis of a steel frame building. The building was selected through the General Services Administration (GSA) and seismic, blast, and progressive collapse evaluation work have been or are almost completed. Using the same blast and distances, preliminary results show loss of one column but no progressive collapse with the existing (pre-seismic) building, indicating that the benefits of seismic upgrading, while still there, will be less obvious. The results of this phase, along with some general conclusions, will be published as FEMA 439B later this year.

FEMA Support for Technical Seminars. The Earthquake Engineering Research Institute (EERI) is a national, non-profit technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. The objective of EERI, which was founded in 1949, is to reduce earthquake risk by advancing the science and practice of earthquake engineering; to improve understanding of the impact of earthquakes on the physical, social, economic, political, and cultural environment; and to advocate comprehensive and realistic measures for reducing the harmful effects of earthquakes.

With FEMA support, nearly 300 engineers attended well-received technical seminars in Los Angeles, San Francisco, and Seattle to learn about the latest tools emerging from research related to the evaluation and rehabilitation of reinforced concrete buildings. A video of each of the technical presentations will soon be available for download from the EERI web site (http://www.eeri.org) or for purchase as DVDs. EERI also published a highly regarded update of Professor Anil Chopra's monograph, *Dynamics of Structures.* This classic publication is widely used in engineering classrooms and in engineering practice worldwide.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Seismic Rehabilitation of Existing Buildings. NIST published FEMA 547, *Techniques for the Seismic Rehabilitation of Existing Buildings.* The document complements ASCE 41-06 (see FEMA discussion above). NEHRP partner agencies on the Interagency Committee on Seismic Safety in Construction (ICSSC) participated in the project (the document is also known as ICSSC RP-7). The majority of funding for this project was provided by FEMA, with additional funding provided by the GSA, the Department of the Interior (DOI), and the Department of Defense (DoD).

Progressive Collapse Mitigation. NIST drafted guidelines on best practices for mitigating the potential for progressive collapse in buildings that are subjected to extreme loads, including earthquakes. In 2007, the draft guidelines will be made available for public comment and will serve as the basis for workshops for practitioners. NIST hosted four workshops around the U.S. in 2006 to begin familiarizing structural engineers with the guidelines and obtain initial feedback on their first draft. Those workshops were held in Denver, New York City, San Francisco, and Chicago; NIST co-sponsored each workshop with the respective state structural engineers association (all of which are affiliated with the National Council of Structural Engineers Associations). NIST also conducted analytical investigations on the effectiveness of detailing requirements for concrete and steel framed buildings for Seismic Design Categories C and D in mitigating progressive collapse potential.

Structural Connection Modeling. NIST researchers initiated a project to develop improved non-linear dynamic analysis techniques for beam-column connections. This work supports the development of improved analysis tools for use in PBSD and in progressive collapse analysis.

Structural Fire Resistance. In cooperation with practitioners, NIST drafted guidelines for best practices in designing and rehabilitating structures for improved fire resistance, including post-earthquake fire safety. A series of workshops is planned in 2007 to collect feedback on the draft guidelines and to educate practitioners.

Strategic Plan Goal C: Improve seismic hazards identification and risk assessment methods and their use

Program objectives under Goal C are:

- Provide rapid, reliable information about earthquakes and earthquake-induced damage.
- Improve seismic hazard characterization and mapping.
- Support development and use of risk and loss assessment tools.

Important program and agency accomplishments during FY 2005 and FY 2006 are described below for FEMA and USGS.

FEDERAL EMERGENCY MANAGEMENT AGENCY

HAZUS. In 1997, FEMA produced through a contract with the National Institute of Building Sciences (NIBS) the prototype HAZUS97 software, a nationally applicable, computer-based disaster planning and analysis tool to estimate size and location of possible threats; calculate resulting damage and disruption; utilize supporting data from varied sources; and link with other emergency management and planning tools before, during, and after disasters. Since then, HAZUS has helped communities across the United States identify and plan for earthquakes by giving them access, free-of-charge, to specialized databases and Geographic Information System (GIS)-based analytic tools.

FEMA released HAZUS-MH (HAZUS Multihazard) MR2, the second maintenance release of HAZUS-MH, in April 2006. The HAZUS-MH MR2 Earthquake Model provides estimates of damage and loss to buildings, essential facilities, transportation lifelines, utility lifelines, and population based on scenario or probabilistic earthquakes. Direct economic losses are estimated based on physical

damage to structures, contents, inventory, and building interiors. The new release adds new custom building types and permits importing USGS *ShakeMaps* and optimized software for faster performance.

FEMA Region VII (Iowa, Kansas, Missouri, and Nebraska) has worked with the Missouri State Emergency Management Agency to reduce seismic vulnerability of facilities and systems using HAZUS-MH. The Region also partnered with the Heartland HAZUS Users Group and the University of Missouri-Columbia to provide GIS training for potential HAZUS-MH users.

Cascadia Region Earthquake Workgroup

The Cascadia Region Earthquake Workgroup (CREW) is a coalition of private and public representatives working together to increase the ability of Cascadia Region communities in British Columbia, California, Oregon, and Washington to reduce the effects of earthquake events. Established in 1996, CREW (http://www.crew.org) provides an essential link among the Federal Government, local government, private industry and citizens, to promote NEHRP goals. CREW has developed relationships that foster mitigation through its development and distribution of realistic scenarios and through public meetings and workshops, which inform stakeholders of their risks and encourage them to take action to reduce those risks.

In 2005, CREW produced a scenario of a Cascadia region earthquake. The scenario has served as the basis for about 12 major exercises, including 2 which are particularly significant: *Pacific Peril* and *Blue Cascades III*. CREW is analyzing after-action material from these and other exercises and is preparing a compendium document to strengthen the scenario and aid other organizations with future exercises.

The *Pacific Peril* exercise, held in May 2006, focused on coastal communities and tested the delivery of services following a major offshore subduction-zone earthquake and tsunami. The exercise involved approximately 450 participants from 6 Oregon coastal counties, as well as the DoD.

The *Blue Cascades III* exercise, held in March 2006, was developed and conducted by regional public- and private-sector organizations under the direction of the Pacific Northwest Economic Region. This exercise, also based on the CREW Cascadia Subduction Scenario, emphasized inland communities and related infrastructures and focused on mitigation measures to address prolonged disruptions and earthquake-related vulnerabilities, response and related infrastructure interdependency issues, and issues involving restoration challenges. The exercise was attended by about 400 participants.

The CREW Cascadia Subduction Scenario was also used to develop tsunami recovery strategy for the coastal Oregon community of Cannon Beach. The results of this activity will be packaged in a "how-to" document supporting recovery planning activities by other coastal communities.

Central United States Earthquake Consortium

The Central United States Earthquake Consortium (CUSEC) is a partnership of the Federal Government and the States of Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee, the states most affected by earthquakes in the New Madrid Seismic Zone. Established in 1983, the mission of CUSEC (http://www.cusec.org) is to reduce deaths, injuries, property damage, and economic losses resulting from earthquakes in the Central United States.

CUSEC supported its member states through developing HAZUS scenarios and performing loss estimations for Arkansas, Illinois, Kentucky, and Tennessee. CUSEC met with the Mid-America

Earthquake (MAE) Center to examine increasing HAZUS capabilities for the central U.S. and participated in a Consortium of Strong Motion Observation Systems (COSMOS) Workshop to bring new technologies of seismic monitoring to the central United States. CUSEC also is working to enhance the central U.S. seismic monitoring network, through outside funding sources, to support the Advanced National Seismic System (ANSS).

Northeast States Emergency Consortium

The Northeast States Emergency Consortium (NESEC) receives significant funding from FEMA to support the common mission of working with federal, state, and local partners to promote multi-hazard preparedness and risk reduction in support of NEHRP goals. NESEC accomplishes this by providing: support to communities in conducting risk assessments; training on the use of HAZUS; information on obtaining software and technical manuals; and by distributing information on mitigation, resources for communities, including federal grants, state and private funding sources, and guides on many technical and non-technical topics, including how to build public-private partnerships. Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont form the NESEC (http://www.nesec.org).

NESEC continues to operate a HAZUS-MH and GIS Emergency Management Risk Assessment Center. NESEC's priority is to provide direct support to those jurisdictions that do not have resources and staff to develop in-house GIS and HAZUS-MH capabilities. NESEC conducted a number of HAZUS-MH studies of the potential impact of earthquakes striking in New York City, Boston, and Central New England.

Western States Seismic Policy Council

The Western States Seismic Policy Council (WSSPC) is a regional earthquake consortium funded primarily by FEMA and the USGS. WSSPC members are the State Geological Survey and Emergency Management Directors of 13 western states (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming); 3 U.S. territories (American Samoa, Guam, and the Northern Mariana Islands); a Canadian territory (Yukon Territory); and a Canadian province (British Columbia). The mission of the WSSPC (http://www.wsspc.org) is to develop seismic policies and share information to promote programs intended to reduce earthquake losses.

The Basin and Range Earthquake Working Group met in March 2006 under the auspices of WSSPC and the Utah Geological Survey to make consensus recommendations on five seismic-hazard issues in the Basin and Range Province important to the 2007 update of the USGS National Seismic Hazard Maps. Recommendations were published in the *Basin and Range Province Earthquake Working Group Seismic-Hazard Recommendations to the U.S. Geological Survey National Seismic Hazard Mapping Program* Utah Geological Survey Open-file Report 477.

U.S. GEOLOGICAL SURVEY

The USGS directs significant effort toward improving seismic hazard identification and risk assessment methods. The USGS establishes, operates, and maintains national and regional earthquake monitoring networks and associated data analysis information dissemination facilities. These earthquake monitoring activities are reported in Section 6.4 in the discussion of the ANSS.

The USGS also plays a major role in earthquake hazard and risk assessment through: (1) estimating and describing the likelihood and potential effects of moderate-to-large earthquakes in high-risk regions of the United States, such as southern California and the Pacific Northwest, and (2) making this knowledge available to others so it can be used to reduce the impact of potentially damaging earthquakes.

In 2002, the USGS established the Scientific Earthquake Studies Advisory Committee (SESAC), as authorized by the congressional reauthorization of NEHRP in 2000. SESAC reviews all of the scientific work of the USGS within NEHRP and provides independent counsel and advice on the direction and scope of that work.

New Seismic Hazard Map for Alaska. The USGS completed a major update to its seismic hazard map for Alaska, incorporating information learned since the map was last updated in 1999. The most significant new information included was data on the Denali strike-slip fault in south central Alaska, which gave rise to the magnitude 7.9 Denali earthquake in November 2002. The USGS released the map in 2006, following review by the 2008 NEHRP Seismic Provisions Update Committee, which is responsible for determining seismic engineering provisions to be included in future building codes.

Urban Hazard Maps for the Memphis Urban Region. In FY 2006, the USGS released a suite of urban hazard maps for the Memphis and Shelby County, Tennessee metropolitan area. Products included ground-shaking hazard maps, liquefaction susceptibility maps, six first-of-a-kind 1:24,000 scale geologic maps covering the central Memphis metropolitan area, and a new publicly available database of geotechnical and geophysical well-log information for use by local engineers and city planners. To maximize the use of these hazard assessment tools, USGS scientists gave presentations, held numerous workshops, and created publications on a wide range of topics related to urban hazard mapping for technical and lay audiences.

Urban Hazard Maps for the San Francisco Bay Area. In cooperation with the California Geological Survey (CGS), USGS released updated 1:24,000 scale maps of Quaternary deposits in the greater nine-county Bay Area region, as well as new liquefaction susceptibility maps based on this new geologic mapping. Both products were available for the 100th anniversary commemoration of the 1906 San Francisco earthquake in April 2006. The maps were made available as GIS databases for a variety of state and local partners and on web sites with maps that can be zoomed up to the street level to allow the general public to determine the hazard where they reside, work, and go to school. The maps were announced in well-covered press conferences and displayed at public presentations for technical and lay audiences.

Scenario Earthquake Loss Models for Planning. To facilitate planning for catastrophic earthquakes in major urban areas in the United States, the USGS worked with local emergency planning and response officials to develop earthquake loss scenarios for Los Angeles, Memphis, the San Francisco Bay Area, and Seattle. Scenario earthquake losses were estimated using the HAZUS software tool developed by FEMA, and teams of practicing engineers, economists, and emergency managers vetted the results. In the Seattle scenario, developed under the leadership of the EERI and the Washington State Department of Emergency Management Division, a magnitude 6.7 earthquake on the Seattle fault was projected to induce $33 billion in direct economic loss, another $33 billion in indirect losses, and nearly 10,000 buildings destroyed. Scenario development helps to identify key vulnerabilities and to prioritize among actions that can be taken to mitigate loss of life and property, damage to transportation infrastructure, and economic impacts. The Seattle scenario is discussed further in Section 6.2 under EERI.

National Seismic Hazard Maps. These maps form the basis for the seismic elements of model building codes used by communities throughout the United States. During FY 2005 and FY 2006, the USGS continued work on an updated version of the National Seismic Hazard Maps to be released in 2007. To obtain input on the maps, USGS held a series of workshops around the country with stakeholders, including engineers, building-code officials, and other experts. These maps will incorporate the latest results from earthquake monitoring and research and will provide the essential ground motion inputs for the 2009 update of FEMA's *Provisions.*

6.2. PROGRAM ACTIVITY: PROMOTE THE ADOPTION OF EARTHQUAKE HAZARDS REDUCTION MEASURES

This program activity is supported by work under Goal A of the NEHRP Strategic Plan. This work involves federal, state, and local governments, national standards and model code organizations, architects and engineers, building owners, and others with roles in planning and construction of buildings, structures, and lifelines.

Strategic Plan Goal A: Develop practices and policies for earthquake loss reduction and accelerate their implementation

Program objectives under Goal A are:

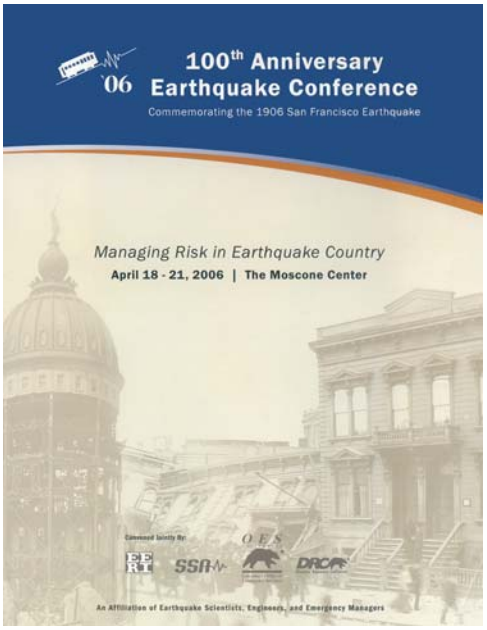
- Develop and provide information on earthquake hazards and loss-reduction measures to decision-makers and the public.
- Promote incentives for public and private sector loss-reduction actions.
- Advocate state and local government practices and policies that reduce losses in the public and private sectors.
- Implement policies and practices that reduce vulnerability of federal facilities.
- Develop the Nation's human resource base in the earthquake field.

Important program and agency accomplishments during FY 2005 and FY 2006 are described below for FEMA, NIST, and USGS.

JOINT PROGRAM ACTIVITY – 1906 SAN FRANCISCO EARTHQUAKE CENTENNIAL

All of the NEHRP agencies, state and local governments, professional societies, and private interests participated in supporting Quake '06, a major international conference commemorating the 100th anniversary of the 1906 San Francisco Earthquake. Quake '06 was organized by EERI, the Seismological Society of America, and the State of California Coalition for a Disaster Resistant California. The Conference, which was attended by nearly 4,000 national and international earthquake experts, featured hundreds of technical sessions in all of the earthquake disciplines, tutorials for elementary and secondary school teachers, policy sessions, poster sessions, and keynote talks by leading earthquake scientists, engineers, social scientists, emergency managers, and local, state, and national political leaders.

The 1906 earthquake is generally regarded as the birth of modern earthquake science. Its 100th anniversary provided a unique opportunity to increase public awareness of seismic hazard as well as earthquake preparedness and mitigation. The USGS and EERI (supported by FEMA) joined with partner groups to form the 1906 Earthquake Centennial Alliance to help coordinate efforts and activities between organizations throughout northern California to commemorate the earthquake. The Alliance brought together policymakers, scientists, engineers, historians, teachers, and emergency responders, took advantage of this unique "teachable moment" to deliver messages to the California public on what scientists know about earthquakes and where earthquake research is going in the future; and encouraged implementation of policies to minimize impacts of future earthquakes.



The cover of the 100th Anniversary Earthquake Conference program, commemorating the 1906 San Francisco Earthquake (Source: Lana Chan, Degenkolb Engineers).

At the heart of the Conference was the debut of a new regional scenario developed with HAZUS, coupled with the latest information on ground motions from the scientific community, to project specific impacts of a repeat of the 1906 earthquake today. *"When the Big One Strikes Again"* found that the earthquake would affect nearly 10 million residents (within a 19 county area) and would cost between $90 and $120 billion to repair or replace more than 90,000 damaged buildings and their contents. Depending upon when the earthquake occurs—day or night—building collapses would cause 800 to 3,400 deaths. Over one-half of these deaths would result from collapses of nonductile concrete, unreinforced masonry, and other vulnerable buildings yet to be strengthened. The scenario garnered enormous national media attention and significantly raised interest in and concern among residents of northern California.

The USGS and its partners prepared and released a suite of new research and information products to support this scenario study, including a database of active faults, a highly detailed simulation of ground motion induced by the 1906 earthquake, and a modern geologic bedrock map for the greater San Francisco Bay Area.

An important document prepared for release during the last morning of the Conference, *The Top 10 Actions*, calls on the region's citizens, businesses, and governments to take action to increase safety, reduce losses, and ensure a speedier recovery when the next major earthquake strikes. EERI has organized a committee to ensure that the goals of the Conference are met over the next few years.

The Conference also generated a widely acclaimed 15 minute video, *The Next Great Quake*, which has been distributed to the 4,000 attendees, more than 100 city managers, hundreds of libraries, numerous media outlets, and countless individuals throughout northern California. It is being shown to city councils and is running on local access television stations throughout northern California. The Conference contributed speakers, interviews, and panelists to several local and national PBS and network television specials related to the 1906 earthquake.

The Conference also stimulated the compilation of an updated version of *Putting Down Roots in Earthquake Country*, discussed below, a 16 page handbook on earthquake hazards in the Bay Area and a homeowner's guide to preparedness. This was first distributed about a year after the 1989 Loma Prieta earthquake as an insert in various Bay Area Sunday newspapers, and has been translated into Spanish, Mandarin, and Braille. The handbook was published as a newspaper insert during the Conference.

FEDERAL EMERGENCY MANAGEMENT AGENCY

Through the National Earthquake Technical Assistance Program (NETAP), FEMA funded the development of training curricula on key earthquake mitigation topics and provided courses for state and local officials and businesses throughout the United States. Course offerings included Procedures for Post Earthquake Safety Evaluation of Buildings (ATC-20); Rapid Visual Screening (RVS) of Buildings for Potential Seismic Hazards (FEMA 154); and Earthquake Hazard Mitigation for Nonstructural Elements. FEMA also is developing a new training course on residential seismic rehabilitation techniques and will offer training on this topic in 2007. In the past year, FEMA funded training courses in Alabama, California, Hawaii, Indiana, Missouri, Nevada, North Carolina, South Carolina, and Utah.

FEMA updated and maintained the NEHRP Earthquake Coordinators web site (http://www.training.fema.gov/emiweb/EarthQuake/welcome.htm). This web site provides state and federal Earthquake Coordinators with training on earthquake basics, hazards, risks, building techniques, advocacy and partnerships, and priorities and successful activities.

In September 2005, FEMA published FEMA 474, *Promoting Seismic Safety: Guidance for Advocates*. This collaborative project was developed among social science and policy researchers at the NSF-funded MAE Center, the Multidisciplinary Center for Earthquake Engineering Research (MCEER), and the Pacific Earthquake Engineering Research (PEER) Center. Researchers at the three Centers distilled findings of previous social science and policy research to provide guidance to seismic safety advocates. The full version of FEMA 474 consists of two parts: Part One is a guidance document for advocates; Part Two is a set of background papers developed by the authors as part of the project. The full version of FEMA 474 is available on the MCEER web site at http://mceer.buffalo.edu. Part One of FEMA 474 is also available at http://www.fema.gov/plan/prevent/earthquake/publications/shtm.

The FEMA web site was completely re-engineered and launched on April 6, 2006. FEMA was the first U.S. Department of Homeland Security (DHS) web site to use its new branding, which will eventually be used across all DHS sites. The redesigned web site for the NEHRP (http://www.fema.gov/plan/prevent/earthquakes) includes new sections designed to inform the public, emergency personnel, businesses, and federal, state, and local agencies of ongoing activities in earthquake mitigation by all of the NEHRP agencies and their partners. In FY 2006, FEMA also completed posting NEHRP technical and non-technical publications in PDF format and text versions on the redesigned site.

In October 2005, the NEHRP Subcommittee on Performance Measures, under FEMA leadership, completed the *Interim Report on NEHRP Performance Measures*. The *Interim Report* provides the basis for taking programmatic and agency-specific performance metrics for NEHRP to the next level, *i.e.*, to continue the process toward developing program measures that focus on the NEHRP mission.

FEMA Region VII promoted the understanding of earthquakes and their effects through outreach presentations with groups such as the Public Relations Student Society of America chapter of the Central Missouri State University, Structural Engineers Association of Kansas and Missouri Annual Meeting, and FEMA Region VII State Hazard Mitigation Officers and State Floodplain Managers.

FEMA Region X includes the States of Alaska, Idaho, Oregon, and Washington. During this reporting period, FEMA Region X staff contributed to the Mitigation/Outreach section of the White House-required Tsunami Preparedness Implementation Plan. Staff also provided input to several Congressional tsunami bills, the new White House National Tsunami Preparedness plan, the General Accounting Office report on the national status of tsunami preparedness, and sections of the National Tsunami Warning and Response System Plan for the National Science and Technology Council Subcommittee on Disaster Reduction (SDR).

FEMA Region X staff also worked on three videos: "Cascadia: The Hidden Fire" about the Cascadia Subduction Zone Earthquake, shown frequently on PBS channels; "Volcanic Ash Impacts and Health Issues," shown several times on Oregon television stations; and interviews on the Seattle Fault Scenario for a future Weather Channel broadcast.

Earthquake Engineering Research Institute

The EERI web-based Mitigation Center, which is supported by FEMA, is now accessible through the EERI web site at http://www.eeri.org. This new web portal provides materials relevant to U.S. communities, as well as resources from around the world, on construction materials, practices, and advocacy projects. This major new EERI program will grow significantly in content and influence in coming years.

In February 2005, a *Scenario for a Magnitude 6.7 on the Seattle Fault* was initially presented to more than 350 public officials, emergency managers, and members of the scientific and engineering communities in Seattle. Since then, copies of the scenario have been disseminated widely throughout the Puget Sound Region and the rest of the country. It has become a model for those considering the development of earthquake scenarios in other parts of the U.S. EERI released a related publication, *Guidelines for Developing an Earthquake Scenario*. The *Guidelines* document was produced with support from FEMA and the EERI Endowment Fund and is being widely disseminated. EERI has had enthusiastic comments from its members in the New Madrid, Anchorage, and Salt Lake areas in particular, and it is anticipated that a major new scenario will be developed in the New Madrid region before the 200th anniversary of the 1811 and 1812 quakes.

Thirty-five students and young professionals received travel support from FEMA and the EERI Endowment Fund to attend the Quake '06 Conference. These young people are tomorrow's leaders in earthquake engineering research and practice, and in many other related earthquake loss reduction fields, and their exposure to the latest technical and policy issues in this forum was invaluable to their professional development.

Each year, EERI offers the prestigious FEMA/NEHRP Graduate Fellowship under the auspices of the Cooperative Agreement with FEMA. In the past 2 years, top students from the University of Texas and the University of California, Berkeley, received the fellowship. Their research has led to the development of a new liquefaction sensor and to broader application of PBSD.

Western States Seismic Policy Council

The WSSPC Awards in Excellence program recognizes achievement in different areas of earthquake mitigation, preparedness, and response. Award categories include mitigation, educational outreach, research, response plans or materials, non-profit agency efforts, seismic legislation, use of new technology, and innovations. Six agency programs from Alaska, Washington, Oregon, California, Idaho, and Utah won WSSPC awards in 2005.

WSSPC members develop and adopt policy recommendations for implementation by local, state, or federal agencies. Four policy recommendations were adopted by the WSSPC membership in 2005 and 2006: Developing Earthquake Risk-Reduction Strategies; Improving Tsunami Warning, Preparedness, and Mitigation Procedures for Distant and Local Sources; Active Fault Definition for the Basin and Range Province; and Real-Time Earthquake Monitoring Networks.

In 2005, the WSSPC conference theme was NEHRP's Next Decade: Challenges for Implementation. The conference was hosted by the Idaho Geological Survey and the Idaho Bureau of Homeland Security and supported by FEMA and the USGS. The conference objective was to revisit the NEHRP goals and what they support—reduced exposure to loss of life, infrastructure, economies, and resources—in light of national realities: western earthquakes, rural earthquakes, and earthquakes in cash-strapped states and communities. WSSPC also was a co-sponsor of the Quake '06 Conference in San Francisco.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

In 2006, the NEHRP Secretariat created a NEHRP web site (http://www.nehrp.gov) to serve as a web portal to all of the NEHRP agencies and to list NEHRP-related developments that are of national interest. Accompanying the web site creation, the Secretariat created a LISTSERV for use in disseminating information related to NEHRP. NIST continues to work with the other NEHRP agencies to add material to the web site, and links to all of the other key agency web sites are provided.

The ICSSC began two major initiatives in FY 2005 and FY 2006 that will provide updated seismic design guidance for federal facilities. First, the ICSSC is updating ICSSC RP6, *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings*, for use by federal agencies. Second, ICSSC is developing guidelines for seismic safety of electric power production and distribution systems.

U.S. GEOLOGICAL SURVEY

The USGS develops and provides information on earthquake occurrence and hazards for engineers, government and private-sector officials responsible for earthquake safety issues and policies, and the general public. Most of this information is available through the USGS Earthquake Hazards Program web site (http://earthquake.usgs.gov). This site, which receives close to 2 million visits per day, was extensively redesigned in FY 2006 to increase its content and ease of use as part of an emphasis on earthquake notification and information services.

Earthquake Outreach Document Released. *Putting Down Roots in Earthquake Country* is a graphically illustrated, color handbook on earthquake science, mitigation, and preparedness. Originally developed by the USGS and Southern California Earthquake Center (SCEC) for Southern

California, a new version of *Roots* for northern California was released in FY 2005. It features current scientific understanding of when and where earthquakes will occur and how the ground will shake as a result. Updated maps of earthquakes, faults, and potential shaking are included, as well as instructions on how to get information after earthquakes. Its "Seven Steps on the Road to Earthquake Safety" provide a simple set of guidelines for preparing and protecting lives and property, and for surviving and recovering from a damaging earthquake. In fall 2004, 760,000 copies were printed, with funding from the California Earthquake Authority (CEA), FEMA, the Red Cross, and other contributors, of which 500,000 were distributed in Bay Area newspapers, and an additional 110,000 copies were printed with funding from the CEA and USGS. Copies of the document are distributed at home improvement centers via the Red Cross and at many other venues. The document also was redistributed as a newspaper insert during the Quake '06 Conference.

Workshops and Training Sessions. Several workshops were conducted during FY 2006, including those related to hazard mapping, *ShakeMap* implementation, ANSS structural instrumentation planning and development, and research. The National Hazard Mapping project and the new Working Group on California Earthquake Probabilities convened several workshops to collect and review the latest scientific information on hazardous faults and their rates of slip.

6.3. PROGRAM ACTIVITY: IMPROVE THE UNDERSTANDING OF EARTHQUAKES AND THEIR EFFECTS

Work under this activity is carried out under Goal D of the NEHRP Strategic Plan. It is focused on the basic and applied research needed to understand the causes of earthquakes, the nature of damaging ground shaking, and the impact of shaking and other earthquake phenomena on communities, buildings, structures, lifelines, businesses, and regional and national economies.

Strategic Plan Goal D: Improve the understanding of earthquakes and their effects

Program objectives under Goal D are:

- Improve monitoring of earthquakes and earthquake-generating processes.
- Improve understanding of earthquake occurrence and potential.
- Improve earthquake hazard assessments and develop earthquake-potential estimates.
- Improve fundamental knowledge of earthquake effects.
- Advance earthquake engineering knowledge of the built environment.
- Advance understanding of the social and economic implications of earthquakes.

Important program and agency accomplishments during FY 2005 and FY 2006 are described below for NSF and USGS.

NATIONAL SCIENCE FOUNDATION

During FY 2005 and FY 2006, the NSF Engineering and Geosciences directorates funded NEHRP-related activities through support to individual researchers, research teams, university-based

consortia and centers, and non-profit organizations. These activities include research programs, education and outreach programs for students (elementary through graduate school) and the public, promotion of earthquake awareness, and partnerships to transfer research findings into implementation.

In FY 2005 and FY 2006, NSF supported earthquake research centers and consortia, *i.e.*, three earthquake engineering research centers (EERCs)—the Mid-America Earthquake (MAE) Center, the Multidisciplinary Center for Earthquake Engineering Research (MCEER), and the Pacific Earthquake Engineering Research (PEER) Center—as well as the SCEC and the Incorporated Research Institutions for Seismology (IRIS). NSF also supported hazards outreach and information dissemination through symposia and through grants to organizations such as the Natural Hazards Center (NHC) at the University of Colorado, Boulder and the EERI and its *Learning From Earthquakes* (LFE) program. Some of the accomplishments of these organizations are highlighted below.

Mid-America Earthquake Center

The NSF-funded MAE Center (http://mae.ce.uiuc.edu), which is headquartered at the University of Illinois at Urbana-Champaign (UIUC), is a consortium of eight core institutions. MAE Center projects fall under four general types: core research, stakeholder research, education, and outreach. Its major activities are described below.

MAEviz. MAE is developing research methods and tools to support Consequence-based Risk Management (CRM), a new paradigm for seismic risk reduction across regions or systems that incorporates identification of uncertainty in all components of seismic risk modeling, and quantifies the risk to societal systems and subsystems. MAEviz is a joint effort between the MAE Center and the National Center for Supercomputer Applications (NCSA) at UIUC to develop the next generation of seismic risk assessment software. MAEviz is leveraging off NCSA's cyber-environment efforts and the University of Michigan's Sakai "collaboratory" to provide an advanced framework for earthquake engineering, as well as general hazard and risk research. The open-source framework of MAEviz employs the latest and most advanced workflow tools to provide a flexible and modular conduit through which the interdisciplinary research and development efforts of the MAE Center are integrated and delivered to end-users. MAEviz follows the CRM methodology, using a visually-based, menu-driven system to generate damage estimates from scientific and engineering principles and data; test multiple strategies; and support modeling efforts to estimate high-level impacts of earthquake hazards, such as impacts on transportation networks and social or economic systems. MAEviz enables policy-makers and decision-makers to develop risk reduction strategies and implement mitigation actions.

DEEPSOIL. This software was originally conceived as a research tool to evaluate non-linear response of deep soil deposits of the Mississippi Embayment. Now available in Version 2.6, the program has evolved into an educational and practical engineering tool with a user-friendly interface. The user can choose to perform either equivalent linear or non-linear site response analyses. The user interface contains many checks to help the user avoid numerous pitfalls encountered in performing non-linear site response analyses.

3-D Damage Characterization. Seismic assessment of buildings with irregular plans needs special attention because plan irregularities cause nonuniform damage levels that are not reflected in existing fragility relationships used in HAZUS and other risk assessment

software. Fragility curves are defined as relationships between ground shaking intensity and the probability of reaching a certain damage state. A new three-dimensional (3-D) damage characterization method was developed that decomposes a 3-D structure into planar frames, detects damage localization, and then provides a single damage index for a building. This enables the derivation of fragility curves for plan-irregular structures. Through comparing fragility curves derived by the 3-D method with previously used damage indices, the existing fragility definitions were shown to underestimate damage for spatially responding structures. Since a large portion of the existing building stock has plan irregularities, making them more vulnerable to earthquakes, the new fragility curves will enable more reliable future seismic loss assessment and will provide a tool for engineering applications.

Multidisciplinary Center for Earthquake Engineering Research

This NSF-funded consortium is centered at the University at Buffalo, The State University of New York (http://mceer.buffalo.edu). The goal of the MCEER is to enhance the seismic resiliency of communities through improved engineering and management tools for critical infrastructure systems and emergency management functions. Funded primarily by NSF, MCEER accomplishes its mission through a system of multidisciplinary, multi-hazard research, education, and outreach initiatives. Major FY 2005 and FY 2006 activities are described below.

Innovative Seismic Base Isolation System. A novel Double-Concave Friction Pendulum (DC-FP) isolation system is being investigated at MCEER. The system can be efficient in reducing seismic forces experienced by nonstructural components and expensive equipment inside acute care facilities. Novel features of the DC-FP system are compact size; very large displacement capacity and capability to adjust behavior for achieving specific objectives; and minimization of impact on secondary systems and equipment. Preliminary shake table testing on a six-story model structure incorporating various designs of the DC-FP have demonstrated its capabilities. Such large-scale tests often constitute the last step to implementation.

Rehabilitation Decision Analysis Toolbox for Acute Care Facilities. A fragility-based decision support system for hospitals embodied in a Rehabilitation Decision Analysis Toolbox (RDAT) is near completion. The system is designed for use by hospitals to make decisions on capital improvements that would most effectively make the facility more hazard-resistant. Input data to RDAT consist of a reference time, seismic hazard information, geotechnical, structural, and nonstructural systems properties, performance criteria, rehabilitation strategies, rehabilitation and repair costs, loss of use, and loss of life, as well as potential monetary benefits of rehabilitation. RDAT rates rehabilitation strategies for structural and nonstructural systems, using estimates of life cycle losses, consequently allowing for the selection of an optimal rehabilitation strategy. RDAT output is being made compatible with STRATACAP, a widely used capital allocation decision analysis software.

Software for Seismic Risk Analysis of Highway Systems. For several years, MCEER has been developing, under the sponsorship of the Federal Highway Administration (FHWA), a new methodology for deterministic and probabilistic seismic-risk analysis of highway systems nationwide. MCEER has recently implemented this new methodology into a public-domain software package named REDARS (Risks from Earthquake Damage to Roadway Systems). This software has since become an important tool in enabling research collaboration among the three EERCs. For example, the California Department of Transportation

(Caltrans) has initiated a trial study to apply REDARS to a region of the Bay Area Highway Network. Although Caltrans funding for this project is from outside the three EERCs, the PEER Center and MCEER-FHWA are providing input to the project. MCEER-FHWA is providing technical support for a more user-friendly demonstration version of REDARS. PEER is sharing data-sets developed in its own Highway Demonstration Project of the Bay Area. The MAE Center is exploring whether REDARS could potentially be used for a small region (*e.g.*, Memphis) to serve as a validation/calibration to the more global loss modeling work by MAE researchers. Facilities and modules in REDARS that are amenable to implementation within MAEviz are also being considered as part of this tri-center collaboration.

Pacific Earthquake Engineering Research Center

Headquartered at the University of California at Berkeley, the NSF-funded Pacific Earthquake Engineering Research (PEER) Center (http://peer.berkeley.edu) focuses on areas west of the Rocky Mountains and emphasizes performance-based design in its research programs. Major activities in FY 2005 and FY 2006 are described below.

Earthquake Ground Motion Data and Hazard Maps. The design of constructed facilities for earthquake effects is generally based on numerical analyses of facilities for input earthquake shaking. To improve this process, PEER has developed one of the largest strong-motion databases in the world. The database, with more than 10,000 ground motions recorded in 173 worldwide earthquakes, is in widespread use by earthquake professionals as a source of design ground motions, and is a key input for new USGS National Seismic Hazard Maps.

Integrated Software for Earthquake Engineering Analysis and Design. PEER developed the Open System for Earthquake Engineering Simulation—or OpenSees—as the first-ever open-source software for numerical simulation of the earthquake response of complex facilities. OpenSees has been used for simulation problems ranging from liquefaction effects on bridge response, to collapse simulation of older buildings, to regional studies of performance implications of current building code design procedures.

Implementation of Performance-Based Earthquake Engineering (PBEE). PEER developed a framework and supporting data and software for detailed earthquake loss modeling of buildings. The framework and software, being implemented jointly with the ATC with significant FEMA funding, enables earthquake engineers to gauge the tradeoffs between design decisions and performance in future earthquakes, and enables owners and other risk decision-makers to make informed decisions about seismic-safety choices. This research supports advancements in PBSD technology.



Future earthquake engineers shake building models in fun educational programs (Photo credit: Tara Hutchinson, PEER).

New Criteria for Seismic Assessment of Existing Concrete Buildings. PEER conducted a series of laboratory experiments to understand collapse risk of older building construction. Working with practicing earthquake professionals, PEER developed new engineering criteria that were presented nationally in a series of seminars and that subsequently were translated into new standards for existing building assessments. In general, the criteria reduce excessive conservatism in current standards, making seismic retrofit programs more effective and tractable.

Building Safety Benchmarking. Building safety during strong earthquakes is a fundamental goal of building codes. Studies at PEER show that advances in reinforced concrete building standards since the mid-1970s have reduced collapse risk in modern buildings to one-fifth of the risk in the older construction. Related studies are being used to calibrate design procedures for new building construction to achieve greater reliability in earthquake safety.

Earthquake Engineering Research Institute

For over 30 years, NSF has supported the EERI LFE program (http://www.eeri.org/lfe.html), which sponsors post-earthquake investigations to document the effects of earthquakes and their causes. This work has enabled researchers from the United States and worldwide to visit the scenes of important earthquakes to rapidly capture geological, geotechnical, engineering, economic, and social science data that can be used to mitigate the effects of future earthquakes.

In 2005, this effort supported natural scientists, social scientists, and engineers documenting impacts of the December 2004 Indian Ocean tsunami and Sumatran earthquake. Over 100 authors prepared papers for a November 2006 special issue of the EERI professional journal *Earthquake Spectra* on all aspects of the tsunami, including field surveys of 10 countries, making this one of the most extensive reports on the tsunami.

In October 2005, a magnitude 7.6 earthquake struck northern Pakistan, doing considerable damage to the built environment, and killing and injuring thousands of people. EERI-LFE dispatched a reconnaissance team to Pakistan, which found that massive land-sliding was a particular feature of the event. The slides caused considerable damage, and cut off access to many remote communities, further exacerbating humanitarian challenges.

EERI has now developed the ability for reconnaissance investigators to upload images from the field directly to a map powered by Internet search engines, linking the photos through latitude and longitude coordinates to the map. Each photo contains basic information, including caption and photographer. Work is underway to expand this and upload images for past events, as well as to develop the capability to upload other kinds of electronic files and link to points on the map. This will have very significant implications for data archiving and retrieval. See http://www.eeri.org/google for examples.

Southern California Earthquake Center

SCEC (http://www.scec.org), which is co-funded by NSF and the USGS and headquartered at the University of Southern California, unites 15 core institutions and 39 participating institutions in a "collaboratory" with a tripartite mission: (1) gather data on earthquakes in Southern California; (2) integrate this and other information into a comprehensive, physics-based understanding of

earthquake phenomena; and (3) communicate this understanding to the community-at-large as useful knowledge for reducing earthquake risk. Major activities in FY 2005 and FY 2006 are described below.

Community Modeling Projects. Recent research results include the use of paleoseismic data and data-synthesis techniques to constrain earthquake recurrence intervals, event clustering, and the interaction of faults. The Center has created a structural representation of the Southern California fault system through three projects: the Community Velocity Model, the Community Fault Model representing more than 140 active faults in the region, and the Community Block Model, which combines the other two models to create multiple parameterizations of the region's crustal structure. These models are available for use by the research community to address many scientific questions, including earthquake predictability, ground motion predictions, and seismic hazard analyses for different earthquake scenarios (http://epicenter.usc.edu/cmeportal/index.html).

One of the highlights of the Center's earthquake hazard assessment work is the SCEC Community Modeling Environment (CME). The SCEC-CME project is a collaborative project of geoscientists from six member institutions of SCEC and computer scientists from the San Diego Supercomputer Center, the Information Sciences Institute, and Carnegie Mellon University. This cyberinfrastructure project is paving the way to better earthquake forecasts and better estimates of strong ground motions through physics-based Probabilistic Seismic Hazard Assessment (PSHA). Future goals of the SCEC-CME include extending the spectrum of ground motion predictions, which is necessary for realistic seismic safety engineering; investigating dynamic rupture complexity for large earthquakes; and computing physics-based probabilistic seismic hazard analysis maps and validating the maps using empirical data. The computation goal is further vertical integration of scientific complexity with advances in hardware, data and computing gateways, and visualization methods.

Southern San Andreas Fault (SAF) Earthquake Study. Researchers at the University of California, San Diego-Scripps Institute of Oceanography (SIO) were funded by the NSF for work on deformation analyses in southern California, using satellite imagers, GPS, and seismic measurements, which led to a substantially improved description and understanding of a major plate boundary fault. These results imply that there is a significant potential for a large earthquake along the southern SAF. The researchers collaborated with the SIO Visualization Center to provide on-line, visually compelling illustrations of these recent results to a broader audience. The work was also featured in the general news media.

Incorporated Research Institutions for Seismology

The Incorporated Research Institutions for Seismology (IRIS) (http://www.iris.edu) is an NSF-funded university research consortium dedicated to exploring the Earth's interior through the collection and distribution of seismographic data. In addition to partnering with USGS to operate the GSN, NSF funding for IRIS supports the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL), which loans seismic sensors, data acquisition, telemetry, and power systems for earth science research; the IRIS Data Management System (DMS), which collects, assesses, archives, and distributes all data from the GSN, PASSCAL experiments, the

ANSS, and other national and international sources; and the IRIS Education and Outreach (E&O) Program, which enables audiences beyond seismologists to access and use seismological data and research for educational purposes.

Natural Hazards Center

The mission of the NHC (http://www.colorado.edu/hazards) at the University of Colorado at Boulder is to advance and communicate knowledge on hazard mitigation and disaster preparedness, response, and recovery. NHC accomplishes its work through four major activities: information dissemination, an annual workshop, information services, and research. The majority of the Center's work is supported by a NSF grant. During this reporting period, nine other federal agencies contributed funds to NSF to support the grant, including FEMA and USGS.

The Center's information dissemination program is composed of three parts: production of the bimonthly newsletter, the *Natural Hazards Observer*; publication of monographs, working papers, Quick Response (QR) research reports, special publications, bibliographies, and other reports, including the *Natural Hazards Review* journal; and Internet activities, which include the distribution of an electronic newsletter, *Disaster Research*, and a LISTSERV for students in hazards and disasters related fields.

U.S. GEOLOGICAL SURVEY

The USGS conducts targeted research on causes, characteristics, and effects of earthquakes. This research has direct application in increasing the accuracy and precision of the agency's earthquake hazards assessments, in earthquake forecasts, and in developing effective mitigation practices. Major accomplishments for FY 2005 and FY 2006 are described below.

Earthquake Occurrence in Space and Time. On-going USGS investigations seek to determine the physical conditions for earthquake initiation and growth; processes of earthquake triggering; how individual faults in the same region interact; why some faults slip slowly without generating earthquakes while others generate earthquakes; and the factors that control variations in recurrence intervals of earthquakes along the same fault.

Parkfield Earthquake Prediction Experiment-Data Analysis. In the mid-1980s, the USGS established an earthquake prediction experiment near Parkfield, California. This region has experienced a series of moderate earthquakes every 20 to 30 years, the last of which occurred in 1966. The next earthquake was predicted to occur before 1993. In response to this prediction, the USGS and the State of California Division of Mines and Geology (now California Geological Survey) blanketed the Parkfield region with instruments designed to detect, in a quantitative manner, physical precursors to the next earthquake and the effects of the earthquake once it occurred. The earthquake predicted before 1993 did not occur; nonetheless, the instruments were maintained and operated for the following decade.

On September 24, 2004, a magnitude 6.0 earthquake struck in the Parkfield area where the dense instrumentation was located and operating. During FY 2005 and FY 2006, extensive analysis was conducted on the collected data and the results were published in a special volume of the *Bulletin of the Seismological Society of America* in 2006. The salient results are:

- There were no observed, unequivocal, short-term precursors to the earthquake upon which a prediction could have been based.
- The variation in strong ground shaking caused by the earthquake on the closely packed instruments was greater than previously observed. Moreover, the strong ground shaking decreased more rapidly with distance than predicted by models underlying current building codes.

While the two-decade Parkfield Earthquake Prediction experiment was not successful in the prediction of the next Parkfield earthquake, it was highly successful as a scientific test of the hypothesis that earthquakes in the Parkfield area could be predicted, and as a concerted effort to collect data on the nature and variation of ground shaking near a fault that breaks during an earthquake. Data collected during the Parkfield earthquake are of significant engineering interest in the design of structures located near active faults.

Earthquake-induced Strong Ground Shaking and its Effects. USGS researchers are investigating how complexities in the earthquake source, Earth's crust, and near-surface soils and deposits influence seismic wave propagation and strong ground motion. Improving current techniques for forecasting the effects of strong ground motion will greatly improve seismic hazard maps for urban regions. These efforts are thus critical for cost-effective earthquake hazard mitigation.

Three-Dimensional Geology and Seismic Velocity Models. In 2006, the USGS released a 3-D computer model of the geology and seismic velocities in the upper 32 km (20 mi) of the Earth's crust in the greater San Francisco Bay Area. The model will enable scientists and engineers to understand the shaking levels of past earthquakes and predict those of future earthquakes. Construction of the 3-D Bay Area model has been a joint effort of the USGS Earthquake Hazards Program and the USGS National Cooperative Geologic Mapping Program. Previous work by the USGS and others has shown that the 3-D structure of the Earth has a significant impact on how strongly an earthquake is felt at different locations and on the duration of the shaking. Because seismic waves propagate through different rock types with differing speeds that depend on the rock properties, the waves can be deflected as they travel and can reflect off interfaces with appropriate velocity contrasts. These phenomena can result in a focusing of seismic energy and areas of intense ground shaking. These effects need to be understood in order to predict the shaking that will be experienced at sites around the Bay Region during future large earthquakes.

Soil Failure during Earthquakes. A USGS research priority is identifying and understanding behavior of weak soils that liquefy and fail when subjected to earthquake shaking. Research on ground failure, carried out in collaboration with structural and geotechnical engineers, will lead to improved design of earthquake-resistant infrastructure and lifelines, such as bridges and airports, commonly built on fill or weak soil.

Detailed Mapping of Soil Stability. In the San Francisco Bay Area, a new methodology was applied in 2005 and 2006 to the probabilistic analysis of liquefaction in geologically young deposits and man-made landfill in Oakland and Alameda that may result from a repeat of the 1906 San Francisco earthquake. The approach is based on detailed subsurface surveys of these deposits using a Cone Penetrometer Testing Truck. Similarly, GIS-based

approaches are being investigated in the Bay Area to determine the location of earthquake-triggered landslides, dependent on the time of year and ground water conditions, resulting from a repeat of the 1906 earthquake.

Daily Earthquake Hazard Forecasts on the Web. The USGS released new public web pages that show the probability of earthquake shaking in the next 24 hours in California. These maps graphically illustrate the change in earthquake probability during aftershock and possible foreshock sequences. The maps are updated at least once an hour and are available to the public at http://pasadena.wr.usgs.gov/step. Seismologists have known for decades that the occurrence of one earthquake makes another event more likely. The probability of one earthquake triggering another has been quantified and depends on magnitude, distance, and time from the triggering event. The new maps represent a synthesis of current scientific knowledge about earthquakes in California. The methodology was developed by a team from the Swiss Federal Institute of Technology (ETH) in Zurich, Switzerland and the USGS, with funding from SCEC, ETH, and the USGS. Implementation of these maps for other areas outside California depends upon both a robust real-time seismic network and the research to establish the average rate of aftershocks for that area.

External Research. The USGS supports investigations and activities funded though external awards that are closely coordinated with and complement the internal USGS program goals. Many of the external projects are co-funded with other agencies and sources, leveraging the effect of USGS support. External program activities include (1) mapping seismic hazards in metropolitan areas; (2) developing credible earthquake planning scenarios including loss estimates; (3) expanding the prehistoric record of large earthquakes; (4) investigating the origins of earthquakes; and (5) improving methods for predicting earthquake effects. By involving the external community, the USGS program increases its geographical and institutional impact, promotes earthquake awareness across the Nation, encourages the application of new hazards assessment techniques by state and local governments and the private sector, and increases the level of technical knowledge within state and local government agencies.

6.4. PROGRAM ACTIVITY: DEVELOP, OPERATE, AND MAINTAIN NEHRP FACILITIES

Public Law 108-360 requires that the NEHRP annual report provide information on major facilities that directly contribute to or support NEHRP research and services. This section provides information on the status and accomplishments of these facilities.

- Advanced National Seismic System
- The George E. Brown, Jr. Network for Earthquake Engineering Simulation
- The Global Seismographic Network

ADVANCED NATIONAL SEISMIC SYSTEM (U.S. GEOLOGICAL SURVEY)

The ANSS is an initiative to expand, modernize, and integrate earthquake monitoring and notification in the United States. ANSS is made up of seismic monitoring activities on three scales: national,

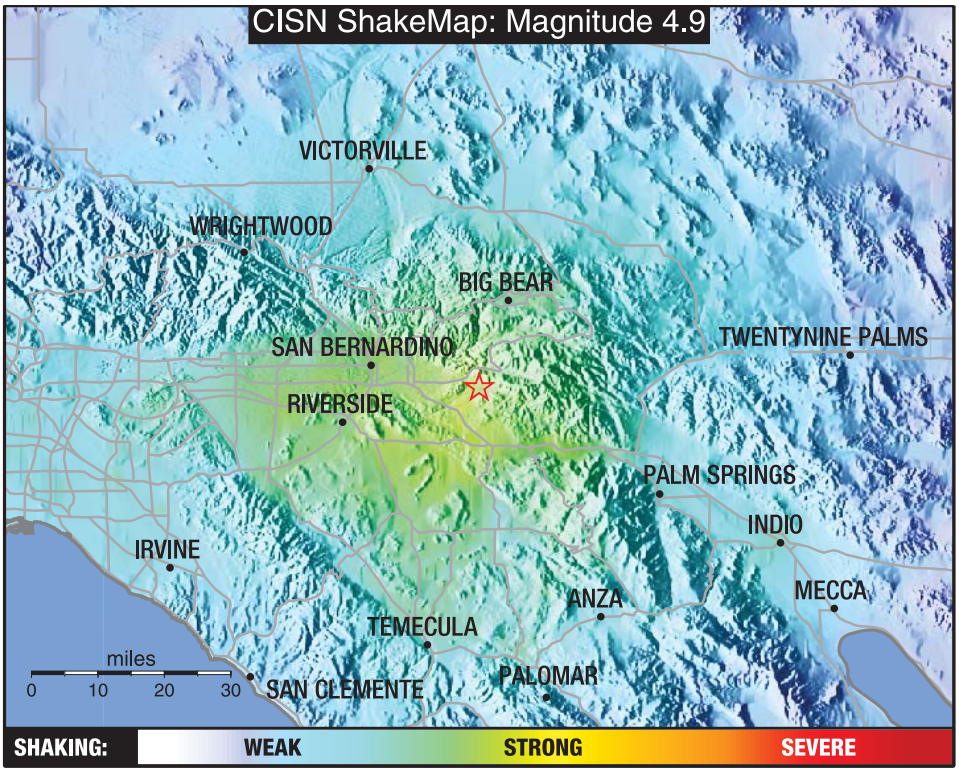
regional, and urban. Different types and densities of instruments are used at each scale of monitoring. The national (or "backbone") network operated by the USGS consists of 97 stations distributed nationwide, all feeding data in real time to the USGS National Earthquake Information Center (NEIC). These seismic instruments are of high quality, capable of recording earth tremors over large magnitude and frequency ranges. Regional networks consist of more densely spaced instruments in areas of high to moderate seismicity. Not all of the instruments in the regional networks meet current standards; one of the major goals of ANSS is to modernize these networks. In urban areas threatened by large earthquakes, the regional networks include even more densely spaced instruments deployed on the ground and in structures to record the ground and building shaking from damaging earthquakes.

Begun in 2000, ANSS implementation efforts to date have focused primarily on installing new urban recording sites in five high-risk metropolitan areas: Los Angeles, Salt Lake City, San Francisco, Seattle, and Anchorage. Increasing seismic monitoring capability in urban regions has two major benefits: (1) providing rapid assessments of the distribution and severity of strong ground shaking just after an earthquake, information that is used by emergency response officials to determine the scope and scale of the crisis they face; and (2) providing detailed and accurate data on the shaking of the ground and structures during a damaging earthquake. These data are vital to the determination of the seismicity of an area and directly affect the design of both new and existing earthquake-resistant buildings and structures.

As of the end of FY 2006, the ANSS was about 10 percent complete. ANSS is tracked by the White House Office of Management and Budget as a major capital investment in information technology, and is carefully managed by USGS for risk, security, architecture, and earned value. To date, ANSS has been consistently scored among the highest of the major investments of the DOI and USGS.

USGS NEIC. A key component of ANSS is the NEIC. Through the President's Tsunami Warning Initiative, NEIC was significantly upgraded in FY 2005 and FY 2006 and full, on-site, round-the-clock operations began in January 2006. New software allows faster identification and analysis of earthquakes in the United States and worldwide, faster reporting of earthquake locations and magnitudes, and improved integration of *ShakeMap* shaking intensity estimation. *ShakeMap* provides near real-time maps of ground motion and shaking intensity following significant earthquakes. These maps are used by federal, state, and local organizations for post-earthquake response and recovery, public and scientific information, as well as for preparedness exercises and disaster planning. *ShakeCast* is an application for automating *ShakeMap* delivery to critical users and for facilitating notification of shaking levels at user-selected facilities. The enhanced system also incorporates a full suite of modern network security measures.

Regional Earthquake Monitoring. As part of ANSS, the USGS and cooperating universities operate regional seismic networks in areas of high earthquake hazard. Data from all U.S. seismic networks are used to monitor active faults in much greater detail than is possible with the national-scale network. When ANSS is completed, each region will have an earthquake information center where data are processed, alerts and other products are issued, and regional catalogs of earthquakes are produced. These data centers will serve as local distribution points for information about earthquakes to the public, local and state agencies, and other regional interests. The



Shakemaps are used by federal, state, and local organizations, both public and private, for post-earthquake response and recovery, public and scientific information, as well as for preparedness exercises and disaster planning. This version of ShakeMap for a magnitude 4.9 earthquake in southern California is formatted for use by television stations (Source: U.S. Geological Survey).

regional data centers will relay earthquake data in real time to the NEIC as well as to other regional networks. They also will provide information about regional earthquake hazards and accepted mitigation practices, and those centers located at universities will provide training and research facilities for students. To date, regional network improvements outside of California have been minimal.

Table 3 lists the regional earthquake monitoring areas and the cooperating institutions of ANSS. Under NEHRP, the USGS provided support to all of the listed institutions in 2006. In many cases, substantial support for network operations is also provided by state governments and other sources.

ANSS Cost-Benefit Study. In 2003, USGS commissioned a study by the National Research Council (NRC) on the economic benefits of improved seismic monitoring. Specifically, USGS asked the NRC to examine how improved monitoring could reduce future losses and to estimate the benefits that could be realized by full deployment of the ANSS. In June 2005, the NRC's Committee on Seismology and Geodynamics released the 148 page report, *Improved Seismic Monitoring—Improved Decision-Making: Assessing the Value of Reduced Uncertainty*. This report represents the most rigorous effort ever performed to examine costs and benefits of earthquake monitoring, and it clearly justifies current and future USGS investments in ANSS. In the

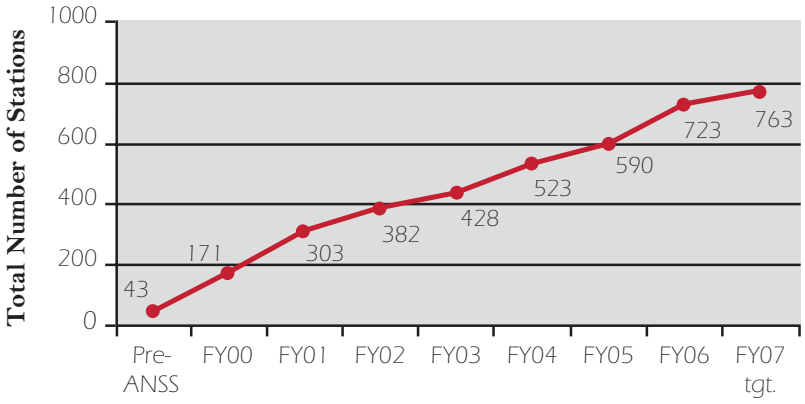
Table 3. ANSS Monitoring Regions

ANSS Earthquake Monitoring Region	Cooperating Institutions
Southern California	California Institute of Technology University of California at San Diego USGS–Pasadena
Northern California	University of California at Berkeley USGS–Menlo Park
Pacific Northwest	University of Washington University of Oregon USGS–Seattle and Vancouver, WA
Alaska	University of Alaska, Fairbanks and Anchorage
Inter-mountain West	Montana Geological Survey University of Utah University of Nevada, Reno
Central United States	University of Kentucky University of Memphis St. Louis University Ohio Geological Survey
Eastern United States	Boston College Columbia University University of South Carolina Virginia Polytechnic Institute

Committee's judgment, potential benefits of improved seismic monitoring far exceed the costs: annualized building and building-related earthquake losses are estimated to be about $5.6 billion. The annualized cost of enhanced seismic monitoring would be about $96 million, less than 2 percent of estimated losses. The Committee found that in just one benefit area, performance-based engineering, benefits are estimated at $142 million annually—about three times the cost of operating the full ANSS.

New ANSS Station Installations. Between FY 2000 and FY 2006, more than 700 earthquake monitoring stations were installed or upgraded under NEHRP funding to ANSS. Most of the sensors were installed in five high-risk

Growth of ANSS Stations Since Inception



Source: U.S. Geological Survey

urban areas (of 26 targeted for dense instrumentation under ANSS): Los Angeles, San Francisco, Seattle, Salt Lake City, and Anchorage. The figure on the previous page shows the growth of ANSS seismic stations since the system was established. In FY 2006, the ANSS Backbone Network was completed in the contiguous United States through a partnership with the USArray element of *EarthScope*, an NSF program. The current 97 station ANSS Backbone Network is capable of locating most felt earthquakes nationwide, provides data in real time to USGS, and supports NSF's *EarthScope* research program. To be completed in FY 2007 is the instrumentation of several structures (buildings and bridges) in high-hazard urban areas. The data produced by these instruments in future earthquakes will form the basis for improvements in building design and construction.

GEORGE E. BROWN, JR. NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION (NATIONAL SCIENCE FOUNDATION)

On September 30, 2004, the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) completed its 5 year, $82 million Major Research Equipment and Facilities Construction (MREFC). The 15 NEES experimental facilities, located at academic institutions across the United States, include shake tables, geotechnical centrifuges, a tsunami wave basin, large strong floor and reaction wall facilities with unique testing equipment, and mobile and permanently installed field equipment. Through the information technology (IT) NEES cyberinfrastructure, these 15 experimental facilities are linked via the Internet2 grid, forming the world's first prototype of a distributed "virtual instrument," and can be connected with similar facilities worldwide to harness the best talent globally for earthquake engineering research.

NEES operations and use of its facilities for research and education began on October 1, 2004, under management by NEES Consortium, Inc. (NEESinc), located in Davis, California (http://www.nees.org). NEESinc is a non-profit organization that works in partnership with the 15 universities to operate the NEES experimental facilities and cyberinfrastructure. NEESinc manages NEES as a national, shared-use resource for research and education for the earthquake engineering community and schedules access to the experimental facilities. NEESinc also provides the system-wide information technology infrastructure of NEES, including repositories for NEES data and simulation tools; manages an education, outreach, and training program; and fosters linkages and partnerships with federal, state, and local government entities, national laboratories, the private sector, and international collaborators.

NEES Experimental Facilities

Cornell University
Lehigh University
Oregon State University
Rensselaer Polytechnic Institute
University at Buffalo, The State University of New York
University of California, Berkeley
University of California, Davis
University of California, Los Angeles
University of California, San Diego
University of California, Santa Barbara
University of Colorado at Boulder
University of Illinois at Urbana–Champaign
University of Minnesota
University of Nevada, Reno
University of Texas at Austin

NEES provides unique opportunities to pursue the high-priority research outlined in the 2003 NRC report, *Preventing Earthquake Disasters – The Grand Challenge in Earthquake Engineering*, to demonstrate the validity of seismic design and rehabilitation concepts, speed the transfer of research into seismic design guidelines and specifications, and develop well-informed disaster preparedness and recovery strategies.

The NEES infrastructure (experimental facilities and cyberinfrastructure) facilitates a variety of innovative experimental approaches that are leading to a better understanding of how the built environment, *e.g.*, buildings, bridges, utility systems, coastal regions, and geomaterials, performs during seismic events. Through three annual program solicitations and Small Grants for Exploratory Research program in FY 2004, FY 2005, and FY 2006, NSF has funded 33 research projects to utilize the NEES facilities to study soil foundation and structure interaction; seismic performance of foundations and reinforced concrete, masonry, and composite structures; behavior of braced steel frames with innovative bracing schemes; seismic design of nonstructural systems; seismic risk mitigation of ports; and the seismic performance of bridge systems with conventional and innovative materials. NEES also provides national resources for developing, coordinating, and sharing new educational programs and materials to train the next generation of the earthquake engineering workforce.

NEES/E-Defense. NEES is leveraging and complementing its capabilities through connections and collaborations with large testing facilities at foreign earthquake-related centers, laboratories, and institutions. NSF and NEESinc have recently developed partnerships to utilize the NEES infrastructure with the 3-D Full-Scale Earthquake Testing Shake Table Facility (E-Defense) of the Japanese National Research Institute for Earth Science and Disaster Prevention (NIED), which became operational in 2005. To facilitate NEES/E-Defense collaboration, NEESinc and NIED signed a Memorandum of Understanding in August 2005. In September 2005, NSF and the Japanese Ministry of Education, Culture, Sports, Science, and Technology signed a Memorandum Concerning Cooperation in the Area of Disaster Prevention Research. Through such partnerships and joint meetings and workshops, NEES shares its expertise in testing and cyberinfrastructure, provides specialized training opportunities, and coordinates access to unique testing facilities and the central data repository. In March 2006, researchers from 19 countries convened in San Francisco for the first World Forum to discuss sharing expertise and coordination in earthquake engineering testing and cyberinfrastructure.

Archiving Perishable Field Data Capturing Devastation to Coastal Communities - The Sumatra Earthquake and Indian Ocean Tsunami. The Sumatra earthquake and Indian Ocean tsunami on December 26, 2004, was one of the deadliest events in modern history, causing approximately 200,000 deaths. The earthquake produced one of the largest tsunamis in history and resulted in vast devastation to the infrastructure of communities along the Indian Ocean coastline. Soon after the tsunami, the NSF Human and Social Dynamics priority area funded six reconnaissance teams to collect perishable field data in Asia on the tsunami's effects on roads, buildings, and communities. The NEES cyberinfrastructure made it possible to collect, organize, and preserve perishable data that were not captured on previous tsunamis. The last two tsunami events with similar magnitudes occurred more than 40 years ago: the 1960 Chilean Tsunami and the 1964 Great Alaskan Tsunami.

Building upon the NEES earthquake engineering data repository, a digital tsunami data repository to archive data from the tsunami is being developed by the NEES Consortium, Inc. This data archive will allow researchers to easily re-examine and re-analyze the data using the latest technologies, which may lead to innovative discoveries for tsunami loss reduction. This is the first time that perishable social sciences and engineering field data from a major tsunami event are being archived for use by a broader community. These data can then be used by future researchers to develop a new understanding of community and individual preparedness and response to tsunamis and how the natural and built environment responds to tsunamis, which may lead to new strategies for minimizing the risks of future tsunamis.

NEESwood Project Shakes Full-Scale Wood Townhouse in Northridge Simulation. NEESwood (http://www.engr.colostate.edu/NEESWood) is a multi-institutional research project funded by NSF that includes researchers from Colorado State University, the lead institution, Cornell University, Rensselaer Polytechnic Institute, Texas A&M University, and the University at Buffalo, The State University of New York.

For the NEESwood test conducted on November 14, 2006, researchers built a three-bedroom, two-bath, 167 square meters (1800 sq ft) wood-frame townhouse on the twin shake tables at the University at Buffalo's Structural Engineering and Earthquake Simulation Laboratory, one of the 15 NEES equipment sites. The townhouse was completely furnished, down to the car in the garage, two water heaters (one anchored, according to earthquake protection measures, and one not anchored), and dishes on the dining room table. During the test, 250 sensors inside the townhouse gathered information about the behavior of each component of the building during the simulated earthquake. A dozen video cameras recorded the shaking as it occurred.

The test has already begun to generate useful data on how to construct wood-frame homes and buildings safer for occupants during earthquakes. Unlike most seismic tests, which are conducted on small models, the NEESwood simulation featured both the full-scale structure and very severe ground motions in three directions. The test demonstrated in a dramatic way how much damage can occur during an earthquake if homeowners do not take the proper precautions. The NEESwood project will culminate with the validation of the new seismic design processes early in 2009, when a six-story wood-frame structure, pre-fabricated in the United States, will be shipped to Miki City, Japan, and tested on the E-Defense shake table.



A multi-year research project funded by the NSF built a wood-frame townhouse on twin shake tables at the University at Buffalo's Structural Engineering and Earthquake Simulation Laboratory, one of the NSF's NEES equipment sites (Photo credit: NEESWood Project).
http://www.engr.colostate.edu/NEESWood

Reducing the Cost of Structures to Withstand California Earthquakes. Construction of the 8 m (25 ft) x 12 m (40 ft) University of California, San Diego (UCSD) outdoor shake table was completed in September 2004 as part of the NEES. This $9 million shake table is the largest in the United States and the only outdoor shake table in the world, which makes it especially suited for testing tall, full-scale structures. Researchers at the UCSD, in partnership with a consortium of California engineering and design companies, used the shake table for the first-ever test of a seven-story building subjected to motion replicating the ground motion recorded during the devastating January 17, 1994, Northridge, California earthquake. This test was part of a series to evaluate new reinforced concrete building designs to improve earthquake resistance and reduce construction costs for residential structures in the densely populated and active seismic regions of Los Angeles and southern California. The test building at UCSD included a structural wall with one-half the amount of reinforcing steel in the wall that would be required by most building codes, but with the steel placed in a more optimal layout. This design made the building much lighter and cheaper to construct than current mid-rise California residential buildings. The test verified analytical predictions and showed that buildings with less reinforcing steel that is positioned precisely can better withstand earthquakes. Such a full-scale shake table test had not been possible before in the United States because of weight, space, and technical limitations of smaller U.S. indoor shake tables.



Large-scale seismic safety tests are completed with the full-scale seven-story concrete building constructed on the outdoor shake table at the Englekirk Structural Engineering Center (Photo credit: José I. Restrepo, Charles Lee Powell Structural Research Laboratories, University of California, San Diego).

GLOBAL SEISMOGRAPHIC NETWORK (NATIONAL SCIENCE FOUNDATION, U.S. GEOLOGICAL SURVEY)

The GSN is a state-of-the art, multi-purpose global monitoring network providing high-quality seismic data to support earthquake disaster management, hazards assessments, national security (through nuclear test treaty monitoring), loss reduction, and research on earthquake sources and the structure and dynamics of the Earth. The GSN is a joint program of the USGS and the NSF, implemented by USGS, the Institute for Geophysics and Planetary Physics (IGPP) of the University of California, and the Incorporated Research Institutions for Seismology (IRIS). NSF provides approximately 30 percent of the GSN support through an award to the IRIS.

Initiated in 1986, the GSN currently consists of 138 stations, installed over two decades by USGS and IGPP. NSF funds the purchase and installation of new stations through IRIS. The USGS is responsible for maintenance and operation, data collection, and quality control of two-thirds of the GSN stations, and IRIS supports the IGPP to operate and maintain the other one-third. Maintenance is accomplished in cooperation with many international partners that, in most cases, provide facilities to shelter the instruments and personnel to oversee the security and operation of each station. USGS tasks include training station operators; troubleshooting problems; providing major repairs; conducting routine service visits to network stations; providing direct financial aid in support of station operations at those sites lacking a host organization; and ensuring data quality and completeness.

Principal end-users of GSN data include the USGS NEIC and a broad range of government agencies and academic researchers, both domestic and international. These include the Comprehensive Test Ban Treaty Organization (CTBTO) and the Air Force Technical Applications Center in their respective nuclear monitoring missions, as well as the National Oceanic and Atmospheric Administration (NOAA) Tsunami Warning Centers in Hawaii and Alaska. Copies of all data from GSN stations are sent to the IRIS Data Management Center (DMC) in Seattle. The DMC is the distribution point for GSN data to users (such as scientists, engineers, and government agencies) worldwide, responding to over 10000 requests for GSN data annually. In addition, data from most GSN stations are currently available within hours of large earthquakes to the worldwide user community via the USGS Live Internet Seismic Server.

GSN real-time data are transmitted continuously to the NEIC where they are used, with other data, to determine locations, depths, magnitudes, and other parameters of earthquakes worldwide. The high quality of GSN data allows them to be used for the rapid determination of the geometric orientation of the fault that caused an earthquake, and to provide an estimate of the length of the fault that ruptured during the earthquake.

Data from the GSN are used extensively in basic and applied research on earthquakes, Earth structure, and other geophysical problems. GSN data are also used in studies conducted and supported by USGS, NSF, the Department of Energy, U.S. Air Force, and other agencies. Some of this research and data support national security through seismic monitoring of nuclear explosions and improved calibration of nuclear explosion monitoring networks.

Given the frequent occurrence of significant earthquakes around the world, the GSN is an important tool in earthquake-related education and outreach. The USGS has worked with IRIS to develop

educational museum displays based on data from the GSN. These displays explain the basic concepts of seismology and earthquake occurrence and have proven to be quite popular with the public. Displays are in place at the Smithsonian Institution in Washington, D.C., the American Museum of Natural History in New York, the Carnegie Museum in Pittsburgh, the New Mexico Museum of Natural History in Albuquerque, and the Franklin Institute's traveling "Powers of Nature" exhibit.

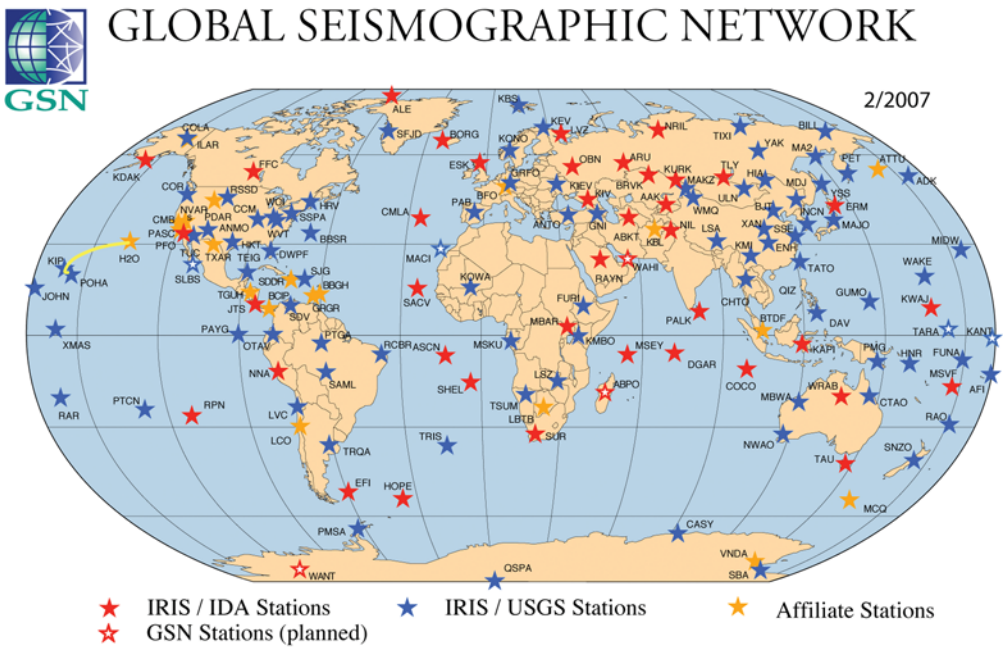
Response to the Sumatra Earthquake and Indian Ocean Tsunami. The December 2004, Sumatra earthquake and Indian Ocean tsunami was the world's largest earthquake since the 1964 Good Friday Alaskan earthquake and the largest event since the advent of digital seismology. As a result, this catastrophic event provided the first major test of the design of the GSN and highlighted the critical contribution of GSN data to the USGS and NOAA for earthquake and tsunami alerting. Within 21 minutes after the rupture started, vibrations from the earthquake were being recorded at every GSN station around the world. The open data policy of the GSN made it possible for researchers to access data quickly to study the earthquake and its rupture process in detail, and GSN recordings of the Sumatra earthquake have been extensively used in scientific studies of the event. Over the coming years, GSN recordings of the Sumatra earthquake will help scientists understand the physics of earthquake rupture and dynamics of subduction zones—studies that will have a direct bearing on the assessment of hazards associated with the Cascadia subduction zone in the Pacific Northwest and the Aleutian Islands subduction zone in Alaska.

In response to this devastating event, the President's Tsunami Warning Initiative provided funding for improvements to the GSN in support of both NOAA's tsunami warning responsibility and the USGS responsibility for earthquake notification and hazard reduction. To improve the rapidity of global earthquake reporting, the USGS has made substantial progress in expanding the number of GSN stations that deliver real-time data to NEIC, with over 89 percent of stations now sending continuous data to NEIC. USGS is partnering with IGPP, NOAA, and CTBTO to add telemetry links or expand bandwidth to improve communications at GSN sites.

To improve the detection and rapid assessment of earthquakes in the Caribbean and Atlantic under the President's Tsunami Warning Initiative, five new GSN stations were installed in the Caribbean in 2006. These new stations will provide data through NEIC to the NOAA tsunami warning centers.

During FY 2005, the USGS worked actively with the U.S. State Department to obtain agreements for installing two new GSN stations on Kanton and Tarawa Atolls in Kiribati, in the Central Pacific Ocean region, and with Spain for permits for one station in the Canary Islands in the Central Atlantic. This work is supported with NSF funds provided by IRIS.

GSN Telemetry Upgrade. Also as part of the President's Tsunami Warning Initiative, the USGS expanded and improved telemetry links to GSN stations in FY 2006. The long-term goal is to establish real-time links at a minimum of 95 percent of GSN stations; the President's tsunami action plan calls for upgrades to 39 GSN stations. Ten of these stations currently have no telemetry connection. The remaining stations have telemetry, although it is not sufficient to provide reliable continuous waveform data. USGS is contracting with the University of California, San Diego (UCSD) to upgrade the IGPP stations that are regularly operated and maintained by UCSD. The USGS is working with NOAA and CTBTO to establish communications or add bandwidth to improve telemetry at several USGS-operated stations. Only a handful of GSN stations will require visits by USGS field engineers for upgrades.



The Global Seismographic Network includes 138 stations in more than 80 countries on all continents. The GSN dramatically improves the quality, coverage, and quantity of data for earthquake reporting and research. The NSF-supported IRIS university consortium is responsible for network management and data archiving, and GSN stations are operated by the USGS, the University of California San Diego's Project IDA, and affiliated partners (Source: U.S. Geological Survey and IRIS).

Global Earth Observation System of Systems (GEOSS). To plan future development of the GSN, the USGS and IRIS (supported by NSF) co-funded an international workshop, held on August 23 and 24, 2005, on GSN in the context of the GEOSS. Although the primary focus of the GSN is the collection of seismic data, the flexible data acquisition system provides a platform for expanded Earth observatories. Many GSN stations are already equipped with auxiliary sensors such as GPS receivers and microbarographs. Because the GSN already provides infrastructure, host-country involvement and on-site support, international agreement on data sharing and, in most places, real-time communications, the GSN is ideally suited to serve as a global backbone for *in-situ* Earth Observation. Fifty people from 14 nations participated in this workshop. The GSN will be represented by the Federation of Digital Seismographic Networks in the on-going GEOSS discussions.

Related Non-NEHRP Activities Conducted and Planned by NEHRP Agencies for FY 2007 and FY 2008

Chapter 7

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, requires that the annual report to Congress include a description of activities that are being carried out by NEHRP agencies and contributing to NEHRP, but are not included in the Program. Highlights of three programs are described below.

EARTHSCOPE

EarthScope is an earth science research facility funded by the National Science Foundation (NSF). The multi-purpose array of instruments and observatories that comprise *EarthScope* will greatly expand the observational capabilities in the earth sciences and help to advance our understanding of the structure, evolution, and dynamics of the North American continent. The program provides an integrative framework for research on fault properties and the earthquake process, strain transfer, magmatic and hydrous fluids in the crust and mantle, plate boundary processes, large-scale continental deformation, continental structure and evolution, and composition and structure of the deep-earth. In addition, *EarthScope* offers a centralized forum for earth science education at all levels and an excellent opportunity to develop cyberinfrastructure to integrate, distribute, and analyze diverse data sets.

EarthScope is designed to continually incorporate technological advances in geophysics, seismology, geodesy, information technology, drilling technology, and downhole instrumentation. The primary elements of the *EarthScope* observatory are the Plate Boundary Observatory (PBO), the San Andreas Fault Observatory at Depth (SAFOD), and the USArray.

Plate Boundary Observatory. The PBO is the geodetic component of *EarthScope* that will facilitate the study of deformation across the active plate boundary zone between the Pacific and North American plates along the western United States coastline. At its completion, PBO will consist of 116 new and 20 existing GPS stations along the western U.S., including Alaska, dense clusters of 775 permanent GPS receivers and 103 strainmeters, and 100 portable campaign GPS receivers for temporary deployments and rapid response. To date, approximately 500 GPS stations and 25 strainmeters have been deployed.

The U.S. Geological Survey (USGS) will use data from PBO geodetic instruments for monitoring at Mt. St. Helens, Augustine, and other volcanoes with the data readily available. USGS and UNAVCO Inc. (the NSF awardee for PBO) cooperate at the operational level. For example, with most volcanoes located on public lands, PBO sites will provide an important augmentation to existing USGS deformation networks monitoring earthquake and volcano hazards. Incorporation of about one-half of PBO's continuous GPS and borehole seismic sites into USGS analysis streams and upgrading them to near-real-time capability is a major task that is still getting underway. Development and/or purchase of hardware and software for collecting and archiving these data and development of analysis methods will be needed to make full use of the PBO network and to fulfill the USGS mission in earthquake and volcano hazard assessment.

San Andreas Fault Observatory at Depth. While drilling to create the new SAFOD, scientists tapped into the active zone of the SAF at a depth of about 3 km (2 mi) under the Earth's surface. The drill hole, near Parkfield, California, starts on the Pacific tectonic plate, west of the SAF, goes through the active earthquake zone, and ends in the North American Plate, east of the fault. The SAFOD drill hole is designed to house instruments to collect data at intervals from the surface to the depth where earthquakes form. Fluid pressure, temperature, and geophysical data collected around the clock will be used to observe the physical and chemical changes that take place as earthquakes occur.

A large contingent of USGS scientists is involved in all aspects of SAFOD, including the planning and management of the project and the analysis and interpretation of data. The USGS-run Northern California Seismic Network operation has provided extensive logistical support. SAFOD data are of great importance to scientists working on problems related to earthquake physics, such as the physical conditions on faults and the initiation and propagation of earthquake faulting. These problems are fundamental to the understanding of earthquake processes and to the development of a foundation for the reliable prediction of future earthquakes.

USArray. The third major component of *EarthScope* is the USArray, a combination of permanent, intermediate-term, and short-term seismograph installations. USArray permanent seismic stations have been installed in partnership with USGS to help complete an equally spaced network of seismic stations that can detect and record earthquakes of magnitude 3.0 or greater across the contiguous United States. Intermediate-term (up to 2 years) and short-term Transportable Array stations are providing even more detailed earthquake, earth structure, and ground shaking information. The initial Transportable Array deployment of 400 unmanned broadband seismometers, which started in 2005, is scheduled for completion in 2007 and will cover a 700 km (450 mi) x 1400 km (870 mi) swath of the western U.S. with a uniform spacing. USArray also includes the 2111-seismometer Flexible array and 27 magnetotelluric sensors that provide constraints on temperature and fluid content of the lithosphere.

The USGS Albuquerque Seismological Laboratory has cooperated with IRIS to install and upgrade ANSS Backbone stations. These will serve both the USGS for earthquake notification as well as NSF as a fixed network for benchmarking Transportable Array stations as they sweep across the country.

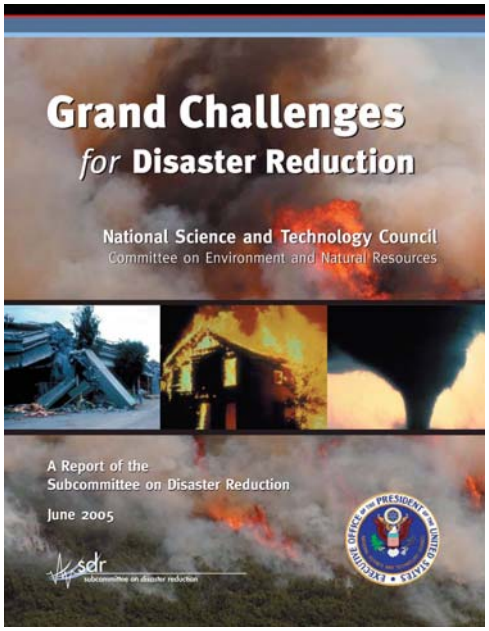
The initial deployment of the Transportable Array has made extensive use of existing ANSS broadband stations in California that are part of the California Integrated Seismic Network (CISN), an ANSS regional network, particularly in Southern California because of the TriNet stations deployed after the Northridge earthquake. These stations are operated by Caltech with support from USGS and the State of California. This partnership greatly reduced the number of stations sites that had to be selected and permitted during the initial phase of USArray.

GRAND CHALLENGES FOR DISASTER REDUCTION

While the NEHRP partnership represents the core of federal activities related to earthquake loss reduction, many additional federal agencies play important roles in this arena. Coordination for the full spectrum of science and technology contributions is provided by the White House National Science and Technology Council's Committee on Environment and Natural Resources, Subcommittee on Disaster Reduction (SDR), which is charged with establishing national goals

for federal science and technology investments in disaster reduction. In support of this mission, the SDR provides a senior-level interagency forum to leverage expertise, inform policymakers, promote technology applications, coordinate activities, and promote excellence in research and development.

In 2005, the White House released the SDR document *Grand Challenges for Disaster Reduction*, available at http://sdr.gov, which provides an overview of the risks facing the Nation from natural and technological hazards and identifies the 10 year priorities for focused federal investment in science and technology for disaster reduction, including earthquakes. In partnership with local, state, federal, and international experts, the members of the SDR identified four key characteristics of disaster resilient communities. First, relevant hazards are recognized and understood. Second, those at risk know when a hazard event is imminent. Third, individuals at risk are safe from hazards in their homes and places of work. Finally, disaster resilient communities experience minimum disruption to life and economy after a hazard event has passed. In support of these goals, the members identified six Grand Challenges for disaster reduction science and technology and the corresponding key research requirements and major technology investments. An earthquake-specific implementation plan, coordinated by the NEHRP partners, will be published in 2007.



This report from the White House National Science and Technology Council's Subcommittee on Disaster Reduction provides an overview of the hazard risks facing the Nation and identifies the 10 year priorities for focused federal investment in science and technology for disaster reduction, including earthquakes (Source: NOAA).

U.S. JAPAN PANEL ON WIND AND SEISMIC EFFECTS – U.S. JAPAN PROGRAM ON NATURAL RESOURCES

In response to the need for stronger technical links between the United States and Japan in wind and seismic effects, the two countries created the Panel on Wind and Seismic Effects (Panel) in 1969 to conduct joint research and cooperative programs and to exchange technical data and information, researchers, and research equipment.

The Panel, which is part of the 1964 bilateral U.S.-Japan Program on Natural Resources (UJNR), operates through 18 U.S. agencies and 10 Japanese agencies. The NEHRP member agencies play important roles in the panel on Wind and Seismic Effects and the panel on Earthquake Research, the U.S. sides of the panels being chaired by NIST and USGS, respectively.

The panel on Earthquake Research met in California in October 2004, where latest results in earthquake research and warning in the United States and Japan were shared and discussed over a 3 day period.

In the panel on Wind and Seismic Effects, NSF and USGS chair two of the seven Task Committees, where work on specific technical issues is achieved through joint collaboration with representatives of private sector organizations. The other five Task Committees are chaired by NEHRP partnering agencies. The work of the Panel has resulted in improved building and bridge standards and codes and design and construction practices in hydraulic structures in both countries. The Panel's work involved the following:

- Exchanging more than 200 guest researchers who performed short- and long-term joint cooperative research assignments that enhanced the research mission of both countries and contributed to improved structural standards and building codes.
- Annually visiting major public works construction projects that employ innovative civil engineering techniques and research laboratories with unique test and measurement capabilities. This enhanced the joint Panel's understanding of research, design, and construction procedures used by both countries.
- Performing joint post-disaster surveys and making entrees for counterpart Panel members to participate in post-disaster surveys of wind, earthquake, and tidal wave damages. The results are shared with the professional community, which contributes to improved building quality control measures.
- Conducting specialty symposia that advanced technology transfer to participants and stimulated greater attention to promoting disaster mitigation programs.
- Translating into English two Ministry of Construction reports: *Manual for Repair Methods of Civil Engineering Structures Damaged by Earthquakes* and the 2-volume Base Isolation Systems for Building. The publications were distributed to the U.S. civil engineering community as improved practices.
- Performing Cooperative Research Programs whose accomplishments improved design and construction practices for both countries in areas of reinforced concrete structures; lifeline facilities; *in-situ* testing methods for soil liquefaction; masonry structures; steel structures; hybrid control; precast seismic structural systems; seismic performance of composite and hybrid structures; countermeasures for soil liquefaction; and seismic performance testing of bridge piers.

The Panel's accomplishments assisted the United States and Japan in improving their seismic design and construction practices by:

- Producing data that advanced retrofit techniques for bridge structures.
- Producing full-scale test data that advanced seismic design standards for buildings.
- Advancing technology for repairing and strengthening reinforced concrete, steel, and masonry structures.
- Improving *in-situ* measurement methods for soil liquefaction and stability under seismic loads.
- Creating a database comparing Japanese and U.S. standard penetration tests to improve prediction of soil liquefaction.

Grants and Activities to Promote Implementation of Research Results

Chapter 8

The Federal Emergency Management Agency (FEMA) allocates a portion of its National Earthquake Hazards Reduction Program (NEHRP) funds as grants to state governments, administered by FEMA National Preparedness Directorate. FEMA also administers a Pre-Disaster Mitigation (PDM) Grant Program, which provides funds to states and communities on a competitive basis. With funds from these and other programs, state and local agencies undertake numerous activities to protect their citizens from the earthquake hazard. Highlights of successful state, territorial, and local government efforts in support of NEHRP are described below.

ALASKA

Alaska is using *VRiskMap* software, which facilitates risk and vulnerability analysis from earthquakes and other natural hazards. With the software, Alaskan communities are developing Local Hazard Mitigation Plans to identify risks, vulnerabilities, and economic impact to Alaska's population and infrastructure from natural hazards.

Two real-time earthquake monitoring systems are used in the Alaska State Emergency Coordination Center to provide immediate earthquake notification. The systems graphically relate earthquakes to adjacent communities and allow the Center to quickly contact communities to gather impact data for potential damage estimates. The monitoring systems and their attendant networks of seismometers, data collection centers, and data analysis facilities are supported by the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), and the State of Alaska.

Alaska and the NOAA National Weather Service (NWS) conducted a test of the Tsunami Warning System on March 29, 2006. While tests of the State's Emergency Alert System (EAS) are conducted monthly, this test was the second "live" test where actual tsunami warning codes were used. This test, which was a resounding success, brought to light additional areas needing improvement to the warning equipment and NWS warning processes.

Alaska funded the printing of 4,000 copies each of the children's books: "Molly and the Earthquake," "Heidi and the Tsunami," "James and the Volcano," and "Spencer and the Wildfire." The books tell fictional stories of a family's natural hazards experiences and give safety tips on what to do before, during, and after the events.

ARIZONA

An earthquake swarm that occurred southeast of Flagstaff, Arizona, combined with early summer earthquakes in California, generated significant interest in seismic hazards in Arizona. Although the region is relatively unpopulated and no significant damage occurred, the largest earthquakes were felt over much of central and northern Arizona. The Arizona Earthquake Information Center in Flagstaff recorded the swarm with its regional seismic network and responded to many

public inquiries on earthquake activity and potential hazards with Arizona State University, the University of Arizona, and the Arizona Geological Survey (AZGS). In September, AZGS staff presented a general synthesis of paleoseismic and historical seismic information for Arizona at a national public awareness forum organized by the Western States Seismic Policy Council (WSSPC).

ARKANSAS

Arkansas sent *Earthquake Toolkit for Schools* packages to a number of school districts. The packets contain flyers and Kids Activity Pages, new publications from NEHRP, a memo about "Duck, Cover and Hold" versus "Triangle of Life," along with the Center for Earthquake Research and Information (CERI) Toolkit CD. Over 100 packages were sent out before EQ Preparedness Week. Arkansas also premiered a new earthquake web site (http://www.adem.state.ar.us/documents/Earthquake/earthquakeweb.htm) that includes new brochures, Kids Activity Pages, and the Earthquake Word Search & Scramble.

CALIFORNIA

The California Safety Assessment Program (SAP) utilizes structural engineers, civil engineers, architects, and building officials in post-disaster assessments of building safety. There are now more than 4,000 SAP volunteers registered and current in their training.



Napa, CA, Feb. 14, 2006 - A home is retrofitted with earthquake straps and bolts to prevent movement in the event of an earthquake (Photo credit: FEMA).

The California Governor's Office of Emergency Services (OES) provides financial support to the California Integrated Seismic Network (CISN) for expanding and operating the CISN Region of the Advanced National Seismic System (ANSS). CISN *Display* is an integrated web-enabled earthquake notification system designed for emergency management round-the-clock operations centers. After the 2004 Sumatra earthquake and Indian Ocean tsunami, CISN *Display* was cited as one of the technologies that would be used to distribute earthquake and tsunami information to South Asian nations as part of the U.S. contribution to expanding the worldwide tsunami notification system. OES is using post-earthquake Hazard Mitigation Grant Program (HMGP) funding to expand and enhance CISN.

The California Earthquake Prediction Evaluation Council (CEPEC) met several times to consider policy implications of several predictions and developing technologies. In January 2005, CEPEC reviewed a web site developed by the USGS that gives the probability of earthquake shaking of Modified Mercalli Intensity VI in the next 24 hours from the background hazard (the National Seismic Hazard Maps), modified by the short-term probability associated with earthquake clustering. CEPEC agreed that the approach is an extension/improvement of existing aftershock forecasts.

In 2005, the California OES Specialized Training Institute offered Earthquake Preparedness and Response courses attended by 375 local government personnel and public and private utilities.

A month before the 2004 Sumatra earthquake and Indian Ocean tsunami, OES presented a toolkit workshop to emergency managers from the 15 California coastal counties. That workshop and the tsunami generated demand for presentation of individual county (Operational Area) planning and exercise workshops during the spring in San Diego, Ventura, San Mateo, San Francisco, and Orange Operational Areas. Tsunami Task Forces were established in Los Angeles, Ventura, and Orange Operational Areas and supported by staff from the Earthquake Program and Southern Region.

In October 2005, the California Geological Survey (CGS) hosted a workshop on potential tsunami sources in California's coastal waters. The workshop examined the state of understanding of tsunami sources, both earthquakes and submarine landslides, and considered probabilistic approaches to evaluating the tsunami run-up hazard. Participants included experts in California offshore tectonics and landslide mapping and in tsunami modeling.

Evacuation planning maps were produced by OES Coastal Region GIS staff and distributed to Operational Areas and approved recipients in response to multiple requests. Coastal evacuation areas have been analyzed, mapped, and field verified in a number of counties, including San Francisco, San Mateo, Santa Cruz, and Los Angeles.

HAWAII

The Hawaii State Earthquake Advisory Committee (HSEAC) enhanced HAZUS by incorporating soil properties for the County of Hawaii generated by a 2004 study. The HAZUS data products demonstrated its capability and provided predictions for future earthquakes on the Big Island. The Pacific Disaster Center also developed a series of HAZUS predictions. This atlas of likely events is now available for immediate planning reference by emergency responders.

In 2005, Hawaii State Civil Defense conducted two statewide tsunami exercises. In April, an exercise for a distant tsunami was conducted that included the Pacific Tsunami Warning Center and all counties in Hawaii. In October, an urgent local tsunami exercise was conducted utilizing a scenario depicting a tsunami originating off the west (Kona) coast of the Island of Hawaii. This exercise was coordinated with monthly testing of warning sirens. Tsunami mapping continues through an effort coordinated by State Civil Defense with the University of Hawaii to upgrade existing one-dimensional tsunami evacuation maps. These inundation maps, which will be published in digital form on the Internet, will be used to draw new evacuation maps that will replace the one-dimensional evacuation maps now in telephone books.

IDAHO

The northeastern region of Idaho received a 2005 PDM award to complete community all-hazard mitigation plans for Bonneville, Butte, Clark, Custer, Fremont, Jefferson, Lemhi, Madison, and Teton counties, the areas most at risk from earthquakes. The Idaho Bureau of Homeland Security also accepted a 2005 PDM award to update and expand the Idaho State All-Hazard Mitigation Plan. This project will include the collection and storage of geo-data for all state facilities. The data collected will be used for additional analysis using HAZUS and for prioritizing the State's seismic mitigation priorities.

INDIANA

Indiana DHS and the Indiana Geological Survey developed an earthquake video that has been distributed to all 92 county Emergency Management Agencies (EMAs), Red Cross Chapters, and school districts. Indiana also is preparing for the New Madrid Catastrophic Planning Initiative and is developing plans that will address response to moderate earthquakes in Southwestern Indiana and Western Ohio.

MISSOURI

Missouri continues to promote earthquake loss-reduction practices and policies by encouraging mitigation, sponsoring earthquake awareness and preparedness programs, and developing better response and recovery capabilities through exercises. An important task for the program in recent months has been developing a catastrophic event annex to the State Emergency Operations Plan.

NEVADA

Nevada conducted and participated in several earthquake awareness projects and potential earthquake damage scenarios to increase public knowledge about future earthquakes. Nevada has prepared, in collaboration with the USGS, 84 maps showing the probabilities of earthquakes of varying magnitudes from 5 to 7 on the Richter Scale for 21 of Nevada's largest communities. These maps are available on the web. The California Seismic Safety Council, in cooperation with the CGS, the Nevada Earthquake Safety Council, the Nevada Bureau of Mines and Geology (NBMG), and the Nevada Seismological Laboratory, produced a new Earthquake Shaking Potential Map for Portions of Eastern California and Western Nevada (NBMG Open File Report 05-2) for decision makers and the general public.

The NBMG has run Level 1 HAZUS-MH scenarios for each of the State's 17 county seats. The scenarios are based on local earthquake hazards identified for each community and give emergency managers overviews of potential losses and consequences from damaging earthquake in their communities.

Nevada has continued to develop the "Nevada Education Seismic Network" by installing seismometers in urban and rural high schools. These seismometers are part of the state seismic network and provide teachers and students with learning experiences that promote earthquake awareness. Workshops were held in 2006 to train teachers involved with the program on seismology and how to use the programs provided with the seismometers.

OREGON

Oregon enacted new loss-reduction policies that focus on identifying and mitigating critical community facilities such as public schools, fire and police stations, and hospitals. These new laws adopt FEMA techniques (FEMA 154), establish a long-term grant program, and allocate state bond funds for seismic rehabilitation.

PUERTO RICO

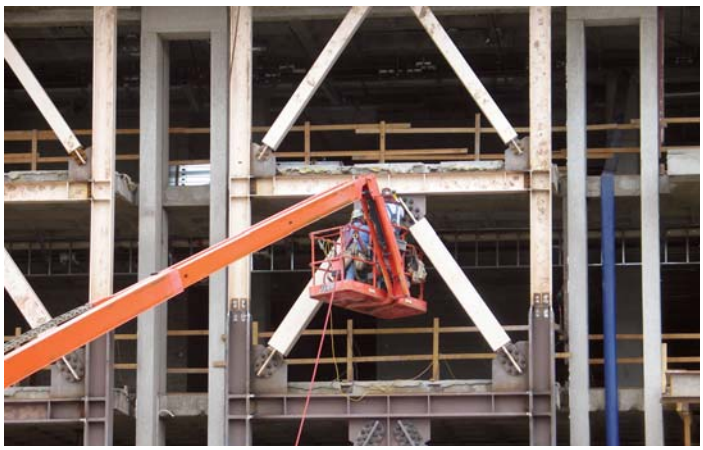
The University of Puerto Rico Mayaguez campus leads the Tsunami Awareness Program, which started as a HMGP project. Since January 2006, the Mayaguez campus also has participated in the creation and development of the Caribbean Tsunami Warning System and attended the international meetings sponsored by the United Nations. The Municipality of Mayaguez has been recognized by NOAA as the first Caribbean community to be tsunami-ready. For the first time, Puerto Rico has been awarded funds under the 2006 National Tsunami Hazard Mitigation Program (NTHMP) to develop creative outreach programs for communities under high tsunami risk. A tsunami brochure was developed as one of the educational tools.

SOUTH CAROLINA

South Carolina continues to promote its annual Earthquake Awareness Week. A Governor's Proclamation is declared, news releases containing information about earthquakes and their effects are issued; earthquake literature is mailed to county emergency managers and schools; and a *Drop, Cover, and Hold* drill is held with participation from schools. A new *Earthquake Preparedness for Schools* web page was created in 2005 to aid teachers in preparation for Earthquake Awareness Week (http://www.dnr.sc.gov/geology/Education.htm#presentations).

UTAH

In Utah, several major seismic rehabilitation projects are underway in the Salt Lake region, including a $200 million State Capitol effort that includes a state-of-the-art base isolation system and strengthening of the rotunda. The J. Willard Marriott Library at the University of Utah Campus is undergoing major rehabilitation and was selected for a nationally competitive PDM grant.



Unbonded steel braces are used as part of the seismic rehabilitation of the J. Willard Marriott Library on the University of Utah campus. FEMA provided partial funding of this project through the PDM grant program (Photo credit: Kelly Peterson, University of Utah).

The Utah Seismic Safety Commission partners in earthquake education, outreach, and mitigation activities with three other key players in Utah's state earthquake program: the Utah Division of Emergency Services & Homeland Security; the Utah Geological Survey (UGS); and the University of Utah Seismograph Stations. Notable projects include implementing ANSS in Utah; developing the next generation of seismic hazard maps in partnership with the USGS; using HAZUS software, coupled with scenario *ShakeMaps*, for effective loss estimation; and carrying out state earthquake exercises. The Commission and its partners will produce a Utah-specific version of *Putting Down Roots in Earthquake Country* for Utah's seismically hazardous Wasatch Front urban corridor. The Commission also is planning to produce an earthquake scenario brochure for a major earthquake on the Wasatch fault in the Salt Lake Valley.

Utah held the fourth annual meetings of Utah's Ground Shaking, Quaternary Fault Parameters, and Liquefaction Working Groups in February 2006. Each working group discussed 2005 research results, upcoming 2006 projects, and set priorities for 2007 research. The Utah Earthquake Working Group meetings are organized by the UGS and cooperatively funded by the UGS and USGS under the NEHRP.

WASHINGTON

The Washington Division of Geology and Earth Resources developed and produced tsunami inundation maps for Anacortes and Whidbey Island. The maps will be used to develop tsunami evacuation brochures and to develop an earthquake/tsunami risk communications program for citizens and visitors. Washington also completed tsunami evacuation maps for 10 coastal communities in Grays Harbor and Pacific Counties and published the NEHRP site class maps and liquefaction maps for 39 counties.

In Washington, April is designated "Disaster Preparedness Month." Educational materials are distributed to local jurisdictions, state agencies, schools, businesses, and the general public. More than one and a half million citizens participated in the statewide earthquake "Drop, Cover, and Hold" drill. In September, which is designated "National Preparedness Month," preparedness materials are distributed to citizens, state partners with the NWS, and to retailers to make NOAA Weather Radios affordable.

The Washington Emergency Management Division (EMD), Washington State Patrol, and the Lummi Indian Nation hosted an Earthquake Workshop for Tribes in June 2005. The workshop educated tribal officials and responders on the earthquake and tsunami threat and provided educational materials and training opportunities specifically for tribes. EMD continued to partner with Federal Signal to develop the All Hazard Alert Broadcasting (AHAB) Radio System that provides both tone and voice alert notification to at-risk communities for any hazardous situation.

EMD continues to partner with the Institute of Geological and Nuclear Sciences on assessing education and preparedness of citizens. Activities included an assessment of school education programs around Mount Rainier and an assessment of preparedness efforts at hotels and motels along the coast. The assessment provided information to develop a Disaster Response Guide Book for Hotels and Motels. One-on-one training sessions have been completed with 19 businesses.

ABBREVIATIONS AND ACRONYMS

ACEHR	Advisory Committee on Earthquake Hazards Reduction
AHAB	All Hazard Alert Broadcasting
ANSS	Advanced National Seismic System
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
AZGS	Arizona Geological Survey
BSSC	Building Seismic Safety Council
Caltrans	California Department of Transportation
CEA	California Earthquake Authority
CEPEC	California Earthquake Prediction Evaluation Council
CERI	Center for Earthquake Research and Information
CERL	Construction Engineering Research Laboratory
CGS	California Geological Survey
CISN	California Integrated Seismic Network
CME	Community Modeling Environment (SCEC)
COSMOS	Consortium of Strong Motion Observation Systems
CREW	Cascadia Region Earthquake Workgroup
CRM	Consequence-based Risk Management
CRSC	Code Resource Support Committee
CTBTO	Comprehensive Test Ban Treaty Organization
CUREE	Consortium of Universities for Research in Earthquake Engineering
CUSEC	Central United States Earthquake Consortium
DC-FP	Double-Concave Friction Pendulum
DEEPSOIL	MAE Center software tool for the analysis of 1-D seismic response of soil columns
DHS	Department of Homeland Security
DMC	Data Management Center (IRIS)
DMS	Data Management System (IRIS)
DoD	Department of Defense
DOI	Department of the Interior
EAS	Emergency Alert System
EERC	Earthquake Engineering Research Center
EERI	Earthquake Engineering Research Institute
EMA	Emergency Management Agency
EMD	Emergency Management Division
E&O	Education and Outreach (IRIS)
EQ	Earthquake
ETH	Swiss Federal Institute of Technology
ETS	Episodic Tremor and Slip
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FY	Fiscal Year
GEOSS	Global Earth Observation System of Systems
GIS	Geographic Information System

GSA	General Services Administration
GSN	Global Seismographic Network
HAZUS	Hazards U.S. (FEMA's Earthquake Loss Estimation Methodology)
HMGP	Hazard Mitigation Grant Program
HSEAC	Hawaii State Earthquake Advisory Committee
IBC	International Building Code
ICC	International Code Council; NEHRP Interagency Coordinating Committee
ICSSC	Interagency Committee on Seismic Safety in Construction
IGPP	Institute for Geophysics and Planetary Physics
IGS	Idaho Geological Survey
IRC	International Residential Code
IRIS	Incorporated Research Institutions for Seismology
IT	Information Technology
LFE	Learning From Earthquakes Program (EERI)
LISTSERV	E-mail list management software
MAE	Mid-America Earthquake Center
MAEviz	MAE Center seismic loss assessment system
MCEER	Multidisciplinary Center for Earthquake Engineering Research
MMC	Multihazard Mitigation Council
MREFC	Major Research Equipment and Facilities Construction (NEES)
NBMG	Nevada Bureau of Mines and Geology
NCSA	National Center for Supercomputer Applications
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEHRP	National Earthquake Hazards Reduction Program
NEIC	National Earthquake Information Center
NESEC	Northeast States Emergency Consortium
NETAP	National Earthquake Technical Assistance Program
NFPA	National Fire Protection Association
NHC	Natural Hazards Center
NIBS	National Institute of Building Sciences
NIED	National Research Institute for Earth Science and Disaster Prevention
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NTHMP	National Tsunami Hazard Mitigation Program
NWS	National Weather Service
OES	Office of Emergency Services (California Governor)
OMB	Office of Management and Budget
OpenSees	Open System for Earthquake Engineering Simulation
OSTP	Office of Science and Technology Policy
PACT	Performance Assessment Calculation Tool
PASSCAL	Program for Array Seismic Studies of the Continental Lithosphere
PBEE	Performance-Based Earthquake Engineering
PBO	Plate Boundary Observatory
PBSD	Performance-Based Seismic Design
PCWG	Program Coordination Working Group
PDM	Pre-Disaster Mitigation Grant

PEER	Pacific Earthquake Engineering Research Center
PSHA	Probabilistic Seismic Hazard Assessment
QR	Quick Response reports (NHC)
RDAT	Rehabilitation Decision Analysis Toolbox
REDARS	Risks from Earthquake Damage to Roadways Systems Software
RVS	Rapid Visual Screening
SAF	San Andreas Fault
SAFOD	San Andreas Fault Observatory at Depth
SAP	Safety Assessment Project (California)
SCEC	Southern California Earthquake Center
SDR	Subcommittee on Disaster Reduction
SESAC	Scientific Earthquake Studies Advisory Committee
SIO	Scripps Institute of Oceanography
STRATACAP	Capital allocation decision analysis software
UCSD	University of California, San Diego
UIUC	University of Illinois at Urbana–Champaign
UJNR	U.S.–Japan Program on Natural Resources
UGS	Utah Geological Survey
USACE	U.S. Army Corps of Engineers
USArray	A component of *EarthScope* designed to collect detailed seismic images of the North American lithosphere
USGS	U.S. Geological Survey
VIEWS	Visualizing the Impacts of Earthquakes with Satellites
WSSPC	Western States Seismic Policy Council