THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM: PAST, PRESENT AND FUTURE

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED EIGHTH CONGRESS

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THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM: PAST, PRESENT AND FUTURE

THURSDAY, MAY 8, 2003

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH,
COMMITTEE ON SCIENCE,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:10 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Nick Smith [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The National Earthquake Hazards Reduction Program: Past, Present and Future

Thursday, May 8, 2003

2:00 PM – 4:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Mr. Anthony Lowe
Administrator
Federal Insurance Mitigation Administration

Mr. Robert Olson
President
Robert Olson Associates

Dr. Lloyd Cluff
Director
Geosciences and Earthquake Risk Management
Pacific Gas and Electric Company

Dr. Thomas O'Rourke
President
Earthquake Engineering Research Institute

Dr. Lawrence D. Reaveley
Professor and Chair
Department of Civil and Environmental Engineering
University of Utah

HEARING CHARTER

SUBCOMMITTEE ON RESEARCH
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The National Earthquake Hazards Reduction Program: Past, Present, and Future

THURSDAY, MAY 8, 2003
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

On Thursday, May 8th, 2003, the Research Subcommittee of the House Science Committee will hold a hearing to examine the current status of the National Earthquake Hazards Reduction Program (NEHRP) in preparation for program reauthorization later this year. NEHRP is a long-term, comprehensive, multi-agency earthquake hazards mitigation program established by Congress in 1977 to minimize the loss of life and property from earthquakes. Four agencies participate in this effort: the Federal Emergency Management Agency (FEMA), U.S. Geological Survey (USGS), National Science Foundation (NSF), and National Institute of Standards and Technology (NIST).

2. WITNESSES

(Note: The Subcommittee will also receive written testimony from USGS, NSF, and NIST.)

Mr. Anthony Lowe is the Administrator of the Federal Insurance Mitigation Administration (FIMA), a division of the Emergency Preparedness and Response (EPR, formerly FEMA) Directorate of the Department of Homeland Security. He will be accompanied by *Mr. Craig Wingo,* Director of the FEMA Engineering Science and Technology Division.

Dr. Lloyd S. Cluff is the Director of Geosciences and Earthquake Risk Management for Pacific Gas and Electric Company, and also Chair of the USGS Scientific Earthquake Studies Advisory Committee. Dr. Cluff's expertise includes identification of seismic faults and their potential ground motion, and a member of the National Academy of Engineering.

Dr. Thomas O'Rourke is President of the Earthquake Engineering Research Institute (EERI), a nonprofit technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. He is also a Professor of Civil and Environmental Engineering at Cornell University, and a member of the National Science Foundation Engineering Advisory Committee. His research interests include geotechnical engineering, earthquake engineering, lifeline systems, underground construction technologies, and geographic information technologies.

Dr. Robert Olson is President of Robert Olson Associates, where he consults on areas of earthquake hazards mitigation, emergency management, disaster operations, recovery assistance, and public policy development. Previously, Mr. Olson served as Executive Director of the California Seismic Safety Commission. He has chaired numerous committees, including the Governor's Task Force on Earthquake Preparedness and the Advisory Group on Disaster Preparedness to the California Joint Legislative Committee on Seismic Safety.

Dr. Lawrence D. Reaveley is Professor and Chair of the Department of Civil and Environmental Engineering at the University of Utah.

3. OVERARCHING QUESTIONS

The hearing will address the following overarching questions:

1. What have been the notable accomplishments and shortcomings in the first 25 years of NEHRP? What is the current status of the program, and what

is the appropriate level of funding? How should this funding be prioritized among various research and mitigation activities?

2. How can Congress improve NEHRP strategic planning and coordination to foster a more unified effort to reduce earthquake hazards?
3. How will NEHRP be affected by the recent transition of FEMA, formerly an independent federal agency, into the Emergency Preparedness and Response Directorate of the Department of Homeland Security?
4. How can NEHRP accelerate the implementation of knowledge and tools developed from earthquake-related research?

4. OVERVIEW/ISSUES

- Damaging earthquakes are inevitable, if infrequent. Most states face at least some danger from earthquakes, and total annualized damages in the United States are estimated to be about $4.4 billion in direct financial losses (repair costs, inventory loss, and business interruption). The 1994 Northridge earthquake in California (magnitude 6.7) was the most costly in U.S. history, causing over $40 billion in damage.
- NEHRP was created in 1977 in response to growing concerns about the threat of damaging earthquakes. The program was originally focused on research into geotechnical and structural engineering and earthquake prediction. Over time, researchers recognized that earthquake prediction was an unrealistic goal, and its focus was significantly de-emphasized within NEHRP, while efforts were expanded to include activities such as seismic retrofitting and rehabilitation, risk assessment, public education and outreach, and code development.
- NEHRP Agency responsibilities include:

  FEMA—overall coordination of the program, education and outreach, and implementation of research results;

  USGS—basic and applied earth science and seismic research;

  NSF —basic research in geoscience, engineering, economic, and social aspects of earthquakes

  NIST—problem-focused R&D in earthquake engineering aimed at improving building design codes and construction standards.
- The program has achieved significant progress since inception, and is generally considered to be a successful undertaking. Loss of life and injuries sustained from earthquakes has decreased substantially, seismic risk assessment capabilities have significantly improved, and technological advances in areas such as performance-based engineering, information technology, and sensing and imaging have provided valuable knowledge and tools for mitigating earthquake hazards.
- New knowledge and tools, however, have not translated into decreased overall vulnerability. End-user adoption of NEHRP innovations has been incremental and slower than expected. This is in part because current building codes tend to focus on protecting the lives of the occupants rather than minimizing nonstructural damage and economic losses. Further, the cost of rehabilitating existing structures to become more earthquake resistant is often too high, as is the cost of building new structures to minimize risk. The private sector has not had adequate incentives, and State and local governments have generally not had adequate budgets, to take steps to address these challenges.
- This slow implementation of new mitigation technologies, combined with continued widespread development in areas of high seismic risk, has resulted in a rapid and steady increase in societal vulnerability to a major earthquake event. Potential loss estimates of a future large earthquake in a major U.S. urban area now approach $200 billion.

5. BACKGROUND OF NEHRP

History

A culmination of efforts, largely in response to the great Alaskan earthquake of 1964 and San Fernando earthquake of 1971, led to the creation of NEHRP in the Earthquake Hazards Reduction Act of 1977 (P.L. 95–124). The original program called on 10 federal agencies to implement the objectives of the program, though only the USGS and NSF were authorized appropriations. Those objectives were to:

— implement a system for predicting damaging earthquakes;

— develop feasible design and construction methods for new and existing buildings and lifelines for earthquake resistance;
— identify, characterize, and evaluate seismic hazards; develop model building codes and land-use policy recommendations;
— increase use of scientific and engineering knowledge to mitigate earthquake risks; and
— educate public officials and the public about earthquake phenomena.

In 1979, a governmental reorganization initiative created FEMA to lead government-wide efforts to respond to emergencies. The Earthquake Hazards Reduction Act of 1980 (P.L. 96–472) designated FEMA as the lead agency for NEHRP and authorized funding for both FEMA and the National Bureau of Standards (now NIST) to become part of NEHRP. While NEHRP has been reauthorized nine times, the only other substantive changes were made in 1990 (P.L. 101–614). This act clarified and expanded program objectives and agency responsibilities, required federal agencies to adopt seismic safety standards for new and existing buildings, and attempted to improve program coordination by requiring NEHRP agencies to complete a strategic plan to be updated every three years, prepare biennial reports on program progress, and submit a unified NEHRP budget to OMB each year with their budget request.

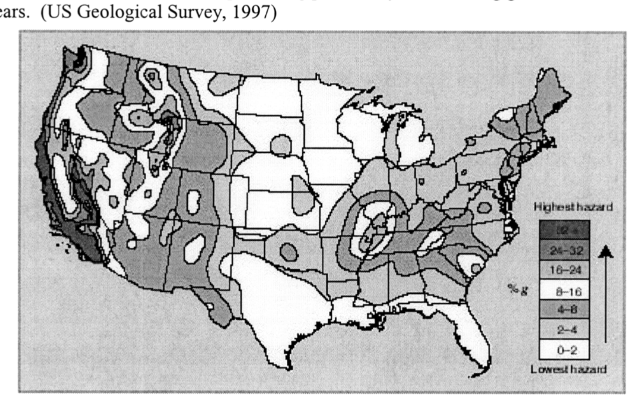
Accomplishments and Goals

NEHRP has accomplished a great deal since its inception. Perhaps most notable is the vast improvement in the ability to design a built environment that can resist significant earthquake shaking with little or no damage. NEHRP research and mitigation has also produced valuable tools for mitigating earthquake hazards, including new national hazard maps (Figure 1), improved seismic design provisions for new buildings, guidelines for the rehabilitation of existing buildings, loss estimation methodologies, performance-based design methodologies, and real-time shake maps for first responders and other public officials.

Today the goals of NEHRP are to:

— Develop effective practices and policies for earthquake loss reduction and accelerate their implementation;
— Improve techniques to reduce seismic vulnerability of facilities and systems;
— Improving seismic hazard identification and risk assessment methods and their use;
— Improve the understanding of earthquakes and their effects.

Figure 1. National Seismic Hazard Map showing probability of exceeding ground motion values in next 50 years. (US Geological Survey, 1997)



Transition into the Department of Homeland Security

On March 1st, 2003, FEMA officially became part of the Emergency Preparedness and Response Directorate for the Department of Homeland Security (DHS). It is unclear how this change will affect the execution of NEHRP, but it is likely that the new arrangement will present both challenges and opportunities for the program.

While it seems appropriate that natural disaster mitigation programs should be housed in the DHS Emergency Preparedness and Response Directorate, many are concerned that the Department's primary focus on acts of terrorism could reduce the attention paid to NEHRP and other natural disaster efforts. Conversely, though, it is clear that risk reduction efforts such as strengthening buildings and lifelines and developing comprehensive building databases would also benefit counter-terror operations, and may therefore benefit from the Department's primary mission.

NEHRP Budget

Original funding for NSF and USGS earthquake research activities in 1978 was $67 million (Chart 1). Though program activities have expanded substantially, today's NEHRP budget is well below its original level in real dollars. Also, funding for the program has tended to be reactive, going through periods of gradual decline only to be followed by sharp increases after significant earthquake events. Expanded program activities and inconsistent, declining funding, combined with the fact that the cost of performing research has increased faster than inflation, have clearly limited the ability of NEHRP to effectively meet program objectives.

The FY 2004 total funding request for NEHRP is $112.9 million (Table 1). This level is essentially flat, both in total and across agencies, compared to the appropriated levels of the last three years (with the exception of NSF, which has had a gradual decrease due to the planned completion of the George E. Brown, Jr. Network for Earthquake Engineering Simulation, NEES). NEHRP is funded through three different appropriations bills (VA/HUD, Interior, and Commerce-State-Justice), none of which include agency lines for NEHRP programs. This factor, along with the often unclear budget request breakdowns for the program, have made NEHRP budget and activities difficult to interpret and analyze.

The Science Committee has been particularly concerned with the lack of funding for the Advanced National Seismic System (ANSS), a network of instruments for monitoring and providing early warning of earthquakes. ANSS was authorized by the most recent NEHRP reauthorization law in 2000 (P.L. 106–503) at $170 million over five years. In each of its first three years, it has been funded at only about 10 percent of the authorized level.

Table 1. Recent NEHRP Budgets *(dollars in millions)*

NEHRP Agency	Fiscal Year				
	2001	2002	2003 Auth. Level*	2003 Appropriation†	2004 Request
FEMA	18.9	14.7	21.6	18.2	19.0***
USGS	46.3	47.6	99.6**	47.6**	46.0
NIST	2.3	2.4	2.5	2.3	1.9
NSF	59.1	61.5	38.1	50.5††	45.7
TOTAL	**127.0**	**126.2**	**161.6**	**118.6**	**112.7**

* The current NEHRP authorization expires in FY 2003

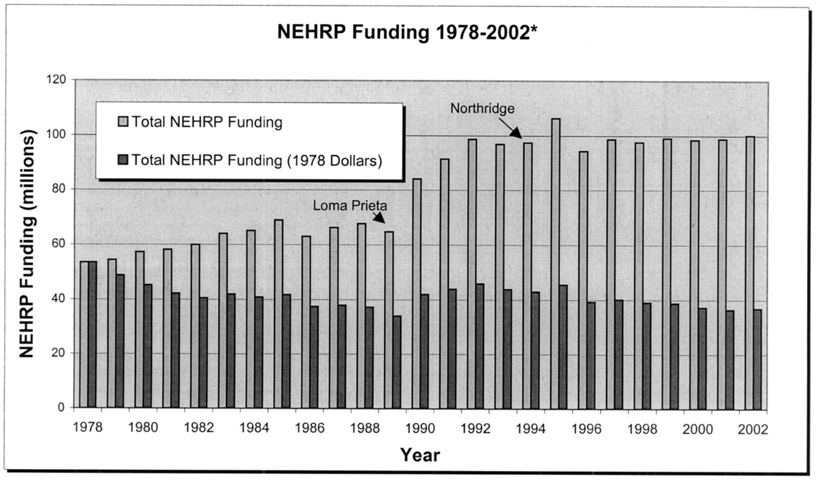
** The difference between the USGS authorized and appropriated levels is primarily due to the low request for the Advanced National Seismic System (ANSS, authorized at $35.1 million but requested at $2.0 million in FY 2004)

***New in FY 2004, FEMA has proposed that the NEHRP state grant program will be administered from the DHS Border and Transportation Security Directorate's Office of Domestic Preparedness. This amount is still included as part of the FEMA request for simplicity and comparison.

† Approximate.

†† Request level. Because NSF grants are based on received applications, specific amounts will be unknown until the end of FY 2003.

Chart 1. NEHRP Appropriations, 1978-2002 *(dollars in millions)*



* FY 2001 and FY 2002 figures do not include appropriations for the George E. Brown Jr. Network for Earthquake Engineering Simulation ($28 and $24 million, respectively)

6. ABOUT EARTHQUAKES

— When the crust of the earth is subject to tectonic forces, it bends slightly. But because the crust is rigid, when the stress or pressure from the tectonic forces exceeds the strength of the rocks, the crust breaks and snaps into a new position. This creates vibrations called seismic waves, which travel both through the earth and along its surface. These seismic waves cause the ground shaking we call earthquakes.

— It is estimated that there are 500,000 detectable earthquakes in the world each year. 100,000 of those can be felt, and 100 of them cause damage.

— In the 20th century, more than 100 earthquakes occurred worldwide that each resulted in losses of more than 1,000 lives. The deadliest earthquake in modern times occurred in 1976 in Tangshan, China, killing more than 250,000 people. In 1990, a major earthquake in Iran killed 40,000 people.

— Almost 40 states are subject to either moderate or high seismic risk. Alaska is the most earthquake-prone state and one of the most seismically active regions in the world. Alaska experiences a magnitude 7 earthquake almost every year. The largest recorded earthquake in the United States was a magnitude 9.2 that struck Prince William Sound, Alaska on March 28, 1964.

— Southern California experiences 10,000 earthquakes a year. Only about 15–20 of these are above magnitude 4.0. On the other side of the spectrum, there were four states that did not have any earthquakes from 1975–1995: Florida, Iowa, North Dakota, and Wisconsin.

— While most earthquakes in the United States occur on the West Coast and in Alaska, a major fault line also exists in the Central United States. Known as the New Madrid Fault, a series of major earthquakes occurred on this fault line in 1811 and 1812. The effects of shaking from these magnitude 8+ earthquakes reportedly caused church bells to ring in Boston and moved furniture in the White House.

8. WITNESS QUESTIONS

The witnesses were asked to address the following questions in their testimony:

Question for all witnesses

What factors have limited the success of NEHRP, and what policy changes would you recommend to remove these limitations? How can the NEHRP participating agencies improve planning, coordination, and general administration of NEHRP to better meet the vision for the program set forth by Congress?

Questions for Dr. Lloyd Cluff

- Discuss how geology and earth sciences research related to earthquake processes has improved our understanding of seismic hazards. How have these advancements contributed to our ability to protect from the loss of lives and property due to earthquakes? How has the focus of NEHRP earth sciences research evolved since the inception of NEHRP?
- How would a major earthquake potentially affect the operations of critical lifelines such as utilities, hospitals, and communications centers? How does Pacific Gas and Electric utilize NEHRP research and activities to protect against such disasters?
- In your capacity as Chairman of the USGS Earthquake Studies Advisory Committee, discuss the findings and recommendations of your Committee with regard to the U.S. Geological Survey's role in NEHRP.
- How would you prioritize limited federal funds among specific NEHRP research and mitigation activities (earthquake monitoring, hazard assessment, performance-based engineering, lifeline reinforcement, code development and adoption, education and outreach, post-earthquake response and investigation, etc.)?
- How will the transfer of FEMA into the Department of Homeland Security affect the success of NEHRP? How do NEHRP research and mitigation activities benefit other efforts to increase our preparedness for all types of hazards, such as hurricanes, floods, tornadoes, and terrorist events?

Questions for Mr. Anthony Lowe

- Discuss the significant achievements of the NEHRP program during its first 25 years. What factors have been most important in contributing to this success? In what areas may the program not be realizing its full potential? How does the NEHRP of 2003 differ from the program that was originally established in 1977?
- Provide an overview of FEMA's NEHRP activities, including information on efforts related to: (1) planning and coordination of the program with participating agencies; (2) promoting the implementation of earthquake hazard reduction measures by Federal, State, and local governments, as well as private entities; (3) accelerating the application of research advances into practice; (4) combining measures for earthquake hazards reduction with measures for reduction of other natural hazards; and (5) harnessing the potential of information technology in meeting NEHRP goals.
- How will the transfer of FEMA into the Department of Homeland Security affect the success of NEHRP, and how will FEMA ensure that the program receives adequate support within the expanded layers of government in the DHS structure? How do NEHRP research and mitigation activities benefit other efforts to increase our preparedness for all types of hazards, such as hurricanes, floods, tornadoes, and terrorist events?
- Please provide with your testimony a detailed budgetary breakdown of each participating agency's NEHRP activities, as well as a status report and estimated timetable for the completion of the strategic plan required by Public Law 101–614.

Questions for Mr. Robert Olson

- Discuss the evolution of federal earthquake mitigation efforts over the last 40 years, from initial interest in the 1960's, through establishment of NEHRP in 1977, to where we are today. What notable successes have these efforts produced? What significant events and developments have impacted the program, both negatively and positively?
- How can the resources and expertise of non-NEHRP emergency preparedness activities (hurricane, flood, tornado mitigation) and agencies (i.e., NASA, NOAA) best partner with NEHRP to further the goals of the program?
- How will the transfer of FEMA into the Department of Homeland Security affect the success of NEHRP? How do NEHRP research and mitigation activities benefit other efforts to increase our preparedness for all types of hazards, such as hurricanes, floods, tornadoes, and terrorist events?

Questions for Dr. Thomas O'Rourke

- Discuss how research in structural, geotechnical, and other engineering disciplines has improved our ability to protect lives and property from earthquake hazards? How has the focus of NEHRP engineering research evolved since the inception of NEHRP?
- Discuss the findings and recommendations of the comprehensive EERI report "Securing Society Against Catastrophic Earthquake Loss: A Research and Outreach Plan in Earthquake Engineering." How should policy-makers prioritize limited federal funds among and within the five program areas discussed in the report (Understanding Seismic Hazards, Assessing Earthquake Impacts, Reducing Earthquake Impacts, Enhancing Community Resilience, and Expanding Education and Public Outreach)?
- Discuss the potential of information technology to contribute to earthquake mitigation. To date, has NEHRP effectively harnessed this potential?
- How will the transfer of FEMA into the Department of Homeland Security affect the success of NEHRP? How do NEHRP research and mitigation activities benefit other efforts to increase our preparedness for all types of hazards, such as hurricanes, floods, tornadoes, and terrorist events?

Questions for Dr. Lawrence Reaveley

- Discuss how research in structural engineering has improved our ability to protect lives and property from earthquake hazards? How has the focus of NEHRP structural engineering research evolved since the inception of NEHRP?
- How would you prioritize limited federal funds among specific NEHRP research and mitigation activities (earthquake monitoring, hazard assessment, performance-based engineering, lifeline reinforcement, seismic rehabilitation, code development and adoption, education and outreach, post-earthquake response and investigation, etc.)?
- What are the major impediments to improving the overall seismic performance of buildings, both new and existing? Is the pace and extensiveness of code development and adoption improving? Is there anything the Federal Government can do to facilitate increased adoption of seismic codes in areas of high seismic risk? Is seismic rehabilitation an economical use of earthquake mitigation funds?

Chairman SMITH. The Subcommittee on Research will be in order. I thank all of the witnesses for being here today, and I apologize for holding up the starting at the beginning of this committee session on the important topic of reauthorizing NEHRP and how do we best protect ourselves from earthquakes in this country and help with our advice and technology around the world. You know, NEHRP was established in 1977, created as the Federal Government's response to several large earthquakes in the United States and around the world that served, probably, as a wake up call to the significant threats that earthquakes posed to the people and infrastructure of many of our heavy populated metropolitan areas.

And I think it is important that we stress that this just isn't a West Coast problem. It is certainly the best known location for earthquake risks lately, but it is not the only part of the country vulnerable to earthquake hazards. Alaska is even more seismically active than California, in fact. The—a massive 7.9 magnitude earthquake underneath the Trans-Alaskan Oil Pipeline struck just last November and we will hear from witnesses of this quake that went unnoticed, largely thanks to some of our witnesses today and the foresight and funding to mitigate the hazard when the pipeline was being constructed.

The Eastern United States is not immune, either. A very large fault centered in eastern Missouri was the site of one of the largest earthquakes in American history, which had consequences all the way to James Madison's White House and the bells in Boston. More recently, two smaller but noticeable quakes, one last week in Alabama and one on Monday near Charlottesville, Virginia, I think, surface to remind us that the threat is constant and far reaching and indeed deserves the attention and the funding of taxpayers from all over the Nation.

I look back at the progress from the first 25 years of NEHRP and it shows that the program has contributed significantly to our ability to protect against earthquake hazards. Our understanding of fault lines and seismic risks has improved dramatically, and we know much more about how to build structures that perform well even during severe earthquakes. And the question I think and the challenge before us is how do we implement these precautions that we know how to construct at the moment.

And without objection, the rest of my statement will be going into the record, and I would call on the Ranking Member.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF CHAIRMAN NICK SMITH

Good afternoon and welcome to the first Research Subcommittee meeting of the 108th Congress. Today we meet to review the National Earthquake Hazards Reduction Program, NEHRP, in preparation for reauthorization later this year.

Established in 1977, NEHRP was created as the Federal Government's response to several large earthquakes in the United States and around the world that served as a wake-up call to the significant threats that earthquakes posed to the people and infrastructure in many of our heavily populated metropolitan areas.

While the West Coast—and California in particular—is certainly the best-known location for earthquake risks, it is not the only part of the country vulnerable to earthquake hazards. Alaska is even more seismically active than California—in fact a massive 7.9 magnitude earthquake underneath the trans-Alaskan oil pipeline struck just last November. As we will hear from our witnesses this quake went unnoticed, largely thanks to the foresight and funding to mitigate this hazard when the pipeline was being constructed.

The Eastern United States is not immune either. A very large fault centered in Eastern Missouri was the site of one of the largest earthquakes in American history—which in 1812 famously rang church bells in Boston and moved furniture in James Madison's White House. And more recently, two smaller but noticeable earthquakes—one last week in Alabama and one on Monday near Charlottesville, Virginia—serve to remind us that the threat is constant and far reaching. Indeed, earthquakes are clearly not just a state or regional problem, but a nationwide problem, demanding nationwide mitigation.

A look back at the progress from the first 25 years of NEHRP shows that the program has contributed significantly to our ability to protect against earthquake hazards. Our understanding of fault lines and seismic risks has improved dramatically. We know much more about how to build structures that perform well during even the largest of earthquakes. And we now have technologies available for seismic monitoring that provide real-time earthquake information to public officials and emergency responders.

Despite these advances, our vulnerability to earthquakes has continuously increased. Widespread development still occurs unabated in areas of high seismic risk. Development, adoption, and enforcement of pertinent building codes have been incremental and slower than expected. And now we see funding for available mitigation technologies at all levels of government has steadily declined in real terms. The only exceptions are two brief increases following the 1989 and 1994 Loma Prieta and Northridge earthquakes, respectively. While the reactive nature of Congressional support for programs like NEHRP is a political reality, disasters should not be the only time we acknowledge the importance of earthquake mitigation.

It is clear that NEHRP needs to be strengthened. In addition to funding challenges, several aspects of program leadership and coordination continue to be an ongoing problem. The low visibility of the program has also limited its success. Knowledge and awareness of these needs within the Office of Management and Budget, relevant appropriators, and even to some degree NEHRP agencies—has been too low. Many outside of this committee and a small outside community of earthquake interests—are unaware that this coordinated effort even exists. These factors need to be addressed as we reauthorize the program.

Finally, I want to note my disappointment with the continued under-funding of the Advanced National Seismic System (ANSS), the real-time seismic monitoring system for which we authorized funds for construction and operation as part of the last NEHRP authorization bill over three years ago. The earthquake community is in almost unanimous agreement that funding ANSS should be a top priority—the NEHRP Strategic Plan, the EERI Research and Outreach Plan, and the USGS Advisory Committee recommendations all cite ANSS as the top priority—but this has not translated to funding requests anywhere near the levels this committee authorized. We need to find a way to fund ANSS. We may not be able to do this with all new funding, but rather have to find some trade-offs elsewhere in NEHRP, but we have to follow up our recognition of its importance with funding.

Certainly we know that earthquakes cannot be prevented. But we can mitigate their impact. That is why the NEHRP exists, and that is why we are here today to discuss how we can improve the program.

We have a very esteemed panel of witnesses before us today that will present some innovative ideas and opinions on how to best bring about meaningful improvements to NEHRP. I thank them for appearing here today, and look forward to a productive discussion.

Ms. JOHNSON. Thank you very much, Mr. Chairman. I thank you for calling this hearing, and I am pleased to join you in welcoming our witnesses today for this initial hearing on the National Earthquake Hazardous—Hazards Reduction Program. This hearing will begin to lay the groundwork necessary for the Research Subcommittee to develop authorizing legislation for this interagency program. NEHRP was established 25 years ago to address the serious seismic hazard in the United States. It has the major goal of determining how to lower the risks to people and to the built environment.

Today, 75 million Americans and 39 states are directly vulnerable to a serious earthquake. The potential economic losses in a large metropolitan area due to a major earthquake could be over $100 billion. These facts make the justification for NEHRP self-evident and its relevance even after 25 years continues.

The Subcommittee's attention will be directed to other questions about the program. These include: how well is it being run, is it focused on the highest priority issues, and is it adequately funded to meet the goals? The witnesses today, hopefully, will describe the accomplishments of NEHRP, and there have been many, but as we approach the reauthorization of this program, it is important to consider the areas where more needs to be done. On such—one such area is the technology transfer that will bring into practice what has been learned from the research activities—most effective and economically ways for enhancing the seismic safety of the built environment. Also, attention must be directed to deficiencies in the planning and administration of the program.

In 1993, the former Chairman of the Science Committee, Mr. George Brown, wrote the President to express his concerns about NEHRP. He cited the lack of strategic planning, insufficient coordination and implementation of research results, and a lack of emphasis on mitigation. Unfortunately, most of these concerns are still valid.

I am particularly disappointed with the performance of FEMA in its role as the lead agency for NEHRP. The strategic plan FEMA is statutorily mandated to develop and submit to Congress has been in limbo for a very long while and has only now surfaced, just in time for today's hearing, but about 10 years overdue. In the last NEHRP reauthorization in 2000, Congress directed FEMA to work jointly with the other NEHRP agencies to prepare a detailed implementation plan and budget for the program for submittal to OMB during the budget formulation process. I doubt that this has been done for any budget year since the requirement was put into place.

FEMA was not able to provide a breakout of the various agencies' NEHRP budgets on the day the President's fiscal year 2004 budget was released. Developing a NEHRP authorization bill, the Subcommittee must reassess the current structure of the program, including the roles and responsibilities of participating agencies. We must determine whether FEMA, in its new status as a component of the Department of Homeland Security, is willing and able to provide the leadership needed to ensure a well coordinated, carefully planned, and effectively executed NEHRP.

Another major issue I look forward to exploring in this hearing is the adequacy of the resources available for NEHRP. I invite the witnesses to comment on whether the current funding is allocated in optimum ways and to identify what they consider the most serious deficiencies of the program. If NEHRP were to receive an infusion of funding, what are the priorities that deserve attention? I would also welcome suggestions on how NEHRP could help accelerate the transfer of research findings to practical mitigation practices.

Mr. Chairman, I want to thank you for calling the hearing. And I might have to leave since I am working with another Committee, but I do—I would like the answers. Thank you very much.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Mr. Chairman, I am pleased to join you in welcoming our witnesses today to this initial hearing on the National Earthquake Hazards Reduction Program. This hearing will begin to lay the groundwork necessary for the Research Subcommittee to develop authorizing legislation for this interagency program.

NEHRP was established 25 years ago to address the serious seismic hazard in the United States. It has the major goal of determining how to lower the risk to people and to the built environment. Today, 75 million Americans in 39 states are directly vulnerable to a serious earthquake. The potential economic losses in a large metropolitan area due to a major earthquake could be over $100 billion.

These facts make the justification for NEHRP self evident, and its relevance, even after 25 years, continues. The Subcommittee's attention will be directed to other questions about the program. These include: how well is it being run, is it focused on the highest priority issues, and is it adequately funded to meet its goals?

The witnesses today will describe the accomplishments of NEHRP, and there have been many. But, as we approach the reauthorization of the program, it is important to consider the areas where more needs to be done. One such area is the technology transfer that will bring into practice what has been learned from the research activities about the most effective and economical ways for enhancing the seismic safety of the built environment. Also, attention must be directed at deficiencies in the planning and administration of the program.

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In the last NEHRP reauthorization in 2000, Congress directed FEMA to work jointly with the other NEHRP agencies to prepare a detailed implementation plan and budget for the program for submittal to OMB during the budget formulation process. I doubt that this has been done for any budget year since the requirement was put in place. FEMA was not able to provide a breakout of the various agencies' NEHRP budgets on the day the President's FY 2004 budget was released.

Mr. Chairman, in developing the NEHRP authorization bill, the Subcommittee must reassess the current structure of the program, including the roles and responsibilities of the participating agencies. We must determine whether FEMA, in its new status as a component of the Department of Homeland Security, is willing and able to provide the leadership needed to ensure a well coordinated, carefully planned, and effectively executed NEHRP.

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Mr. Chairman, I want to thank you for calling this hearing and thank our witnesses for appearing before the Subcommittee today. I look forward to our discussion.

Chairman SMITH. The Chair would like to align himself with your comments, Congresswoman Johnson, particularly your suggestion to FEMA that better late than never, but better on time than being late. And so with that, if there is no objection, all additional opening statements by the Subcommittee Members would be added to the record. And without objection, so ordered.

At this time, I would like to introduce our panelists. Mr. Anthony Lowe is the Administrator of the Federal Insurance Mitigation Administration for FEMA. Mr. Robert Olson is President of the Robert Olson Associates, Incorporated. Mr. Lloyd Cluff is Director of Geosciences and Earthquake Risk Management at Pacific Gas and Electric Company and Chair of the USGS Federal Advisory Committee for NEHRP. And Dr. Tom O'Rourke is the President of the Earthquake Engineering Research Institute at Cornell University and civil and environmental engineering professor. And Dr. Lawrence Reaveley is Professor of Civil Engineering, but will be more completely introduced by Mr. Matheson.

Mr. MATHESON. Well, thank you, Mr. Chairman, and Ranking Member Johnson. I appreciate having the opportunity to introduce my constituent, Dr. Lawrence Reaveley. And very briefly, he has 40 years of experience in structural engineering, earthquake code development, and earthquake risk mitigation, and he also assessed damaged concrete buildings following the 1999 earthquake that devastated Turkey as part of an Advanced Technology Council Survey Team. Currently, Dr. Reaveley is Professor and Chair of the Department of Civil and Environmental Engineering at the University of Utah. He also serves as the President of the Structural Engineering Association of Utah. He was just telling me he was involved in the seismic retrofit of the Federal building in downtown Salt Lake City for which he—GSA [General Services Administration] recognized that effort with an award.

Thanks to the Utah Legislature, I no longer have that building in part of my district, so my office is no longer in that building, but we were there for the construction. Dr. Reaveley, it is really a pleasure to have you here today, and I want to thank you for your participation in this hearing and look forward to your comments.

Chairman SMITH. Thank you. And we no longer formally administer the oath, but you are, in effect, under oath testifying before a panel of the United States Congress. And Mr. Lowe, as best you can, limit to about five minutes, but thereabouts we would be comfortable with. Mr. Lowe.

STATEMENT OF MR. ANTHONY S. LOWE, ADMINISTRATOR, FEDERAL INSURANCE MITIGATION ADMINISTRATION; DIRECTOR, MITIGATION DIVISION, EMERGENCY PREPAREDNESS AND RESPONSE DIRECTORATE (FEDERAL EMERGENCY MANAGEMENT AGENCY), DEPARTMENT OF HOMELAND SECURITY

Mr. LOWE. Thank you. Thank you so much. Chairman Smith, Ranking Member Johnson, Members of the Subcommittee, my name is Anthony S. Lowe, Federal Insurance Administrator and Director of the Mitigation Division of FEMA in the Department of Homeland Security. On behalf of the National Earthquake Hazard——

Chairman SMITH. Mr. Lowe, just a second. Sorry for the interruption. What is happening now? It is—they are calling a vote, which sometimes disrupts the proceedings, but we will go along with at least your testimony and then we will recess for five minutes to make the vote. So excuse the interruption.

Mr. LOWE. Thank you so much. I am used to being over on the Senate side where the buzzer is a little different, and you have got the clock with the lights on it. So I was looking around the room, but I didn't see one. Okay. I guess we need lights over there. You are a little more sophisticated on this side, I think.

Nevertheless, as I said, on behalf of the National Earthquake Hazards Reduction Program, NEHRP, we appreciate the invitation to appear today before the Subcommittee on Research. The Committee has asked me, and so I am joined by Craig Wingo, head of our Engineering Science and Technology Program. Congress assigned the Federal Emergency Management Agency, FEMA, the core of the Department of Homeland Security's Emergency Preparedness and Response Directorate, to serve as the lead agency for NEHRP. Our role, in reality, is leadership among equals. And that also includes the United States Geological Survey, USGS, the National Science Foundation, NSF, and the National Institute of Standards, NIST.

This past year, as you know, marks the 25th year since Congress first authorized NEHRP, and I am pleased to report that it is sound. In our role as lead federal agency, we are implementing a number of results-oriented management initiatives so that we can build upon the program's past successes and current strengths. We will accomplish this while maintaining strong partnerships with other NEHRP agencies and stakeholders. These partnerships have been vital to our success over the past 25 years, and they are also key to our future success.

As you may be aware, we recently co-sponsored a forum with the other NEHRP agencies and the National Academy of Sciences to celebrate the 25th anniversary of the program and its many successes. Mr. Chairman, with your permission, I would like to present a brochure from that forum that illustrates just ten of the programs accomplished over the past 25 years.

[Note: The information referred to is located in Appendix 3: Additional Material for the Record.]

Thank you so much. Two other more notable accomplishments are we now have a nationally applicable seismic building standard that serves as a basis for the Nation's modeling—model building codes, and many states are adopting those provisions in their own codes. Also, we have made significant progress in providing seismic design guides for the Nation's lifelines, such as power, water, transmission, and the critical infrastructure such as bridges and hospitals.

Fundamental to NEHRP's mission is that our earthquake loss reduction efforts are built upon a solid foundation of basic as well as applied research. To further that goal, FEMA, in concert with other NEHRP agencies, has completed the development of the NEHRP strategic plan, which has been referred to by the Committee.

Mr. Chairman, with your permission, I would also like to submit another copy, for the record, of the strategic plan.

[Note: The information referred is located in Appendix 3: Additional Material for the Record.]

As you know, this plan represents considerable coordination among our NEHRP——

Chairman SMITH. Is that a different——

Mr. LOWE. No, it is the same.

Chairman SMITH [continuing]. Plan from the first?

Mr. LOWE. No. This plan represents considerable coordination among our NEHRP partner agencies and stakeholders to arrive at a national consensus document, and we all are pleased with the results. Now, however, that the strategic plan is in place, I have consulted with my counterparts from the other NEHRP agencies, which is called the Policy Coordination Council, PCC, to begin to develop a management plan.

I am going to just divert from my remarks a little bit and say a couple of words in reference to what has been said so far by both you, Mr. Chairman, as well as the Ranking Member. At the 25th anniversary celebration, what we were able to do is certainly celebrate the 25 years of accomplishments, but we did so without the strategic plan, which of course, really was the guiding document for the work that had been begun even before its passage and now really sets the stage. But with the strategic plan, my objective there and now was to operationalize that strategic plan. And the first part of that was to call for the first meeting of the PCC, the political heads, as well as the executive policy heads of the four NEHRP agencies, because in order for us to thoroughly carry out the strategic vision that the strategic plan calls for, it needs the commitment, both monetarily as well as staff-wise and expertise-wise, and also, if you will, the commitment of the synergy of our missions to really achieve the results that we are looking for. And so sitting with the four principals, we all decided that what we really needed was a management plan. And the purpose of that management plan, of course, is to provide monetary and control, both the systems to monitor as well as the process to, if you will, begin to implement the strategic plan.

In addition, I called for, at that time, an annual plan, which would be really the operation and the program of work by which the ICC, which are Craig and the other program level folks who, if you will, take care of the day-to-day operations, would lead their work by, that way we all could look at what we are asking them to do that is coming from the strategic plan and then be able to monitor that against a set of performance metrics, which the management plan would call for and would be monitored.

We also, of course, during that process, want to be able to continually evaluate programming, budgeting, planning, execution. We want to begin to be able to do that at the management level. And so I think this process allows us to do that.

[Slide.]

The next slide, very quickly, shows the many advisory groups that have been involved in this strategic planning process up to this point. The last thing I would say about the management plan is the purpose here in part is to carry out the full spirit of Section 206, which I—which really has to be done at the highest level of all of the agencies.

That concludes my testimony. I look forward to any questions you may have.

[The prepared statement of Mr. Lowe follows:]

PREPARED STATEMENT OF ANTHONY S. LOWE

Chairman Smith, Ranking Member Johnson, and Members of the Subcommittee,

I am Anthony S. Lowe, Federal Insurance Administrator, and Director of the Mitigation Division of the Emergency Preparedness and Response Directorate in the Department of Homeland Security. On behalf of the National Earthquake Hazards Reduction Program, or NEHRP, we welcome and appreciate the invitation to appear today before the Subcommittee on Research. I am joined by Craig S. Wingo, head of our Engineering Science and Technology Unit.

I would like to do three things today: first, share with the Subcommittee what we

have accomplished under NEHRP during the past two years; second, review for the Members our roles and responsibilities as lead agency of NEHRP; and finally, look to what lies ahead for NEHRP, especially in the post-9/11 environment.

Congress assigned the Federal Emergency Management Agency (FEMA), now the core of the Department of Homeland Security's Emergency Preparedness and Response Directorate, to serve as the lead federal agency for NEHRP. Our lead role is in reality a leadership among equals that also include the United States Geological Survey (USGS), the National Science Foundation (NSF), and the National Institute of Standards and Technology (NIST).

This past year marked 25 years since Congress first authorized NEHRP. We are pleased to report that the state of NEHRP is sound, and, in our role as lead federal agency, we are implementing a number of results-oriented management initiatives so that we can build upon the program's past successes and current strengths. Further, we will accomplish this while maintaining strong partnerships with the other NEHRP agencies, State and local governments, academia, the research community, code enforcement officials, design professionals, and the remainder of the private sector. These partnerships have been vital to the success of NEHRP during the past 25 years, and they will be key to our continued success in what lies ahead to reduce the exposure of our people, our economy, and our overall security as a nation to the threats of earthquakes and other related hazards.

Specifically, we are responsible for the overall coordination of the NEHRP, both within the Federal Government and with external constituencies. By Congressional mandate, we prepare a consolidated multi-year plan and periodic reports to Congress. We also translate the results of research and technology into effective earthquake loss reduction methodologies, and we administer a program of grants and technical assistance to States and multi-state consortia. These activities heighten public awareness of the earthquake hazard and foster plans to reduce seismic vulnerability.

We also support the development and dissemination of improved seismic design and construction criteria for new buildings and retrofit guidance for existing buildings. This material is made available to design professionals, and Federal, State and local entities for voluntary use through model building codes and standards.

NEHRP is a key component in the Department's mission to secure and protect this nation because earthquakes represent the largest single potential for casualties, damage, and economic disruption from any natural hazard facing this country. All but 11 States and territories are at some level of earthquake risk.

The National Security Council (NSC) in 1982 underscored the threat of earthquakes to the United States and estimated that a large magnitude earthquake in urban areas could cause thousands of casualties, and losses approaching $200 billion. The NSC issued a report identifying the need for FEMA to develop a federal interagency response plan for the life-saving and life-protecting phases of a disaster operation to assist States and localities since States and localities would, in many cases, be overwhelmed in the first days after a catastrophic earthquake. In the 20 years since this report was completed, our improved knowledge of the earthquake hazard has only served to buttress the Council's findings.

Recent findings from the USGS show a significantly increased potential for damaging earthquakes in both southern and northern California. Studies also show higher potential of earthquakes for the Pacific Northwest, the New Madrid fault zone in the central U.S., and coastal South Carolina. This exposure is in addition to other areas of earthquake risk, such as New England and the Wasatch front in Utah. We know that while earthquakes may be inevitable, earthquake disasters are not.

Furthermore, earthquakes in critical locations can have national economic consequences. For example, a major earthquake in the central United States on the New Madrid fault might well disrupt oil and gas distribution to the Northeast, gridlock barge traffic on the Mississippi River, and disrupt travel and communications hubs that serve national and international markets.

The good news is that we *can* reduce the earthquake risk that our nation faces through a shared responsibility under the NEHRP. In the face of this threat, NEHRP is working and succeeding.

Since we last appeared before you, our country has experienced several large-scale events, most notably the Nisqually earthquake outside of the Seattle area in February 2001. The Nisqually event was roughly the same magnitude as our largest recent earthquake disaster, the January 1994 Northridge earthquake. That latter event, located on the fringe of a major metropolitan area, caused over $30 billion in damage. However, the epicenter of the Nisqually earthquake was fairly deep in the earth, and this depth served to significantly reduce surface ground motions and resultant damages. Nonetheless, we need to recognize the City of Seattle for their significant mitigation activities and the effective building code which helped further reduce the impact of the event. By comparison, the Kobe, Japan earthquake demonstrated the impact of an event of similar size located directly under a major metropolitan area. The result was over $100 billion in damages and approximately 5,500 fatalities in Kobe, a city strikingly similar to Oakland, California in its proximity to the sea with resultant poor soil conditions, and the fault which runs through the middle of the city.

The depth of the Nisqually earthquake, which served to reduce its effects at the surface by at least a full point of magnitude, and the timing of both the Northridge earthquake, which occurred at four in the morning on a holiday, and the Loma Prieta earthquake, which shook the San Francisco Bay area on a day when many had left work early to watch the World Series game, all worked to lessen the impact of these events. Thus, thankfully, we avoided the types of losses that Kobe suffered, but we cannot ignore their warning signs.

Many of NEHRP's activities include taking what research has discovered and what technology has developed and translating those findings into practical seismic risk reduction measures as well as training, education, and advocacy for earthquake hazard mitigation measures. In these activities the NEHRP agencies work together, work with other Federal and State agencies, universities, and private, regional, voluntary and professional organizations. The end results are safer buildings, safer infrastructures, more aware citizens, and more proactive State and local governments.

As you may be aware, we were pleased to have recently co-sponsored a forum with the other NEHRP agencies and the National Academy of Sciences celebrating the 25th anniversary of the program and its many successes. Mr. Chairman, I have a brochure from that forum that illustrates just 10 examples of the program's successes over the past 25 years. With the Committee's permission, I would like the brochure to be included in the record. A number of representatives of the stakeholder community who have been so instrumental in the success of the NEHRP provided input for this brochure, and I am pleased to see some of them here today.

In addition to the 10 examples listed in the 25th anniversary brochure before you, there have been many more successes. Among them are the following:

- At the program's inception 25 years ago, the geologic theory of plate tectonics was less than 10 years old, and we really did not understand how earthquakes worked. We now have significantly more knowledge of the faults located throughout our country and how they work. This may allow us eventually to forecast, if not actually predict, future activity.
- When Congress first authorized NEHRP in 1977, the only State with an adequate seismic building code was California, and that code was not applicable outside of the State. We now have a nationally applicable seismic building standard. It serves as the basis for the seismic requirements in the Nation's model building codes, and many States are adopting those provisions in their own codes.
- We now have earthquake engineering research centers throughout the country funded through NSF that are continuing to add to the body of knowledge about earthquakes and their effects. Soon we will have a national high-speed Internet system in place that will allow researchers to access and participate in research work from anywhere in the country.
- We now have design guidance in place that addresses the risk from existing buildings, and we have facilitated the introduction of this material into the Nation's building codes and standards.
- We have begun the process of providing seismic design guidance for the Nation's lifelines, such as buried pipelines and water systems, and other critical infrastructure.
- We now have seismic expertise at the State and local level throughout the country that has done much to implement the program and reduce future losses.

While the Program has been a success by all measures, it is not without its challenges.

The Earthquake Hazards Reduction Act of 1977 (Act) designated FEMA as the lead agency of a program consisting of four federal agencies with different cultures and different charters, each with its own budget. The Act did not, however, authorize us to direct resources to where the Program may have the greatest need. In spite of this challenge, the NEHRP has accomplished what it has through collaboration and cooperation.

That spirit of cooperation must continue. Toward that end, I assure this subcommittee that the Interagency Coordinating Committee, consisting of the four agencies' program managers, will continue to meet on a bimonthly basis to improve communication with respect to our program activities. In addition, I recently held a meeting of the Policy Coordination Committee, with my three counterparts from the other NEHRP agencies, and I plan to hold these meetings three times a year.

But fundamental to NEHRP's mission is that the Nation's earthquake loss reduction efforts are built upon a solid foundation of basic and applied research. To further that goal, FEMA, in concert with the other NEHRP agencies, has completed the development of the NEHRP Strategic Plan, *Using Knowledge to Reduce Earthquake Losses*. Mr. Chairman, with your permission, I would like to submit this strategic plan for the record.

All four agencies worked closely throughout this process, and we believe this Plan and the way it was developed have been responsive to the March 1997 letter cosigned by then-Chairman Sensenbrenner and Ranking Member Brown. That letter raised the concerns that the NEHRP was not sufficiently focused on actions to reduce future earthquake losses and specifically requested the development of a strategic plan for the program. This Plan is the product of a considerable amount of coordination among our NEHRP partner agencies as well as all of our outside partners, and we are all pleased with the results.

This process required more time than we anticipated, but the Plan before you has the approval of the NEHRP agencies and its stakeholders. While the production of the Plan itself may have been delayed, let me assure you that the material contained in the Plan, the four goals and all that they represent to the Program, have been in use by the four agencies and many of our partners for quite some time.

The NEHRP Strategic Plan cites the following mission for NEHRP to provide effective, timely guidance as we work to improve seismic safety in this country:

> *"The mission of the National Earthquake Hazards Reduction Program is to develop and promote knowledge and mitigation practices and policies that reduce fatalities, injuries, and economic and other expected losses from earthquakes."*

To achieve this mission, the Strategic Plan spells out four goals:

A. Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation;

B. Improve techniques to reduce seismic vulnerability of facilities and systems;

C. Improve seismic hazard identification and risk-assessment methods and their use; and

D. Improve the understanding of earthquakes and their effects.

The goals are deliberately ordered, beginning with the most important, that is, reducing losses, followed by successive goals, each of which provides a basis for the previous one, ending with a solid foundation of basic and applied research.

With the completion of the NEHRP Strategic Plan, the next challenge is the coordination of program research within that framework.

While research alone increases our knowledge of earthquakes, it must be coordinated and applied to reduce future losses to be effective. Dr. Dan Abrams of the Mid America Earthquake Center recently wrote an excellent article detailing this need for improved coordination of research.

To this end, I have directed the formation of a subcommittee of the FEMA-chaired Interagency Coordination Committee to specifically address research coordination issues. The National Science Foundation has volunteered to chair the initial term. This Research Coordination Subcommittee is charged with developing a Research Coordination Plan of Work, which will be an operational component of the overall NEHRP Strategic Plan. This Subcommittee will be chaired on a rotating basis by each of the three NEHRP agencies that conducts research.

While research will always be an integral component of NEHRP, we believe that NEHRP will need to shift the program's emphasis from primarily one of research to the application of research results to reduce losses. Our knowledge has now reached the point where we have to effectively implement the results of this work to reduce earthquake losses. I have directed the Research Subcommittee to address this issue in its work. I have also directed this group to reassess the NEHRP role, particularly the USGS, in producing cost-effective earthquake prediction technology, as called for in the 1977 legislation. This is a key complementary component to enhance the existing seismic monitoring program within the USGS.

I will make certain that the work of this subcommittee is closely coordinated with my colleagues. I intend to coordinate this subcommittee's work with the new Department of Homeland Security Science and Technology Directorate to leverage efforts in both areas in an all-hazards framework which will benefit both NEHRP and the Science and Technology Directorate.

Building upon the NEHRP Strategic Plan and my goal of a performance-driven, results-oriented Program, I would like to present our vision for the future of the Program. For NEHRP to remain relevant in the 21st century, it is no longer enough to study the earthquake problem; we must also develop and implement effective mitigation solutions. This means that the Program agencies must continue to evaluate our priorities and focus our activities in ways that will emphasize implementation of the Program. The Program must be able to provide not only the tools needed to reduce future losses, but also the incentives to encourage their use.

NEHRP has been extremely successful in developing an impressive array of mitigation technologies that have been used very effectively by engineers, architects and building regulators when they have been given the resources to address the hazard. The problem, however, is that there has been little incentive or public demand to provide the resources necessary to reduce the risk.

This is partially due to a lack of understanding or knowledge of the actual seismic threat which exists in any given area. It is also due to the faulty assumptions that designing and building to the building codes currently in place in many communities will result in a completely damage-free structure and that when there is damage, the Federal Government will invariably fund the necessary repairs through disaster assistance to make the building whole again. Both assumptions are false.

Building codes in general only provide the *minimum* level necessary to protect lives, and do little to prevent damage. In addition, as you know, federal disaster assistance was never meant to replace insurance.

Changing perceptions is key to serving the basic mission of NEHRP. Just as the American consumer has come to consider the safety of a vehicle to be a significant factor when buying a car, we envision a future where one of the key criteria in buying a house or building will be its safety from all hazards—how well was the building designed and constructed and whether it is certified to meet or even exceed a certain level of code performance and an associated level of safety.

Unfortunately, one of the major weaknesses of the NEHRP is our lack of leverage for local and State levels of government to implement earthquake risk-reduction measures. So we must look for and find ways to provide this leverage with incentives and rewards for communities at risk that adopt and enforce adequate mitigation standards.

The current public policy emphasis on pre-disaster mitigation and on improving the preparedness of local emergency management offers new avenues that we need to pursue in order to get our earthquake disaster-resistance message into the hands of those who can best use this information. Our hope is that pre-disaster mitigation activities will serve both as the catalyst and the foundation for future risk-reduction activities by public and private sector interests.

Ultimately, the Program will need to explore possible incentives that will encourage the use of our technology by the American public. Several years ago a study done by the Earthquake Engineering Research Institute, with NEHRP funding from FEMA and the State of California, provided some possible incentives. The findings of this study need to be pursued. I have directed the FEMA earthquake program staff to explore possible incentives and develop recommendations that would allow us to promote their use.

However, all of this will require a careful review to ensure the best use of the resources of all of the parties—public and private. This means that we need to emphasize those aspects of our program that offer the greatest promise of helping communities and individuals acknowledge their risk, accept responsibility for reducing that risk, and take appropriate actions to become more disaster-resistant. It is the intention of the Program to use this strategic planning process to focus more heavily on this facet of our responsibilities.

As I have indicated, a key to the success of NEHRP has been, and will continue to be, an effective translation of research to practice. A major element of this translation is a strong approach to communicating risk to different audiences in different parts of the country. The perception of the earthquake threat in California, where earthquake loss reduction is viable and risk perceived as probable, is far different than in other areas of the country, such as the New Madrid region with its high loss and low probability of occurrence, where the perception of risk is minimal. The general population of New England and other areas on the east coast represent an even greater contrast in that there is little perception of earthquake risk. A risk communications strategy will need to acknowledge these differences.

The NEHRP agencies need to shift some of the focus of their research efforts to put a greater emphasis on behavior to understand how to influence perceptions, how to effectively communicate information in a way that helps those affected to not only understand their risk but begin to manage it as well.

We have already started this shift in emphasis. This Subcommittee tasked FEMA with determining how effective the Program is in addressing the needs of at-risk populations, such as the elderly, people with disabilities, non-English-speaking families, single-parent households, and the poor. We found that there were a number of documents and delivery mechanisms directed at some of these audiences. The results, however, were mixed.

It is apparent from the conclusions of the report, *The National Earthquake Hazards Reduction Program and At-Risk Populations,* which I have previously submitted under separate cover, that there are strategic opportunities that can increase the effectiveness of NEHRP agencies in addressing at-risk populations. Specifically, we found that there are five broad-based areas of opportunity:

1. **Leadership:** Increase emphasis at the national and regional levels.
2. **Research:** Encourage the development of a research agenda that integrates the vulnerabilities of the at-risk populations with earthquake science, risk communication, risk mitigation, and disaster management.
3. **Communications/Educational Outreach:** Develop risk-reduction outreach that is relevant to at-risk populations.
4. **Technology:** Promote the application of research, informational tool development, and building and social science technology issues to the at-risk populations.
5. **Policy:** Reflect commitment through new and renewed policy approaches.

One area of opportunity that our report cites is the schools. They provide the best immediate mechanism for affecting a positive change and disseminating information to at-risk populations on hazards and how to reduce or avoid them. In addition, working through the schools offers a number of possibilities for working with other federal partners, such as the Department of Education and Centers for Disease Control and Prevention, which are not directly involved in the NEHRP but have an extensive involvement with various aspects of education policy and procedures. By taking advantage of these opportunities in a collaborative, inclusive manner, the Program will further achieve its defined mission and reduce losses among the most socially vulnerable populations.

With the Program's new emphasis on risk communication, we will bring a systematic approach to taking our understanding of people in their environment and apply it to the way in which we disseminate technically based information. Included in this systematic approach will be the development of metrics to evaluate the effectiveness of our communications in raising awareness and motivating risk-reduction activities at the individual and community levels.

One of FEMA's roles as lead agency under NEHRP is to present this subcommittee with a report covering our activities for fiscal years 2001 and 2002. I have previously provided the completed NEHRP Biennial Report under separate cover.

The Biennial Report outlines many activities of the agencies and highlights State and local efforts to reduce earthquake risk. It illustrates how the Strategic Plan is already being used as a guide by the earthquake community in their efforts to meet the four program goals. The report gives you an idea of just how much is being accomplished from this relatively small program.

The final NEHRP lead agency responsibility I want to mention is our reporting on the NEHRP budget. The actual Program budget numbers for the last two fiscal years have already been sent to Committee staff under separate cover. We have already reported on the other three NEHRP agencies' budgets for FY 2003. FEMA's FY 2003 NEHRP budget, approximately $19 million, represents level funding from FY 2002, less a Congressional rescission of 0.65 percent, applied to all programs. The FY 2004 budget request will be at the FY 2003 level. However, approximately $4.4 million will be transferred from the Emergency Management Performance Grant program to the Office of Domestic Preparedness.

The breakout among the agencies continues to be approximately 48 percent for the USGS; 35 percent for NSF; 15 percent for FEMA; and a little over 2 percent for NIST. Over and above those figures are: The USGS Global Seismic Network at approximately $3.5 million; and NSF's George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) at $24.4 million last year and $13.5 million this year.

One of the best examples I can offer of how we are effectively using our resources is the updating of the *NEHRP Recommended Provisions for New Buildings*. This document serves as the basis for the Nation's seismic code language and is updated for us every three years by the National Institute of Building Sciences' Building Seismic Safety Council to maintain its consensus backing. This updating relies heavily on the efforts of volunteers, and it has been estimated that we get eight dollars of work for every dollar we spend.

I would also like to share with the Subcommittee the role of NEHRP as FEMA has become an integral part of the Department of Homeland Security.

This consolidation of agencies into DHS focuses greater resources on protecting people and property from all hazards—natural and man-made. The creation of the Department of Homeland Security offers us the opportunity to share our successes and the lessons learned from NEHRP and our other natural hazard mitigation programs and leverage them to address other perils.

That does not mean that there is any reduction in focus or commitment to serve the underlying mission of the NEHRP; however, since earthquakes do not happen with sufficient regularity to remain in the collective memory, it often appears that there has been a diminished earthquake presence in the NEHRP agencies. The earthquake threat is still very real, and it is this hazard that still holds the greatest potential of all natural hazards to cause death and destruction in a single moment. Several faults in this country have the potential to create the most catastrophic disaster we have ever faced. The earthquake hazard is a critical part of our all-hazards work.

NEHRP is one of the only federal programs that has experience in preparing for, responding to, recovering from, and mitigating the future effects of large-scale disasters. This experience can be transferred to the Nation's work and mission to protect our nation from the threats of terrorism.

Some examples where this experience can support the Nation's risk of terrorism include the following:

- Seismic design criteria developed under the NEHRP have been proven to provide a significant level of resistance to other outside loads, such as blast, and has proven to prevent progressive collapse such as that which occurred in the Oklahoma City bombing.
- The NEHRP has already developed and is currently implementing a plan to improve the protection of lifelines and critical infrastructure. The current American Lifelines Alliance, supported by FEMA's NEHRP funds and based on a plan developed by NIST, has already accomplished much to address the protection of this vital link, and we are expanding this program to improve protection from man-made hazards.
- The NEHRP has made significant investments in improving post-event reconnaissance and the collection and analysis of damage data, and these investments have already had direct benefits after 9/11. The ability to rapidly examine buildings after a damaging event and tag them based on their level of damage and habitability is critical after a large disaster. The NEHRP funded an existing system known as "ATC–20," that was quickly modified by New York engineers and used after the WTC attacks to evaluate surrounding buildings. Such a resource will be needed after future damaging events, no matter what the cause, and we are working with ATC to expand this program to other hazards.
- The ability to design a new building or an upgrade to an existing building to achieve a defined level of performance to mitigate a specific hazard is critical to reducing future losses economically. FEMA, through the NEHRP, has already funded the first two phases of a project to develop Performance-Based Design Guidance to meet this capability. We have already taken steps to expand this program beyond seismic hazards to include fire and blast as well.
- The ability to screen, evaluate, and upgrade existing buildings to improve their resistance to external forces is an important process in reducing the risk from structures built prior to current building codes. Current FEMA–NEHRP publications provide guidance on how to visually screen existing buildings to identify those that are potentially hazardous, how to perform more detailed evaluations on those potentially hazardous buildings, and how to upgrade those buildings to satisfy minimum safety criteria. Such a system of guidance publications has considerable applicability in addressing man-made hazards, and we are working to adapt these publications to reflect this.
- The urban seismic networks that the USGS is trying to develop under the Advanced National Seismic System (ANSS) would be capable of detecting, locating, and timing explosive blasts in urban areas. The WTC impacts and col-

lapses, the Pentagon impact, and the Oklahoma City bombing were all recorded on seismographs.

- NEHRP assets were used in the development of our current Urban Search and Rescue Program, and helped fund the development of some recent technologies such as robots for search, rescue and recovery following earthquakes and other natural hazard events. It was this same Urban Search and Rescue Program that was so visible immediately after the 9/11 attacks.
- NEHRP investments in earthquake disaster risk assessment such as the development of Hazards US, or HAZUS, have been extended to include multi-hazard risks from hurricane, wind and coastal flooding, and to develop integrated risk assessment methodologies to manage social and infrastructural vulnerability.
- NEHRP investments in testing equipment and cyber infrastructure, including the NSF's George E. Brown, Jr. Network for Earthquake Engineering Simulation, are used to investigate and mitigate earthquake vulnerability in critical infrastructure systems. These facilities are also used for study of infrastructure performance and damage under any kind of hazard.
- Building on previous work under the NEHRP, NIST is already working with the private sector to develop needed tools and guidance for improving overall structural integrity by mitigating progressive collapse.

Through the Hazard Mitigation Grant Program (HMGP), which is authorized under Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, FEMA has funded several projects that have improved earthquake resistance, even though the availability of funding was triggered by a different event. As a result of the WTC attacks, FEMA and the State of New York have funded the seismic upgrade of two major transportation facilities: the George Washington Bridge and the Port Authority Bus Terminal for a total of $61 million. This is an excellent example of how the NEHRP has helped to shape decisions at the State and local level, and has influenced their priorities.

In conclusion, in spite of its many challenges, the NEHRP has been a success and has done a great deal to improve this nation's ability to prepare for, respond to, recover from, and mitigate future earthquakes.

It is beneficial to look back and celebrate our successes over the last 25 years, and we have many to be proud of. It is also meaningful to look forward and plan where we are heading in the next 25 years. As part of the Department of Homeland Security, I can assure you that we will continue to lead the NEHRP to protect the American people from the earthquake hazard.

I want to express my appreciation for the consistent support and counsel of this subcommittee and look forward to our continuing association in addressing the challenges before us.

Thank you, and I will be happy to answer any questions that the Subcommittee may pose.

Biography for Anthony S. Lowe

Anthony S. Lowe was appointed director of the mitigation division of the Emergency Preparedness & Response Directorate/FEMA, in the newly created Department of Homeland Security, in March 2003. He continues to serve as the Federal Insurance Administrator, a role to which he was nominated by President Bush in March 2002. Mr. Lowe is responsible for providing leadership for some of the Nation's leading multi-hazard risk reduction programs, which seek to secure the homeland from hazards both natural or manmade. His areas of oversight include the National Flood Insurance Program, the National Earthquake Hazards Reduction Program, the National Dam Safety Program and the National Hurricane Program. In his position, Mr. Lowe works closely with public and private risk managers, as well as leaders in government, industry, research and academia.

Before assuming this post, Mr. Lowe was the senior legislative counsel for the U.S. Senate Judiciary Subcommittee on Antitrust, Competition and Business Rights and on the staff of the Subcommittee on Terrorism, Technology and Government Information. Previously, he was the deputy prosecutor with the King Country Prosecutor's Office. He also was a commissioner on the city of Redmond's planning commission.

Earlier in his career, Mr. Lowe was associate director at the International Center for Economic Growth and International Center for Self-Governance programs of the Institute of Contemporary Studies, in Washington, D.C. Mr. Lowe also served as legal counsel to the Washington State Senate majority office and as legislative assistant to U.S. Senator Slade Gorton of Washington.

A native of King County, Wash., Mr. Lowe holds a Bachelor of Science degree in international political science from University of Washington, a law degree from the University of Santa Clara and a Master of Divinity degree from Virginia Union University.

Chairman SMITH. We have about seven minutes to get to our vote, so excuse us, but the bad news is there are four votes. So we will have one 15-minute vote and four 5-minute votes, but we go over about two minutes on each of the time limits. I would ask staff, in our period of recess, with your permission, I would ask staff to maybe discuss with you some of the questions that we have put together that we would like to know if you would get some of those more detailed answers, and we will try to return in the next, I am guessing, 20 minutes. With that, the Subcommittee is in recess.

[Recess.]

Chairman SMITH. The Subcommittee on Research has reconvened, and we would turn to Mr. Olson for his statement.

STATEMENT OF MR. ROBERT A. OLSON, PRESIDENT, ROBERT OLSON ASSOCIATES, INC.

Mr. OLSON. Thank you very much. It is a pleasure to be here. I will very quickly summarize my written testimony.

I wish I had the time, we had the time today, actually, to close our eyes, close all of our eyes for four minutes, and try to imagine the non-stop violent shaking, the noise associated with buildings coming apart, the unsteadiness of large blocks of earth as they slip away beneath us, and hearing the occupants' and victims' screams of terror. This is what happened in Alaska, 1964. And that particular earthquake is what got people thinking about the threat to other metropolitan areas where earthquakes have occurred and could be expected.

I won't go into details on that, but we can trace the origin of that program, of the current program, to that event in 1964. Your action here in Congress represented a public policy decision to look at the earthquake risk nationally, one, as you noted, that is shared by at least 39 states. The act of 1977 was a political action that took many years to achieve, actually. And three key Members of Congress, including the Science Committee's former Chairman, Representative Mosher from Ohio played a key role in this along with Congressman George Brown and Senator Alan Cranston.

On February 20, I had a challenging request to attend the forum that has been referred to and to summarize what I heard that day. And I thought I would just take my time to hit the high points of what I heard people talk about in the context of the earthquake program. There is a concern, and it has been reflected already, about the budget stagnation and erosion. In terms of real dollars, the earthquake program's purchasing power has declined steadily to the level where essential program activities are being sacrificed, because the actual appropriations have not kept pace with at least inflation.

There is a concern in the community about program leadership, particularly as the new Department of Homeland Security comes on line, a very large agency. And FEMA, of course, didn't exist in

1977, but was given the leadership role in 1980. And how this leadership responsibility will be continued or performed within the new, and frankly, huge Department of Homeland Security, this is some concern to us in the earthquake community.

You have touched on the strategic plans. Well, there are two or three out there, new programs and strategic plans now exist on which we might be able to base long-term modifications to the act. Much like the years leading to the original act's passage, there now exists several of these plans that could provide a new foundation for amending the earthquake legislation to set the program's direction for, well, the next decade or two.

There are a lot of agencies who have significant roles to play in the earthquake program, and we must find better ways to involve and support these participating agencies that are involved heavily in construction and in financing construction and others. Patience is needed, also. Knowledge is cumulative, and sometimes it is slow in coming. And a great deal of our effort in the last two decades has been spent on research, and—as it must. And that has helped develop knowledge as well as a large pool of human resources: better educated students, more practicing earthquake engineers, and others. We must keep that benefit in mind, as well.

But there is a need to balance the investments in research with the program's commitments to improving practice and governments as well. You have touched on it already. We must speed up the rate of applying knowledge. This is a real challenge. And while new research leads to improved knowledge, there exists a gap in applying what is known and what is accepted already, the results of previous investments in research. We have got to find better ways to accelerate the application of knowledge.

Earthquake risk is increasing. This worrisome condition is due partly to growing populations and to little or no attention being given to the hazard in areas that we believe are subject to the risk. During its existence in the last 25 years, the program has fostered the development of intellectual and organizational capabilities to the earthquake program that simply didn't exist before.

I would like, also, to make note that understanding the context is critical to achieving earthquake risk reduction. Risk reduction decisions are made in a social context by individuals, by companies, by governments at all levels. And their abilities to address this kind of a risk varies greatly depending on their location, their priorities, the knowledge of the risk, and other values, and we must be able to intervene in those processes to affect future decisions.

The agencies, and you have heard about them, work in very complex and competitive contexts and environments. While the earthquake program is just one program, these agencies house—have activities—other activities, missions, priorities, levels of funding, and so on that make these settings for the agency people very, very complicated.

Earthquake prediction was a popular item at the time of the original passage, and it may be time to revisit it with the advent of new technologies and theories. I don't know. I am not an earth scientist, but it might be worth putting back on the list to see if we might get there this time. Certainly the investment in earthquake prediction in those days led to much stronger and better forecasting abilities, which have had a major impact.

So let me conclude with one recommendation that this committee as the full Science Committee to convene a truly independent panel to look at the charter legislation after 25 years and to see how it might be modified to help reduce earthquake risk over the next 25 years for across the United States.

Thank you very much.

[The prepared statement of Mr. Olson follows:]

PREPARED STATEMENT OF ROBERT A. OLSON

INTRODUCTION

The National Earthquake Hazards Reduction Program—"NEHRP" as it is commonly called—is governed by a "sunset" provision requiring the Science Committee to review and to reauthorize the program every two years. This hearing is particularly appropriate because the Science Committee was the program's committee of origin, and 2002 was the NEHRP's 25th birthday. Such sunset provisions provide a regular means for Congress to review the status, progress, and needs of important programs beyond the normal annual appropriations processes.

In response to your invitation, my comments address several subjects: (1) the key role of this committee and the origins of the program beginning in about 1964 following the occurrence of two significant earthquakes in Alaska and Niigata, Japan; (2) some observations I offered recently at a National Academy of Sciences' forum on the earthquake program's 25th anniversary, and (3) some reminders based on my practitioner's observations during the last 22 years as an emergency management consultant.

I have been involved in emergency management, disaster assistance, and hazard mitigation issues since joining a FEMA predecessor agency in 1964 in Washington, DC and then moving to a regional office where I became involved in earthquake mitigation activities, including serving as a volunteer advisor to a California legislative committee. I left federal service in 1972 to help establish the San Francisco Bay Area's Metropolitan Transportation Commission while I continued my volunteer service to the legislature. Governor Ronald Reagan and the legislature agreed on the need to establish a state Seismic Safety Commission to address the continuing earthquake threat in California. I was selected as the Commission's first Executive Director, a post I held for seven years. During the last 22 years I have been providing consulting and research services to federal agencies, State and local governments, and private clients. I was educated in Political Science, with an emphasis on American Government.

NEHRP: AN HISTORICAL OVERVIEW

If we had the time, I would ask everyone here to close their eyes for four minutes and try to imagine non-stop violent shaking, noise associated with buildings coming apart, unsteadiness as large blocks of land give way under us, and hearing the occupants' and victims' screams of terror. Soon after, the coastal areas would be devastated by a tsunami. This happened in Alaska on Good Friday, 1964.

The Great Alaska earthquake, one of the most powerful ever recorded, affected about 50,000 square miles and triggered many research and applications activities that were based on a simple fear: What would be the consequences of an event like this one somewhere in the "lower 48" in an area that was known to have earthquake risk: the Wasatch Front in Utah, Northern California (a repeat of 1906), the Mississippi Valley (a repeat of the 1811–12 events), Southern California (a repeat of the 1857 earthquake), the Puget Sound area of Washington, or other locations with a significant but less well known hazard?

The act establishing the program represented a national public policy decision to reduce earthquake risk, one that is shared to varying degrees by at least 39 states. The Earthquake Hazards Reduction Act (EHRA, Public Law 95–124) of 1977 was a political action that took many years to achieve by an "advocacy coalition" composed of three key members of Congress including the Science Committee's former chairman, Representative Mosher from Ohio, who had a particular interest in science and technology associated with earthquake prediction research, and Senator Alan Cranston and Representative George Brown. They were supported by influential members of the "earthquake community" from outside and inside the Federal Government. Moreover, the Carter Administration was "receptive" to the proposal, sending a clear signal to Congress that it should proceed with the legislation.

Years before its enactment, however, the NEHRP's foundation was laid by a series of program and budget oriented studies and reports that taken together defined the program as we know it today. The President's Science Advisor recommended a 10-year program of earthquake prediction research in May 1965. This was followed in June 1967 by a Federal Council on Science and Technology (FCST) 10-year recommended earthquake hazards reduction program, which was later updated in October 1968. Three more expert reports were issued in 1969: the National Academy of Engineering's (NAE) report on earthquake engineering research and applications needs, the National Academy of Science's (NAS) report on the status of seismological research and its needs, and the NAS' multiple volume report on the Alaskan earthquake. In 1970 the Office of Science and Technology issued a proposed an updated 10-year program of earthquake hazard reduction.

Several other studies and reports contributed to eventually framing the NEHRP during those years. These included a report on the status of state and local disaster preparedness (1972), studies of other damaging earthquakes and even possibly successful predictions here and abroad (e.g., China, Nicaragua, Romania, Guatemala, Italy), a technology assessment of earthquake prediction technology (1975), and another examining the social and public policy implications of earthquake prediction (1975).

This collection of needs assessments, state of knowledge reviews, and recommended programs and budgets provided a "critical mass" on which to base a national earthquake hazards reduction program. It all came together in what we refer to as the "Newmark-Stever Report" that was titled *Earthquake Prediction and Hazard Mitigation: Options for USGS and NSF Programs*. This carefully crafted and skillfully negotiated program and budget document provided the administration and the Congress with a scope of work, agency responsibilities, and three recommended funding levels.

The proverbial "window of opportunity" that set the stage for NEHRP's enactment was the February 9, 1971 San Fernando, California earthquake "on the fringe of a densely populated metropolitan area," according to an early post-earthquake report by a panel of the National Academy of Sciences (NAS). Close to the heart of Los Angeles and only a moderate (6.3 Richter magnitude) event, it caused 65 deaths (most in a federally-owned building), but this earthquake again raised the question about the vulnerability of our heavily populated metropolitan areas.

Three bills were introduced in the Senate in 1972; four in the House and three in the Senate in 1973; ten bills in the House and one in the Senate in 1974; and one each in the House and the Senate in 1977. The resulting legislation, H.R. 6683 and on the Senate side, S. 126, passed in October 1977 and became the Earthquake Hazards Reduction Act. Understandably, the new legislation had a strong research orientation. We had to know more about the earthquake hazard (and if we could predict them) and how we could prevent future disaster losses. Thus, the new act focused mostly on strengthening the earth science programs of the Geological Survey (USGS) and the earthquake engineering research program of the National Science Foundation (NSF). The National Bureau of Standards, now the National Institute of Standards and Technology (NIST) also was included.

In short, according to a FEMA-funded study, *To Save Lives and Protect Property: A Policy Assessment of Federal Earthquake Activities, 1964–1987* (Robert Olson Associates, 1988):

> Events leading to the EHRA's enactment and its implementation up to 1987 have spanned the terms of five presidents (Johnson, Nixon, Ford, Carter, and Reagan) and thirteen sessions of Congress.
>
> A few general observations may be helpful. First, many attempts were made to enact a national earthquake program prior to 1977. However, several factors converged in the 1975–76 period to create a climate for successful passage of the Act and its signing into law. They included a "killer year" for earthquakes (1976), the euphoria over potential earthquake prediction, the presence of legislative and executive leaders in key places, and the completion of an expert report containing the proposed content and budget for legislation (Newmark-Stever, 1976).
>
> . . .prior to the 1971 San Fernando, California earthquake experts who were designing the scope of the future program had based their ideas largely on the lessons learned from the 1964 Alaska earthquake. San Fernando post-earthquake studies produced large quantities of data that significantly added to the understanding of earthquake effects on relatively modern urban areas. (9)

The Federal Emergency Management Agency (FEMA) did not yet exist. It was created in May, 1979, and it was given the NEHRP leadership role in 1980 by an amendment to the act. FEMA, more of a mission-oriented than a research-oriented agency, thus had two responsibilities: promote earthquake hazard mitigation and disaster preparedness measures by working primarily with local and state governments and "carry the NEHRP flag" as the program's designated leader.

A QUARTER CENTURY RETROSPECTIVE

On February 20 I had the welcome opportunity to participate in a National Academy of Sciences' forum on the status of the NEHRP. The day's speakers collectively spoke to a number of points central to the continued effectiveness of the NEHRP and the challenges it is facing. Some of my summary observations included:

- *Budget stagnation and erosion.* In terms of real dollars, NEHRP's "purchasing power" has declined steadily to the level where essential program activities are being sacrificed because appropriations have not kept pace with at least inflation. Additionally, the community has identified other important needs that will speed risk reduction if funding can be provided.
- *Program leadership and the new Department of Homeland Security (DHS).* The EHRA was passed in 1977, the Federal Emergency Management Agency (FEMA) was formed in 1979, and FEMA was assigned to lead the NEHRP in 1980. In about 1983 a program review panel, in a "management letter" to the then FEMA director, pointed out that the agency, unlike the other three involved (NSF, USGS, and NBS [now NIST]) had two duties: (1) internal mitigation and preparedness program operations and (2) multi-agency leadership. How the leadership responsibility will be performed within the new and huge DHS is of some concern to the earthquake community.
- *New program and strategic plans exist on which to base program modifications.* Much like the years leading to the EHRA's passage, there now exists several documents that could provide a "new" foundation for amending the NEHRP legislation to set the program's direction for the next decade or two. For example, the Earthquake Engineering Research Institute (EERI) has released one focusing on research, and the interagency strategic planning process has been reinvigorated with the FEMA-led NEHRP strategic plan soon to be released.
- *Ways must be found to better involve and support the "participating agencies."* Over the decades, really only three agencies (FEMA, NSF, USGS) and NIST (to a much lesser extent) have benefited from funds appropriated to the NEHRP. Yet, many other federal agencies, such as DOD, DVA, and GSA, are directly involved in construction and others greatly influence construction financing and lending. While the NEHRP acknowledges these participating agencies, stronger mechanisms are needed to integrate their risk reduction activities more fully because the results of their activities and decisions directly effect the safety of the built environment.
- *Patience is needed: knowledge is cumulative and sometimes slow in coming.* The core of the NEHRP has been the support of research: knowledge and human resources development. This objective is fundamental to the program and has contributed mightily to new information, better practices, and more capable practitioners. Research, experimentation, instrumentation and testing continues to be an important program need. It must be understood, however, that knowledge most often accumulates relatively slowly and incrementally as theories and data are developed, tested, and finally accepted. Thus, there remains a need to balance NEHRP's investments in research with its commitments to improving practice and governance.
- *We must speed up the rate of applying knowledge.* While new research leads to improved knowledge, there exists a gap in applying what is known and accepted already—the results of previous research investments. There is a growing literature about the barriers and facilitators that affect the adoption and implementation of earthquake risk reduction measures, most of which are attributable to risk communication and acceptance and governmental and private institutional factors. Nationally, and especially in the lower risk areas, we need to give attention to processes and methods for overcoming these obstacles to public safety. In the final analysis, applying knowledge has real effects on our people, buildings, and infrastructure.
- *Earthquake risk is increasing.* This worrisome condition is due partly to growing populations and little or no attention being given to managing the risk in many vulnerable areas. This is a very complex issue consisting of what to do about the existing built and future built environments, and there is a need to better understand decision-making processes to see how risk reduction

measures can be included in such processes effectively. Central to this challenge is to find better ways of communicating earthquake risk information repeatedly through multiple channels in ways that compete successfully for attention and lead to decisions and the commitment of resources to increase safety.

- *During its existence the NEHRP has fostered the development of intellectual and organizational capabilities.* Not only have NEHRP-funded activities increased knowledge, they have helped develop new practitioners and researchers who are influencing professional practices, such as through the three earthquake research centers and other programs. Emphasis on this intergenerational mentoring should be continued so that the knowledge pool is widespread, locally influential, and knitted together by such organizations as EERI.
- *Understanding the context is critical to achieving earthquake risk reduction.* Information is received and decisions are made in societal contexts (e.g., individuals, families, small businesses, large companies, public agencies, charitable groups). Their abilities to address items important to them varies greatly depending on their location, priorities (agendas), wealth, values, and others. Applying risk reduction measures must be understood and promoted in specific relevant contexts, and improved techniques are needed to define and influence the controlling contexts.
- *The NEHRP agency representatives work in very complex and competitive contexts and environments.* While the NEHRP is just one program, the agencies housing its activities have other missions, priorities, and levels of funding. Some of these are legislatively, administratively, technically, or politically determined. Any changes to the NEHRP, if they are to be successful, must be sensitive to these environments and address the organizational, administrative, regulatory, and financial capabilities needed to implement them successfully.
- *Earthquake prediction may deserve to be revisited.* The earlier euphoria associated with earthquake prediction contributed significantly to theory development, measurement technologies, international observations, socio-economic impact studies, and other advances. It definitely has led to vastly improved "earthquake forecasting" abilities—defining the risk and probabilities of occurrence in ways that were impossible when I first became involved in the mid-1960s. While predicting earthquakes with precision (i.e., date, time, magnitude, etc.) remains elusive, new technologies and theories and accumulated knowledge and other earth science-related programs may advance our abilities if we try again. Only if we had a season like hurricanes or rains or snow melt to watch for flooding!

REMINDER: LOSS PREVENTION/MITIGATION REFLECTS AMERICAN FEDERALISM

The Constitution of the United States of America defines the authority relationships between the national government and the states. Individual state constitutions define similar relationships between state and local governments.

The Federal Emergency Management Agency (FEMA) defines mitigation "as any sustained action taken to reduce or eliminate long-term risk to human life and property from a hazard event." Sometimes known as "disaster prevention" in some cultures, mitigation's objective is to reduce the direct and indirect losses in ways that protect life, physical assets, and national wealth.

Mitigation programs must be understood within this context of "shared governance." Thus, some mitigation programs are administered by the national government (e.g., nuclear power plant safety) while others provide incentives and penalties to encourage state and local participation (e.g., planning grants). Some state programs are enacted and administered directly by state governments (e.g., public school construction in California), enacted by the state but administered directly by local governments (e.g., Safety Elements of General Land Use Plans in California), others contain shared administrative responsibilities (e.g., California's Special Studies Zones Act), and in many areas some mitigation programs are enacted and administered directly by local governments (e.g., zoning regulations and building codes).

REMINDER: MITIGATION OCCURS IN TWO PRINCIPAL TIME FRAMES

Hazard mitigation occurs within two temporal contexts: (1) prospective and (2) retroactive. In general, programs that address the future ("prospective") are easier to adopt and implement than are programs to correct past ("retroactive") deficiencies.

Incremental changes to building codes that apply to new buildings can be incorporated into new designs relatively easily and inexpensively, but laws or codes that require the strengthening or replacement of existing buildings are difficult to enact, controversial to implement, and costly in terms of construction and social costs (e.g., dislocation of tenants, loss of rental income). For these reasons, most mitigation programs are prospective, and if enacted at all, retroactive requirements follow decades later.

REMINDER: MANY FACTORS AFFECT DECISIONS TO REDUCE FUTURE LOSSES

While disasters often create "windows of opportunity" to introduce new mitigation efforts, they are not in and of themselves sufficient conditions. Moreover, differing mitigation decision-making situations exist: (1) regulatory (i.e., government enacts laws demanding compliance), (2) voluntary (i.e., a company strengthens buildings it owns to protect its assets), or (3) mixed (i.e., government provides incentives for those taking voluntary private action).

Some factors that affect decisions to mitigate against disaster losses include: (1) the perception and understanding of risk to support decision-making, (2) organizational "champions" to advocate the adoption and implementation of mitigation measures, (3) successfully competing with other items on decision-making agendas, (4) sufficient wealth to pay for the desired mitigation measure, (5) the possibility of achieving multiple benefits from investing in mitigation, (6) achieving other organizational goals as part of mitigation programs, and (7) convincing those that pay for mitigation now will accrue benefits in the future.

CONCLUSION

Hazard mitigation as a concept is simple to understand: act now to prevent future disaster losses. It often takes a long time for the benefits of mitigation to be achieved, however. We have a very short recorded earthquake history, but when we examine the geologic and seismologic evidence we are reminded that earthquakes remain a national problem potentially affecting 39 states. Some have paid attention to their risk, but many have not. Regardless, a major to great earthquake near or in any of our major urban areas will have devastating and eye-opening effects.

Laws, policies, and programs must be thought through carefully to achieve their desired results, and they must be modified periodically to reflect current conditions. While ideas and knowledge about successful mitigation programs can be transferred easily, their adoption and implementation must be acceptable in particular social, economic, cultural, and political environments.

Does the legislation governing the NEHRP need to be changed? My biased answer is "yes" because conditions, knowledge, technology, contexts, research and applications needs and other factors have changed over the past 25 years. It is important that laws, regulations, procedures, organizations, duties and responsibilities, and budgets be reviewed and changed to assure or enhance the NEHRP's future effectiveness.

Perhaps a new "advocacy coalition" needs to be mobilized so, like the one that existed from about 1964 to 1977, it can influence the political agenda and engage the process to amend the Earthquake Hazards Reduction Act. The program's associated implementation and administrative processes then will need to be modified so the program will continue to lessen the Nation's earthquake risk.

Thus, I have one simple recommendation: this subcommittee ask the full Science Committee to use NEHRP's 25th anniversary to convene a truly independent panel to advise the Committee on the future of the NEHRP—via another long range program plan with priorities and a recommended funded level similar to what as done in 1976 (the "Newmark-Stever Report"). The ingredients are there on which to proceed. As former California State Senator George Moscone said to us in 1970, "Bring this legislative committee your best recommendations, and we will take care of the politics."

I look forward to continuing a partnership with the House's Science Committee, especially this subcommittee, as we progress steadily toward reducing our nation's earthquake risk and to contributing to lessening the risks from other hazards including, sadly, human-caused emergencies, where I am spending an increasing amount of my time working with state and local governments and private firms.

BIOGRAPHY FOR ROBERT A. OLSON

Robert Olson is President of Robert Olson Associates, Inc., where he consults on areas of earthquake hazards mitigation, emergency management, disaster operations, recovery assistance, and public policy development. Previously, he served as the first executive director of the California Seismic Safety Commission. He has chaired numerous committees including the Advisory Committee to the National Information Service of Earthquake Engineering, the Governor's Task Force on Earthquake Preparedness, and the Advisory Group on Disaster Preparedness to the California's Joint Legislative Committee on Seismic Safety. Mr. Olson also held a variety of research positions in various times at the Center for Environmental Design Research, the Institute of Governmental Studies, the Mid-America Earthquake Center, and the Pacific Earthquake Engineering Research Center. As part of the CUREE Kajima research program, Mr. Olson has had affiliations with PEER, Stanford University, Caltech, and the University of Southern California. He received his Bachelor's degree in political science from the University of California at Berkeley and his Master's degree from the University of Oregon.

April 8, 2003

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to testify before the U.S. House of Representatives Committee on Science on May 8, 2003 for the hearing entitled *The National Earthquake Hazards Reduction Program: Past, Present, and Future*. In accordance with the Rules Governing Testimony, this letter serves as formal notice of the Federal Funding I currently receive in support of my research and consulting:

- CMS-9814239, National Science Foundation, FY 1998-1999 (direct award).
- Consultant to the Mid-America Earthquake Research Center, University of Illinois (National Science Foundation funds).
- Earthquake Committee, National Institute of Building Sciences, (Federal Emergency Management Agency Funds).
- Subcontractor to the URS Group, Inc. on the Hazard Mitigation Technical Assistance Program contract (Federal Emergency Management Agency Funds).

Sincerely,

Robert A. Olson, President

Chairman SMITH. Thank you. We wrote that down plus being in the record.

Dr. Cluff, thank you all for being here, of course. And thank you, Dr. Cluff, for your foresight in determining where we should protect our Alaska Pipeline. Please proceed.

STATEMENT OF DR. LLOYD S. CLUFF, DIRECTOR, GEOSCIENCES DEPARTMENT AND EARTHQUAKE RISK MANAGEMENT PROGRAM, PACIFIC GAS AND ELECTRIC COMPANY

Dr. CLUFF. Thank you, Chairman Smith and Committee Members. I am honored to be here today. And I have a few slides to enhance my oral presentation.

I come from the perspective of a user of NEHRP products. I was involved from the beginning. I was on the Newmark-Stever Panel that created—helped create this program, and I have been on several other advisory committees.

Chairman SMITH. Dr. Cluff, I am going to interrupt you. Do we have the where with all to keep the disks and reproduce the slides for the other Members? We do. Thank you. Proceed, Dr. Cluff.

Dr. CLUFF. And I have color handouts that have been given for all of the Members of my presentation. Thank you.

So let me move through.

[Slide.]

From the geosciences point of view, we have learned a lot from earthquakes. We are really developing products on national hazard maps, surface falls rupture characteristics, ground motions, regional hazard assessments, and earthquake forecasts to build on Bob Olson's comments about prediction. These are really the elements in the next slide.

[Slide.]

This is a slide of the San Francisco Bay area. You see San Francisco and the bay and the faults that have potential for very damaging earthquakes with forecasts of the likelihood of large, destructive earthquakes in the next 20 years, 70 percent aggregated for the whole region. PG&E's service territory, this is the heart of it. And Pacific Gas and Electric is the large—one of the largest investor-owned utilities in the United States with millions of customers, hundreds of thousands of transmission gas and electric lines at the heart of the sixth largest economy in the world. We have 70 percent of the San Andreas faults traversing our service territory.

The earthquake risk management policy that we developed in conjunction with the Seismic Safety Commission where I was Chairman of the Commission right after the Loma Prieta earthquake, a program to understand the hazards and our system vulnerabilities, a plan to implement the risk management options dedicated staff, dedicated budget, and accountability. We have developed and are involved in NEHRP public/private partnerships. One of the good ones across the Nation is the American's Lifelines Alliance, sponsored by FEMA, ALA, USGS, PG&E, the National Bureau of Standards, and others shown on this list, are all involved to improve the performance of particularly utilities and transportation systems across the U.S. Other partnerships, the Lifelines User Driven Research Program at the Pacific Earthquake Engineering Center at Berkley, a consortium of academic institutions, PG&E, Caltrans, and the California Energy Commission, and other stakeholders, the USGS, FEMA, and the California Earthquake Center. I came up in 1996 with some money out of PG&E's funds, and I said I am tired of not being able to use research results from the academic community. They are good—it is good research, but we can't implement it. We wanted to create a user-driven research program. We put money into it so that we set the research agenda and then the researchers learned from us what was important. And then once results were reached, we could implement them immediately. Out of that, working with these other partners that are on this program, we have leveraged $13 million in user-driven research for a NEHRP program.

[Slide.]

Here is another partnership that we have with the U.S. Geological Survey. The lines on this map are the active faults, the heart of PG&E's territory. This program is one to help do applied research for the need for PG&E and our customers.

[Slide.]

Let me show a series of maps, same faults. This is our gas transmission pipelines, our electric system. You can see, all of these are traversed by these faults. Our electric substations, about 100 of these are critical to keep the lights on, and then our major service centers and buildings in the heart of our service territory.

[Slide.]

And here are all of the PG&E facilities. On one map is the Internet GIS map within PG&E that every decision maker can have access to at any time.

[Slide.]

And then here is a new—the NEHRP project from the USGS shake map. When an earthquake like this occurs, within two or three minutes, we have this downloaded on to our Internet—our decision-makers to deploy people to go to the field and know exactly where to go. We have our performance improvement for our major customers. We have been guiding Caltrans, East Bay MUD, the major water system in East Bay, the Bay Area Rapid Transit District, and the San Francisco Water Department. Since Loma Prieta, these combined expenditures for those customers only, including PG&E, is $15 billion.

Let me tell the story about the Trans-Alaska Pipeline. I was involved and invited by the oil companies to do the earthquake and fault displacement study. The Denali Fault does cross the pipeline route. I, with a team of earthquake engineers, delineated the zone, how much displacement the fault could take, and then we constructed the pipeline above ground. We put in these—the designers put in the supports with Teflon with shoes under the pipeline that also had Teflon that would allow the pipeline to freely let the ground move beneath it. The fault ruptured on November 3 of last year. It crossed the pipeline.

[Slide.]

And here is the design drawing from my report to the Alaska folks, the pipeline crossing. We designed the pipeline to accommodate faulting within a 1,900-foot wide zone. The—a yellow zone is where we expected the rupture to take place. The November '02 earthquake was 7.9, 18 feet of displacement horizontal, 2.5 feet with minor compression. The red zone is where it actually displaced. We got it right, and the pipeline performed without spilling one drop of oil. This is a NEHRP-type study that we need. Newmark and I brought this into the NEHRP hearings to show what things could be done.

[Slide.]

Here is the pipeline as the ground moved beneath it, not disrupting the pipeline. The left side photo is before. The right side is after. The only thing you can see is that one straight segment of it is now bowed because of two meters of compression. The pipeline was designed to accommodate that.

So let me conclude that unless seismic safety is afforded priority that is now lacking throughout 39 states with significant earthquake exposure, the Nation will experience unacceptable, but avoidable, deaths and economic losses from earthquakes. There is an urgent need to fully implement the USGS advanced national seismic system through appropriations that are consistent with Congressional authorizations.

I recommend the Subcommittee endorse the report that will be talked about in the next speaker, securing society against catastrophic earthquake losses from EERI. Dr. O'Rourke will present that. And I recommend we seize the opportunity of FEMA's new position in the Department of Homeland Security to recognize the synergy between addressing earthquake threats and terrorist threats.

Last week, I was in Puerto Rico, and Anthony Lowe was there awarding 75 million to the electric utility there. The papers got it wrong. It should be for all hazards, to protect from earthquakes and terrorists, not only hurricanes.

Chairman SMITH. You mean FEMA put more money down there than our total United States earthquake NEHRP program?

Dr. CLUFF. 79 million—75 million. But I think the papers got it right, because Anthony Lowe knows that all hazards are important. My last recommendation is——

Chairman SMITH. Mr. Cluff, I am going to have to interrupt you.

Dr. CLUFF. All right.

Chairman SMITH. I have four minutes to make this vote. I am guessing we should be back in about 12 minutes. My first question after we finish the testimony is going to be what is more important to what effect in terms of developing new and better technology and how much of our emphasis should be on implementing that technology? And second, how do we get the private sector more involved in doing things that is going to protect their lives and their property?

And with that, recess at the call of the Chair.

[Recess.]

Chairman SMITH. The Subcommittee is in order. It doesn't seem to work. It is not his fault. Are we capable of taking testimony and recording it without the speaker?

Mr. WEIRICH. It is very minimal. I really wouldn't like to do it.

Chairman SMITH. I think we will ask you to record the last 20 words of Dr. Cluff. You just had—so good. Dr. Cluff, you were concluding.

Dr. CLUFF. Thank you very much. My last conclusion and recommendation was we need an independent oversight panel, similar to what Mr. Olson mentioned, to guide and report to Congress annually.

And I want to end with a quote that is up on the board: "Where there is no vision, the people will perish." We have got to have vision to prevent the people from perishing.

Thank you.

[The prepared statement of Dr. Cluff follows:]

PREPARED STATEMENT OF LLOYD S. CLUFF

I was invited to prepare the following testimony for the Subcommittee on Basic Research's hearing entitled *The National Earthquake Hazards Reduction Program: Past, Present, and Future*. My purpose in preparing this testimony is to guide the Committee on Science as they prepare to reauthorize the program during the 108th Congress.

Having been involved since the inception of the National Earthquake Hazards Reduction Program (NEHRP), I have been asked to discuss my perspectives based on my experience with the program throughout its lifetime. I was a member of the Advisory Group on Earthquake Prediction and Hazard Mitigation, known as the "Newmark-Stever Panel," convened at the request of the President's Science Advisor in 1976. Our report, "Earthquake Prediction and Hazard Mitigation Options for the USGS and NSF Programs," dated September 15, 1976, formed the basis for the Congressional enactment of the National Earthquake Hazards Reduction Act of 1977.

I have served on various NEHRP expert review committees over the past 25 years to give guidance on ways to improve the program to reduce earthquake risks. I have also had the opportunity to present testimony during past Congressional NEHRP reauthorization hearings, most recently on March 1, 1990 to the Subcommittee on Science, Research, and Technology. At that time, my testimony was from the perspective of Chairman of the California Seismic Safety Commission, where I served California as a Seismic Safety Commissioner for almost 15 years.

For my testimony today, I have been asked to speak from the perspective of Director of the Geosciences Department for Pacific Gas and Electric Company in San Francisco, one of the Nation's largest-investor owned gas and electric utilities, as well as from the perspective of Chairman of the Congressionally mandated Scientific Earthquake Studies Advisory Committee (SESAC). The SESAC was appointed by the Secretary of the Interior to advise on the NEHRP activities of the U.S. Geological Survey. The first SESAC report to Congress, dated September 21,2002, is appended to my testimony. I have been asked to include specific comments on current NEHRP activities, as well as to recommend how federal earthquake mitigation efforts can be strengthened.

NEHRP After 25 Years

During the 25 years since the National Earthquake Hazards Reduction Program was established, the NEHRP has provided insightful scientific and engineering leadership toward reducing earthquake risks. This leadership has resulted in major advances in identifying and characterizing active faults (earthquake sources) and understanding the destructive effects of earthquakes that will eventually be released by slip on these faults. Twenty-five years ago, there was hope that short-term earthquake predictions would have been realized by now. Although that capability has not been realized, reliable estimations of the locations of future major earthquakes, their size, their likelihood of occurrence, and the character and extent of their effects are now possible.

Additionally, a wealth of information has been developed to enhance our knowledge of the vulnerabilities of the built environment to earthquakes. We now better understand the factors that influence good as well as poor earthquake performance of utilities and transportation systems, as well as specific types of structures and buildings. This improved knowledge has resulted in useful tools that, if applied, have the potential to bring unacceptable risks under control.

However, the risk is growing faster than our ability to provide effective mitigation. In spite of the increased knowledge and the good work that has been done, particularly in regions of high seismic exposure, earthquake risk continues to grow nationwide. This is largely due to (1) uncontrolled growth in earthquake-prone areas, (2) the lack of effective land-use planning in the hazardous areas, (3) the lack of implementation and enforcement of appropriate building standards, and (4) the high cost of strengthening the existing built environment. This trend has positioned the Nation in an unacceptable situation, one that will eventually result in catastrophic losses. Studies such as the 1999, National Research Council publication, *The Impacts of Natural Disasters: A Framework For Loss Estimation,* show the per-event costs could reach thousands to tens of thousands dead, hundreds of thousands injured and homeless, and direct and indirect economic losses that could exceed $200 billion. This trend will not be reversed until the earthquake-prone communities in all 39 vulnerable states understand the threat and take action to mitigate unacceptable risks.

Value of NEHRP to Private Industry

In addition to its concern for employee and customer safety during earthquakes, Pacific Gas and Electric Company has a strong economic interest in "keeping the lights on." PG&E has vast resources in dams and power plants, transmission and distribution systems, and administrative buildings. Although protecting these resources from earthquake damage is important, equally important is functionality following an earthquake. The ability to continue to provide utility service to customers will assist emergency response efforts and reduce recovery time, as well as assure a continuing income stream during a particularly challenging time. Functionality also affects the communities PG&E serves, as businesses having gas and electricity can remain open, lessening the overall economic impact to the community.

PG&E has been able to leverage their efforts to improve earthquake safety and reliability of their gas and electric systems through the development of user-driven, public/private research partnerships, funded in part by NEHRP programs. Three examples are presented below.

PG&E/U.S. Geological Survey—The 1989 Loma Prieta earthquake provided an opportunity and motivation for PG&E to focus on better understanding the nature and character of earthquake hazards in Central and Northern California, PG&E's service territory. After extensive discussions with the USGS Menlo Park office in 1992, PG&E entered into a non-financial Cooperative Research and Development Agreement (CRADA) with the USGS. We agreed to cooperate on research on earthquake hazards throughout the greater San Francisco Bay Area. Based on the success of this effort, in 1996 the agreement was modified into a financial CRADA. Over the next few years PG&E provided $4.4 million in funding for projects with USGS scientists that would focus on PG&E's needs for system safety and reliability improvements. Generally, the projects include studies to better understand the location and characteristics of specific active faults, the effects of strong ground shaking, local site effects known to influence the degree of damage at particular locations, and the nature of ground failure mechanisms (landslides and liquefaction). Many projects have been completed, and the results are being used to help reduce earthquake risks not only to PG&E facilities, but also to PG&E's industrial customers, private homeowners, and the public at large.

Pacific Earthquake Engineering Research Center—The research results from the PG&E/USGS cooperative program feeds directly into another user-driven, applied research, public/private partnership, the PEER Lifelines Research Program. Program partners include PG&E, Caltrans, and the California Energy Commission (CEC), under the auspices of the Pacific Earthquake Engineering Research Center (PEER), at the University of California at Berkeley.

In 1996, PG&E and the University of California entered into an agreement to focus applied research efforts toward improving the earthquake performance (safety and reliability) of gas and electric systems in California. The concept of the users driving the research agenda, in collaboration with the best earthquake researchers, was the focus of this initial partnership. PG&E engineers are intimately involved in selecting research topics, as well as guiding the research. This collaboration provides a mechanism for research results to be immediately implemented to improve system performance during earthquakes.

The initial funding from PG&E was $3.5 million, however, the user-driven concept interested Caltrans for their earthquake safety and reliability research program for bridges and highways, and a matching funding arrangement was established. The combined leveraged funding from PG&E, Caltrans, and the CEC to support the PEER Lifelines Research Program is now at $13 million, through 2004. We are seeking additional partners to participate in the benefits of the research and to join in future funding of user-focused applied research. Additional matching funding from NEHRP funding agencies would provide opportunities to enhance the user-driver research.

American Lifelines Alliance—The formation in 1997 of the American Lifelines Alliance (ALA) initially by FEMA and the American Society of Civil Engineers (now with the Multi-hazard Mitigation Council within the National Institute of Building Sciences, NIBS) is in direct response to needs for improved lifeline performance that were identified more than ten years ago, and was specifically required in the 1990 reauthorization of the NEHRP. Leaders from lifeline organizations strongly endorsed the need for developing and adopting seismic design guidance for lifelines in a 1997 Lifeline Policy-makers' Workshop.

The ALA's objective is to facilitate the creation, adoption, and implementation of design and retrofit guidelines and other national consensus documents that, when implemented by lifeline owners and operators, will systematically improve the performance of lifelines during natural hazard and human threat events. The current participants in the partnership include FEMA, NIBS, U.S. Geological Survey, U.S. Bureau of Reclamation, PG&E, Rohn Industries, Pima County, Arizona, and various private sector consultants.

Although the formation of the ALA was closely tied to concerns regarding earthquake threats, the consideration of multiple hazards was determined necessary by the ALA to facilitate decisions on design and retrofit measures to achieve improvements in reliability on a national scale, where the level of risk from various natural hazards is highly variable. The initial focus of ALA guidance development was on all natural hazards, including earthquakes, floods, windstorms (including hurricanes and tornadoes), icing, and ground displacements (including landslides, frost heave, and settlement). However, following the September 11, 2001, terrorist attacks, FEMA directed the ALA to address hazards posed by human threats, including blast, chemical, biological, radiological, and cyber threats. The utility and transportation systems appropriate for the ALA process include electric power transmission and distribution, natural gas transmission and distribution, potable water conveyance and distribution, waste water transportation and processing, oil and liquid fuel handling, transport, and storage, highways, railroads, ports and inland waterways, air transportation, and telecommunications.

The ALA is working closely with the Lifelines Subcommittee of the Interagency Committee on Seismic Safety in Construction, which is charged with assisting federal departments and agencies to develop and incorporate earthquake hazard reduction measures in their ongoing construction programs. The ALA's efforts to develop national consensus guidance documents are aligned with many of the objectives of the Lifelines Subcommittee. ALA products will provide appropriately qualified seismic guidance, and the Lifelines Subcommittee can help in the preparation and adoption of such guidance by federal agencies. The ALA has developed matrices that define the current status of natural and manmade hazards guidance available in the United States for lifeline system operators and other interested parties.

ALA guidelines published in the last two years include Seismic Fragility Formulations for Water Systems, Guidelines for the Design of Buried Steel Pipe, Seismic Design and Retrofit of Piping Systems, Extreme Ice Loads from Freezing Rain, and Guidelines to Define Natural Hazards Performance Objectives for Water Systems. Guidelines currently in preparation include those to evaluate the performance of electric power, oil and natural gas pipelines, and waste water systems during natural hazard and terrorist threat events.

Misplaced Complacency

Many public policy-makers know that earthquakes are infrequent and assume they can be safely ignored in favor of more pressing issues; but they can be assured that if a catastrophic earthquake occurs on their watch, the truth will be revealed. Public perception, it could be said, might be that the United States is not that vulnerable to earthquakes, because the number of lives lost has been exceptionally low compared with that in other countries. The fact is, it has been a matter of luck that earthquake deaths have not been higher in the United States. Thirty-nine states have an earthquake threat, and it is just a matter of time before disaster strikes. We cannot afford to rely on good fortune to minimize earthquake loss of life. Let's look at a few examples.

1971 San Fernando, California Magnitude 6.7 Earthquake—The San Fernando earthquake was a direct hit beneath the San Fernando Valley, a few miles north of downtown Los Angeles. The earthquake occurred at 6:00 A.M., when most people were safe at home. The Lower San Fernando Dam was severely damaged and would have experienced massive failure, except the reservoir had been drawn down for maintenance a few days before the earthquake. We were lucky that the duration of the shaking was short. Had the earthquake lasted a few more seconds, the dam would have massively failed, releasing the water in the reservoir onto the 80,000 people living directly downstream. The first floor of the outpatient facility at the new Olive View Hospital massively collapsed, but it was unoccupied because of the early morning hour of the earthquake; later in the day, the facility would have had hundreds of patients.

1989 Loma Prieta, California Magnitude 7.1 Earthquake—In spite of the fact that a major earthquake struck the San Francisco Bay Area on October 17, 1989, losses were minimal; there were only 63 deaths. We take credit for the fact that we had an aggressive program of seismic safety improvements throughout the Bay Area, and that helped limit the losses. However, we were lucky. The center of the energy release along the San Andreas fault was in the Santa Cruz Mountains, 30 to 50 miles from the major cities. Had the earthquake been closer, damage, particularly to the older building stock that had not been seismically upgraded, would have been disastrous. It occurred at 5:04 P.M., commute time, the worst time of day for an earthquake according to earthquake scenarios, because the streets are filled with people and the freeways are jammed with traffic. An upper section of the Bay Bridge dropped onto the lower deck, and the Cyprus double-decker freeway in Oakland massively collapsed. These two structural failures could have been the source of hundreds of deaths. But we were lucky. The World Series Earthquake, as it has been called, occurred at the beginning of the third game of the World Series between the two Bay Area teams, the San Francisco Giants and the Oakland Athletics. The freeways and bridges were eerily empty while people were inside, watching the game. It was also fortunate that, because of the game, we had media coverage of the earthquake that lasted more than two weeks, helping to raise awareness of the earthquake threat.

1994 Northridge, California Magnitude 6.7 Earthquake—The Northridge earthquake also occurred during the early morning hours, 4:31 A.M., on Martin Luther King Day. Had the earthquake occurred only a few hours later on the national holiday, the near-massive collapse of the Bullocks Department Store in Northridge would have resulted in more deaths in that one building than all the deaths (57) in the entire region affected by the earthquake. Thousands of commercial buildings were badly damaged and many collapsed, and many freeway bridges collapsed, but they were all virtually empty at the time of the earthquake.

2001 Nesqually, Washington Magnitude 6.8 Earthquake—The February 28, 2001 earthquake that struck the Nesqually district of Seattle, Washington resulted in only minor casualties and localized damage. The lack of significant damage and casualties were due to two important factors: the focal depth of the earthquake of was two to three times deeper (55 km) than most damaging earthquakes, and for the past few decades the Seattle region has adopted an aggressive seismic safety improvement program, particularly with support from FEMA's Project Impact during the 1990s. However, just prior to the earthquake, due to Mardi gras-related riots in Pioneer Square and the Sodo District, the police had barricaded the area to public access. We were lucky because in this old part of the city, unreinforced masonry walls fell into the streets when the earthquake struck, and would have resulted in many casualties had people been allowed normal access.

2002 Denali Fault, Alaska Magnitude 7.9 Earthquake—The second largest earthquake ever to strike the United States, the magnitude 7.9 earthquake on November 3, 2002 on the Denali fault, was a media non-event. This was partly because the earthquake struck a very remote region of Alaska. We were lucky this large earthquake was released on a fault in Alaska, rather than along one of the many faults close to major population centers in California. A similar earthquake along any of the faults associated with the San Andreas fault would have resulted in thousands of deaths and direct and indirect economic losses that could have easily exceeded $200 billion.

But it was also a media non-event because the only significant structure situated in the path of this potentially devastating earthquake did not fail. It was *not* a matter of luck that the Trans-Alaska Pipeline performed so well. It was exceptional scientific assessment of the earthquake hazards and innovative engineering design that prevented an oil spill. The Denali fault experienced 18 feet of horizontal and 2.5 feet of vertical displacement at the pipeline crossing of the fault. Thirty years ago, state-of-the-art NEHRP-type scientific evaluations of the hazards and innovative engineering design were applied to assure the pipeline was well prepared to accommodate the earthquake.

Seventeen percent of U.S. crude oil flows through the Trans-Alaska Pipeline. The State of Alaska depends on the pipeline for eighty percent of its revenue. If damaged, the pipeline could have been disabled for many months, causing gas prices to soar. It is possible that if the pipeline had broken, the resulting environmental disaster would cause the pipeline never to be restored.

Recommendations

Earthquake Monitoring—Most of the earthquake monitoring instrumentation that has been installed and maintained over the past 50 or more years is focused on identifying the source of earthquakes and understanding the overall physics of the earth. Although these seismic networks have provided important data contributing to the development of seismic hazard maps, they do not provide engineers and emergency responders the strong-motion information needed to maximize our understanding of how essential lifelines, system components, and specific buildings were affected during damaging earthquakes. There is an urgent need to fully implement the Advanced National Seismic System (ANSS), designed to expand, and at some locations, replace current earthquake monitoring systems to provide critically needed information for the benefit of the earthquake engineering and emergency response communities.

The ANSS was authorized by Congress in 2000, but is not yet fully appropriated. Strong-motion information is critical to making the next breakthrough in understanding how to economically halt the growth of earthquake risk and reduce it to acceptable levels. The next major destructive earthquake is overdue in a wide variety of locations across the country. The ANSS is the most important new program needed by the NEHRP. Installing this instrumentation after the next destructive earthquake will be too late; we need the data that can be recorded during that earthquake.

Leadership—Leadership has been an issue since the inception of NEHRP. The Program has experienced fragmentation, frustrating the attempts to achieve the Act's goal of a coordinated hazard reduction effort. A few examples of the fragmentation will highlight the problem. The budget process is divided among four agencies, four different budget examiners at the Office of Management and Budget, and three subcommittees of the House Appropriations Committee. There is no single line item in the President's budget for the Earthquake Hazards Reduction Program, even though there is statutory authority for the program.

The Act provides broad, multiple goals, all of which are important elements of a comprehensive earthquake hazard reduction program. The existence of multiple goals, tight fiscal constraints, and no strong, centralized mechanism to guide and coordinate agency efforts and expenditures results in the available resources being spread too thin.

The NEHRP 5-year strategic plan *(Expanding and Using Knowledge to Reduce Earthquake Losses: The National Earthquake Hazards Reduction Program Strategic Plan 2001–2005,"* March 2003) should be a guiding document, and each agency's budget should be in step with it, but they are not. At present, there is no provision for meaningful accountability. Without an incentive to carry out priorities, participating agencies need not follow the plan. As a result, multiple approaches to the same problem, imbalances between user needs and federal services and products, competition among agencies, and lack of cooperation make the program less effective.

Earthquake programs and hazard-reduction priorities are too important to risk being lost among competing demands and priorities. In California, important earthquake programs were but a small portion of the overall responsibilities of departments responsible for emergency response, geologic hazards, and structural engineering. The State responded by establishing a Seismic Safety Commission as an independent and single-minded body charged with making certain that earthquake safety is never overlooked. A similar independent, permanent oversight advisory body should be established to direct the NEHRP.

I propose that a NEHRP advisory committee be established to advise the four participating agencies (FEMA, USGS, NSF, and NIST). The committee would be composed of non-Federal Government experts from State and local government and the private sector who are involved in reducing earthquake risks. The advisory committee would help the NEHRP agencies set goals and priorities and see that they are being met, provide coordination, and assure that a consistent, focused national program is followed. This body would be independent of the member agencies, and would report to Congress annually. It would provide overall direction, stature, and visibility to the program.

I recommend the Subcommittee consider amendments to assure the National Earthquake Hazards Reduction Program and its component parts are managed in an integrated manner. The Act should be amended to provide for strong coordination and accountability.

The Future

The National Earthquake Hazards Reduction Program is at a crossroads, and this reauthorization provides a meaningful opportunity for an overall look at the program. We should seize the opportunity of FEMA's new position within the Department of Homeland Security (DHS) and recognize the synergies between addressing earthquake threats and terrorist threats.

I was at the annual meeting of the Seismological Society of American in San Juan, Puerto Rico last week, and read in the morning paper (*San Juan Star,* May 2, 2003) that Anthony Lowe, head of FEMA's Mitigation Division, was in town to give $75 million to the Puerto Rico Electric Power Authority to protect the metropolitan area's electric system against hurricane-strength winds. The FEMA could have leveraged the value of this funding if it had been realized that putting electric grids underground would also make them less vulnerable to earthquakes and terrorism. The American Lifelines Alliance, mentioned earlier, has realized that you get more bang for the buck if you have an all-hazards perspective. I believe FEMA's new situation within DHS gives NEHRP an exciting opportunity to be part of a much larger effort to protect the Nation against not only other natural hazards, but human threats, as well.

Even greater strides could be made if other federal agencies that have responsibilities in seismic safety were included in national planning for earthquake hazards reduction. The Department of Energy, Department of Defense, Department of Transportation, Department of Housing and Urban Development, General Services Administration, Veterans' Administration, Corps of Engineers, NASA, and the Bureau of Reclamation all have (or should have) programs that address earthquakes. The NEHRP should consider and give guidance to the efforts of these agencies.

The NEHRP needs to continue under an improved organizational structure and proceed along the lines of the overdue, but recently published, NEHRP Strategic Plan. The Strategic Plan outlines a course of action for the best use of existing funding and prioritizes opportunities for accelerating the program as additional funding becomes available. It outlines a balanced and accelerated approach that calls for Federal-level leadership and incentives focused on the adoption of proper public policy and expanded funding for the activities needed to develop new design techniques aimed at making mitigation affordable.

A strong, viable NEHRP must include proactive implementation through increased funding, incentives for risk reduction, new public policy, and inspired leadership. As pointed out in the recent Earthquake Engineering Research Institute report, *Securing Society Against Catastrophic Earthquake Losses* (Earthquake Engineering Research Institute, Oakland, California, 2003), at current funding levels, it will likely take 100-plus years to secure the Nation against unacceptable earthquake risks. Based on EERI's research and outreach plan, implementing an expanded program that has three times the funding and includes full appropriations for ANSS and NEES, will provide the needed earthquake risk reduction results in the next 20 to 30 years. The next major earthquake will demonstrate that 100 years is much too long to wait.

Unless seismic safety is afforded a priority that is now lacking throughout the 39 states that have significant earthquake exposure, the United States will experience unacceptable and avoidable deaths and economic losses from future earthquakes. We have been lucky, we cannot afford to base our earthquake public policy on dumb luck.

Thank you for the opportunity to address the Subcommittee.

Biography for Lloyd S. Cluff

PROFESSIONAL EXPERIENCE

Pacific Gas and Electric Company, San Francisco, California, 1985–Present

Manager, Geosciences Department

- Responsible for assessments of PG&E facilities with respect to earthquake and geologic hazards, soil and rock foundation conditions, and groundwater contamination
- Program Manager of the Diablo Canyon Long-Term Seismic Program
  - —Responsible for technical and administrative management of the program
  - —Directed studies in seismic geology, geophysics, seismology, earthquake engineering, and probabilistic risk assessment, which were required by the U.S. Nuclear Regulatory Commission for the comprehensive re-evaluation of the seismic safety of the Diablo Canyon Nuclear Power Plant
  - —Manager of PG&E's Earthquake Risk Management Program

California Seismic Safety Commission, Sacramento, 1985–1999

Commissioner

Vice Chairman, 1986–1988; Chairman, 1988–1990 and 1995–1997; Chairman of Research Committee, 1988–1999; Cellular Telecommunication Seismic Risk Task Group, 1991–1992; Chairman of Committee on Acceptable Earthquake Risk Policy for State Buildings, 1990–1991

Woodward-Clyde Consultants, San Francisco, California, 1960–1985

Vice President, Principal, and Director

- Responsible for technical and administrative functions related to geologic, seismologic, geophysical, and earthquake engineering investigations and evaluations
- Projects included siting and design studies for critical facilities worldwide

University of Nevada, Reno, Nevada, 1967–1973

Associate Professor of Geology and Geophysics (Visiting)

Lottridge, Thomas and Associates, Salt Lake City, Utah, 1960

Geologist

El Paso Natural Gas Company, Salt Lake City, Utah, 1957–1959

Junior Geologist

University of Utah, Salt Lake City, Utah, 1958–1960

Teaching Assistant

EDUCATION

Brigham Young University, Provo, Utah 1951–1954

University of Utah, Salt Lake City, Utah, B.S., Geology, 1960

REGISTRATIONS

Geologist: California No. 1725

Certified Engineering Geologist: California No. EG567

AFFILIATIONS

Association of Engineering Geologists—Board of Directors, 1966–1970; Vice President, 1967–1968; President, 1968–1969

Earthquake Engineering Research Institute—Board of Directors, 1976–1980 and 1991–1995; President-Elect, 1992–93; President, 1993–1995; Past President, 1995–1996; Learning from Earthquakes Committee, 1985–1997

California Earthquake Safety Foundation—Board Member, 1989–1997; Vice President, 1991–1997

Geological Society of America International Association of Engineering Geology—Vice President, 1970–1974; Chairman, Commission on Seismicity, 1970–1976

Seismological Society of America—Board of Directors, 1980–1986; Vice President, 1981–1982; President, 1982–1983

Structural Engineers Association of Northern California

HONORS

U.S. Department of Interior, Geological Survey; John Wesley Powell Award, 2000

California Earthquake Safety Foundation; Alfred E. Alquist Medal, 1998

Earthquake Engineering Research Institute; elected Honorary Member, 1996

California Academy of Sciences; elected Fellow, 1992

Structural Engineers Association of Northern California; Degenkolb Award, 1992

Pacific Gas and Electric Company; Excellence Award, 1992

Pacific Gas and Electric Company; Excellence Award, 1991

Woodward-Clyde Consultants; Woodward Lecturer Award, 1979

National Academy of Engineering; elected Member, 1978

International Atomic Energy Agency; Distinguished Lecturer Award, 1975

American Society for Testing and Measurements; Hogentagler Award, 1968

Listed in Engineers of Distinction, Who's Who in Science, and Who's Who in America

RELATED EXPERIENCE

Post-Earthquake Field Studies

Post-earthquake field studies of many destructive earthquakes throughout the world including Hebgen Lake, Montana 1959; Alaska 1964; Parkfield, California 1966; Caracas, Venezuela 1967; Dasht-E Bayaz, Iran 1968; Santa Rosa, California 1969; Peru 1970; San Fernando, California 1971; Managua, Nicaragua 1972; Oroville, California 1975; Guatemala 1976; Romania 1977; Tabas, Iran 1978; Livermore, California 1980; Algeria 1980; Egypt 1981; Mexico City 1985; Soviet Armenia 1988; Loma Prieta, California 1989; Manjil, Iran 1991; Cape Mendocino, California 1992; Landers-Big Bear, California 1992; Northridge, California 1994; Kobe, Japan 1995; and Lijiang, Yunnan, China 1996; Kocaeli, Turkey, 1999; Chi-Chi, Taiwan 1999; and Duzce, Turkey 1999.

Active Fault Field Studies

Studies of the relationship of tectonics, seismic geology, and seismicity of many active fault zones throughout the world including those in New Zealand, Australia, Chile, Argentina, Peru, Bolivia, Ecuador, Colombia, Venezuela, Costa Rica, Nicaragua, Honduras, E1 Salvador, Guatemala, Mexico, Japan, Taiwan, India, Nepal, Pakistan, Iran, Afghanistan, Turkey, Armenia, Georgia, Russia, Morocco, Algeria, Egypt, Israel, Lebanon, Jordan, Romania, Switzerland, Spain, Portugal, Italy, western United States, British Columbia, and Alaska. Served as an advisor to the governments of many of these countries regarding the evaluation of earthquake and geologic hazards and risk and the formulation of seismic safety guidelines and public policy, especially in the siting, design, and construction of critical facilities.

Publications

Authored and co-authored more than 180 technical papers on subjects relating to seismic geology, paleoseismicity, regional seismicity, earthquake hazards and risk, earthquake engineering, and seismic safety of critical facilities. These papers have been published in the proceedings and journals of national and international scientific and engineering associations and societies.

Lectures

Invited lecturer and keynote speaker on seismic geology, seismicity, paleoseismicity, earthquake hazards, engineering geology, and seismic safety at numerous national and international symposia, conferences, universities, associations, and societies.

Research, Consulting, and Professional Activities

2002-present—Alyeska Pipeline Service Company; member, Senior Earthquake Advisory Panel to advise on seismic safety issues following November 3, 2002 Denali Fault Earthquake.

2002-present—Scientific Earthquake Studies Advisory Committee; Chairman of committee that advises on National Earthquake Hazards Reduction Program activities of the U.S. Geological Survey.

2000—National Research Council, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine; member of U.S./IRAN Interacademies Cooperative Initiative, a delegation to the Islamic Republic of Iran to normalize relations between the U.S. and Iran.

1999–2002—World Bank and People's Republic of China; member of Dam Safety Review Panel for Baise Dam Project, southwestern China.

1999–2001—Sunol Valley Water Treatment Plant, City of San Francisco Hetch-Hetchy Water System; advise on seismic issues of proposed construction near Calaveras fault.

1998–2000—Federal Emergency Management Agency; member of National Pre-Disaster Mitigation Program Advisory Panel.

1997–1999—National Academy of Sciences, National Research Council; member of Committee on Assessing the Costs of Natural Disasters.

1997–1999—Institute for Business and Home Safety, the Subcommittee on Natural Disaster Reduction, and the President's Office of Science and Technology Policy; member of organizing committee for Public-Private Partnership, PPP–2000, Forums on Public Policy Issues in Natural Disaster Reduction.

1997–1999—Government of Portugal; Empresa de Desenvolvimento a Infraestruturas do Alqueva, S.A.; evaluated seismic hazards and risks for the proposed Alqueva Dam. The dam will create the largest reservoir in Europe; reservoir-triggered seismicity is a concern for the environment.

1996–2001—Southern California Earthquake Center; member of Advisory Board.

1996–1999—National Academy of Sciences; member of Board On Natural Disasters to advise Congress, the President's Office of Science and Technology Policy, and government agencies with regard to reducing losses from natural disasters.

1994–2002—Greater Vancouver Water District; member of Seismic Review Board evaluating and providing advice on the seismic safety of the district's major dams.

1993-present—Israel Electric Corporation; Chairman of Seismic Review Board providing advice on the seismic safety of siting and constructing a commercial nuclear power plant in Israel.

1993–1996—U.S. Department of Energy, U.S. Nuclear Regulatory Commission, and Electric Power Research Institute; member of Senior Seismic Hazard Analysis Committee to develop state-of-the-art implementation guidelines and methods for the performance of probabilistic seismic hazard analyses for the seismic regulation of nuclear power plants and other critical facilities.

1990–1994—Los Angeles Harbor Department; member of 2020 Program Technical Review Committee to evaluate and provide advice on seismic hazards affecting proposed harbor development scheduled for completion in the year 2020.

1991–1993—B.C. Hydro; member of Provincial Seismic Review Panel to evaluate and provide advice on the seismic hazards to British Columbia's hydroelectric facilities and power systems.

1991—National Academy of Sciences; member of Project Site Evaluation Review Committee, Laser Interferometer Gravitational-Wave Observation (LIGO), at the California Institute of Technology.

1990–1992—Yukon Pacific Corporation; member of Earthquake Consulting Board advising on the feasibility of design and construction of a Liquefied Natural Gas Terminal near Valdez, Alaska.

1989–1990—National Academy of Sciences; member of U.S. National Committee for the Decade for Natural Disaster Reduction.

1986–1990—The National Earthquake Prediction Council; member of Working Group on California Earthquake Probabilities, which published two reports (1988 and 1990) on the probabilities of large earthquakes on the San Andreas and associated fault systems.

1986–1989—National Academy of Sciences; member of Committee Advisory to the U.S. Geological Survey (USGS), advising the Director of the USGS and Chief Geologist on the broad spectrum of activities within the USGS.

1987–1988—National Academy of Sciences and National Academy of Engineering; member of Super-Conducting Supercollider Site Selection Committee to review fifty proposed sites and select seven for consideration by the Department of Energy.

1988—Department of Energy Defense Program; member of New Production Reactors Seismic Design Criteria Team to develop site-specific earthquake design criteria for Savannah River and Idaho nuclear facilities.

1987—National Earthquake Hazards Reduction Program; member of Expert Review Committee to review NEHRP program, identify critical issues, and provide recommendations to assist in revising the Five-Year Hazards Reduction Plan and proposed budget.

1984–1987—National Academy of Sciences; member of subcommittee to evaluate earthquake programs of the U.S. Geological Survey.

1982–1986—High and Aswan Dam Authority, Ministry of Irrigation, Government of Egypt, and U.S. Agency for International Development; director of a comprehensive program to evaluate earthquake activity and dam stability. There was concern for reservoir-induced seismicity and the potential for large earthquakes to affect the Aswan High Dam and the safety of Egypt.

1982—U.S. Agency for International Development and National Science Foundation; Chairman of Aswan High Dam Seismic Safety Review Panel formed at the request of the Government of Egypt following the occurrence of a damaging earthquake beneath the reservoir of the High Dam in 1981.

1969–1986—Commission Federal Energia Atomica and Commission Federal de Electricidad, Mexico; advised on siting nuclear power plants in Mexico.

1982–1985—National Academy of Sciences; member of Panel on Active Tectonics.

1972–1985—Interconnection Electrica, S.A.; directed studies of seismicity and seismic hazards for the feasibility of siting large dams, reservoirs, and related hydroelectric facilities throughout Colombia, including Ituango, Canafisto, Alto Sinu, Rio Negro, San Carlos, Penderisco, and Troneras.

1974–1985—Israel Electric Corporation; provided advice on earthquake hazard evaluations regarding the technical feasibility of siting a commercial nuclear power plant.

1970–1985—Government of Venezuela; directed geologic and seismic studies regarding the siting of major dams, reservoirs, and related hydroelectric facilities including Yacambu, Uribante-Caparo, La Honda, La Vueltosa, and Borde Seco.

1969–1985—International Atomic Energy Agency, Vienna; Nuclear Power Plant Siting Missions. On behalf of the agency and according to the IAEA siting criteria, evaluated the siting of nuclear power plants in Mexico, Chile, Portugal, and Venezuela. These assignments included site visits, fieldwork, evaluating the likelihood of successful licensing, meetings with the applicant, and writing reports on behalf of the IAEA.

1981–1984—National Academy of Sciences; member of Geological Sciences Board.

1978–1984—National Science Foundation and U.S. Geological Survey; member of Earthquake Hazards Mitigation Advisory Panel.

1972–1984—Washington Public Power Supply System: Hanford Nuclear Siting Studies; responsible for geologic and seismologic investigations to select sites of proposed nuclear power plants Satsop Nuclear Power Plant; responsible for geologic and seismologic investigations that resulted in the licensing of the Satsop site in Washington.
1973–1983—Ente Nazionale Per L'Energia Elettrica (Italian Electric Utility, ENEL); directed detailed seismic studies toward the licensing of Italian nuclear power plants. Proposed sites included Tarquina, Montalto di Castro, Torrente Saccione, and Gargano.
1981–1982—INECEL, Ecuador; directed feasibility studies for dams and hydroelectric facilities in Ecuador, including regional fault and earthquake activity studies to assess the earthquake potential of the Salado and Coca river regions.
1979–1982—Southern California Edison Company; San Onofre Nuclear Generating Station licensing studies. Responsible for evaluations of geologic, seismologic, and earthquake engineering factors to develop a strategy for licensing, taking into account U.S. Nuclear Regulatory Commission criteria, and the seismic issues of intervenors.
1978–1982—Atomic Energy Commission of Portugal; identified acceptable regions for nuclear power plant sites, after a capable fault was found to traverse Portugal's first proposed site north of Lisbon, resulting in the site being abandoned. All Portugal was studied to identify regions where nuclear power plant sites would have a high likelihood of being licensed, based on IAEA seismic siting criteria.
1977–1982—Alaska Natural Gas Transportation System Studies, Northwest Pipeline Company and Fluor Engineers and Constructors; responsible for assessing potential seismic hazards along the pipeline corridor, and their significance to pipeline design.
1977–1982—Pacific Gas and Electric Company, Humboldt Bay Nuclear Power Plant Studies; (In 1977, the U.S. Nuclear Regulatory Commission suspended the plant's operating license until adequate studies were completed to address seismic issues.) Directed detailed geologic and seismic investigations to answer specific issues raised by the U.S. Nuclear Regulatory Commission regarding the potential for surface faulting at the site and the basis for defining the vibratory ground motions.
1981—Western States Seismic Policy Council; member of Panel on Regional Tectonics and Seismic Safety.
1981—National Science Foundation; member of committee evaluating National Program for Strong-Motion Earthquake Instrument Arrays.
1980–1981—California Public Utilities Commission; chairman of Seismic Safety Review Panel for proposed Liquefied Natural Gas Facility at Point Conception, California. Previously unknown active faults traversing the proposed site caused a technical and political controversy and a loss of confidence in the safety of the site. At the conclusion of the Panel's evaluation and report, and after extensive hearings, all seismic safety issues were satisfactorily resolved and the site was approved for facility design and construction.
1970–1981—Comitato Nazionale Per L'Energia Nucleare, (Italian Atomic Energy Commission, CNEN); responsible for studies regarding seismicity and geologic conditions at nuclear power facility sites in Italy, including Brasimone, Latina, Tarquinia, Montalto di Castro, and Busalla.
1979–1980—National Academy of Sciences, U.S. National Committee for Rock Mechanics; member of Panel on Rock Mechanics Research Requirements.
1977–1980—National Research Council, National Academy of Sciences; member of Panel on Earthquake Research for the Safer Siting of Critical Facilities.
1972–1980—President's Office of Science and Technology Policy; advised on earthquake hazards and risk evaluations for the San Francisco Bay Area, the Los Angeles Metropolitan Area, and the Salt Lake City Area.
1979—UNESCO; member of Panel on Earthquake Risk and Insurance, Cocoyoc, Mexico.
1979—National Science Foundation; member of Joint U.S./Japan Symposium, Earthquake Safety Through Urban Design, Tokyo, Japan.
1976–1979—National Academy of Sciences; member of Seismology Committee.
1975–1979—President's Office of Science and Technology Policy; member of Newmark-Stever Panel to develop a national program for earthquake prediction and hazard mitigation for the U.S. Geological Survey and the National Science Foundation.
1978—International Association for Earthquake Engineering, UNESCO, and the National Science Foundation; member of International Workshop on Strong-Motion Earthquake Instrument Arrays.

1977–1978—U.S. Army Corps of Engineers, New Melones Dam regional and site studies, California; directed evaluations of faults as sources of future earthquake activity, the potential for surface faulting, and the potential for reservoir-induced seismicity at the site of the New Melones Dam on the Stanislaus River.
1976–1977—U.S. Bureau of Reclamation, Auburn Dam regional and site studies, California; directed detailed fault and earthquake investigations to assess the earthquake and faulting potential at the proposed dam site, characterize the earthquake ground motions, and evaluate the potential for reservoir-induced seismicity.
1975–1978—Secretary of the Interior; member of Earthquake Advisory Panel to evaluate earthquake programs of the U.S. Geological Survey.
1975–1977—California Seismic Safety Commission; member of Task Committee on Seismic Hazards and State-Owned Structures.
1974–1977—Pacific Gas and Electric Company; directed Regional Inland California Nuclear Power Plant Siting Studies, extensive and comprehensive regional geologic, seismologic, microearthquake, earthquake engineering, and groundwater hydrology studies, as part of PG&E's evaluation of potential sites for nuclear power plants in the inland areas of central and northern California.
1972–1977—Atomic Energy Office of Iran; directed national nuclear power plant siting studies of seismicity and earthquake faults to select power plant sites within the Zagros Mountains and the Persian Gulf Coast regions of Iran.
1970–1976—UNESCO; member of International Panel of Experts on Seismic Phenomena Associated With Large Reservoirs.
1972–1974—Ministry of Planning, Managua, Nicaragua; directed post-earthquake studies and earthquake hazards evaluations to assist the people of Nicaragua in rebuilding following the devastating 1972 earthquake. Studies resulted in a comprehensive seismic safety plan to rebuild Managua.
1972–1974—Alyeska Pipeline Service Company; directed Trans-Alaska Pipeline Siting Study, a comprehensive program that identified and evaluated geologic and seismic factors to be considered in the siting and design of the pipeline. Where the proposed pipeline crossed active faults, developed design values for surface fault displacements.
1970–1974—California Legislature's Joint Committee on Seismic Safety; member of Advisory Group on Land-Use Planning.
1970–1974—California Governor's Earthquake Council; member
1972–1974—International Atomic Energy Agency, Vienna; provided advice regarding seismic and geologic criteria for the siting of nuclear power plants.
1969–1973—U.S. Atomic Energy Commission, provided advice regarding seismic and geologic criteria for the siting and design of nuclear power plants.
1968–1973—San Francisco Bay Conservation and Development Commission; charter member of the Earthquake Engineering Criteria Review Board.
1970–1972—Atomic Energy Commission of Chile; provided advice regarding seismic review and siting of nuclear power plants in Chile.
1967–1972—President of Venezuela's Earthquake Safety Commission; provided advice regarding seismic safety in Venezuela and recommended the establishment of FUNVISES, the National agency charged to monitor seismic safety.
1966–1970—State of Utah and the Utah Geological and Mineralogical Survey; member of Governor's Earthquake Council regarding earthquake and geologic hazards in Utah.
1969—Office of the President and Secretary of the Interior; member of Santa Barbara Channel Oil Spill Panel to evaluate the 1969 Santa Barbara Channel oil well blow-out and recommend measures to minimize future impact.
1968–1969—Commission Federal de Electricidad, Mexico; provided advice regarding seismic review and feasibility of the proposed Sumidero Canyon hydroelectric project.

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July 29, 2003

The Honorable Nick Smith
Chairman, Research Subcommittee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Smith:

Thank you for the invitation to testify before the U.S. House of Representatives Science Committee, on May 8 for the hearing entitled *The National Earthquake Hazards Reduction Program: Past, Present and Future*. In accordance with the Rules Governing Testimony, this letter serves as formal notice to report that I received no federal funding directly supporting the subject matter on which I testified, in the current fiscal year or either of the two proceeding fiscal years.

Sincerely,

Lloyd S. Cluff

Chairman SMITH. Dr. O'Rourke.

STATEMENT OF DR. THOMAS D. O'ROURKE, PRESIDENT, EARTHQUAKE ENGINEERING RESEARCH INSTITUTE; THOMAS R. BRIGGS PROFESSOR OF ENGINEERING, CORNELL UNIVERSITY

Dr. O'ROURKE. Chairman Smith and Members of the Subcommittee, it is, indeed, an honor to be here to be able to testify on behalf of the Earthquake Engineering Research Institute.

This is an organization of about 2,500 people. They come from the geosciences, the engineering, and social science communities, so it is a very integrated group of people. We are dedicated to seismic risk reduction in the United States.

I have a Power Point presentation that I am looking for in the projection here.

[Slide.]

This—I think we need to recognize that the National Earthquake Hazards Reduction Program has been a highly successful program. It has got a number of notable accomplishments that are very important for the United States and also set a model for the rest of the world. We have been able to develop very good earthquake hazard maps, seismic design provisions for new buildings, rehabilitation guidelines for existing buildings, and loss estimation methodologies, which, as I mentioned before, are a model for the rest of the world. And FEMA has been an implementer of these particular provisions but has worked very closely with other NEHRP agencies that have developed the research bases for these accomplishments.

In terms of recommendations, we believe, that is the Earthquake Engineering Research Institute, that we need to maintain a strong, viable NEHRP. So we urge that Congress do that. We think that there are some recommendations that could be followed for improved leadership and agency integration. We urge you to support the Advanced National Seismic System and the George E. Brown network for earthquake engineering simulation. We also believe that NEHRP, during its reauthorization, should be done so with a thought for increased funding reflecting the—our research and outreach plan.

As you know, the Advanced National Seismic System will be putting in 6,000 new stations. These are critically important for monitoring seismic events in the United States. There is a concentration on urban centers where our risk is the highest. And the ANSS also produces shake maps, which provide almost in real time an estimation of what the magnitude and severity of earthquake ground motion, which is used by emergency responders. And this is a very important aspect of this, very important aspect of information technology application.

The George E. Brown network for earthquake engineering simulation purports to put together a laboratory, which involves the entire United States. Currently there are 15 sites at different universities across the United States that are accessible by the entire earthquake and—earthquake engineering and other communities. It will be establishing, through high-performance Internet, the capability of doing research and testing at very high and sophisticated levels in a way that can be done at a number of different locations contemporaneously and represents a marvelous advancement in the application of practical information technologies and a great boost for the education system.

Some of the leadership improvements that we envision for NEHRP involve that NEHRP should have a visible place and designated staff within each NEHRP agency, especially Department of Homeland Security. We also recommend that some consideration be given that OMB assign, perhaps, one of the participating examiners to coordinate the budgeting within the four agencies so that the funds are invested—that are invested will be balanced and prioritized in a programmatic way. We recommend that Congress ask the President to create an independent committee of external experts responsible for oversight of NEHRP. This oversight committee would report to Congress no less than biannually, and we note that similar recommendations have been made by experts previously convened to provide advice on NEHRP.

NEHRP funding has been subjected to eroding levels of support. This is really quite serious, because we are not able to accomplish what we need to and what we are able to do. NEHRP funding has declined by 40 percent in real dollars since 1978. And this has been hurtful. We must recognize that this type of funding situation is serious and has consequences that none of us wish to have. Perhaps in the future, funding levels could be indexed at a computer—through the consumer price index to at least provide some protection against inflation.

And then we also urge you to consider the EERI Research and Outreach Plan. That plan is called “Securing society against catastrophic earthquake losses.” This is a consensus document. It has been thoroughly reviewed by—reviewed and approved by the community. It provides a comprehensive 20-year plan. Part of that plan is focused on increasing current allocations by over three-fold to about $360 million a year for the first five years. And there is an explicit game plan given for how that money would be allocated and spent in important areas that contribute to our seismic safety. This recognizes still 20 times less than annualized losses from earthquakes in the United States.

These are the five components of the program. In the written testimony, there is a demonstration of the proportion of funding for the first 5-year period of time, where that money would be spent. The five different programs here, you will notice one is education and outreach. This is public education outreach. But in each of the other programs, at least 35 to 50 percent of the funding is focused on implementation. Now what we mean by outreach is implementation, technology transfer, and education.

Now I want to point out that there are tremendous contributions of earthquake engineering to our U.S. national technological infrastructure. Earthquake engineering advances are leveraged beyond earthquakes. They are leveraged to other natural disasters. They are leveraged to civil infrastructure improvements. They are leveraged to applied information technology, and they are leveraged to homeland security. There are examples in the written testimony that spell some of these examples out, which I think are very important to consider. They involve active and passive controls developed in earthquake applications, which are now applied for wind control that are being considered for blast protection, advanced geographical information systems, particularly with respect to lifeline networks, the kinds of gas and electrical and water supplies that Dr. Cluff was talking about. There are the ATC 20 inspection procedures and a number of others.

And I would just like to illustrate the importance of this by looking at the Applied Technology Council 20 protocols, which were developed under NEHRP for rapid investigation and decision making with respect to earthquake damage to buildings. This was an off-the-shelf protocol coming from NEHRP that was available after the World Trade Center disaster, and it was used to examine explicitly and in detail 460 buildings that surrounded the World Trade Center site. And as you remember during that event, it was critically important to restore these facilities so that we had financial market security. Most of those buildings surrounding the World Trade Center site were buildings that were the housings of—for financial institutes, for banks, and so forth that needed to be operational so that the markets could start the following week.

This technology was available because of NEHRP. So our—excuse me, our final recommendations again are to have a strong, viable NEHRP, to consider a leadership situation in which we have an external board of experts that can help to plan and provide oversight for the activities of NEHRP, and then finally to remember us in terms of the funding needs and the value that this particular program supplies. It is leveraged in ways that are very, very important for a whole variety of different technologies, and especially homeland security. We like to look at earthquakes as an example of extreme events. And some of the things that we do are applicable to other extreme events.

So I will end with a plea and with asking your consideration for assistance with, sort of, stemming the tide of this eroding funding situation and thinking very seriously about the model that has been proposed by the Earthquake Engineering Research Institute for increased support for this very valuable program.

Thank you very much, Chairman Smith.

[The prepared statement of Dr. O'Rourke follows:]

PREPARED STATEMENT OF THOMAS D. O'ROURKE

On behalf of the Earthquake Engineering Research Institute (EERI), I am pleased to testify before the Subcommittee on Basic Research of the House of Representatives Committee on Science, and thank the members of the House for providing this opportunity. My testimony has been prepared in coordination with past president Chris Poland and the other members of the Board of Directors of the Earthquake Engineering Research Institute, and I thank them for their insights and assistance.

Benefits of NEHRP

For the past 25 years, The National Earthquake Hazard Reduction Program (NEHRP) has been the backbone for protecting U.S. citizens from the deadly and economically disruptive effects of earthquakes and for seismic risk reduction throughout our nation. Unfortunately, over 75 million Americans in 39 states are directly vulnerable to serious earthquakes, all Americans are vulnerable to the economic and social upheaval that earthquakes incur, and despite the remarkable advances that have been made over the past 25 years, the earthquake risk to the U.S. remains unacceptably high. Direct economic losses from the 1994 Northridge earthquake in the Los Angeles area were in excess of $40 billion.[1] One year later, a severe earthquake struck Kobe, Japan, causing over $100 billion2 in direct damage to buildings and facilities. There were more than 5500 deaths[2] as a result of the Kobe earthquake in a country that, like the U.S., is among the most technologically advanced in the world.

We face inevitable earthquakes that will affect our urban centers nationwide. The cost could reach $100 to 200 billion dollars each, with the potential loss of thousands of lives. At a time when our country is faced with threats of every kind, we need a strong and enhanced NEHRP. The problem is two-fold, involving the lack of implementation of appropriate building standards and the high cost of strengthening the existing built environment. We need to expand the protection and technologies that NEHRP is providing to reduce cost to affordable levels and encourage the mitigation activities that will provide the needed protection.

NEHRP not only contributes to improved seismic performance, but contributes markedly to improved performance and reliability under both normal operation and extreme events associated with other natural hazards (e.g., hurricanes, floods, strong wind, etc.), severe accidents, and terrorist activities. As will be demonstrated later in this testimony, NEHRP investments are leveraged into improved safety and reliability of all components of the Nation's civil infrastructure, including buildings,

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[1] Eguchi, R.T., J.D. Goltz, C.E. Taylor, S.E. Chang, P.J. Flores, L.A. Johnson, H.A. Seligson, and N.C. Blais (1996), "The Northridge Earthquake as an Economic Event: Direct Capital Losses, Analyzing Economic Impacts and Recovery from Urban Earthquake: Issue for Policy Makers," EERI Conference, Pasadena, CA, October 10–11, pp. 1–28.

[2] United Nations Center for Regional Development (1995), "Comprehensive Study of the Great Hanshin Earthquake, Nagoya, Japan: UNCRD." The damage cost was estimated at 9.916 trillion yen by the Hyogo prefectural government, which, at an average exchange rate of 100 yen = one U.S. dollar, converts to U.S. $99.2 billion (p. 194). This does not include indirect costs following the earthquake (for example, loss of port revenue and disruption to other business activities). The fatality total was 5,502 (p. 42).

transportation systems, water supplies, gas and liquid fuel networks, electric power, telecommunications, and waste disposal facilities.

Much has been accomplished under NEHRP, and earthquake engineering and planning have made substantial advances because of its support. Major NEHRP products include national earthquake hazard maps developed by the U.S. Geological Survey (USGS), seismic design provisions for new buildings developed by the Federal Emergency Management Agency (FEMA), guidelines for the rehabilitation of existing buildings and bridges developed by FEMA and the Federal Highway Administration (FHWA), loss estimation methodologies developed by FEMA and FHWA, and performance-based design procedures developed by FEMA and FHWA. Many of these products are derived from fundamental research sponsored by the National Science Foundation (NSF) with supplemental investigations and testing by the National Institute for Standards and Technology (NIST).

Because of the multitude of products and the need to compress information into a focused testimony, it is only possible to illustrate with a few select examples how research under NEHRP has improved our ability to protect lives and property from earthquake hazards. Through geoscience research, for example, national seismic hazard maps have been developed and adopted by the International Building Code in 37 states. The maps affect billions of dollars of new construction, and are used in seismic retrofits, earthquake insurance, community planning, and the design of schools, hospitals, bridges, dams, and power systems. Through geotechnical engineering research, for example, the effects of site response and local soil conditions on strong shaking have been quantified. Provisions for characterizing the amplifying effects of different ground conditions have been introduced into building codes where they are used to design public works, housing, and critical facilities.

Geotechnical engineering research has also made enormous progress in characterizing and stabilizing soils subject to liquefaction. During liquefaction, strong ground shaking generates high water pressures in saturated sandy soil that, in turn, converts solid ground into a liquid that loses its capacity to support structures and moves laterally, rupturing underground pipelines and damaging building foundations and waterfront facilities. Research in geotechnical engineering has produced effective design procedures for liquefaction, developed equipment and maps for identifying liquefiable soils, and advanced ground stabilization technologies to remove or substantially reduce the risk of liquefaction.

The current reconstruction of the Nation's transportation networks under the ICE TEA and TEA–21 programs has significantly benefited from NEHRP-sponsored research, including the USGS mapping program. The newest design guidelines and codes for bridge design being utilized in many parts of the country include advanced seismic design provisions and proper characterization of the seismic potential. The hundreds of billions of dollars our nation is investing in infrastructure reconstruction are better protected from significant earthquake effects because of the NEHRP program.

Structural engineering research under NEHRP has resulted in profound improvements in the ways we analyze and design buildings for earthquake shaking, the methods we use to rehabilitate existing structures to perform safely in future earthquakes, and the advanced technologies we apply to isolate or control buildings from the damaging effects of seismic motion. A good example of applied structural research is the SAC project[3,4,5] in which university and industry participants combined to resolve problems related to welded steel moment frame buildings. Over 200 buildings of this structural type suffered brittle fractures at welded connections during the 1994 Northridge earthquake, and 10 percent of similar steel frame buildings in Kobe collapsed during the 1995 Kobe earthquake.[3] The SAC Joint Venture was formed with FEMA sponsorship in mid-1994 to respond to this crisis. The structural research, which was produced under fast track conditions, resulted in practical and cost-effective standards of practice for the repair and upgrading of damaged steel frame buildings, the design of new steel buildings, and the identification and rehabilitation of at-risk steel buildings.

The results of structural, geotechnical, and earth science research come together in seismic design provisions, guidelines for rehabilitation of buildings, and loss esti-

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[3] Federal Emergency Management Agency (2000), "Recommended Seismic Design Criteria for New Steel Moment Frame Building," FEMA–350, Federal Emergency Management Agency, Washington, D.C.

[4] Federal Emergency Management Agency (2000), "Recommended Seismic Evaluation and Upgrade for Steel Moment Frame Building," FEMA–351, Federal Emergency Management Agency, Washington, D.C.

[5] Federal Emergency Management Agency (2000), "Recommended Seismic Evaluation and Upgrade for Steel Moment Frame Building," FEMA–352, Federal Emergency Management Agency, Washington, D.C.

mation methodologies that have been distributed throughout the Nation and adopted by building codes and communities in virtually every state of the union. The engine that drives earthquake-resistant practices and seismic risk reduction is the research made possible by NEHRP. U.S. research and engineering practices for earthquakes are models for the rest of the world, and are emulated globally. Not only does the research supported by NEHRP protect lives and property from earthquake hazards, it distinguishes the U.S. as being at the forefront of globally important and life-saving technology. Our nation gains leverage from earthquake engineering research through worldwide improvements in safety, protection of life, and the exportation of our technology and engineering services overseas.

Evolution of NEHRP

Over the past 25 years, NEHRP agencies have developed a wide variety of products to improve significantly the practice of earthquake engineering. During this period the agencies have evolved and adopted their own roles and specific practices within NEHRP.

FEMA, which has oversight responsibility for NEHRP, has taken on the role of sponsoring the development of guidelines and standards for the seismic evaluation and rehabilitation of existing buildings and for the design of new structures. Before FEMA involvement, there was little coordinated work in this area. The effort consists of developing consensus guidelines, code provisions, and background materials, all of which have fostered significant improvements in design worldwide, encouraged the adoption of appropriate codes in earthquake-prone communities, and have allowed billions of dollars to be spent better on appropriate seismic mitigation and hardening. FEMA's role for new buildings began in 1982 when the agency assumed responsibility for developing and updating seismic code provisions, which have become the basis for all national seismic codes and standards. FEMA's role for existing buildings began with a planning workshop in 1984 that set the course for what products were needed. Over the subsequent 18 years, the work plan, twice updated, has been implemented and professional practice greatly enriched.

The NEHRP agencies in their latest Strategic Plan,[6] provide an objective look at what now needs to be accomplished to advance the state of practice to the next level. Many EERI members were participants in the development of this plan, and we endorse the balance it calls for between research and outreach activities. Unfortunately, this plan, while completed in 2000, has never been published nor implemented. Without the guidance of such a plan, integrated and effective mitigation programs are hampered. With continued FEMA support, we look forward to the implementation of strategic planning and the development of mature tools, techniques, and policies to reduce seismic vulnerability in the U.S.

One of the key policies needed to stimulate implementation involves financial incentives. Unlike other national programs, such as the National Flood Insurance Program, the current NEHRP legislation contains no explicit provision and no authorized funding for encouraging communities to mitigate the adverse effects of earthquake hazards. We believe that a more concerted effort to encourage mitigation is needed and recommend that a flexible program of incentives, tailored to the specific needs and resources of localities, be developed. EERI published a report, entitled *Incentives and Impediments to Improving the Seismic Performance of Buildings,*[7] which outlines the opportunities. We recommend that FEMA undertake a concerted study to identify incentives, both tangible and intangible, that have motivated seismic rehabilitation of existing buildings, and design an incentive program that is applicable to both local public and private buildings. To support such a study, as much as five percent of the increased funding recommended for FEMA under the forthcoming section, entitled EERI Research and Outreach Plan, could be allocated to design and implement this incentive program.

The USGS has successfully developed a procedure for translating earth science into the information needed for seismic design. This process has grown from individual efforts by USGS researchers to a collaborative program that regularly produces hazard maps for use by design professionals. They have developed a hazard mapping office in Golden, CO that works closely with various guideline and standards organizations to assure that the information is immediately useful. This collaboration has allowed the design community to assess seismic hazards on a site-

[6] NEHRP Agencies (2003), "Expanding and Using Knowledge to Reduce Earthquake Losses: The National Earthquake Hazards Reduction Program Strategic Plan 2001–2005," FEMA, NIST, NSF, and USGS, March.

[7] Earthquake Engineering Research Institute (1998), "Incentives and Impediments to Improving the Seismic Performance of Buildings," Earthquake Engineering Research Institute, Oakland, CA, June.

by-site basis with increasing detail and reliability. The information produced by USGS affects hundreds of billions of dollars of construction each year. USGS is currently building the Advanced National Seismic System (ANSS) that will modernize and expand the earthquake monitoring system in the U.S., with concentrations in urban environments and the collection of data pertaining to actual building response. If we are to arrest the growth of earthquake risk in the United States, the USGS must continue to refine our understanding of the seismic potential throughout the country so that we can better pin-point the areas that need concentrated mitigation activities. This problem is so large and expensive that we can not afford to rely solely on the current information to guide our policy decisions.

NSF research started as a program that primarily involved individual researchers in the early days of NEHRP. Although curiosity-driven, individual researcher support is still a vigorous component of the NSF plan, a significant part of its earthquake engineering research has evolved into a collaborative effort involving engineering research centers (ERCs). There are currently three earthquake ERCs and an additional center focused on the earth science aspects of earthquakes, each of which involve a large number of universities, enlist the support of industry, and engage in active outreach programs and K–12 education. The Centers are geographically distributed, with headquarters in California, Illinois, and New York. They work on problems that are both regional and national in scope, and they collaborate in areas of common expertise and interest. NSF also sponsors collaborative programs with researchers in other countries that have a significant commitment to earthquake engineering, such as Japan, Taiwan, and Turkey. NSF is currently building the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), which will consist of state-of-the-art experimental facilities distributed across the U.S. working in unison through advanced telecommunications and high performance Internet. If we are to arrest the growth of earthquake risk in the U.S., we must discover new techniques for understanding the vulnerability of structures and more cost efficient methods for reducing the vulnerabilities to acceptable levels. This requires NSF sponsored basic research, coordinated research, and development, all of which include simulation and testing with the NEES equipment sites.

As the Nation's standards agency, NIST has been the leader in the development of seismic evaluation, rehabilitation, and design standards for federally owned, leased or funded facilities. It serves as the secretariat agency of the Interagency Council for Seismic Safety in Construction (ICSSC). NIST has assisted in the development of new structural systems that have advanced the state of practice in earthquake engineering. Most recently, NIST made significant contributions to the development of a hybrid, pre-cast, reinforced concrete structural system that achieves significant construction efficiencies and cost saving without sacrificing seismic performance. This innovation, which is known as the Pre-cast Hybrid Moment Frame (PHMRF) System, has been implemented successfully in the construction of the Paramount, a 39-story apartment tower in San Francisco.

Unfortunately, NIST's work over the life of NEHRP has been constrained due to a lack of funding. The capabilities of NIST need to be expanded and leveraged to support the development of codes and standards. NIST needs to be authorized to provide the applied research that is needed to speed the translation of basic research into practice. NIST is in the process of publishing a report[8] on this "missing link" that clearly identifies the work that needs to be done.

We also recommend that the Federal Government deal immediately and in a proactive manner with its own inventory of buildings. Federal leadership, in terms of design requirements for federal buildings, rehabilitation standards and programs for existing buildings, minimum seismic standards for leased buildings and federally funded projects are a key to stimulating nationwide interest in seismic safety. We not only need the Federal Government to lead by example, we also need to protect the millions of federal employees and guests that occupy federal buildings that do not meet the governments own standards for earthquake safety.

EERI Research and Outreach Plan

EERI is a national, nonprofit technical society of engineers, geoscientists, architects, planners, public officials, and social scientists. The 2,500 members of EERI include researchers, practicing professionals, educators, government officials, and building code regulators. The objective of EERI is to reduce earthquake risk by advancing the science and practice of earthquake engineering, improving the understanding of the impact of earthquakes on the physical, social, economic, political and

[8] Applied Technology Council (2003), "The Missing Piece: An Initiative to Improve Seismic Design and Construction Practices," ATC–57, Applied Technology Council, Redwood City, CA, in press.

cultural environment, and by advocating comprehensive and realistic measures for reducing the harmful effects of earthquakes.

EERI convened a panel, representing a broad and multidisciplinary cross-section of its membership, to develop a Research and Outreach Plan.[9] The plan includes both practical and basic research, and contains an outreach component that addresses implementation, education, and technology transfer. This plan began with the careful deliberations of the panel, and has been prepared with the counsel of the NEHRP agencies. It has undergone careful and intense scrutiny by our members as well as experts outside our membership. It represents the first comprehensive, consensus document from the entire earthquake engineering community about what needs to be done from earth science, through structural engineering and architecture, to social science and public policy. This plan is currently in publication and is receiving the endorsement of most of the significant stakeholders, users, and researchers who have dedicated their careers to achieving an acceptable level of earthquake safety. As of the preparation of this testimony, the organizations endorsing the EERI Research and Outreach Plan include Applied Technology Council, California Seismic Safety Commission (CSSC), Cascadia Region Earthquake Workgroup (CREW), Central United States Earthquake Consortium (CUSEC), Consortium of Universities for Research in Earthquake Engineering (CUREE), Council of American Structural Engineers, Mid-America Earthquake Center, Multidisciplinary Center for Earthquake Engineering Research (MCEER), National Fire Protection Association, Natural Hazards Center, Oregon Department of Geology and Mineral Industries, Pacific Earthquake Engineering Research Center (PEER), Public Entity Risk Institute, Seismological Society of America (SSA), and Structural Engineers Association of California (SEAOC).

At current funding levels, we believe that it will take over 100 years to secure the Nation against unacceptable earthquake risks. Based on the recently released Research and Outreach Plan, *Securing Society Against Catastrophic Earthquake Losses,*[9] we believe that if program funding is augmented 3 times the current level, we will achieve the needed results in the next 20 years. The cost is estimated to be on average $330 million per year for the 20-year duration of the plan, which is less than one twentieth of the annual projected losses from earthquakes in the U.S.[10]

We believe that this Research and Outreach Plan provides the essential basis for seismic risk reduction by providing tools that will be easily understood, feasible, cost beneficial, and adaptable. It calls for a five-fold program, consisting of research and development pertaining to *Understanding Seismic Hazards, Assessing Earthquake Impacts, Reducing Earthquake Impacts, Enhancing Community Resilience, and Expanding Education and Public Outreach*. Detailed descriptions of topics and work are provided in the document for each program area, and interested parties should refer to it for specifics.

Figure 1 shows the recommended funding proportions during the first five years of the program. Separate categories for capital investments and information technologies are indicated in each pie chart. The recommended capital investments pertain to NEES experimental facilities, ANSS, and field instrumentation. It is assumed that the first five-year cycle of the program occurs in FY04–08. The recommended annual level of funding in the first five-year period is nearly $360 million, with a yearly $330 million average over 20 years.

[9] Earthquake Engineering Research Institute (2003), "Securing Society Against Catastrophic Earthquake Losses," Earthquake Engineering Research Institute, Oakland, CA, March.

[10] HAZUS 99, "Estimated Annualized Earthquake Losses for the United States," (2000), FEMA–366, Federal Emergency Management Agency, Washington, D.C.

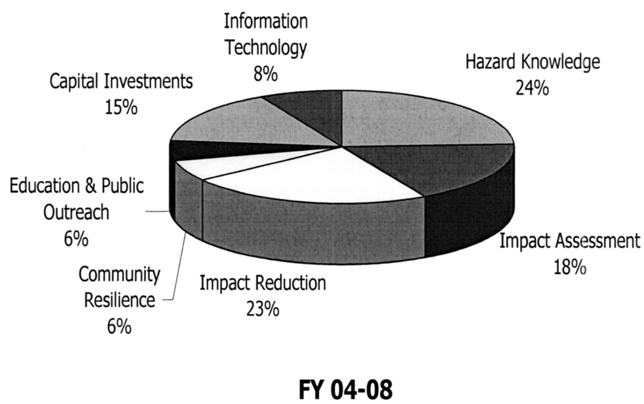

Figure 1 Recommended Funding Proportions for Program Areas, Capital Investments, and Information Technology in EERI Research and Outreach Plan

We strongly recommend that NEHRP be reauthorized at an augmented level consistent with the EERI Research and Outreach Plan. We believe that this will require the funding authorization for FEMA related to NEHRP to be increased to approximately $70 million per year, NIST to $20 million, NSF to $140 million, and USGS to $130 million.

We believe that the basic proportions illustrated in Figure 1 represent the appropriate funding allocations within the NEHRP program. As the level of overall funding increases, we will achieve the goal of reducing the effects of earthquakes at an accelerating rate. As a minimum, we firmly believe that support significantly exceeding current funding horizons is critically important for ANSS and NEES in FY04–08.

ANSS is fundamentally important for NEHRP. Advancements in earthquake understanding and earthquake engineering occur after major earthquakes. The response of the built environment to strong shaking continues to provide real time clues to what works and what doesn't. To maximize our understanding, we need to know how strong the ground is shaking, and we need to understand fully the extent of damage that has been caused. ANSS will consist of 6,000 new instruments concentrated in high-risk urban areas to monitor ground shaking and the response of buildings and structures, together with upgraded regional and national networks and data centers. ANSS will provide scientists with high quality data to understand earthquakes, engineers with information about building and site response, and emergency response personnel with near-real-time earthquake information.

Appropriations for ANSS are only proceeding at one-tenth the planned rate. Every year that we delay the deployment of ANSS we run the risk of missing the opportunity to record the shaking in a manner that will be useful to the engineering community. ANSS is the most critical new program needed by NEHRP. Putting the instrumentation in after the next earthquake will be too late.

NEES is a nationwide resource of advanced research equipment sites networked through the high performance Internet. The network is focused on improving the seismic design and performance of U.S. public and private works through advances in the technologies applied in civil, mechanical, and telecommunication systems. The network will use state-of-the-art experimental and simulation capabilities to understand the behavior of critical facilities under complex earthquake loading and to test and validate the analytical and computer models needed for effective engineering. NEES will link sites throughout the U.S. and globally to create a shared resource that benefits from open access and the contributions of leading researchers at multiple locations. Participation in NEES will involve educators, students, practitioners, public sector organizations and interested individuals, all of whom will have access to equipment, data, models, and software developed through the network. Because the network is distributed throughout the Nation, it will draw attention to earthquake vulnerability nationwide and the need for proper implementation and mitigation activities.

Support for NEES is support for our future and a significant boost for our education system. It is an effective means of promoting U.S. leadership in the engineering of critical civil and mechanical systems and in applying telecommunications to energize the development of innovative and advanced technologies that benefit each American citizen.

Information Technology and Earthquake Mitigation

Information technology (IT) enhances our ability to monitor seismic motion, predict how the ground will shake during a future earthquake, and model how structures respond. It provides the basis for rapid sensing and structural controls that will make buildings perform better during seismic excitation. It provides for remote data acquisition and interpretation coupled with rapid communication and visualization to direct emergency response. In the future, we will find that IT becomes a unifying and complementary force for decision-making that will be embedded in the most basic and fundamental units of our communities. Hence, IT has the potential to improve how communities accomplish the necessary tasks to reduce vulnerability, coordinate local with regional planning, and prevent catastrophic earthquake loss.

Securing Society Against Catastrophic Earthquake Losses[9] presents an overview of IT applications to earthquake engineering, some of which are paraphrased here to highlight opportunities for mitigating earthquake hazards. New developments in micro-electromechanical sensors for acceleration, strain, pore water pressure, and other quantities will significantly enhance our ability to collect and process large volumes of data. Digital video, infrared, ultrasound, radar and lasers provide unprecedented opportunities for damage assessment. Satellite imaging, remote sensing, and high-resolution aerial photography provide new capabilities to capture and update inventory information on the natural and built environment prior to an earthquake, and to provide near real-time damage assessments after an event. Since high-end computers will likely realize petaflop scale (10^{15} floating point operations per second) computing well before 2010, computational simulation of the ground motion in an entire region, with unprecedented accuracy in simulation of the built environment and interpretation of data collected through sensors, will soon be possible.

In the post-earthquake environment, IT is providing a more efficient way of collecting data, coordinating reconnaissance teams, monitoring reconnaissance, and analyzing and distributing data. Information technology improves our ability to capture a wide range of observations and lessons after earthquakes. Data that would otherwise have perished after earthquakes can now be collected, stored, and made accessible via IT advances.

One of the most important earthquake engineering applications of IT involves the utilization of large numbers of sensors and related large-scale data collection. Wide-area wireless networking is a key technology to link sensors to modern communication networks. NEHRP-sponsored programs are already early adopters of this technology. After the Northridge earthquake, FEMA funded an upgrading of the southern California seismic network with digital, broadband recording instruments that report on measurements in virtual real time. The upgraded network, which is known as TriNet, has proven its ability by rapidly locating the epicenters and determining the magnitudes of several significant earthquakes within minutes of their occurrence. Maps showing the distribution and severity of ground shaking, known as a "ShakeMaps," were released swiftly and accessible through the Internet. This application of IT is immensely useful to emergency management officials, and the web sites showing contours of earthquake severity have become an integral part of the decision-making process for allocating resources and organizing emergency response. Extending these concepts, a city fully instrumented with networked sensors could include tens of thousands of sensors providing the data needed for radically improving the knowledge base of earthquake response; video or other imaging systems would be used in damage assessment, emergency response, and disaster recovery.

Experience with TriNet was so successful that USGS used it as a framework for developing ANSS. As discussed previously, ANSS will expand on the regional application of advanced IT in southern California to provide nationwide coverage specifically targeted on urban areas, where much of our vital public works and critical infrastructure are located.

Another example of advanced IT development and application under NEHRP is the support that NSF provides to deploy a large-scale permanent global positioning system (GPS) geodetic array in southern California, known as the Southern California Integrated GPS Network (SCIGN). The array contains 250 stations. It uses satellite measurement data to monitor small (sub-centimeter) movements between stations, and thus determine the earth deformations that are a prelude to serious earthquakes. Using the SCIGN data, scientists and engineers can learn how strains build over time before their sudden release during an earthquake.

NSF with NEHRP support is driving a revolutionary application of IT through the creation of NEES. As discussed previously, NEES is a new major research equipment, computation, and networking initiative. The system architecture is based on grid computing that enables coordinated, flexible, and secure resource sharing and problem solving in real time among geographically dispersed facilities and users. Through its IT innovations, NEES will provide a world-renown resource for earthquake engineers to conduct advanced experiments, collect data, collaborate in improved simulations, and use all this information to improve design.

In summary, NEHRP to date has successfully harnessed IT. In many ways, NEHRP is a model for introducing IT into the public arena, where it serves as a catalyst for further public interest and incorporation in community activities. Because NEHRP involves several engineering and science-based agencies, it is able to benefit from and capitalize on the cross-fertilization of ideas and technologies of diverse researchers and practitioners. This is a great strength of NEHRP, which has contributed to cutting-edge development and application of IT to protect life and property. This type of synergy needs support, and in return leverages investments into technologies that not only reduce losses, but substantially enhance the functionality and reliability of our nation's infrastructure.

NEHRP Improvements and Policy Changes

As effective as NEHRP has been in supporting research and implementation of great value to our country, it has been subject to some significant limitations that need to be remedied if NEHRP is to achieve its full potential. *The most significant limitations affecting NEHRP are leadership and the eroding level of funding.*

A new leadership model could be of great benefit for NEHRP. We recognize that leadership is the joint responsibility of all NEHRP agencies, with FEMA taking a lead role. We understand and support the fact that NEHRP was wisely split among four separate agencies, which allows the expertise of each agency to contribute to a significant national problem. We recognize and support the need for a lead agency with the responsibility to coordinate and facilitate the program. Unfortunately, each agency is within a different department of the executive branch, with its own Office of Management and Budget (OMB) examiner and Congressional oversight committee. As a result, the coordination and cooperation among the agencies are hindered, especially when it comes to the budgeting details. Previous reauthorizing legislation has attempted to correct this problem by calling for strategic planning and an interagency coordination committee. Although these adjustments in program administration have had beneficial results, additional improvements are also needed.

We recommend that more be done to bring consistency and collaboration to NEHRP. We believe that the program should have a visible place and designated staff within each agency. We recommend that OMB assign one of the participating examiners to coordinate the budgeting within the four agencies so that the funds invested will be balanced and prioritized on a programmatic basis. We recommend that the Congressional Oversight and the Appropriations Committee also take steps to bring together the members who oversee each of the related agencies, so that they too will watch the program in its entirety and promote balance. Finally, we recommend that Congress ask the President to create an independent committee of external experts responsible for oversight of NEHRP. This oversight committee would report to Congress no less than biannually. We note that similar recommendations have been made by experts[11,12] previously convened to provide advice for NEHRP. We believe that it is time to take up the implementation of this recurrent advice and make the improvements that will enhance NEHRP productivity.

NEHRP funding has fallen approximately 40 percent in real dollars since its inception in 1978.[6] Committees convened in the past to recommend NEHRP improvements have consistently emphasized the serious erosion in capability and potential that the steady decline in real dollars has incurred.[11,12] The report of the Expert Review Committee[10] convened to guide FEMA in the development of the NEHRP Five-Year Plan for 1989–1993, stressed the importance of increased funding and recommended more than a three-fold increase in the annual budget. Recognition of the

[11] Expert Review Committee (1989) "Commentary and Recommendations of the Expert Review Committee 1987," FEMA–164, Federal Emergency Management Agency, Washington, DC, Jan.

[12] Cheney, D.W. (1989), "The National Earthquake Hazards Reduction Program," 89–473 SPR, Congressional Research Service, The Library of Congress, Washington, DC, Aug.

steady decline in fiscal support is echoed today in the EERI Research and Outreach Plan, which recommends and provides justification for a similar increase in Congressionally authorized funding. If NEHRP is to provide the seismic risk reduction required by this country in a reasonable amount of time and achieve its potential in developing advanced technologies to safeguard U.S. infrastructure, then increased fiscal support for the program needs to be authorized by Congress. *We strongly recommend that increases in funding consistent with those proposed in* Securing Society Against Catastrophic Earthquake Losses[9] *and outlined above be authorized and appropriated by Congress*. To reduce the effects of inflation, the resulting funding levels should be indexed to the Consumer Price Index, as many federal activities are, thereby protecting earthquake mitigation support against the funding erosion that has affected NEHRP since its inception.

FEMA Transfer to the Department of Homeland Security

FEMA is the designated lead agency for NEHRP. It is well qualified for this role. Of all NEHRP agencies, it has the most direct responsibility and experience with reducing losses from all natural disasters. It is focused on implementation, and has long-term collaboration and working relationships with code development organizations, professional societies, and state, local, and private sector groups responsible for reducing earthquake hazards.

The transfer of FEMA to the Department of Homeland Security (DHS) brings about significant mission, administrative, and cultural changes for the agency, for which it is too premature to make pronouncements and prognostications of effect or outcome. It is not too premature, however, to voice honest and supportive concern about such a transfer. For NEHRP to continue its mission in a productive manner and realize its potential, it needs a strong and dedicated group within DHS to provide oversight for and to administer the program. This requires a clear identity within DHS with designated staff and agency commitment to the program. NEHRP must be visible, and must be maintained as a clearly identified line item in the Congressional budget.

FEMA is a results-oriented agency with expertise in the implementation of research findings. It has management responsibility in contrast to the research responsibilities of NSF, USGS, and NIST. Steps must be taken to work across the cultural divide of management and research. We believe that an external expert oversight committee will help substantially to achieve this goal.

The transfer of FEMA to DHS provides substantial opportunities. DHS will have responsibilities for research and implementation programs to support security of U.S. home property and assets. Earthquake hazards are an integral part of this package, and have important characteristics in common with the types of extreme events that DHS has been created to control. Hence, the expertise of the earthquake engineering community under NEHRP has both immediate and ongoing value to DHS not only in seismic risk reduction, but in the protection of our communities from a variety of hazards, related to natural, accidental, and pre-meditated causes. As discussed under the next heading, the research and implementation created by NEHRP have immense beneficial effects on U.S. technology and the reliability of its civil infrastructure. Such outcomes leverage the value of NEHRP investments well beyond their very positive influence in reducing earthquake losses.

NEHRP Effects on US Technology and Preparedness

Investments in earthquake engineering through NEHRP have resulted in technical advances that apply beyond earthquakes to other hazards, civil infrastructure, applied information technology, and homeland security. A few of the many examples include passive/active building control for wind hazards, advanced geographical information systems (GIS) for lifelines and civil infrastructure management, fiber-reinforced polymers for bridge/building repair and restoration, inspection protocol for buildings applied after the World Trade Center (WTC) Disaster, seismic monitoring of nuclear tests, and social science contributions to federal emergency response plans, early warning systems, and community perception of risk.

One of the most dramatic examples of the application of earthquake engineering to extreme events occurred immediately after the World Trade Center (WTC) Disaster of September 11, 2001.[13] This attack on our urban infrastructure was unprecedented and beyond planning scenarios for serious urban accidents in terms of scale and intensity. Fortunately, procedures developed for earthquakes under FEMA

[13] Federal Emergency Management Agency (2002), “World Trade Center Building Performance Study,” FEMA–403, Federal Emergency Management Agency, Washington, DC, May.

sponsorship[14] were available and rapidly deployed to investigate and identify the condition of surrounding buildings. For years before the WTC Disaster, engineers had been responding to earthquakes that caused damage at scales comparable to and exceeding the destruction resulting from the terrorist attacks of September 11. Through NEHRP support, they had developed the tools to deploy rapidly, examine, and assess the condition of buildings in a simple, practical way that allows for decisions about structural integrity. This process was of critical importance in the aftermath of the WTC Disaster, when determination of building integrity surrounding the WTC complex was needed to protect lives and property, and to decide on reoccupancy of buildings with critical telecommunications, financial banking, and securities trading capabilities essential for the restoration of world business markets. As a result of NEHRP, the inspection procedures to initiate WTC recovery were available "off the shelf." Although an unexpected and unintended outcome of NEHRP, this example nonetheless illustrates the immense benefits that accrue from our nation's investment in earthquake protection.

In other cases, the influence of earthquake engineering investments are more subtle, though still of substantial importance. For example, research and implementation of fiber-reinforced polymers (FRPs) for the seismic retrofitting of bridges and overpasses after the 1989 Loma Prieta earthquake were a very important catalyst in proving the technology and advancing its practical application under field conditions. Now this technology is used routinely for repair and rehabilitation of buildings and bridges throughout the country to enhance normal functionality and extend facility life. The use of FRPs is extending the useful life of bridges, obviating the need to replace expensive infrastructure throughout the U.S. They also can improve the blast resistance of many existing buildings.

Another example includes the development of active and passive control to dampen or isolate building response from the effects of earthquake shaking. Active control uses sensors feeding into electrically activated devices that countermand seismic motion, whereas passive control involves the use of base isolators and resisting members to substantially reduce transient movement within structures. Active and passive control technology developed for earthquake effects has immediate benefits for similar systems to offset the effects of natural hazards like wind and hurricanes. Active and passive control systems also have potential for reducing blast effects, thereby protecting critical facilities against terrorist attacks.

In 1996, the authors of FEMA 277, *The Oklahoma City Bombing: Improving Building Performance through Multi-Hazard Mitigation,*[15] suggested that the physical damage and extent of progressive collapse inflicted on the Alfred P. Murrah Federal Building might well have been lessened if the original design had incorporated seismic detailing. Conceptually, this idea has taken root in the structural engineering industry and is currently under study by various investigators. If validated, seismic engineering and design could make a very significant contribution to the homeland security aspects of our built environment. Additional research in this area is warranted.

One of the most successful loss estimation products is the software program, HAZUS, developed through FEMA to estimate physical damage, casualties, and other societal impacts from earthquakes. HAZUS is an excellent example of how NEHRP-sponsored research converges in a single platform, readily transportable through GIS and computer technology to communities throughout the U.S. HAZUS embodies a multitude of algorithms and correlations originating from NSF- and USGS-sponsored research into a program implemented by FEMA for national use. The process and program architecture in HAZUS are adaptable to other natural hazards, and are currently being applied to floods and hurricane wind. Hence, NEHRP investments in this case have direct application for other natural hazards because, in addition to earthquakes, HAZUS will become the platform for loss estimation related to flood and hurricane wind.

NEHRP plans for the future involve a Lifelines Initiative that is required through public law, whereby FEMA, in consultation with NIST, will develop a plan for design and construction standards for lifelines. Lifelines include transportation systems, water supplies, gas and liquid fuel networks, electric power, telecommunications, and waste disposal facilities. They are the distinguishing characteristic of modern communities, and deliver the resources and services necessary for safety, security, and economic well-being.

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[14] Applied Technology Council (1989), "Procedures for Post-earthquake Safety Evaluation of Buildings," ATC–20, Applied Technology Council, San Francisco, CA.

[15] Federal Emergency Management Agency (1996), "The Oklahoma City Bombing: Improving Building Performance through Multi-Hazard Mitigation," FEMA–352, Federal Emergency Management Agency, Washington, D.C.

NEHRP has been a hotbed for innovation and IT applications in lifeline systems. Research sponsored by NSF, USGS, and NIST have resulted in sophisticated models of lifeline network performance under various damages scenarios associated with earthquakes. Much of this work has involved innovative use of GIS, probabilistic hazard analyses, network reliability procedures, advanced remote sensing and characterization of geotechnical hazards, strong motion simulation, and applications of regional economic analyses and community recovery models. The overall outcome of this activity is a rich and technically advanced framework for the simulation and evaluation of complex infrastructure systems under extreme events.

I can attest personally to the importance of this branch of NEHRP activity by reference to NSF-sponsored research on the earthquake performance of the water supply system in San Francisco.[16,17] Before the 1989 Loma Prieta earthquake, hydraulic network and system reliability analyses of the Auxiliary Water Supply System (used for fire protection) in San Francisco were preformed. They demonstrated that the water distribution pipeline network in that city would be compromised in a severe earthquake because of liquefaction-induced ground deformation and shaking effects. The City of San Francisco and the San Francisco Fire Department responded to this research by successfully petitioning for a substantial bond issue to upgrade and retrofit the Auxiliary Water Supply System. As part of the fire department response, special vehicles, known as hose tenders, were commissioned to convey nearly a mile of special hose to the waterfront and hook into the fireboat, which would pump water through the hose and portable hydrants deployed inland to locations of earthquake-generated fire. During the Loma Prieta earthquake liquefaction-induced ground deformation, as predicted, ruptured critical water distribution pipelines, leaving the Marina without pipeline water. The hose tenders were successfully deployed to the Marina and extinguished the major fire that erupted there. Without these benefits of research and implementation under NEHRP, it is likely that the fire loss from this earthquake would have been substantial, costing orders of magnitude more than the research that prevented it.

Water supply and other critical infrastructure, such as electric power, telecommunications, and transportation systems, are vulnerable to a variety of hazards related to natural, accidental, and pre-meditated causes. The research and implementation for lifelines under NEHRP have established an excellent baseline and ready resource for simulating and protecting our vital infrastructure networks. It is important that Congress consider the immense leverage from NEHRP for improvements and security of buildings, transportation systems, water supplies, gas and liquid fuel networks, electric power, telecommunications, and waste disposal facilities. NEHRP provides an enormous return on investment that substantially reduces our nation's vulnerability to earthquakes and improves the performance of its civil infrastructure.

Summary

The earthquake risk to the United States is unacceptably high. We are facing inevitable earthquakes that will cost the Nation $100 to $200 billion each, with the potential loss of thousands of lives. We believe that the growth of this risk can be arrested and reduced to an acceptable level. This requires continuous research, expanded seismic monitoring, and nationwide mitigation.

For the past 25 years, The National Earthquake Hazard Reduction Program (NEHRP) has provided resources and leadership that have lead to significant advances in understanding the sources of earthquake risk and have provided useful tools for arresting its growth. In spite of all the good work that has been done in the regions of highest seismicity, our earthquake risk is still unacceptably high because of the lack of implementation of appropriate building standards and because the cost of strengthening the existing built environment is too high. This trend will not be reversed until earthquake risks are understood by communities in all 39 vulnerable states, existing mitigation procedures are used more extensively, and new techniques are developed to better define and reduce earthquake risks.

First and foremost, we need Congress to maintain a strong and viable NEHRP. It needs to continue under the current organizational structure and proceed along the lines of the recently developed NEHRP Strategic Plan.[6] This plan outlines a

[16] O'Rourke, T.D., Ed. (1992), "The Loma Prieta, California, Earthquake of October 17, 1989—Marina District," U.S. Geological Survey Professional Paper 1551–F, U.S. Government Printing Office, Washington, DC.

[17] O'Rourke, T.D. and Pease, J.W. (1992), "Large Ground Deformations and Their Effects on Lifeline Facilities: 1989 Loma Prieta Earthquake," *Case Studies of Liquefaction and Lifeline Performance During Past Earthquakes,* NCEER–92–0002, T.D. O'Rourke and M. Hamada, Eds., National Center for Earthquake Engineering Research, Buffalo, NY, April, pp. 5-1–5-85.

course of action for the best use of existing funding and prioritizes opportunities for accelerating the program as additional funding becomes available.

At current funding levels, we believe that it will take 100 plus years to secure the Nation against unacceptable earthquake risks. Based on our recently published research and outreach plan, *Securing Society Against Catastrophic Earthquake Losses,*[8] we believe that implementing an expanded program, which includes ANSS and NEES with triple the funding, will allow the needed results to be achieved throughout U.S. communities within the next 20 to 30 years. We believe that 100 plus years is much too long to wait. *A strong NEHRP that includes proactive implementation through leadership, incentives, requirements, and new public policy needs to be maintained.*

A new leadership model is needed to enhance consistency and collaboration in NEHRP. *The program should have a visible place and designated staff within each NEHRP agency, including a strong and dedicated group in DHS. Congress should create an independent oversight committee of external experts to provide guidance on enhancing productivity and strategic orientation for NEHRP.*

The Advanced National Seismic System (ANSS), authorized by Congress in 2000, is intended to expand the current monitoring system and provide essential information. Strong motion data are critical to making the next advance in understanding how economically to arrest the growth of earthquake risk and reduce it to an acceptable level. *ANSS is the most critical new program proposed for NEHRP.* Putting the instrumentation in after the next earthquake will be too late.

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), established by NSF, will expand the state of knowledge in earthquake engineering through new methods for experimental and computational simulation. Currently many new experimental research sites are established around the country, and a system to link them into a sophisticated testing and simulation complex is being developed. Unfortunately, funds to carry out the research that will make use of this new equipment and simulation technology are not available at the needed levels. Knowledge developed through experiments and simulation methodologies provide the essential scientific knowledge base for improving codes and guidelines. Social science and education research will complement this by helping to understand and communicate better the implications and choices that must be made. *An immediate investment in NEES is needed to reduce the cost of seismic design and strengthening to affordable levels and stimulate significant mitigation activities.* NEES will also advance the use of IT nationwide, set new standards for the synchronous use of geographically distributed experimental facilities, and be a significant boost for our education system.

We recommend, above all else, that NEHRP be reauthorized with increases in the spending levels for each agency consistent with the NEHRP Strategic Plan[6] *and the EERI Research and Outreach Plan.* Funding for the EERI Plan,[8] *Securing Society Against Catastrophic Earthquake Losses,* will require $358 million per year for the first five years, with a yearly average of $330 million over the 20-year program.

Finally, it is important to recognize the immense leverage from NEHRP for improvements in the reliability and security of buildings, transportation systems, water supplies, gas and liquid fuel networks, electric power, telecommunications, and waste disposal facilities. NEHRP provides an enormous return on investment that substantially reduces our nation's vulnerability to earthquakes and, at the same time, improves the performance of its civil infrastructure for both normal operation and extreme events.

BIOGRAPHY FOR THOMAS D. O'ROURKE

Thomas R. Briggs Professor of Engineering, Civil and Environmental Engineering, Cornell University, 273 Hollister Hall, Ithaca, NY 14853–3501

Education

Ph.D., University of Illinois at Urbana-Champaign, 1975

M.S.C.E., University of Illinois at Urbana-Champaign, 1973

B.S.C.E., Cornell University, 1970

Experience

Professor O'Rourke has been a member of the teaching and research staffs at Cornell University and the University of Illinois at Urbana-Champaign. His teaching and professional practice have: covered many aspects of geotechnical engineering including foundations, earth retaining structures, slope stability, soil/structure interaction, underground construction, laboratory testing, and elements of earthquake engineering. He has authored or co-authored over 280 publications on geotechnical, underground, and earthquake engineering.

He was elected a member of the National Academy of Engineering in 1993. He was awarded the C.A. Hogentogler Award from ASTM in 1976 for his work on the field monitoring of large construction projects. In 1983 and 1988, Prof. O'Rourke received the Collingwood and Huber Research Prize, respectively, from ASCE for his studies of soil and rock mechanics applied to underground works and excavation technologies. In 1995 he received the C. Martin Duke Award from ASCE for his contributions to lifeline earthquake engineering and in 1997 he received the Stephen D. Bechtel Pipeline Engineering Award from ASCE for his contributions to the profession of pipeline engineering. In 2002 he received the Trevithick Prize from the British Institution of Civil Engineers and was designated as an NSF Distinguished Lecturer. He received the 2003 Japan Gas Association Best Paper Award and the 1996 EERI Outstanding Paper Award. In 1998, he was elected to the EERI Board of Directors and serves as President from 2003–2005. In 1998, Prof. O'Rourke received Cornell University's College of Engineering Daniel Lazar '29 Excellence in Teaching Award. In 2000 he was elected a Fellow of the American Association for the Advancement of Science and received the Distinguished Alumnus Award in Civil and Environmental Engineering from the University of Illinois. He testified before the U.S. House of Representatives Science Committee in 1999 on engineering implications of the 1999 Turkey and Taiwan earthquakes and in 2003 on the reauthorization of the National Earthquake Hazards Reduction Program. He has served on numerous earthquake reconnaissance missions, and holds a U.S. patent for innovative pipeline design.

Professor O'Rourke has developed engineering solutions for problems concerning foundation performance, ground movement effects on structures, earth retaining structures, pipelines, earthquake engineering, tunneling, and infrastructure rehabilitation, both on a research and consulting basis. He has served as chair or member of the consulting boards of several large underground construction projects, as well as the peer reviews for projects associated with highway, rapid transit, water supply, and energy distribution systems. He has assisted in the development and application of advanced polymer and composite materials for the in-situ rehabilitation of water supply and gas distribution pipelines. He has developed techniques for evaluating ground movement patterns and stability for a variety of excavation, tunneling, micro-tunneling, and mining conditions. He has developed analytical methods and siting strategies to mitigate pipeline damage during earthquakes, analyze and design high pressure pipelines, and has established full-scale testing facilities for transmission and distribution pipelines. He has developed geographical information systems and network analysis procedures for water supply systems in areas vulnerable to earthquakes and other natural disasters.

He is a member of the ASCE, ASME, ASTM, AAAS, ISSMEE, EERI, and IAEG. He is a member of the NSF Engineering Directorate Advisory Committee, and serves on the Executive Committees of the Multidisciplinary Center for Earthquake Engineering Research and the Institute for Civil Infrastructure Systems. He was chair of the U.S. National Committee on Tunneling Technology and a member of the NRC Geotechnical Board and Board on Energy and Environmental Systems. He is a past chair of the UTRC Executive Committee and both the ASCE TCLEE Executive Committee and Technical Committee on Gas and Liquid Fuel Lifelines. He is a past Chair of the ASCE Earth Retaining Structures Committee, as well as past President of the ASCE Ithaca Section, and was a member of the inter-municipal water commission in his home town.

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April 30, 2003

The Honorable Nick Smith
Chairman, Research Subcommittee
U.S. House of Representatives
Committee on Science
Suite 2320 Rayburn House Office Building
Washington, DC 20515-6301

Dear Representative Smith:

The purpose of this letter is to disclose sources of funding related to my testimony before the Subcommittee on Research of the Committee on Science at the May 8, 2003 reauthorization hearing related to the National Earthquake Hazards Reduction Program.

For the previous two years and during the current fiscal year, I have served as a Principal or Co-Principal Investigator at Cornell University on research projects funded or co-funded by the National Science Foundation (NSF). A listing of these projects and project funding levels is attached.

I am the President of the Earthquake Engineering Research Institute (EERI), which receives financial support from governmental agencies. I am compensated in this service for travel and lodging expenses only. A letter summarizing the sources and funding received by EERI from governmental agencies is attached.

Sincerely,

T.D. O'Rourke

T.D. O'Rourke
Thomas R. Briggs Professor of Engineering
Civil and Environmental Engineering

Summary of Governmental Support for Research Projects on which T.D. O'Rourke is Principal or Co-Principal Investigator, Fiscal Years: 2001, 2002, 2003*

Project	Funding Agency	NSF Cooperative Agreement Number	Fiscal Years (s)	Average Annual Amount
Earthquake Resistant Design and Remediation of Lifelines and Deep Foundations	NSF	CMS-9904921	2001 and 2002	$62,000
Rehabilitation Strategies for Lifelines: LADWP Water Systems	MCEER**	MCEER NSF Master Agreement No. EEC9701471	2001, 2002 and 2003	$128,000
Site and Foundation Remediation, and Geotechnical Issues in Acute Care Facilities	MCEER**		2001, 2002 and 2003	$15,000
Networking	MCEER**		2003	$10,000
Large Displacement Soil-Structure Interaction Facility for Lifeline Systems at Cornell University	NSF	CMS-0217366	2003	$1,050,000

***Fiscal year extends from Oct. 1 to Sept. 30. For example, fiscal year 2002 started Oct. 1, 2001 and ended Sept. 30, 2002.**
****MCEER – Multidisciplinary Center for Earthquake Engineering Research receiving supporting funds from NSF**

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE

April 30, 2003

The Honorable Sherwood Boehlert
Chairman, Science Committee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Boehlert:

Thank you for the invitation to EERI's president, Thomas O'Rourke, to testify before the U.S. House of Representatives Committee on Science, on May 8, 2003, for the hearing entitled *The National Earthquake Hazards Reduction Program: Past, Present, and Future.* In accordance with the Rules Governing Testimony, this letter serves as formal notice of the Federal funding that the Earthquake Engineering Research Institute currently receives from the NEHRP agencies.

- EMW-2001-CA-0237 M001, FEMA, NEHRP Constituency Support, 2001-2002, $520,000
- CMS-0131895, NSF, Learning from Earthquakes, 2001-2003, $1,268,204
- EMW-2002-GR-0101, FEMA, Designing for Earthquakes, 2002-2003, $125,000
- 02HQGR0093, USGS, 7th National Conference on Earthquake Engineering, 2002-2003, $20,000
- CMS-0130009, NSF, The Earthquake Research Plan, Research Needs and Opportunities for Earthquake Engineering, 2001, $100,000
- CMS-129366, CUREE/NSF, George R. Brown Jr. Network To Earthquake Engineering Simulation 'NEES' Consortium Development Project, 2001-2002, $160,000
- CMS-0217015, NSF, 7th National Conference on Earthquake Engineering, 2001-2002, $50,000
- CMS-0219482, NSF, Designing for Earthquakes, 2001-2004, $100,000
- CMS-0243665, NSF, 7th U.S. and Japan Workshop, 2002-2004, $99,990

Sincerely,

Susan K. Tubbesing
Executive Director

Cc: Board of Directors

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Chairman SMITH. Thank you, Dr. O'Rourke. Dr. Reaveley.

STATEMENT OF DR. LAWRENCE D. REAVELEY, PROFESSOR AND CHAIR, DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING, UNIVERSITY OF UTAH

Dr. REAVELEY. Chairman Smith and Members of the Subcommittee, it is with great respect that I speak to you today.

The National Earthquake Hazards Reduction Program is a program that I know well and which I have a significant experience. It is my deeply held belief that the NEHRP program is primarily responsible for most of the major advances in structural engineering that have been achieved during the last 25 years.

Research interest in blast loaded structures began to wane in the early 1970's while the 1971 San Fernando Valley earthquake sparked interest in seismic design to the poor performance of many structures. Without the knowledge gained from the NEHRP program, it would have not been possible to understand nearly as well the behavior of buildings that were recently damaged by terrorist activities. The best example of this technology transfer is that the modeling parameters that are contained in FEMA 356, "Prestandard and Commentary for the Seismic Rehabilitation of Buildings." This document contains guidance for assessing the behavior of structural components of all building types when required to resist the effects of various loading. These loading may range from service conditions to extreme loading. The methodology embodied in FEMA 356 will undoubtedly be the technical basis of future performance-based design codes, which, I believe, will address the major technical and social economic issues that are important in the earthquake study.

There also have been great advances in understanding the nature of ground motion associated with earthquakes. In the—in Salt Lake City, it was virtually impossible to gain the professional and public support for the seismic design of buildings until Lloyd Cluff and others established, through trenching studies, that the Wasatch Fault was still an active fault-producing system. These studies were completed in the mid-1970's and provided the necessary proof that a major earthquake would happen in the future. These were important benchmark studies. Out of this type of study has grown a body of knowledge that allowed for the development of new maps for the determination of how much ground shaking one might expect from an earthquake anywhere in the United States of America. These maps are now used in current building codes. The value of these maps is that they are based upon current scientific knowledge and will easily—be easily updated as new knowledge is acquired. The old seismic code maps were somewhat subjective in nature and were sometimes influenced by political pressure. This more—this most important advancement was made possible through NEHRP funding.

NEHRP funding for the FEMA "yellow book" series of publications that deal with structural engineering guidelines and standards has been critical for the process of technology transfer to the design professional community. The typical structural engineer would be completely lost without them. In fact, the process of creating these documents has clearly identified the research needs in the overall field of structural engineering.

We have much more to learn about where and how the ground will shake. How buildings and other structures respond to ground motion is still at a rudimentary stage of prediction. Soil structure interaction is not very well understood, and it is critical, because we can not close the gap between the ground shaking and the structure model without this information. This information will allow the country to be more efficient in the allocation of resources. We will have a greater knowledge as to where and with what frequency the ground will shake. We have the ability to better allocate construction dollars within a particular structure to achieve a desired outcome following an earthquake. We will be in a better position to understand which buildings might be economically rehabilitated to resist the effects of ground motion.

The fact that there is such a limited few dollars in the NEHRP budget is simply not justified from a basic economic point of view, in my opinion. The expenditure of previous funds has helped minimize the losses in the most recent domestic earthquakes. Every dollar spent on creating an earthquake-resistant structure also creates a more blast-resistant structure, or one that might be resistant to high winds. I personally had a building that I designed for earthquake that was hit by a—the only tornado we know about in Salt Lake. It was hit broadside, a 14-story building. It didn't twitch a bit. A full tornado hit it. Progressive collapse is also minimized. If dollars are limited, which I hope they are not, my opinion is that the following tasks, in order of priority, should be emphasized, but all of the programs should be kept alive, because they are important.

One, strong motion networks in regions of high-probable ground shake, ground—strong ground motion are essential to our progress. Free field data and data from instrumented buildings are absolutely necessary for the advancement of our abilities to understand the behavior of structures. Lack of this type of data and the almost negligible amount of funding to study such data is a major roadblock in advancing our understanding of the physics of the earthquake problem.

I brought with me copies of the report titled, "The Plan to Coordinate NEHRP Post-earthquake Investigations." The major NEHRP agencies cooperated in the production of this report. This report summarizes most of the issues with respect to the topic.

Two, Performance Based Engineering is an all-encompassing concept, and it should be a structure upon which all of the various elements of the program are fit together to achieve the goals and objectives of NEHRP. It must be funded.

Three, this crosses the line between governmental agencies, as Mr. Hanson spoke. I personally believe that the most overlooked factor in improving the overall performance of buildings is the lack of qualified personnel at the local government level. Plan review and inspections are critical and are not being done, even in areas of high seismic risk. Perhaps some sort of incentives could be fashioned. Since the direct losses from a major earthquake in an urban environment can be in the tens of billions or to the hundreds of billions, it seems that we are being foolish in not realizing the overall benefit of a better funded program. The United States has never, in modern times, experienced the impacts of what will occur if a real big one does strike in a major urban center. I believe that economic consequences of a major earthquake and their effects on the surviving population should drive NEHRP and be the defining parameters in setting priorities. Unless there is a significant increase in funding, it will not be possible to create a program that can meet the objectives associated with the visions set forth by Congress.

Now this turns out to be a common theme, which was not orchestrated and independently written by all of the panelists. There is a need to empower a central authority to coordinate the activities of the various agencies that expend NEHRP funds. This authority should be charged with achieving the goals and objectives set forth by Congress. There should be established a review mechanism drawing on experts with leadership and technical experience to assist in identifying and prioritizing program initiatives.

Thank you.

[The prepared statement of Dr. Reaveley follows:]

PREPARED STATEMENT OF LAWRENCE D. REAVELEY

Chairman Boehlert, and Members of the Subcommittee, it is with great respect that I speak before you today. The National Earthquake Hazards Reduction Program (NEHRP) is a program that I know well and with which I have significant experience.

Introduction

The art and science of structural engineering is constantly evolving as we gain knowledge about the performance of buildings and other structures when subjected to extreme loads. Extreme loads may come from natural phenomenon, such as wind or earthquake ground motion. Other conditions that lead to extreme loading can come from accidental or purposely induced explosive forces. Although there are some differences in the specifics of extreme loadings caused by these individual sources, the basic effect is to cause the structural elements to deform excessively and subsequently be permanently damaged or to collapse. The primary goal of a structural engineer is to make the capacity of a structure greater than the demand placed upon it by the various loads that it is anticipated to experience. The capacity is determined by the size, shape, materials, and details utilized in the construction of restructure. Different details might be utilized for different loading conditions, but in general, a structure that is designed for one extreme loading condition has most of the desired attributes that are required for others.

It has been primarily through examining or observing components of structures that have experienced extreme loads that we have advanced the technology of structural engineering. In the laboratory we are able to make precise measurements while the loading is applied. This provides the needed information for developing analytical models that allow for predicting the performance of other structures that may experience similar loads. We need more specific information of this nature. An efficient way of gaining good information is to instrument buildings that are likely to experience an extreme load. Over time, we will be able to gather needed information to develop improved computer models that will produce relatively accurate predictions for structural response and performance. This last step requires much more empirical data than currently exists.

Comments

Now, it should be asked what has this preamble to do with this hearing titled, “The Past, Present, and Future” (NEHRP).

It is my deeply held belief that the NEHRP program is primarily responsible for most of the major advances in structural engineering that have been achieved during the last 25 years. Research interest in blast loaded structures began to wane in the early 1970’s, while the 1971 San Fernando Valley earthquake sparked interest in seismic design due to the poor performance of many structures. Without the knowledge gained from the NEHRP program, it would not have been possible to understand nearly as well the behavior of the buildings that were recently damaged by terrorist activities. The best example of this is the modeling parameters that are contained in FEMA 356, "Pre-standard and Commentary for the Seismic Rehabilitation of Buildings." This document contains guidance for assessing the behavior of structural components of all building types when required to resist the effects of various loadings. These loadings may range from service conditions to extreme loadings. While developed for existing buildings, it provides guidance that may be used for the design and construction of new facilities. FEMA 356 summarizes the state of the art knowledge as of the late 1990's. It was written to be able to adapt to the increasing knowledge gained from testing and post disaster studies. It is recognized that there are many specific areas about which we have insufficient knowledge. The methodology embodied in FEMA 356 will undoubtedly be the basis of future performance-based design codes.

There also have been great advances in understanding the nature of ground motions associated with earthquakes. In Salt Lake City, it was virtually impossible to gain the professional and public support for the seismic design of buildings until Lloyd Cluff and others established, through trenching studies, that the Wasatch Fault was still an active earthquake producing fault system. These studies (USGS) were completed in the mid 1970's and provided the necessary proof that a major earthquake would happen in the future at some point in time. These were important benchmark studies. Out of this type of study, has grown a body of knowledge that allowed for the development of new maps for the determination of how much ground shaking one might expect from an earthquake anywhere in the United States of America. These maps are now used in the current building codes. The value of these maps is that they are based upon current scientific knowledge and will be easily updated as new knowledge is acquired. The old seismic code maps were somewhat subjective in nature and were sometimes influenced by political pressure. This most important advancement was made possible through NEHRP funding.

NEHRP funding for the FEMA "yellow book" series of publications that deal with structural engineering guidelines and standards has been critical for the process of technology transfer to the design professional community. The typical structural engineer would be completely lost without them. In fact, the process of creating these documents has clearly identified the research needs in the overall field of structural engineering.

There have been tremendous advancements during the past 25 years that have allowed for the development of a rational base upon which to build. Current code requirements are more firmly founded on scientific principles and are certainly more rational than previous generations of building code requirements. But, they are deficient with respect to what they might be if further development work is funded. We have much more to learn about where and how the ground will shake. How buildings and other structures respond to ground motion is still at a rudimentary stage of prediction. Soil-structure interaction is not very well understood.

Better information will allow the country to be more efficient in the allocation of resources. We will have greater knowledge as to where, and with what frequency, the ground will shake. We will have the ability to better allocate construction dollars within a particular structure to achieve a desired outcome following an earthquake. We will be in a position to better understand which buildings might be economically rehabilitated to resist the effects of ground motion. The economics of structural rehabilitation is an emerging area of study that needs much work. Rehabilitation is a serious concern in that it can be very costly, but with improved knowledge of design and construction methods it can produce buildings that are safe and that can meet various performance expectations. There are some buildings that can be rehabilitated with simple and relatively inexpensive techniques. There are others that are simply too costly to improve. We are beginning to understand this process better, but there is much to learn in this area. New materials and energy dissipation devices are making a difference in being able to economically rehabilitate structures.

It is too costly to replace all of the inadequate structures that are vulnerable to ground shaking or to other extreme loads, so it is imperative that we learn how to economically improve those structures that are a threat to life, those that are critical to the economic vitality of the country, and those that are critical to the functioning of our cities.

A Relevant New Report

A very important new report has just been produced in partnership with NIST by the Applied Technology Council (ATC). The ATC document number is 57, and it is titled "The Missing Piece: Improving Seismic Design and Construction Practices." This document deals with the subjects of this hearing and was produced by some of the leading professionals associated with the NEHRP activities. A portion of the preface to this document is as follows:

PREFACE

In 2001, the Applied Technology Council (ATC) commenced a broadly based effort to define a problem-focused knowledge development, synthesis and transfer program to improve seismic design and construction practices. Input was sought from seismic design and construction industry leaders, and a Workshop was convened in the summer of 2002 to develop the program. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is the result of an industrial collaboration. It provides a framework for creating a knowledge bridge and allows the Nation to more fully realize its NEHRP investment in practical terms—safer buildings.

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES had its genesis in the strategic planning process for the National Earthquake Hazards Reduction Program (NEHRP), which was undertaken by the Federal Emergency Management Agency (FEMA) from 1998 to 2001. In the course of that strategic planning process, representatives from the design and construction industry determined and documented, as one of their major findings, that a technology transfer gap has emerged within NEHRP, and that it limits the adaptation of basic research knowledge into practice. To resolve this problem, industry participants recommended that NEHRP agencies develop a much-expanded, problem-focused knowledge development, synthesis and transfer program that will:

1. Develop standards and guidelines that incorporate the best knowledge available in a practical way.
2. Facilitate the development of new mitigation technologies.
3. Improve the productivity of the engineering and construction industries.

Included in this report are:

- A definition of what needs to be done;
- Background information on the impetus for THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program, on how technology transfer works, and a history of the decline in engineering and construction productivity in the United States; and
- THE MISSING PIECE program plan.

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program emphasizes two subject areas, with a total of five Program Elements proposed:

- **Systematic support of the seismic code development process.**

  Program Element 1 Provide technical support for the seismic practice and code development process.

  Program Element 2 Develop the technical basis for performance-based seismic engineering by supporting problem-focused, user-directed research and development.

- **Improve seismic design and construction productivity.**

  Program Element 3 Support the development of technical resources (e.g., guidelines and manuals) to improve seismic engineering practice.

  Program Element 4 Make evaluated technology available to practicing professionals in the design and construction communities.

  Program Element 5 Develop tools to enhance the productivity, economy and effectiveness of the earthquake resistant design and construction process.

The full body of the report (ATC 57) is provided in Appendix A. The goals and objectives set forth in program elements one through five captures the vision of NEHRP.

Specific responses to the questions contained in the invitation to testify at the hearing are provided as follows:

- *Discuss how research in structural engineering has improved our ability to protect lives and property from earthquake hazards? How has the focus of NEHRP structural engineering research evolved since the inception of NEHRP?*

There have been great strides made in our ability to design and construct facilities that are earthquake resistant to earthquake ground motion. The developments over the last twenty-five years are remarkable, and can be traced to the NEHRP program. The advent of computer technology has greatly facilitated this advancement.

Structural engineering research has evolved from dealing with assumed static linear behavior to realistically confronting the problem of non-linear time dependent behavior. This requires component testing that considers structural dynamics and the full range of large displacement behavior. Computers are critical but they will not eliminate the need for the physical testing of structural components. There is a notion of that computer models can replace the need for actual physical testing, but this is not true at this time. Physical testing is necessary for the calibration and development of new simulation models.

The advent of the concept of performance-based design is a product of trying to develop standards for the seismic rehabilitation of existing buildings.

- *How would you prioritize limited federal funds among specific NEHRP research and mitigation activities (earthquake monitoring, hazard assessment, performance-based engineering, lifeline reinforcement, seismic rehabilitation, code development and adoption, education and outreach, post-earthquake response and investigation, etc.)?*

The fact that there is such a limited few dollars in the NEHRP budget its simply not justified from a basic economic point of view. The expenditure of previous funds has helped minimize the losses in the most recent domestic earthquakes. Every dollar spent on creating an earthquake resistant structure also creates a more blast resistant structure. Progressive collapse is minimized. If dollars are limited my opinion is that the following tasks in order of priority should be emphasized, but all of the programs should be kept active because they are important:

1. Strong-motion networks in regions of highly probable strong ground motion are essential to our progress. Free field data, and data from instrumented buildings are absolutely necessary for the advancement of our abilities to understand the behavior of structures. Lack of this type of data, and the almost negligible amount of funding to study such data as has been recorded, is the major roadblock in advancing our understanding of the physics of the earthquake problem. Significant expenditures are required to install and maintain the networks, and for providing a *Major Contingency Fund for post-earthquake detailed analysis* of individual buildings. Also, complete damage surveys in and around areas of intense ground shaking are greatly needed. Only then will we be able to calibrate our models of structural vulnerability. Current damage prediction models are based on opinion, not statistically viable data. Our understanding of soil/structure interaction is very primitive. We need data from instrumented buildings to be able to predict what the actual loading from earthquake ground motions will be. We have crude models that are currently being used (see Appendix B).
2. Performance Based Engineering (PBE) is an all-encompassing concept. To be able to implement the vision of mitigating the effects of a major earthquake in this country, it will take a major coordinated effort. PBE should be a structure upon which all the various elements of the program are fit together to achieve the goals and objectives of NEHRP. It must be funded.
3. I personally believe that the most overlooked factor in improving the overall performance of buildings is the lack of qualified personnel at the local government level. In most locations outside of California, there are few qualified building officials to address the seismic plan checking issue. In most jurisdictions, plan-checking fees are considered general revenue, and are not utilized to insure compliance with the building codes. Code development and adoption mean very little if the codes are not enforced. It is a sensitive issue for the Federal Government to deal with, but it is imperative that this issue be addressed. Perhaps some sort of incentive program can be devised.

- *What are the major impediments to improving the overall seismic performance of buildings, both new and existing? Is the pace and extensiveness of code development and adoption improving? Is there anything the Federal Government can do to facilitate increased adoption of seismic codes in areas of high seismic risk? Is seismic rehabilitation an economical use of earthquake mitigation funds?*

The major impediment to improving the performance of buildings lies in the lack of code enforcement at the local level. This was stated previously. The other major impediment is the lack of financial incentive to create a seismically resistant structure. Developers expect to sell a new building prior to the next earthquake, and the existing stock of vulnerable buildings cost considerably more to improve than what it takes to correctly build a new building.

The pace and format of code development has improved. FEMA has greatly influenced positive major changes in this area. The pace is adequate, but funding for code development and maintenance is critical. The process is just too demanding to be effectively done by volunteer efforts.

Seismic rehabilitation is very effective in certain situations. There are certain situations where the consequence of failure is unacceptable. Generally, it can be cost effective if accomplished within a window of opportunity that is provided as part of a remodel program that deals with an updating of architectural finishes. Federal funds might be used to provide incentives, but they cannot possibly fund the total cost of improving privately owned buildings.

- *What factors have limited the success of NEHRP, and what policy changes would you recommend to remove these limitations? How can the NEHRP participating agencies improve planning, coordination, and general administration of NEHRP to better meet the vision for the program set forth by Congress?*

The most obvious factor that has limited the success of NEHRP has been insufficient funding. There is a huge amount of beneficial research that could be accomplished over time if a continuous flow of sufficient funds were made available. These research projects exist across the range of NEHRP activities.

The most difficult task for the NEHRP program officers is setting the program priorities when there are limited funds available for competing worthy program elements. Since the direct losses from a major earthquake in an urban environment can in the tens of billions of dollars, it seems that we are being foolish in not realizing the overall benefit of a better-funded program. The United States has never experienced the impacts of what will occur if a "real big one" does strike a major urban center. It seems that the element of decision-making that is missing has to do with the economic realities of such an event. I have come to believe that major loss of life is not the defining issue. *I believe that the economic consequences of a major earthquake, and their effects on the surviving population should drive NEHRP and be the defining parameters in setting priorities*. Unless there is a significant increase in funding, it will not be possible to create a program that can meet the objectives associated with the vision set forth by Congress.

There is a need to empower a central authority to coordinate the activities of the various agencies that expend NEHRP funds. All agencies are producing valuable contributions, but an effective program requires an oversight authority to integrate the various activities. This authority should be charged with achieving the goals and objectives set forth by Congress. There should be established a review mechanism, drawing on experts with leadership and technical experience, to assist in identifying and prioritizing program initiatives.

Closing

It is my view that the USGS, NIST, NSF, and FEMA all have strong roles to play in achieving the NEHRP objectives, but there needs to be a strong central coordinating authority to manage the program. Each agency cannot operate independently. Performance-based engineering should be the structure upon which the various elements of the program are fit together to achieve the goals and objectives of NEHRP. The NEHRP program is critical to our nations future. It has been underfunded and needs to be renewed. The Nation's economic health may depend upon the successes of this program. Every structural advancement made in this program will be applicable to other hazards, be they manmade or otherwise.

Appendix A

PREFACE

In 2001, the Applied Technology Council (ATC) commenced a broadly based effort to define a problem-focused knowledge development, synthesis and transfer program to improve seismic design and construction practices. Input was sought from seismic design and construction industry leaders, and a Workshop was convened in the summer of 2002 to develop the program. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is the result of an industrial collaboration. It provides a framework for creating a knowledge bridge and allows the nation to more fully realize its NEHRP investment in practical terms––safer buildings.

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES had its genesis in the strategic planning process for the National Earthquake Hazards Reduction Program (NEHRP), which was undertaken by the Federal Emergency Management Agency (FEMA) from 1998 to 2001. In the course of that strategic planning process, representatives from the design and construction industry determined and documented, as one of their major findings, that a technology transfer gap has emerged within NERHP, and that it limits the adaptation of basic research knowledge into practice. To resolve this problem, industry participants recommended that NEHRP agencies develop a much-expanded, problem-focused knowledge development, synthesis and transfer program that will:

1. Develop standards and guidelines that incorporate the best knowledge available in a practical way.
2. Facilitate the development of new mitigation technologies.
3. Improve the productivity of the engineering and construction industries.

Included in this report are:

- A definition of what needs to be done;
- Background information on the impetus for THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program, on how technology transfer works, and a history of the decline in engineering and construction productivity in the United States; and
- THE MISSING PIECE program plan

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program emphasizes two subject areas, with a total of five Program Elements proposed:

- **Systematic support of the seismic code development process.**

Program Element 1	Provide technical support for the seismic practice and code development process.
Program Element 2	Develop the technical basis for performance-based seismic engineering by supporting problem-focused, user-directed research and development.

- **Improve seismic design and construction productivity.**

Program Element 3	Support the development of technical resources (e.g., guidelines and manuals) to improve seismic engineering practice.
Program Element 4	Make evaluated technology available to practicing professionals in the design and construction communities.

Program Element 5	Develop tools to enhance the productivity, economy and effectiveness of the earthquake resistant design and construction process.

Also included in this report are six issue papers commissioned to develop the basis for the proposed program, along with a list of project participants and other supplementary information.

ATC gratefully acknowledges the broad range of industry representatives who participated in the process. Charles C. Thiel Jr. served as the report editor and is the principal architect of the report. The project Steering Committee consisted of James E. Beavers, Lloyd Cluff, James M. Delahay, Robert D. Hanson, James Harris, Richard E. Neal, Christopher Rojahn, Paul Somerville, Charles C. Thiel, Jr., and Charles H. Thornton. The issue paper authors consisted of Edwin T. Dean, Ronald T. Eguchi, Ronald O. Hamburger, Roberto Leon and selected Steering Committee members. Workshop participants consisted of the above named individuals as well as Daniel Abrams, Gerald Brady, Joe Brewer, James Cagley, Alan Carr, Gene Corley, Ian Friedland, John Gillengerten, Melvyn Green, Gayle Johnson, H. S. Lew, Lee Marsh, Ed Matsuda, Peter McDonough, Bernadette Mosby, Chris Poland, Maurice Power, Woody Savage, Charles Scawthorn, Tom Schlafly, Paul Senseny, Daniel Shapiro, Shyam Sunder, Susan Tubbesing, and Ray Zelinski. Gail H. Shea served as Production Editor and Michelle Schwartzbach served as the Report Production Specialist.

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Christopher Rojahn
ATC Executive Director

ATC-57

The Missing Piece: Improving Seismic Design and Construction Practices

by

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2003

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1 THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES

When the National Earthquake Hazards Reduction Program (NEHRP) was established in 1976, our knowledge of when and where earthquakes occurred and how to engineer structures to provide a life-safe environment was limited. It was limited by our scientific understanding of earthquake physics and hazards, the nature of earthquake forces on structures, and of how engineering materials and systems respond. Twenty-five years later, the base of earth sciences and engineering knowledge has been expanded significantly through NEHRP efforts. In the summer of 2002, thirty-seven national leaders in earthquake engineering design, practice, regulation, and construction fields met to assess the state of knowledge and practice. Their assessment was guarded as to whether full advantage was being made of this increased knowledge. The consensus of these recognized leaders was that the gap between engineering and scientific knowledge and its practical application (for design and construction of economical, earthquake-safe structures) has dramatically widened because so much more is now known. As a result, the amount known and developed during the last 25 years of NEHRP exceeds the knowledge put into practice. While there have been notable successes, e.g., the FEMA-sponsored SAC[1] effort to develop guidelines for the seismic design, evaluation, upgrade, and repair of welded steel moment frame buildings, such achievements have been sporadic and generally narrowly focused. The informational link between theory, research results, and practice is weaker than it should be. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES proposes to correct this weak link in the chain and thereby improve seismic safety.

The engineering professions recognize this weakness and seek its correction. THE MISSING PIECE program is intended to be a giant step towards (1) achieving a safer and acceptably functional earthquake structural environment through bringing the latest technical research and results to practicing engineers and (2) improving the productivity of the seismic design and construction community. The goal is to realize—in real life and in real buildings—the potential of the significant investment the nation has made in the past 25 years. We are at the juncture where the knowledge base has been sufficiently expanded that we can now reap the rewards in improved practice—achieve better earthquake safety, adequate post-earthquake functioning, and more economy in construction. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES establishes a framework through which the practicing engineering professions can form a permanent link with the information and research resources of the federal government and universities and colleges, so that what is known can be put into practice.

1.1 WHAT IS TO BE DONE

The goal of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is development of more efficient, effective, and technically reliable practice for earthquake engineering design and construction. Two subject areas with a total of five Program Elements are proposed:

- ***Systematic support of the seismic code development process.***

Program Element 1	Provide technical support for the seismic practice and code development process.
Program Element 2	Develop the technical basis for performance-based seismic engineering by supporting problem-focused, user-directed research and development.

[1] SAC is a joint venture partnership of the Structural Engineers Association of California, the Applied Technology Council, and Coalition of Universities for Research in Earthquake Engineering

- ***Improve seismic design and construction productivity.***

Program Element 3	Support the development of technical resources (e.g., guidelines and manuals) to improve seismic engineering practice.
Program Element 4	Make evaluated technology available to practicing professionals in the design and construction communities.
Program Element 5	Develop tools to enhance the productivity, economy and effectiveness of the earthquake resistant design and construction process.

The purpose of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is simply to make the above Program Elements full partners in the NEHRP program and provide a framework to bridge the research-practice gap so that the earthquake safety goals set by NEHRP legislation can be achieved.

The actions recommended in THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES are necessary if the National Earthquake Hazards Reduction Program is to be as successful in reducing the national vulnerability to earthquake-caused death and destruction as it could be. This is the last major element of the NERHP program needed to respond to the lofty goals set by Congress in 1976. Without THE MISSING PIECE effort, it will take too long to achieve the results we need—that is, improved seismic design and construction practices.

IT IS TIME TO ACT!

2 BACKGROUND

2.1 NEHRP AND THE NATIONAL EARTHQUAKE RISK

At the center of the National Earthquake Hazards Program (NEHRP) is the Congressional Goal to reduce the lives lost in earthquakes and their impact on the U.S. economy. Earthquakes represent an enormous threat to the nation (Figure 1). Significant earthquakes have occurred since the nation's founding in every area of the United States—Northeast, Southeast, Southwest, Midwest, Mountain, Northwest, Alaska—and the Caribbean, and Pacific Islands. When these faults slip again, and they will with certainty someday, death and destruction will be all the greater in this era of significantly greater population and increased building density and value. Not only will more lives and structures be lost, but, depending on the location of the earthquake, entire regions and the whole nation could be affected economically. To differing degrees, portions of most regions of the United States face the risk of a catastrophic earthquake and the entire country bears the economic burden when one occurs. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES seeks to enhance the likelihood that those damages are mitigated.

Although damaging earthquakes occur infrequently at any location, their consequences can be staggering. As recent earthquakes around the world have demonstrated, high population densities and development pressures, particularly in urban areas, are increasing the exposure and vulnerability of people, buildings, and the economy. Unacceptably high life loss and enormous economic consequences are associated with recent global earthquakes (1999 Koaceli Turkey, 1999 Chi Chi Taiwan, and 2001 Bhuj India earthquakes caused 17,000, 2,400 and 20,000 deaths respectively and economic losses of $5, $14 and $6 billion). It is only a matter of time before the United States faces a similar experience with economic losses significantly larger than we have ever experienced. The 1989 Loma Prieta and 1994 Northridge, California earthquakes are harbingers of much greater U.S. earthquake-caused catastrophes yet to happen. Imagine what the results would be if one of these earthquakes was centered under a major population center instead of in an outlying area, as was the case for both of these events.

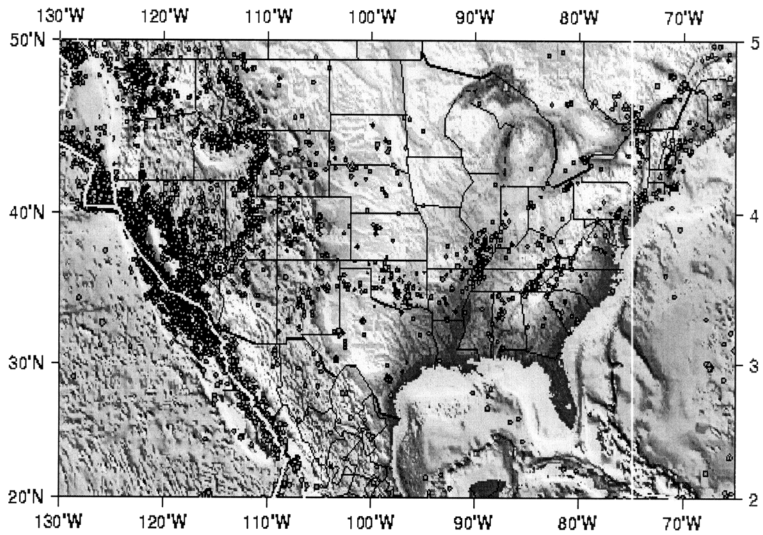

Figure 1. Seismicity of the conterminous United States (source: USGS).

Earthquakes cannot be prevented, but their impacts can be managed to a large degree so that loss to life and property can be reduced. To this end, NEHRP 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. NEHRP is authorized and funded by Congress and is managed as a collaborative effort among the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the United States Geological Survey (USGS). These four Federal organizations work in close coordination to improve the Nation's understanding of earthquake hazards and to mitigate earthquake effects. The programs of the USGS in monitoring earthquakes, assessing seismic hazards, and basic earth science research, NSF in advancing fundamental knowledge in earthquake engineering, earth sciences processes, and societal preparedness and response, NIST in evaluating advanced technologies and developing measurement and prediction tools, and FEMA's efforts with states, local governments, and the private sector to develop tools and improve hazard mitigation policies and practices—all will achieve greater effectiveness, earthquake safety, and reduce losses when put to their fullest use and application in the engineering design office.

These programs have been ongoing for over 25 years and have budgetary levels of approximately $100 million per year, but the weak link has always been putting this storehouse of information out to practitioners, where it will ultimately do the most good. This deficiency is widely recognized by the design community and others, including those involved in the most recent NEHRP Strategic Planning process, which was conducted from 1998-2001 under the leadership of FEMA. Among the major findings of that strategic planning effort, currently in draft stage, are that (1) a technology transfer gap has emerged that limits the adaptation of basic research knowledge into practice, and (2) this gap is expected to widen as NEHRP embarks on the development of a new generation of performance-based seismic design provisions and guidelines for buildings and lifeline systems, including bridges, ports, airports, and utility lifeline systems for the distribution of power and water. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES will change all that. It will provide a permanent framework for putting theory and research results into general engineering and construction practice.

2.2 DECLINE IN CONSTRUCTION PRODUCTIVITY

The productivity of the construction industry (as measured by constant contract dollars per hourly work hour) has gradually declined (with some exceptions) over the past 35 years (Figure 2). The United States led worldwide construction productivity as late as 1970, but in the ensuing decades, it has been steadily declining and has been consistently down in the past nine years. This is alarming when compared to the *increasing* labor productivity in all other non-farm industries, which have enjoyed an increasing productivity of 1.77% per year over the same time period. The spread between these two productivity indices became even more pronounced during the 1990s, confirming that the seismic design and construction communities seriously lag other industries in productivity.

Figure 2 shows that the design/construction industry productivity seriously lags other industries and suggests that there are significant opportunities to improve the quality and efficiency of facility design and construction practices. Studies from the U.S. Department of Commerce show that productivity in the United States construction industry has fallen when compared to other

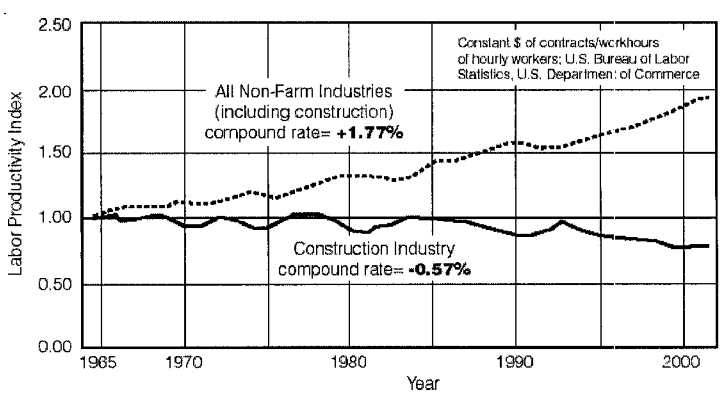

Figure 2. Labor productivity index for U.S. construction industry and all non-farm industries from 1964 through 2001.

industrialized countries. Construction industry executives blame their lack of improving efficiency on the fragmented nature of the industry. This fragmentation is present, but other industries face the same challenges and have increased their efficiency and productivity.

Despite the fact that there has been a significant adoption of new information technology (IT) by the construction industry over the past 35 years, these applications tend to run in a *stand-alone* mode that does not permit improved collaboration by the project design and construction team. For example, each designer uses a separate computer-aided design (CAD) or computer-aided engineering system, and computerized project management is independent of cost control, which is independent of project changes to the drawings and specifications. Thus, while computers now generate much information, they ultimately produce a paper output, which then must be manually reviewed so that relevant data can be entered into another program (for example, CAD drawings are plotted so that estimators can use them for making a cost estimate). This fragmentation causes increased effort and time and has greatly reduced the ability of the project team to respond quickly and effectively to changes in scope, site conditions, and other parameters—not to mention change orders. Thus, despite the widespread use of IT, it has not resulted in better overall productivity performance.

The building industry is characterized by a large number of small clients, vendors, suppliers, designers, and contractors who are often not in a position to provide leadership for the adoption of new technology and practice. In other industry segments, such as process and power, this is not the case and there has been more rapid change and a significant increase in the productivity of both design and construction. For example the capital cost per kilowatt-hour of output from a power plant has steadily declined over the past decade. The opposite is true in commercial construction.

This inability to communicate effectively has created tremendous waste and inefficiency, estimated at up to 30% of the total cost of a building project. In the United States this amounts to $240 billion of annual savings, or 3.9% of the U.S. gross domestic product. Additional large potential savings are directly linked to the lack of effective communications, coordination, and data sharing in building operations. For example, in the United States commercial building stock uses energy valued at approximately $100 billion per year. Field data show that exceptional buildings designed by skilled designers using appropriate systems and products can reduce energy use by 50%. These potential savings are not captured due to numerous factors, many of which are connected to IT problems and the lack of effective data exchange, including coordination between architectural and engineering teams and communication of design intent to facility operations. If the lack of effective interoperability accounts for only 20% of this total in energy use, the savings opportunity is $10 billion/year. The same holds for design inefficiency costs that cause construction to accommodate gravity and lateral loadings of structures, particularly extreme loads, e.g., those due to earthquakes.

Providing adequate seismic life safety requires structural systems that are strong and durable, and their cost increases with the degree of threat. The Midwest, Southeast and Northeast all have experienced significant damaging earthquakes in the past, and are now known to be at sufficient seismic hazard to warrant specific earthquake-resistant design. A major impediment in these regions to implementing life-safety seismic design is the incremental cost over conventional non-seismic design. Increases in building costs of up to 5% for seismic design compared to non-seismic design are not unexpected. Such increases have a major impact on attitudes and on the likelihood of implementing seismic safety practices in regions where the perception of the seismic hazard is low. In the West, seismic design coefficients have increased 50% or more from what they were 25 years ago, and the requirements for material detailing have become more restrictive. The net impact of these changes is the perception that the cost of seismic design has increased, notwithstanding that good design to the new requirements can cost less than mediocre design to the older requirements.

2.3 Inter-Organizational Design Process

Design and construction of buildings is a technically demanding and competitive endeavor, with significant cost and schedule constraints. Practices are dominated by small organizations; there are no major or dominant organizations in any aspect of practice. The process of design is one that merges science and art with a professional's judgment. A project typically proceeds through several distinct steps:

Planning

- Goal and program determination, project conceptualization
- Financing

Design

- Schematic determination of the form of the structure and its geometric form, structural system, and structural materials to be used
- Design of the structure
- Production of construction documents, including plans and specifications
- Permit application and review

Construction

- Shop drawings
- Construction, including design modifications and alterations, observation, inspection, and materials testing
- Job completion
- Leasing and operation

The design team consists of architects, engineers (geotechnical, structural, mechanical, electrical, and plumbing), contractors, materials suppliers, and specialty consultants on many specific issues. All of these groups have specific areas of responsibility that merge in the completed structure, under the ultimate direction of the owners or their representatives. The design and development team is, in modern management sciences terminology a *virtual corporation*, in that for each project, a large number of organizations team together to realize a project and disband when it is completed.

The process of design is often sequential, with the architect setting the configuration and massing of the structure, the geotechnical engineer setting the foundation conditions, the structural engineer arraying the structural elements and materials, the mechanical, and the electrical and plumbing engineers providing the schematic design of the utility services of the building. In some cases, particularly mechanical and electrical systems, and often for cladding and roof truss systems, the actual design is completed by a specialty contractor as part of a design/build effort during construction. At each of these design steps, plans will be altered based on the architect/owner/developer's vision of the resulting project. One of the challenges to the design team is to efficiently accommodate the needs of others in the preparation of its plans. Too often, the process of integration is an afterthought. The opportunities for improved efficiency and economy are potentially large.

It is instructive to examine how other industries have progressed. In the 1970s, General Dynamics Electric Boat division was designing and manufacturing nuclear submarine structures using state of the art CAD/CAM (Computer Aided Design/Computer Aided Manufacturing). Engineers sitting at CAD stations performing analytical calculations, detailing, design and drafting were immediately linked to machine tools cutting out sections of the submarine. Twenty years ago submarine construction at General Dynamics was paperless.

While the automotive, shipping, and aircraft industries, as well as electronic manufacturers have continued over the last 25 years to significantly increase their productivity through the use of computers, business-to-business internet, and interoperability, the construction industry has lagged far behind, with an actual decline in productivity averaging almost 2% per year for the last 30 years. Construction industry executives blame their lack of improving efficiency on the fragmented nature of the industry. While this fragmentation is present, it is not a reason, it is an excuse.

2.4 TECHNOLOGY TRANSFER

Improvements in seismic design and construction will depend on increasing the use of both existing information and new knowledge developed from research and experience. It is clear that simply publishing the results of research, and depending on the end user to find and interpret it is not a particularly effective method of getting information to those who need it.

A key Program Element of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is effective technology transfer. In order to truly change the way structures are built so that they can better withstand earthquakes, the knowledge gained from earthquakes and through research must be placed in the hands of the practitioners who are actually designing them. In this way, future losses of life and property can be avoided through improving the design process. The mechanisms of this technology transfer must consider the participants in the process and be structured in a way that best fits that group and also takes into consideration the industry's needs. An effective approach to technology transfer is to place the potential user in a prominent position. Under THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program, potential users will have primary input to both identification of needs and to the evaluation of effectiveness of the actions taken.

Research suggests that the most effective approaches to increase use of technical innovations and change are those that focus on involvement of the non-researcher (that is, those whose actions are to be influenced, or individuals representative of those groups). These influential individuals include decisionmakers, consultants, and advisors who are viewed within their communities as leaders. Means of involvement include workshops, prototype studies, priority-setting exercises, advisory groups and any other approach that exposes them to the problem, approaches to resolution and the details of problem resolution. Experience is the key to affecting their future actions. Successful utilization depends both on the careful selection of individuals to participate and on constant rotation, bringing new individuals into the process.

Four groups in United States society play key roles in shaping, promoting, and implementing the use and development of technology in the engineering design and construction professions:

- **Private sector.** The private sector is comprised of the owners, designers, consultants, builders and occupants/users. The underlying fabric of the private sector is economic. The private sector garners many economic benefits through the implementation of new technologies.
- **Academia.** Academia consists of the universities, colleges, and individual researchers who educate, and develop new knowledge, through science and applied research.

Academic research is fundamental to shaping new technology and fulfilling academia's roles as educators and a depository of knowledge.

- **Government.** Government, primarily at the state and federal levels, plays both a regulatory role in standardizing and codifying technology as well as advancing science and technology to protect the public welfare. Government has the financial resources and mandate to fund basic and applied research, mitigate the hazards posed by earthquakes, and provide emergency response after earthquakes. Local governments also take on the role of regulators, but in the form of the local community building officials who must enforce the building code requirements that often develop from the new technology.
- **Collaborative organizations.** Collaborative organizations are the professional and technical societies, trade groups, and not-for-profit organizations that work as consensus networks in advancing technological development. Collaborative organizations provide the vehicle for the effective synthesis and distribution of technology from research into practice—technology transfer.

Individually, each group fosters different incentives for advancing seismic engineering technology. Collectively, all of these groups and society at large will benefit through technological advancements.

Each of these groups plays a role and shares in the responsibility for advancing the progress of technical innovation. The challenge of moving technical innovation in seismic engineering into mainstream professional engineering practice requires the focused effort of all of these groups. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES proposes a coordinated, goal-oriented, cooperative technology transfer effort as an integral part of every action.

Technology transfer is accomplished where specific needs or limitations in current technology are identified and the best resources are targeted to be brought to the challenge of bringing applicable research into practice to address these needs. The technology transfer process is continuous and dynamic, and THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES will provide a permanent structure and framework for accomplishing this and for adjusting to ongoing changes in priorities, earthquake events, and funding availability. Resources are drawn from the four groups that play the most significant roles in shaping the development of technology. From these resources, researchers and practitioners are drawn together to meld the latest research into practical application in a consensus process under a collaborative organization assisted, advanced, and funded by the government.

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is a problem-focused program, and promotes a technology transfer agenda as an integral focus within all of it activities. The advances of the past 25 years have shown that basic research does not always provide the information needed to fully support the development of all the new technologies that could be directly utilized in improving general engineering practice. To this end, a technology transfer master plan will need to be established as an integral part of THE MISSING PIECE. The program will succeed only if the needed technology is transferred to the general practice of seismic engineering. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES proposes to do just that.

3 PROGRAM PROPOSAL—THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES

The goal of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is development of more efficient, effective, and technically reliable practice for earthquake engineering design and construction. As indicated at the outset of this document, two subject areas with a total of five Program Elements are proposed:

- ***Systematic support of the seismic code development process.***

Program Element 1	Provide technical support for the seismic practice and code development process.
Program Element 2	Develop the technical basis for performance-based seismic engineering by supporting problem-focused, user-directed research and development.

- ***Improve seismic design and construction productivity.***

Program Element 3	Support the development of technical resources (e.g., guidelines and manuals) to improve seismic engineering practice.
Program Element 4	Make evaluated technology available to practicing professionals in the design and construction communities.
Program Element 5	Develop tools to enhance the productivity, economy and effectiveness of the earthquake resistant design and construction process.

These action areas were determined through a workshop of 37 leading earthquake engineers, regulators, and contractors in the summer of 2002. The Workshop meet for two days in San Francisco to assess the state-of-the-art and state-of-practice in earthquake resistant design, regulation, and construction. Six background papers were commissioned and distributed to the participants to form the basis for Workshop deliberations. The topics and authors of the papers were selected by a Steering Committee through several preparatory meetings and discussions. The six background papers are:

1. *Productivity Tools* by Charles C. Thiel Jr. and Charles H. Thornton
2. *Systematic Technical Support for the Seismic Code Development Process* by James R. Harris and Charles C. Thiel Jr.
3. *Problem-Focused Study in Performance-Based Seismic Engineering* by Ronald O. Hamburger and Roberto T. Leon
4. *Development of Technical Resources and Associated Problem-Focused Research for Improved Seismic Engineering Practice* by Christopher Rojahn and Ronald T. Eguchi
5. *Technology Transfer Mechanisms and Programs* by Edwin T. Dean and James M. Delahay
6. *Program Management* by Robert D. Hanson and James E. Beavers

The six commissioned papers are reproduced, as revised, in Appendices 1 through 6. These papers formed the basis for Workshop discussions and were a resource for the drafting of this main report. The Program Elements proposed in this report are distinct from these papers, but derived significant value from the thoughts and opinions expressed therein. Also at the end of this report, in Appendix 7, are brief resumes of the principal individuals involved in formulating the recommendations herein. These resumes are provided as background to better understand the breadth and perspective of the project participants.

3.1 SYSTEMATIC SUPPORT OF THE SEISMIC CODE DEVELOPMENT PROCESS

3.1.1 Background

Public safety, as embodied in the police power of a government, is not a power that the U.S. Constitution enumerates for the federal government. Rather, this power is reserved to the individual states, which in turn delegate it to local governments. Locally enacted laws governing building construction have traditionally been called "building codes," and there are thousands of such codes in the United States. In the past half century, there has been a move toward states reclaiming their authority with statewide building regulations. In some states, these statewide requirements encompass most forms of construction, while in others it is of limited scope, for example, covering schools or for manufactured housing only.

Preparation and maintenance of a building code requires substantial creative and collaborative effort. Few local governments can, in fact, devote such resources to this process. Furthermore, the interests of interstate commerce advocate a commonality among building codes. Therefore, model building codes have become popular in the United States. A local or state government can adopt a model code with amendments appropriate for local conditions. This has currently evolved to two model codes of nationwide scope: one promulgated by associations of building regulatory officials, and one promulgated by an association of individuals interested in fire safety.

Most of the technical provisions in model codes are not actually written by the developers of the model codes. A large number of voluntary national and international consensus standards and guidelines exist that are developed and maintained by organizations interested in a particular technical sphere. Model codes incorporate many technical provisions from such volunteer-developed standards, and in many other cases they simply cite accredited standards by reference. Accredited voluntary national/international standards are documents developed by groups with scopes of (at least) nationwide interest and with procedures that ensure general agreement on the technical contents of the standard. With respect to earthquake engineering, there are several standards of interest. A very short list includes:

1. ASCE 7 *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers
2. ACI 318 *Building Code Requirements for Structural Concrete*, American Concrete Institute
3. AISC LRFD/ASD *Design Specifications for Steel Buildings* and its supplement, *Seismic Provisions for Structural Steel Buildings*, American Institute of Steel Construction
4. AF&PA/ASCE 16 LRFD *Engineered Wood Construction* and its Allowable Stress Design companion *National Design Specification for Wood Construction*, American Forest and Paper Association and ASCE
5. TMS 401/ACI 530/ASCE 5 *Building Code Requirements for Masonry Structures*, The Masonry Society, with ACI and ASCE

A particularly important guidance document for earthquake engineering has been *Recommended Lateral Force Requirements and Commentary*, the SEAOC "Blue Book," (Structural Engineers Association of California). Similarly, the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, produced by the Building Seismic Safety

Council with partial NEHRP/FEMA support, has played a significant role in the development of seismic provisions in model codes and standards.

The volunteer-supported model code development process has been aided by FEMA's support to prepare the NEHRP *Recommended Provisions for Seismic Regulation of New Buildings and Other Structures* and its efforts in specific areas such as wood framed housing and seismic rehabilitation of existing buildings (e.g., preparation of the FEMA 273 *Guidelines for the Seismic Rehabilitation of Buildings*). These efforts have addressed large, pressing needs, but have not generally involved basic, practical research that would form the basis of individual technical decisions, or provide a basis for advancing the structure of the code.

There are two pressing needs if the effectiveness of this process is to be improved, as it must be to achieve the NEHRP goals:

- Provide specific technical support to the committees that develop model codes and the documents upon which the model codes depend. This support is needed to address in a timely manner critical, highly specific technical issues and problems encountered in the code development process. This will foster development of more effective, efficient, and technically reliable design regulations. The result will be safer buildings that are more functional following an earthquake and fewer lives lost in an earthquake.
- Support problem-focused studies in performance-based seismic engineering that can form the technical basis of future code development. Current codes are specification based, that is, specific prescribed and proscribed steps to be followed and verified. The goal of performance-based design is to focus on structural performance and provide means to evaluate whether a design objectively meets these performance objectives.

The building code development and publication cycle is a regular process in which the provisions are considered and revised to reflect changes in understanding and knowledge. Typically, the cycle is that a new edition is published every three years. Figure 3 shows how this process proceeds and its ongoing, regenerative process. The current edition is evaluated, and over a period of two years or so, revisions are suggested, balloted for approval, and ultimately considered by the code-writing body for acceptance. Following publication of the new code communities at interest consider its recommendations and modify their code (as/if appropriate) in the next few years—usually not less than one, and on average, about three years.

The work of the code development process is voluntarily performed, with members and their organizations contributing the effort, generally with no compensation for time or expenses. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES proposes to support the code development practice by:

- Short-term practical or research projects intended to directly support making sound technical decisions for the current revision cycle.
- Long-term projects or research intended to supply technical answers for future code revision cycles.

These recommended activities are described below in Program Elements 1 and 2, and discussed in more detail in Appendix 2, "Systematic Technical Support for the Seismic Code Development Process" and in Appendix 3, "Problem-Focused Study in Performance-Based Seismic Engineering."

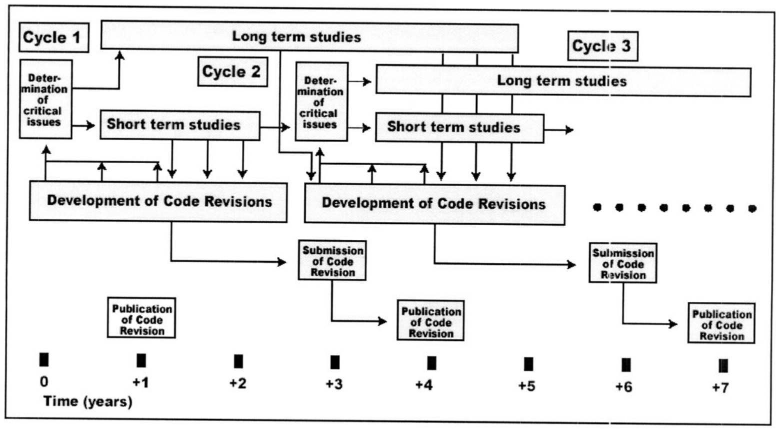

Figure 3. The code development cycle showing where the short-term and long-term projects fit into the development process. Short- and long-term projects are currently either not performed, completed at a rudimentary level, or completed by those with vested interests that may not be consistent with the community's best interests. Each code publication cycle starts anew about one year after publication of the previous code.

3.1.2 Program Element 1: Technical Support for Seismic Practice and Code Development

The objective of this Program Element is to support short-term practical, applied research projects to better realize the goals of NEHRP in improved seismic design practice and code development. The objective is not to restructure existing standards development processes. Program Element 1 will be accomplished by systematically identifying needs and resources, then prioritizing, designing, conducting, vetting, and communicating the results of the studies intended to answer the needs.

A short list of current research and development needs is identified in Appendix 2, "Systematic Technical Support for the Seismic Code Development Process." Examples from the larger list of Appendix 2 are:

- Examination of the consequences no longer restricting particular structural systems in high hazard areas, particularly in light of modern interpretations of favored systems that conflict with older interpretations.
- A rational method of accounting for geometric instability in a linear static analysis where the real behavior is dynamic and nonlinear (the P-delta problem).
- Methods to identify circumstances in which the torsional response of structures is significant, and how best to account for such response in linear analyses.

- Methods to approximate nonlinear response when designing by with a linear analysis (the R factor problem).
- Simple methods for predicting the nonlinear dynamic response of components supported by structures.
- The need for and utility of quantitative design provisions to account for the redundancy in a structural system, specifically focusing on the effect of such provisions on the reliability of performance (the rho factor problem).
- The reliability implications of the present methods for linear analysis and design that incorporate load and resistance factors calibrated for gravity and wind loads.

3.1.3 Program Element 2: Problem-Focused Research to Support Development of Performance-Based Seismic Design Concepts and Guidelines

The objective of this Program Element is to support longer-term projects that focus specifically on performance-based seismic engineering and its application in the next generation of seismic codes. Performance-based seismic engineering (PBSE) is an area of engineering practice that is rapidly developing, and which will have wide application to the evaluation and upgrade (rehabilitation and retrofit) of existing structures and the design and construction of new structures. Described broadly, performance-based seismic engineering envisions a related series of technologies, that:

- Enable the development of structures that will provide predictable and desirable performance in future earthquakes.

From this perspective, performance-based seismic engineering may be thought of as closely related to performance-based engineering for other hazards including, for example, fire and blast.

FEMA has recently initiated a major effort to develop performance-based seismic design guidelines for buildings. The effort is broadly based and will produce next-generation guidance on a broad range of issues pertaining to the performance of structural components, the performance of nonstructural components, and risk management strategies. Ultimately, this guidance will be converted into provisions that can be incorporated directly into the NEHRP *Recommended Provisions for Seismic Regulation of New Buildings and Other Structures* and the FEMA 273 *Guidelines for the Seismic Rehabilitation of Buildings*, or the FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*. FEMA is also supporting the American Lifelines Alliance project to develop guidance addressing earthquake and other hazards for lifelines (utilities an transportation systems). This Program Element is intended to support the FEMA effort by conducting needed problem-focused research studies to advance performance-based engineering concepts and criteria. Work on Program Element 2 would be coordinated so as to complement, and not duplicate, research on similar topics being carried out in association with Network for Earthquake Engineering Simulation (NEES) and other NSF programs, and to take advantage of the earthquake data collection system, particularly in buildings and other structures, carried out under the USGS-supported Advanced National Seismic System (ANSS).

The primary emphasis of Program Element 2 is to support incorporation of performance-based design concepts into the guidance documents and standards developed by the standards and practice development community. The focus of activity is expected to include all types of structures, not just buildings. Program Element 2 would include development of:

- Standard measures of performance
- Systems for qualifying the performance capability of construction components

- Tools for predicting performance
- Performance translation tools for experimental data
- Construction systems capable of providing desired performance
- Sensors, including their calibration
- Systems for monitoring performance
- Appropriate simulation and experimentation projects

Additional information about the FEMA program and detailed recommendations on needed studies is provided in Appendix 3, "Problem-Focused Study in Performance-Based Seismic Engineering" and in Appendix 4, "Development of Technical Resources and Associated Problem-Focused Research for Improved Seismic Engineering Practice."

3.2 IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRODUCTIVITY

3.2.1 Background

The productivity and effectiveness of the interaction between the seismic design and construction communities is affected by a variety of factors. These include (1) the makeup of the engineering design and construction industry, which consists of a large number of small clients, vendors, designers and contractors; (2) the complexity and wide variety of construction types, including buildings of varying height, size, and construction materials, and a wide range of transportation and utility infrastructure facilities; (3) the availability of modern tools to improve efficiency; and (4) the availability of new technology and information for reducing the effects of earthquakes on the built environment. Given the decline in productivity of the United States design and construction industry over the last decade and the widening gap between NEHRP-developed engineering knowledge and its application, THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES encompasses both a major technology transfer effort and a major effort to improve productivity of the design and construction industry.

THE MISSING PIECE program responds directly to conclusions of the recent NEHRP *Strategic Plan*, which recommends (1) a "much-expanded problem-focused research and guidelines development program to develop future design, construction, evaluation, and upgrade guidelines and standards of practice, and to facilitate the development of new mitigation technologies," and (2) that NIST, in partnership with FEMA, USGS, and NSF, should develop a coordinated NEHRP plan to support an expanded level of problem-focused applied research and development.

THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is intended to address the following needs:

- Provide technical resources, such as tutorials, primers, code commentaries, guidelines, and design manuals that reflect new knowledge and standards of practice. These resources are needed for a wide range of existing prevalent structure types and elements, including buildings and lifelines systems and their structural and nonstructural components. In many instances, the development of such resources will require problem-focused research studies to advance the basis for understanding new methods of practice.
- Evaluate and synthesize available seismic hazard mitigation information and technology, including the wealth of NEHRP-funded research results that have become available over the last 25 years. In some cases, initial results must be updated and revised. Everything should be made available in a format that can be used by practicing professionals in the design and construction communities.

- Reduce inefficiencies in design and construction practice by integrating and advancing existing computer systems and tools used by the various segments of the design and construction industry. There is a clear need to reduce inefficiencies and duplication of effort in document and record keeping, to make more efficient the development and transfer of drawings, and to develop standardized component definitions and details.

Recommended activities to fill these needs are encompassed in Program Elements 3, 4, and 5. Program Elements 3 and 4 involve significant technology transfer activities. Therefore, it is proposed that a technology transfer master plan (see Section 2.4) be developed that defines products, milestones, schedules, review mechanisms, and dissemination strategies.

Additional information about the activities proposed for Program Elements 3, 4, and 5 is provided in Appendix 1, "Productivity Tools," Appendix 4, "Development of Technical Resources and Associated Problem-Focused Research for Improved Seismic Engineering Practice," and in Appendix 5, "Technology Transfer Mechanisms and Programs."

3.2.2 Program Element 3: Problem-Focused Research and Technical Resources Development to Improve Seismic Engineering Practice (Guidelines and Manuals Development)

The conduct of this Program Element recognizes and considers the related efforts of all NEHRP agencies, including:

1. The NSF role in funding studies to advance fundamental knowledge in earthquake engineering, which is carried out in large part by the three NSF-funded earthquake engineering research centers (MAE, the Mid-American Earthquake Engineering Research Center; MCEER, the Multidisciplinary Center for Earthquake Engineering Research; and PEER, the Pacific Earthquake Engineering Research Center).
2. FEMA's role in developing tools to improve seismic engineering practices, including model code provisions for the seismic design of new buildings, and guidelines and standards of practice for the seismic evaluation and rehabilitation of existing buildings and for the seismic evaluation and design of utilities and transportation systems.
3. NIST's current limited program of problem-focused research and development in earthquake engineering aimed at improving building codes and standards for both new and existing construction, and advancing seismic practices for structures and lifelines.
4. The USGS Earthquake Hazard Program, which provides the earth science foundation for NEHRP, and which includes earthquake hazards assessments and maps, seismic monitoring, rapid earthquake information, and research on earthquake physics, occurrence, and effects.

Of special relevance to the program of technical resources development and associated problem-focused research proposed herein is the highly successful FEMA program to develop guidelines, model code provisions, code commentaries, practice handbooks, and other technical resources. Products from the FEMA program, known as the "Yellow Book series," have been broadly accepted by the seismic engineering profession and model code development bodies because leading design professionals, researchers, and regulators were involved in their development. FEMA-funded publications in the Yellow Book series include:

- The *NEHRP Recommended Provisions for the Seismic Regulation of New Buildings and Other Structures* (FEMA 368 and FEMA 369). These have been updated every three years since their initial publication in 1985.

- A *Manual for Reducing the Risks of Nonstructural Earthquake Damage* (FEMA 74).
- The first and second editions of FEMA 154, *Rapid Screening of Buildings for Potential Seismic Hazards: A Handbook.*
- The *NEHRP Handbook for the Seismic Evaluation of Buildings* (FEMA 178), and its successor document, *Prestandard for the Seismic Evaluation of Buildings* (FEMA 310).
- The *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA 273), and its successor document, the *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* (FEMA 356).
- *Procedures for the Evaluation and Repair of Earthquake-Damaged Concrete Wall and Masonry Wall Buildings* (FEMA 306, FEMA 307 and FEMA 308).

FEMA also sponsors and funds the American Lifelines Alliance (ALA), a five-year-old public/private partnership. The goal of the ALA is to reduce risks to utilities and transportation systems from earthquakes and other hazards. Projects undertaken by ALA produce guidelines that are provided to standards developing organizations for consensus development and dissemination. ALA maintains a tabulation of the current status of U.S. natural and manmade hazards. This tabulation is available as a reference for use by lifelines industries and regulators and as a means to identify needs for guidance development or updating.

Program Element 3 is intended to:

1. Expand NEHRP's current responsibilities for the conduct of problem-focused research and development in earthquake engineering.
2. Complement the existing highly successful FEMA effort to develop guidelines, handbooks, standards of practice, and other technical resources for reducing the seismic vulnerability of new and existing buildings.
3. Utilize new understanding and knowledge developed on seismic hazards from research in the earth sciences. The Advanced National Seismic System (ANSS) network may provide a new level of understanding of earthquake ground motion that will allow reconsideration of how earthquake loadings are incorporated into performance-based design.
4. Encompass the broad range of existing structures and newly designed structures needed and used by society today, including:
    - Problem-focused research to advance the state of knowledge relating to needed seismic engineering technical resources.
    - Systematic development of needed guidelines, manuals, and other technical resources for advancing seismic engineering practices.

Problem-focused research conducted under Program Element 3 may be initiated by observations of the performance of building and lifeline structures during severe earthquake-induced ground shaking, or researchers or practitioners may recommend topics with a specific technical resource in mind (e.g., specific guideline or manual). The intent of THE MISSING PIECE program is not to duplicate the NSF research program, but rather to develop specific problem-focused research information for those who develop guidelines, manuals, and other technical resources for advancing seismic engineering practices, and, in the process, put NSF and NEHRP research to practical use.

Examples of high-priority problem-focused research needs include:

- Identify seismic capacities of existing nonductile concrete frame buildings and the number and distribution of such buildings nationwide.
- Test and evaluate the use of carbon fiber for rehabilitation of buildings and lifelines.
- Research innovative connections and systems for buildings.
- Research advanced technologies (e.g., remote sensing, ground penetrating radar) for damage assessment of buried lifelines.

The technical resources development process will necessarily include the review of current standards of practice, and the synthesis and reformatting of available research information from NEHRP-funded investigations, as well as other sources (e.g., NSF, or international efforts). Program Element 3 should focus on design and construction issues complementary to similar efforts already being carried out by FEMA to reduce the seismic hazards of new and existing buildings and certain lifelines. Among the issues with the highest expected impacts are specialized types of facilities (often utility service-related), and specialized construction techniques for which seismic design guidance is not available. Constant communication between NEHRP agencies and FEMA will be needed to eliminate any duplication of effort. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES will provide the conduit through which this information will flow.

Needed technical resources include: tutorials; primers; design guidelines for different structure types and different audiences (ranging from engineers to construction inspectors); manuals of design (for existing as well as new codes and standards); and code commentaries. Examples of high-priority needs include guidelines for the seismic design of:

- Fossil fuel power plants
- Oil and gas pipeline systems
- Port and harbor facilities
- New municipal landfills

3.2.3 Program Element 4: Evaluated Technology for Practicing Professionals in the Design and Construction Communities

One of the critical needs for improving the economy and efficiency of professional earthquake mitigation practice is to provide the design and construction community with relevant, information that can make a difference in a practical way. There is a wealth of information available—much from NEHRP-sponsored activities and not directly available to the practicing professional (or, at least, it is not reaching this audience). The technical literature is becoming too large and technically difficult for most practicing professionals to examine, much less evaluate for use. Furthermore, as the technical literature becomes more complex, designers are reluctant to employ the principles conveyed out of concern that building officials who have jurisdiction may not sanction the ideas.

The goal of this Program Element is to evaluate and synthesize available seismic hazard mitigation data, information, and technology, including the wealth of NEHRP-funded research results that have become available over the last several decades, and to make this information available in a format that can be used by practicing professionals in the design and construction community.

The proposed format for reporting the results of each activity undertaken as part of this Program Element is the technical brief format (*TechBriefs*) pioneered by the Applied Technology Council

(ATC) to spearhead distribution of technical information on earth-science research results to practicing design professionals. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES recommends that ATC continue to take the lead in disseminating, through *TechBriefs*, technical advances of the problem-focused activities conducted under Program Element 3 and the results of the past 25 years of government-funded research. Each *TechBrief* would address a single, focused topic, and its contents would be actionable. Nominally 4-to-12 pages in length, *TechBriefs* are not research papers, but topical, tightly written, and well-illustrated discussions of practical problems faced by many engineering design and construction practitioners. Target audiences are:

- Project engineers, designers and detailers
- Building department personnel who review plans and field construction documents
- Inspection service field personnel
- Construction trades personnel

TechBrief topics will be varied and would likely include the following categories:

1. Distillations of research findings, particularly experimental research, that lead to specific conclusions on structural detailing.
2. Findings of professional committees and task groups on particular seismic design and regulation issues.
3. Results of testing programs for existing materials and assemblies that may have broader application than the reason for the test.
4. Comparative evaluations of typical detailing practice. Most individuals who engage in extensive peer review or building evaluations comment that many commonly used practices are not particularly effective. These include, for example, extending confined collectors in thin concrete slabs, or placement of reinforcing bar curtains in special moment resisting frames. The issue is essentially that many repetitively used details of construction could be significantly improved if they were reviewed and commented upon by knowledgeable designers, and better, more effective details suggested, with a discussion of why they are better. Hence, comparative evaluations of typical detailing practice should provide specific recommendations for typical details and a discussion of when they are good to use, and when they are not, as well as preferred alternatives.
5. Code clarification and interpretation. Building codes are often ambiguous on particular applications or particular circumstances. There needs to be an effective way to communicate clarifications and the basis for them to the design and regulation professions.
6. Guidance on how to utilize real-time earthquake monitoring of structures to evaluate their safety for continued use.
7. Construction means and methods evaluation of options for selected applications.
8. Case studies of typical design decisions to determine a building's expected seismic performance.
9. Observations from what we have learned from earthquakes and performance of structures that bear on specific design practice, observations, and improvements. The NEHRP-funded postearthquake investigations, including the Learning From Earthquakes program of the Earthquake Engineering Research Institute, will be major resources.

3.2.4 Program Element 5: Tools to Enhance the Productivity, Economy, and Effectiveness of the Earthquake-Resistant Design and Construction Process

Program Element 5 is a major programmatic effort under which the National Earthquake Hazards Reduction Program would seek to improve productivity in the design and construction industry by taking the lead in incorporating and integrating all seismic design codes, analysis tools and methods into the International Alliance for Interoperability (IAI) effort.

The global architectural, engineering, and construction community has initiated steps to improve its productivity for economic reasons. One way is to use object based computer systems. IAI is developing industry foundation classes (IFCs) for all products. Industry foundation classes are an object-based approach to defining all of the attributes of the component, and all of its interfaces with all of the other building systems within a particular construction project. Furthermore, interoperability permits the linking of analysis, design, codes, standards, cost estimating, scheduling, maintenance, lifecycle costing, and all other activities of the construction industry. When completed, architects, engineers, and contractors will have object-based databases to fully automate the process from start to finish. The United States participation in this effort has been limited, with no incorporation of seismic design and construction issues to date. This effort could improve significantly the efficiency and economy of the design and construction for structural systems.

At the present time, there are approximately nine international IAI councils around the world. The leadership councils have been in Singapore and the Scandinavian countries of Finland, Sweden, and Norway. Some of the present initiatives are energy simulations, facilities management domains, Construction Specifications Institute (CSI) standardization of specifications, project management domains, steel projects, structural analysis models, reinforced concrete and foundation construction, drafting extensions, precast concrete construction, code compliance support, and building owners' requirements.

This IAI initiative can have significant implications for improving productivity within the seismic community. The entire NEHRP seismic code provisions and their interface with all products and components of a building—some with mass, some without mass—could form an industry foundation class (IFC). This could allow the huge interoperable database in which all industries around the world could use the same object definition and interface. This would go a long way to improve and reduce fragmentation in the design and construction community and could provide a mechanism for more effective competition of U.S. firms in the international design and construction markets.

NEHRP participation in the IAI initiative would add a set of IFCs for structural and seismic components, thus providing IFCs for all components of buildings, bridges and the constructed environment so that they can be incorporated directly into the seismic design, analysis and construction processes.

The effort will likely require systematic and careful planning for implementation, as well as a feasibility study to explore how to best encourage utilization of the completed interoperability capability by the design and construction community. Other tools for improving productivity could also be explored, and implemented, if feasible, as part of this Program Element. Additionally, process oversight should be implemented where major areas of the technology would be evaluated and recommended for implementation. Areas where the technology required significant improvement would be identified for future work.

3.3 Personnel Requirements

The personnel to complete The Missing Piece: Improving Seismic Design and Construction Practices are available and are expected to be willing to participate. Indeed, Workshop participants expressed eagerness to participate. The structural engineering professions are well-known for their wide and extensive participation in code and standards development. The wide participation by the membership associations of structural engineers associations (e.g., the Structural Engineers Association of California, the National Council of Structural Engineers Associations, the Western Council of Structural Engineers Associations) in the technology and standards development efforts of the Applied Technology Council, the Building Seismic Safety Council and other model code groups is an indicator of the capacity and willingness of the professions to work when there is a *perceived* benefit in better earthquake resistant design and construction practices. This below-cost, or voluntary, participation includes all aspects of seismic-design research and code and standards development. The planned level of effort in the work proposed in The Missing Piece: Improving Seismic Design and Construction Practices is a natural extension of what has been done to date.

Through the efforts of FEMA, NIST, NSF and USGS over the past 25 years, NEHRP has proven that the academic and professional communities can perform the types of investigations needed to implement The Missing Piece: Improving Seismic Design and Construction Practices, and can willingly contribute to such efforts.

There are no market place limitations to accomplishing the goals of The Missing Piece: Improving Seismic Design and Construction Practices.

3.4 Budgetary Requirements

The budgetary requirements for The Missing Piece: Improving Seismic Design and Construction Practices for the first three years of its operation, and for the sustaining effort, all in constant dollars, are summarized in Table 1.

The amounts recommended were determined by the assessment and evaluation of Workshop participants as necessary to make significant accomplishments in the intended areas. These amounts are evaluated as realistic to achieve the original Congressional objective of increasing public seismic safety. The amounts recommended in this section are considered the minimum required to achieve the goal of each Program Element. The program starts at a level of $5.25 million, grows to $8.25 million and is recommended for a sustaining level of $6.25 million, adjusted annually for the cost of inflation. It is recommended that if fewer total resources are available, then every effort should be made to fund the individual Program Elements of the program at the indicated levels, and reduce the total amount expended by eliminating some Program Elements, not a proportional reduction of all. It would be better, from both economic and technical standpoints, to stagger initiation of Program Elements rather than to fund them at below-critical levels.

The code development activities of Program Elements 1 and 2, both for short- and long-term (performance-based seismic engineering) efforts, will continue over time and require long-term support. This level of support is consistent with the perceived needs for technical support of the code development process for all building and structural types. The support level for Program Element 3, the development of technical resources (e.g., guidelines and manuals of practice) is modest. It assumes that the major issues in this area continue to be undertaken by FEMA, as they have in the past, and that The Missing Piece: Improving Seismic Design and Construction Practices focus on those types of facilities and applications that are not large enough to engage the concern of the emergency response community, but are sufficiently important to others at interest to attempt to resolve the technical issues before an earthquake exposes them as important.

Table 1. Budgetary Requirements (millions of dollars)

Program Element: ($millions)	Year 1	Year 2	Year 3	Sustaining
▪ ***Code development support program***				
Program Element 1 Technical support for short-term projects that support practice and code development	1.0	1.0	1.0	1.0
Program Element 2 Long-term problem-focused research on performance-based seismic engineering	1.5	2.0	3.0	2.0
▪ ***Improving design and construction productivity***				
Program Element 3 Problem-focused research and technical resources development (guidelines and manuals)	1.0	2.5	2.5	2.0
Program Element 4 Evaluated technologies distilled and distributed through TechBriefs	0.5	1.0	1.0	1.0
Program Element 5 Productivity and interoperability	1.25	1.00	0.75	0.25
Total	5.25	7.5	8.25	6.25

Support of Program Element 4 for the evaluated technologies (*TechBriefs*) development effort is essentially constant. It is anticipated that the perceived need for TechBriefs will increase, as will the number of topics warranting consideration. The proposed budget assumes that other NEHRP agencies will observe the utility of this approach to dissemination of technical information and will initiate similar projects to supplement this effort in other technical areas. Program Element 5, the productivity and interoperability effort, is possible to complete within three years. Following this initial three-year effort, it is anticipated that there will need to be a standing effort to maintain the database system and supplement and augment it as required to meet the needs of the seismic design and construction communities.

There have been other planning efforts within the earthquake hazards reduction community that have addressed these programmatic issues in the context of larger, more comprehensive efforts. The Earthquake Engineering Research Institute (EERI) has vigorously supported the immediate need to fund ANSS and NEES and proposes a sustained, 20-year effort to reduce the nation's earthquake vulnerability. The EERI-recommended program consists of research and development funded at approximately $358 million per year. The NEHRP strategic plan, in draft and not yet finalized, similarly provides a comprehensive program to address the NEHRP legislative objectives. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES is a small element in support of both these proposed efforts and draws strength from them. Workshop participants expressed support for these larger efforts, but focused their recommendations on the narrower objectives presented herein. Potential budgetary resources for THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES are consistent with current NEHRP expenditures.

3.5 SCHEDULE AND MANAGEMENT

It is recommended that THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES program be implemented at the earliest possible moment. Start-up should be rapid, since there has already been a significant amount of effort in defining what is to be done and how it can be accomplished. This report and its appendices will serve as a roadmap.

THE MISSING PIECE recognizes that current NEHRP funding emphasizes the fundamental research programs of the National Science Foundation and the seismic monitoring, hazard assessments, and research of the U.S. Geological Survey and the earthquake engineering codes and practices of FEMA-supported efforts. New funds for problem-focused and applications research are necessary.

It was recommended by Workshop participants that this problem-focused research and development program be user- and needs-driven. Further, it must include appropriate project, task, and personnel evaluations and a willingness to terminate projects not achieving the desired goals and individuals not meeting agreed deadlines. *That is, it should be run like a business enterprise rather than as an academic program.*

To gain the support of the design and construction communities, and for the advocacy of this problem-focused research and development program, it is important that the needs of these design and construction communities be addressed. On this basis, the following recommendations for management are offered:

- Establish a formal external review mechanism, drawing on experts with leadership experience, to assist in identifying and prioritizing problem-focused topical areas and review of program progress. Such reviews should be a regular part of maintaining and updating the program plan, evaluating project effectiveness and direction, and supporting managerial decisions on program implementation.
- For each significant programmatic undertaking, an appropriate project plan, management structure and technical team should be in place, and should be regularly reviewed for effectiveness so that mid-course modifications can be made to assure successful project completion. Management of the activity must consider both the work done, and its relationship to its goals and its specific interim plan.
- The level of effort provided by government, academic and private sector personnel should be balanced to best achieve the objective of the specific project.
- The success of this program depends upon being efficient and effective in reducing earthquake losses by supporting the seismic code development process and improving seismic design and construction productivity. Therefore, at the core of program management must be a focused and dedicated effort to measure the benefits of programmatic outcomes against their costs. Programmatic actions should be based on this independent benefit-cost assessment. To the extent practical these should be concrete, not hypothetical, specific not generalized, and focused on both intended and unintended beneficiaries and costs.

3.6 FEASIBILITY

There are no known impediments that would prevent achievement of the goals set forth in THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES. A principal concern is to keep Program Elements focused on practical "actionable" results that are user- and needs-driven.

Program Element 5, the productivity/interoperability effort, represents the only undertaking with any technical or applicability risk. The risk is associated with the possibility that the global integration goal cannot be achieved at this time, or that it provides tools that are not ready for applications use; that is, it is ahead of its time. The risks of failure are counterbalanced by the extraordinary benefits of success as discussed below.

That the productivity/interoperability framework can be successfully implemented has already been proven. The technologies and information required to implement it are all stable and known to exist. The principal feasibility issue is whether the design and construction community will use the system developed. It is clear, however, that other design and construction industries have successfully implemented these procedures to great economic and societal profit. It is expected that marketplace economics will force use of these productivity and interoperability tools, and that seismic design and construction can only benefit from this increased use of specifications that are interconnected and standardized to the very best of our research knowledge.

3.7 BENEFITS OF IMPLEMENTING THE MISSING PIECE

The benefits of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES can be significant to earthquake safety. Impacts will be in three basic areas:

1. Reduced investment required to achieve acceptable earthquake performance of the built environment.
2. Reduction in the traumatic life loss, injury damage, and economic impacts when earthquakes occur.
3. More rapid recovery and restoration of the physical community and economic activity following an earthquake.

Reductions are hard to quantify at this time. Projections are that earthquakes with over $100 billion and thousands of lives lost can occur at many locations in the United States. Current incremental investment in seismic resistant construction is in excess of $10 billion per year. Reducing the funds directed toward restoring the built environment following an earthquake will free funds for other societal uses that are more productive.

Major benefits may accrue to the construction economy— a one-trillion-dollar segment of the economy and a $3 trillion global market. As much as 50% of all construction is in seismic hazard areas, as determined by USGS hazard maps, so there is opportunity to directly impact construction in seismic regions.

In summary, the benefits of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES are assessed as:

- Better, more technically sound earthquake-resistant engineering design and construction practices.
- More reliable structures that perform better in earthquake shaking.
- Fewer lives lost in a destructive earthquake.
- Lower initial seismic and retrofit construction expenses.
- Mitigation of the consequences of earthquake shaking.
- Increased productivity and interoperability in engineering and construction.
- Better, less intrusive, code enforcement.

If the total cost savings of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES are only 0.1% of annual construction expenditures in seismic regions, then the return will be over 30 times the investment proposed herein. The actual return in reduced costs is expected to be much greater. The rewards of the other non-monetary benefits (e.g., reduction in life loss and injury, maintenance of facility use) are even larger. These benefits are clear in their form, because they are targeted specifically at the people and institutions of the construction economy. THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES could become a major source of *benefits* from the whole NEHRP program, with clearly defined and traceable results that can be directly demonstrated to have impacted practice.

The big unknown in the program is the huge, upside potential of the interoperability Program Element on how all construction is realized, not just that small portion that is dictated by seismic safety and performance concerns—which even in high seismic hazards areas accounts for only a few percent of total construction costs. It is uncertain how quickly or to what degree productivity and interoperability will impact the overall construction industry for nonseismic issues. If it succeeds for all construction issues, then the rewards of THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES will apply not just to productivity of seismic construction, but also to productivity of all construction, whether for gravity and service loads, or those of wind, snow, water, and blast.

If there is but a 1% improvement in efficiency of the construction industry, the benefit will exceed $1 billion annually—and more may be possible. The stakes are huge, but so are the opportunities for significant, systematic productivity improvements. Even if the possibility of success is only 10%, the annual rewards are estimated to be over 50 times the investment proposed for the entire THE MISSING PIECE: IMPROVING SEISMIC DESIGN AND CONSTRUCTION PRACTICES.

Appendix B

In my opinion, one of NEHRP's recent success stories in Utah has been the installation of a multipurpose urban strong-motion network in Utah's dramatically-growing Ogden-Salt Lake City-Provo urban corridor (see www.seis.utah.edu/urban/index.shtml), where 80 percent of Utah's population and economy is sitting on top of the five most dangerous segments of the active Wasatch fault. Thanks to funds and equipment from the U.S. Geological Survey under the Advanced National Seismic System (ANSS) program, coupled with cooperative funding from the state of Utah, 65 strong-motion stations were installed and integrated into the University of Utah's regional seismic network during the past three years as part of a new real-time earthquake information system. The improved urban/regional earthquake monitoring system was emplaced in time for the 2002 Olympic Winter Games but was primarily aimed at meeting Utah's long-term earthquake safety needs.

One of the reasons I call this a success story is because the new urban network and real-time earthquake information system has galvanized interactions among earth scientists, engineers, emergency managers, the Utah Seismic Safety Commission, and other stakeholders - all concerned with practical steps towards improving earthquake safety in Utah. Coincidentally, I and nine other local engineers are members of a state advisory committee guiding the implementation of ANSS in Utah. I am greatly concerned that proposed cuts in ANSS funding, which already are unrealistically low for a national-scale program, threaten to erode the valuable gains in modernized seismic monitoring already made. Authorized funds for the vast majority of ANSS instrumentation planned both for Utah and the rest of the Nation, especially for the instrumentation of structures, have yet to be appropriated by Congress.

Instrumentation of buildings in areas of likely seismic activity is critical. These buildings are the real laboratory specimens that we will learn from. There is a gap in knowledge between ground motion and structural response that can only be filled in through instrumentation programs. Ultimately, all of our design codes/standards must be based upon empirical data so derived.

BIOGRAPHY FOR LAWRENCE D. REAVELEY

Chair and Professor, University of Utah, Department of Civil and Environmental Engineering, 122 Sough Central Campus Drive, Suite 104, Salt Lake City, Utah 84112–0561; Telephone: (801) 581–6931; Fax: (801) 585–5477; E-mail: reaveley@civil.utah.edu

Education

Ph.D. Civil Engineering, University of New Mexico, 1971

M.S. Civil Engineering, University of Utah, 1964

B.S. Civil Engineering, University of Utah, 1963

Academic Experience

January 1993-present—Professor and Chair, Department of Civil & Environmental Engineering, University of Utah, Salt Lake City, Utah.

1975–1993—Adjunct Professor (various rank and intervals), Department of Civil & Environmental Engineering, University of Utah, Salt Lake City, Utah.

1970–1972—Visiting Assistant Professor, Department of Civil & Environmental Engineering, University of Utah, Salt Lake City, Utah.

Professional Experience

1974–January 1993—Vice President, Reaveley Engineering, Inc., Salt Lake City, Utah.

1971–1973—Chief Engineer and Manager, Construction Division, Davidson Lumber Sales, Salt Lake City, Utah.

1967–1970—Research Assistant, University of New Mexico, Eric C. Wang Civil Engineering Research Facility, Albuquerque, New Mexico.

1964–1967—Structural Design Engineer, J.F. Patrick Structural Consulting Engineers, Salt Lake City, Utah.

1963–1964—Materials Engineer, Utah Department of Transportation

1959–1962—Intern, Precast/materials Division, Utah Sand & Gravel (Monroe)

Professional Registration

Registered Professional Engineer, New Mexico.

Professional Affiliations

American Concrete Institute

American Society of Civil Engineers

American Society of Engineering Education

Chi Epsilon Civil Engineering Honor Society

Earthquake Engineering Research Institute

Structural Engineers Association of Utah

Patents

Patent Application "T-Structure Externally Reinforced with composite Materials" (Inventors: Chris Pantelides and Lawrence Reaveley) U–2434. Docket No. 11240, USSN: 859, 935. May 1998.

Composite Connections for Precast Walls, Patent U–2434. Pending, 1999.

Funded Research (Co-P.I., unless otherwise noted)

"FRP Composite Confined Rectangular Columns," Federal Highway Administration/ Utah Department of Transportation. Amount $161,924. Sept. 2002–Dec. 2004.

"Long-term Structural Monitoring of Post-tensioned Spliced Girders and Deck Joints," Federal Highway Administration/Utah Department of Transportation. Amount $194,5000. Mar. 2001–Jun. 2004.

"Fatigue Tests of Cracked and Repaired Aluminum Connections of Overhead Sign Structures," New York State Department of Transportation and Utah Department of Transportation. Amount $70,572. Dec. 2001–Dec. 2003.

"Long-term Durability of Carbon CFRP Composites Applied to R/C Concrete Bridges," National Science Foundation Contract CMS 0099792. Amount $211,787. Sept. 2001–Aug. 2003.

"Long-term Durability of Carbon FRP Composites Applied to R/C Concrete Bridges," Federal Highway Administration/Utah Department of Transportation. Amount $173,000. Mar. 2001–Jun. 2004.

"Long-term Structural Monitoring of Prestressed Girders on New I–15 Concrete Bridges," Utah Department of Transportation. Amount $60,161. Jun. 1999–Dec. 2000.

"Cyclic Pushover Research Study on South Temple Structure," Federal Highway Administration/Utah Department of Transportation. Amount $270,031. May 1999–Jun. 2003.

"Strengthening of R/C Beam-to-column connections with carbon fiber composites," Pacific Earthquake Engineering Research Center. Arnount $38,000. Apr. 1999–Dec. 2000.

"Center of Excellence: Center for Composites in Construction," State of Utah Department of Economic and Community Development. Amount $90,000. Jul. 1998–Jun. 1999.

"Modeling of Reinforced Concrete Joints with Carbon Fiber Composites," Idaho National Engineering and Environmental Laboratory. Amount $130,028. Feb. 1998–Sep. 1998.

"Structural and Geotechnical Testing of the South Temple I–15 Overpass Bridge," Utah Department of Transportation. Amount $64,314. Feb. 1998–Dec. 2000.

"Structural and Geotechnical Testing of the South Temple 1–15 Overpass Bridge," Federal Highway Administration. Amount $187,253. Feb. 1998–Dec. 2000.

P.I. "Bridge Deck Slab Study," Utah Department of Transportation. Amount $42,000. July 1998–July 1999.

Dr. Lawrence Reaveley, Dr. William Van Moorhem, Dr. Rand Decker, Principle Investigators. "Open Burn/Open Detonation Risk Assessment Ground Motion and Related Effects." Tooele Army Depot. Amount $50,000. Dec. 1996.

P.I. "Bridge Deck Reinforcement." SIKA Corporation. Amount $5,000. June 1998–June 1999.

"Structural Testing on I–15 South Temple Bridge," Federal Highway Administration/Utah Department of Transportation. Amount $245,000. June 1999–Dec. 2000.

"Modeling of Reinforced Concrete Joints with Carbon Fiber Composites," Idaho National Engineering and Environmental Laboratory. Amount $117,000. Oct. 1998–Sep. 1999.

"Strengthening of R/C Beam-to-column connections with carbon fiber composites," Pacific Earthquake Engineering Research Center. Amount $35,000. Apr. 1998–Dec. 1999.

"Center of Excellence: Center for Composites in Construction," State of Utah Department of Economic and Community Development. Amount $90,000. Jul. 1998–June. 1999.

"Modeling of Reinforced Concrete Joints with Carbon Fiber Composites," Idaho National Engineering and Environmental Laboratory. Amount $130,028. Feb. 1998–Sep. 1998.

"Structural and Geotechnical Testing of the South Temple I–15 Overpass Bridge," Utah Department of Transportation. Amount $32,600. Feb. 1998–Jul. 1999.

"Structural and Geotechnical Testing of the South Temple I–15 Overpass Bridge," Federal Highway Administration. Amount $66,400. Feb. 1998–Jul. 1999.

"Strengthening of Bridge Joints using Carbon Fiber Composites," National Science Foundation. REU Supplement. Amount $10,000. Sep. 1997–Aug. 1999.

"Strengthening of Bridge Joints using Carbon Fiber Composites," National Science Foundation. Amount $132,648. Sep. 1997–Aug. 1999.

"Strengthening of Bridge Joints using Carbon Fiber Composites," University of Utah Matching. Amount $24,000. Sep. 1997–Aug. 1999.

"Testing of Precast Concrete Connections for Seismic Regions using Carbon Fiber Composites," XXsys Technologies. Amount $142,875. Mar. 1997–Jun. 1999.

"Full-scale Testing of Bridge of Interstate I–15," Utah Department of Transportation. Amount $10,000. Jun. 20, 1996–Jun. 31, 1997.

"Repair/Retrofit of Bridge using Fiber Composites," Utah Department of Transportation. Amount $32,000. Sep. 30, 1995–Jun. 30, 1997.

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Gergely, J. and Pantelides, C.P. "Design of CFRP composite for seismic retrofit of R/C bridge," J. of Bridge Engineering, ASCE, *Under Review,* Aug. 1999.

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Co-Project Director and Co-Team Leader, concrete. "Development of Guidelines for the Seismic Strengthening of Existing Buildings." ATC 33 FEMA 273, in Balloting.

Co-Project Director, and Co-Team Leader for reinforced concrete structures. 1998, "Guidelines for the Seismic Rehabilitation of Building Structures." ATC 33/FEMA 273.

Lead guideline writer, post-earthquake inspection and evaluation volume. "Sac Joint Venture Program to Reduce Earthquake Hazards in Steel Moment Frame Structures, Phase 2." 2000 (in progress)

Original author, "Seismic Rehabilitation of Single Family Dwellings—A Handbook." Based on original document prepared for the Comprehensive Emergency Management Agency, State of Utah. ATC–39. 1999.

Miller, J. and Reaveley L. "Hotel Utah Remodel and Seismic Upgrade," Seismic Rehabilitation of Concrete Structures, edited by Gajanan Sabnis, Avanti Shroff, and Lawrence F. Kahn. ACI 1996.

Mills, L., Reaveley, L. "Similitude Studies in the Dynamic Response of Reinforced Concrete Beams," Vol. lI, Technical Note DE–TN–72–015, New Mexico, July, 1972.

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Applied Technology Council Projects

ATC–21, "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook," funded by the Federal Emergency Management Agency, 1989. Project Engineering Panel Member.

ATC–22, "A Handbook for Seismic Evaluation of Existing Buildings," funded by Federal Emergency Management Agency, 1989. Project Engineering Panel Member.

ATC–26, "U.S. Postal Service Manual for seismic Evaluation of Existing Buildings," funded by the United States Postal Service. Member Project Engineering Panel.

ATC–28, "Development of Recommended Guidelines for Seismic Strengthening of Existing Buildings, Phase I: Issues Identification and Resolution," funded by FEMA, 1990. Member Project Engineering Panel and ATC Board Contact.

ATC–36, Earthquake Loss Estimation Methodologies and Data Base, for Utah." Consultant.

ATC–39, Seismic Rehabilitation of Single Family Masonry Dwellings—A Handbook. Original Author.

ATC–41, SAC Joint Venture, Program to Reduce Earthquake Hazards in Steel Moment Frame Structures, Phase 2. Lead Guideline Writer, Post-Earthquake Inspection and Evaluation.

Professional Service Activities

Jan. 2000–Apr. 2003—Member, Board of Directors. Applied Technology Council.

Jul. 1998–Jul. 2000—Utah State Capitol Preservation Board. Board member appointment form.

1996–1999—Member, Executive Committee, Technical Activities Division, Structural Engineering Institute, The American Society of Civil Engineers.

1996–1998—Member, Code Resources Development Committee (BSSC). For the Building Code (2000).

1996–1998—Member, Steering Committee, Incentives Impediments to Mitigation Project, EERI.

1996—Chair, Nominating Committee, EERI 1997.

1994–1997—Member, Special Design Values Panel. Building Seismic Safety Council (BSSC). Procedures for design based on new generation seismic maps.

1994–present—Member, Partners in Education Committee, American Institute Steel Construction. Chair 1999.
1992–present—Member, ACI Committee #369 Seismic Rehabilitation and Repair.
1993–1995—Member Codes and Standards Committee, American Concrete Institute (ACI 318–95).
1991–1997—Member, Provisions Update Committee (seismic BSSC), NEHRP 1994 and 1997 Editions.
1991–present—Member TS12 Isolation and Energy Dissipation Subcommittee (BSSC), NEHRP, Chair 1994 cycle.
1970–present—Member, ASCE 7, Loads Standard, Seismic Loads Subcommittee, Chair 1998.
1984–1991—Member, Advisory Board of Utah Geological Survey, Chairman, 1989–91.
1980–present—Founding member, Structural Engineers Association of Utah.
1985–1991—Member, Board of Directors of the Applied Technology Council.
2000–2003—ASCE Representative to the Board of the Applied Technology Council.

Honors and Awards

1997—Engineering Educator of the Year, Utah Engineers Council.
1996—Governor's Medal for Science and Technology.
1989 Engineer of the Year, Utah Engineers Council.
1988—Special Award for Implementation Action, National Earthquake Hazards Reduction Program. USGS & FEMA.
American Concrete Institute's National Structural Engineering Award for 1998. "Historic Hotel Utah Remodel and Seismic Upgrade," Special Publication 1610, Seismic Rehabilitation of Concrete Structures, 1996. This award recognizes advanced concepts and techniques related to structural engineering. Awards are made to the author or co-authors of a peer-reviewed paper published by the Institute.
Applied Technology Council's Premier Award—the ATC Award for Excellence for extraordinary achievements in seismic rehabilitation of buildings.
College of Engineering, Outstanding Service Award, "In recognition of your leadership efforts and commitment to enhancing the educational experience of our students during conversion to semesters."

THE UNIVERSITY OF UTAH

Department of Civil &
Environmental Engineering

August 01, 2003

The Honorable Nick Smith
Chairman, Research Subcommittee
2320 Rayburn Office Building
Washington, DC 20515

Dear Congressman Smith:

Thank you for the invitation to testify before the U.S. House of Representatives Science Committee, on May 8 for the hearing entitled *The National Earthquake Hazards Reduction Program: Past, Present and Future.* In accordance with the Rules Governing Testimony, this letter serves as formal notice of the Federal funding I currently receive in support of my research.

For Year 2002

- $720 Paid on ATC-21 Update Project (Funded by FEMA)
- $1,250 Paid on ATC-17-2 Project (Funded by MCEER)
- $920 Paid on ATC-33-1 Project (Funded by BSSC)

Total paid in 2002: $2,890

For Year 2001

- $900 Paid on ATC-21 Update Project (Funded by FEMA)
- $1,080 Paid on ATC-21 Update Project (Funded by FEMA)

Total paid in 2001: $1,980

Sincerely,

L. D. Reaveley

Lawrence D. Reaveley
University of Utah
Civil & Environmental Engineering
Department Chair

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DISCUSSION

Chairman SMITH. Are you suggesting, Mr. Reaveley, that there wasn't collusion in——

Dr. REAVELEY. I am suggesting——

Chairman SMITH [continuing]. Your more resolved clause of all of the witnesses?

Dr. REAVELEY. I am suggesting that I never saw their testimony when I wrote this. I have seen it since, and I am amazed at some of the common experiences we have come to and recommendations.

Chairman SMITH. Each panelist will have five minutes, and I will begin with the question that I suggested earlier and that is, just very briefly, the relationship between what government effort should be in additional research to develop new and better technology and the efforts in implementing what we already have. And start with you, Mr. Olson.

Mr. OLSON. Thank you very much. I have a perspective on this that is a governmental perspective. Research is terribly important. The Federal Government is excellent at supporting research. When you move out of the research, and I am working on some projects like this right now, you move into whole different spheres. And for example, we would like to see more done by local governments. It is the distribution of power in the United States. It is the federal system that we have to work through to make things happen in the public sphere, and so the Federal Government can do a number of things, including regulate things like nuclear power plant safety.

In other cases, the initiative and responsibility really belongs to the state. And so you have to find ways to encourage states to take action in areas they are responsible for. And as Dr. Reaveley mentioned, at the local level, and then you have to depend on local developments to understand the risk and to take actions that they are responsible for.

Chairman SMITH. Okay. But again, the balance—how much—if you were going to come up with a percentage, how much of our effort should go into implementing what we already have versus additional research, whether it is federal, state, or local.

Mr. OLSON. I guess I can make some enemies here, what the heck. I would say we need 40 percent addressed to implementation and the complexities associated with it.

Chairman SMITH. And well, let us just go down the line, Mr. Cluff, and then we will end up with you, Mr. Lowe.

Dr. CLUFF. Yes. Thank you. I come—the perspective of using NEHRP products within a large operating utility and working with a lot of other utilities and transportation providers. I would like to enhance the comments I made on the public/private partnership where you can leverage the funds. Get the NEHRP groups. We have NEHRP funding from NSF, from USGS, and the universities that work with the users, and you allow the users to drive the agenda. That has been the missing problem. On the model we set in the San Francisco Bay Area to allow the users to drive the agenda and then the researchers willing to produce the products that we can immediately implement. The problem has been that it takes 15 to 20 years for a research result to get into effective implementation. With the projects that we have in the pier center, we are able to implement within a few days after we get a research result, because we have structured how the research is done to get a result we can use.

Chairman SMITH. Now this is in private sector——

Dr. CLUFF. Yes.

Chairman SMITH [continuing]. You are talking about mostly?

Dr. CLUFF. Yes.

Chairman SMITH. So when it comes out of their own pocketbook and somebody proves to them that they can add to the assurance that their structure isn't going to be damaged, it is relatively short time for implementation.

Dr. CLUFF. That is right. But it is—but it—we need to provide that model so that more users will get involved to take advantage of this and put money where their mouths are.

Chairman SMITH. And so somehow part of the question is should we be looking at some ways to better encourage the private sector to implement this? I mean, whether it is a homeowner that is going to build a house that is more structurally sound for tornadoes or hurricanes or earthquakes, it seems like the insurance company would say, "Look, we are going to really cut your rates," but that hasn't happened, to my knowledge.

Dr. CLUFF. We really need a mechanism, as Dr. Reaveley mentioned, to motivate those people who have control over building practice and so forth to do it right.

Chairman SMITH. And Dr. O'Rourke, your comment and then Dr. Reaveley.

Dr. O'ROURKE. Excuse me. I would like to make a distinction between implementation of research and research which is implementable. I think when you do research that you want to find come into practice, you have to be thinking about the implementation when you design the research program. And there are some very good models out there. Dr. Cluff referred to one with respect to the Bay Area. The other earthquake engineering research centers also are working with what we call test beds. For example, the Multidisciplinary Center for Earthquake Engineering Research works in—with the Los Angeles Department of Water and Power to look at water supply and electrical systems. This is very important, because what it does is it enjoins the researchers with an actual system, gets them talking to the engineering personnel and the management personnel, and also gets them to learn that the technical problems aren't always the only problem that one has to face.

There are important economic repercussions from earthquake damage. There are important community issues at hand. And when we look at the research being implementable in an integrated way, which not only involves geoscientists and earthquake engineering, but also social scientists, economists and people that understand the community, then we are able to walk across these divides and put together a program that not only addresses the industry issues, but addresses some of the knottier, more difficult community implementation issues——

Chairman SMITH. My time has expired, Dr. O'Rourke——

Dr. O'ROURKE. Sure.

Chairman SMITH [continuing]. But I am going to ask you and Dr. Reaveley to briefly comment, and then we will pass it on to——

Dr. REAVELEY. I think one thought that has been introduced is the difference between applied research and basic research. This earthquake program needs an awful lot of applied research. Relative to the appropriation of money to the local and private sector, we should try to build some incentives to bring on people in a patterning way. And then I don't know how you ever reach down to the building official department level, but they need help and badly, because if in the private sector, outside of institutions, if it is never—if the plans aren't done right and not checked, and then if they are not checked in the field, we will never get earthquake or any high load-resistant structure actually completed.

Chairman SMITH. Congresswoman Lofgren.

Ms. LOFGREN. Thank you, Mr. Chairman. This has been, I think, a very helpful hearing and one that I am very interested in. As you know, I represent San Jose, California. And anybody who went through Loma Prieta, as I did, remembers it well. And actually San Jose fared fairly well, largely because of we had some good luck, but we also had good engineering. And that just proves that we—you know, you can make people and communities safer if you work at it. And so I think it is enormously important that this be reauthorized.

But I am also concerned about funding levels. And as a matter of fact, Mr. Chairman, I think—I am going to be circulating a letter to the appropriators about funding for this earthquake effort, and I am hopeful that maybe we could make that a bipartisan effort, because we can authorize away, but if we don't put the resources in, we are going to pay a terrible price. I mean, it is only a matter of time. It is not an if, it is a when issue. And I do know that the work that we did, for example, in San Jose, saved us hundreds of thousands, millions of dollars. So I am hopeful that we might be able to work together on that.

Chairman SMITH. And if the gentlelady would yield, that was one of my questions also is why wasn't ANSS even in the budget.

Ms. LOFGREN. Right.

Chairman SMITH. And so is it left to Congress to do things that apparently our experts are suggesting should be done? Thank you.

Ms. LOFGREN. I would very much—obviously, we need to pay some attention to ANSS, and I think we should fund it more aggressively so we can get it done. And I guess the question for Mr. Lowe is what efforts have been made to get an adequate budget request for ANSS in the President's budget? Did you all ask and get turned down or——

Mr. LOWE. Well, I am—of course, I am not from USGS, so it is a little difficult to——

Ms. LOFGREN. Right.

Mr. LOWE [continuing]. Do that. I do think, quite frankly, the way that Section 206 has been constructed, yes, we would be—FEMA would, in fact, as the lead agency, be the ones to move that forward. Heretofore, I am not aware of that occurring in that fashion. I do know that there was consultation, you know, with the Committee and so on and so forth to be able to do what has been done. But that is exactly why I am calling for a management plan so we can carry out the spirit of Section 206. When the PCC, the principals of the other NEHRP agencies and we sat down and decided upon a management plan, specifically as a basis was Section 206, so that we all could, in fact, coordinate our budgets and move forward and go to OMB and ask for what Congress told us to do, either request or the recommendation anyway. So——

Ms. LOFGREN. So if I could, the——

Mr. LOWE. Each agency, up to this point, has been left——

Ms. LOFGREN. Right.

Mr. LOWE [continuing]. In essence——

Ms. LOFGREN. Right.

Mr. LOWE [continuing]. Up to their own processes to make requests for their initiatives.

Ms. LOFGREN. And I understand. I mean, with the new Homeland Security Department, and I also sit on the Homeland Security Committee here, there is so much to do in terms of reorganization and the like. It—I just think that to wait while that reorganization goes forward, as, indeed, it must, and not to address the funding issue in this funding cycle would be a mistake. And I think, hopefully, we can remedy that.

Mr. LOWE. We are prepared to move forward with our management plan working with PCC and, of course, the ICC, which is the program level, to leverage that. Obviously in the Department of Homeland Security, we have also dispatched one of our NEHRP staff over to science and technology, who will begin to try to leverage some of the resources there to help us achieve the NEHRP vision as well as to put together a fairly strong——

Chairman SMITH. If the gentlelady would yield again——

Ms. LOFGREN. Yes, certainly.

Chairman SMITH [continuing]. I would be more than generous on the five minutes. But still, in our NEHRP authorization bill three years ago, a little over three years ago, we specifically said that FEMA would guide the budget, a coordinated budget process for NEHRP. And I guess I hear you say that the individual agencies have sort of been on their own, but it seems to me that if the law says FEMA would coordinate and guide that budget process to have a coordinated budget, that should happen.

Mr. LOWE. I agree with you. And again, that is exactly why we called for the first meeting of the PCC to re-establish what we needed to do specifically, not just the letter but the spirit of what Section 206 offered. And so I appreciated Section 206 as a call to, in fact, direct the principals to manage—if you will, lead this—the NEHRP.

Chairman SMITH. I mean, the law said you had to do it.

Mr. LOWE. That is right.

Chairman SMITH. What more do we need to make sure it is done? We ask for reports, but the reports were not timely, and it has been only recently we have received those reports. So maybe somehow more——

Ms. LOFGREN. Well, if I could, too, it—the report itself, which we just received, doesn't really have any numbers in it. And I am just sort of wondering how we could end up with a five percent reduction in the earthquake program in the proposed budget consistent with the strategies that are outlined in the plan without budgetary numbers.

Mr. LOWE. Again, what you have there doesn't really represent what I am talking about.

Ms. LOFGREN. I see.

Mr. LOWE. I think we can do more, and I think we can do it, certainly, in the '04 budget cycle. And frankly, I think it was quite clear when we had our PCC with the principals that we were all committed to doing that. Because the strategic plan is passed, we all know where we are going. That is a consensus document. We all agreed. We all agreed that it is important to do that. We also—part of the management plan was to pick out exactly what is the staffing expertise we need from all of the agencies who participate in this process. So I am, frankly, fairly confident that the agencies are going to work collectively as a coordinated body to fulfill fully Section 206.

Ms. LOFGREN. How much money do we need, do you think? Have you reached that conclusion?

Mr. LOWE. No, I can't say we have. What I would like to be able to do is in our annual performance plan be able to chart out where we are with what we have now——

Ms. LOFGREN. Um-hum.

Mr. LOWE [continuing]. And then be able to come back and tell you, okay, our performance metrics will show here is where we are, provide it X amount investment more, this is where we are. So you can see what we can achieve given whatever resources that we have.

Ms. LOFGREN. Just a final, maybe, question or observation, and I don't want this to be taken as an offensive comment, because it is not meant in that way. I am—I wonder whether, especially now that FEMA has been assigned to the Homeland Security Department, whether FEMA is the best home for this activity. And I say that not to be critical of FEMA, but I—to the extent that FEMA has—is diverted to other activities, that is going to be enhanced, I think, now because of the new Homeland Security responsibilities. And I am not—I don't have a vision for another home for this activity, but I am wondering if—you don't even have to answer now, but if people have thoughts about what might work better than FEMA, especially now that you are Homeland. And we are going to keep you very busy at—in the Homeland Security Department.

Mr. LOWE. Well, I don't—frankly, I think that FEMA is a good home for it now more than even—ever before, because DHS, Department of Homeland Security, is an all-hazard agency. But the all-hazard paradigm is a natural hazard paradigm. An earthquake, just as we saw in New York, is vitally important. When we began to do mitigation work in New York, where did we go? We came to FEMA. Where did we go in FEMA? We came to the NEHRP partners. We did the—had the retrofit designs for the bridges, for the tunnels, for the harboring that is occurring, $417 million worth, and other work.

Ms. LOFGREN. Oh, and by the way, I mean, your agency did a spectacular job in that activity. I mean——

Mr. LOWE. But these are NEHRP earthquake——

Ms. LOFGREN. Right.

Mr. LOWE [continuing]. Is what I am saying. These are earthquake designs to harden for manmade intrusions. Very significant. One of the things that we talked about among our NEHRP agencies, even about this testimony today, is how everybody felt, if you will, about, really, bringing forward the possibilities that are created for moving the earthquake agenda down the road with our ability to use our lessons learned in a manmade environment. And everybody is very positive about that, and so I think that is what you see in the testimony. The ability that we have now working with S&T and all of our NEHRP partners is probably greater than it has been before, because it is all hazard. When we start talking about earthquake, we are talking about an all-hazard design for——

Ms. LOFGREN. I am still—I certainly appreciate that comment, and I think it something that we may want to even think about further as we go forward, because clearly FEMA has many strengths as an agency, but the fact that it took so long to get answers, and we really don't have the answers now, may indicate that there is—the focus isn't quite on the science that we want. And maybe there is a better home.

Chairman SMITH. Well, it has been—in fact, one of our Members of the Science Committee suggested that the lead agency be USGS. And also, there was a suggestion that we have sort of a rotating directorate that would rotate every 18 months or two years that could temporarily be assigned within FEMA or within another agency. But I mean, you have to——

Mr. LOWE. I would like to comment on that.

Chairman SMITH [continuing]. Understand that that is a concern.

Mr. LOWE. Yeah, I have—we have thought about it on a couple of different fronts. First, in terms of the research agenda, yes, we are not a research agency. We use that. We apply that in a real-life situation, so we are interested in research practice. And that is the way—that is a bias that we are going to have, because it needs to be real for FEMA to be able to use to save lives and property. Very true. My thought, which I—is outlined in the testimony, is to create a research subcommittee, which we have done, under ICC with a moving chair to talk about what that research agenda ought to be and then to be able to float that upwards so we can establish priorities, whether it is increasing knowledge or research or practice, opportunities and, again, float that up.

But the next piece, really, that has always been planned and is in the strategic plan that we have never operationalized during the life, as I understand it, of the NEHRP program is that PCC structure. You have got a lot of folks when you look. And I won't go back into my slides, but when you look at all of the advisory groups, we have a lot of advisory groups. But what has got the strategic plan into your hands was a drive—if you will, some really strong driving motion at the highest levels to make it happen, because we have got folks who are technical, who are very committed, who can do a lot, and who have done a lot. But right now, we need some commitment at the highest policy levels of all of these agencies at this point.

And I think that is where you are going to see, frankly, the movement. It doesn't—and it really—and with that model, it really doesn't matter where your head is, because the management plan is we are a leadership of equals. The management plan is going to be the product of all of the NEHRP partners. It is not going to be just a FEMA show at all. And so I welcome your comments. I welcome what you see fit to do, however.

Chairman SMITH. We will start a second round. I don't know what your schedule is, and I know and apologize for the length of time that we have held you here. I need some help understanding a little better our seismic technology and what the potential might be and is it worth pursuing if we can increase our lead time on warning by another eight or ten seconds? So in terms of the seismic technology that is there, is the United States the leading country? Is Japan the lead country? Who would be the lead country for the mechanics of early warning from our technology? You, Mr. Cluff.

Dr. CLUFF. Mr. Chairman, I would say that we are close to being the lead. We are working very closely with the Japanese. They are—they have a big program on earthquake prediction, but their experience shows that they really missed it with the Kobe earthquake. They were—focused all of their money and attention on the area around Tokyo. The people running that program were not paying attention to the Kobe area where we, working with them—I had been over there personally and worked on the active faults in the Osaka area, and we knew that fault that released the Kobe earthquake was an active fault. So they kind of have to redirect their activities. I think trying to short-term predict an earthquake is not socially responsible. I think the forecast that the USGS is doing, the shake—real-time shake maps and so forth is where the future is, and that technology needs a lot more funding to get it dispersed through ANSS throughout the country so we don't miss an opportunity. We have a big earthquake in the mid part of the continent where we don't have enough instruments right now. It will be another several hundred years if we miss recording that earthquake. We have got to get those in. Congress authorized a lot of money to do that. The appropriations are not there. And the budget at the USGS has been cut back. And they lack support from the Department of Interior. I serve on that advisory committee through the Department of Interior, and our committee is very distressed that the USGS does not have strong support from the Department of Interior for their budget on critical items.

Chairman SMITH. And I guess it makes me wonder about somehow doing a better job in communication. Apparently a tremendous lack of understanding about earthquakes, awareness of the technology that is available. I am not advocating, necessarily, more building codes, but certainly a—at least not an aggressive building code program in more high-risk areas. I mentioned insurance that seemed like would be—if you are going to build a building. So we have ended up without some of the understanding and initiative. And I would also suggest, respectfully to our appropriators, there is somewhat of a lack of appreciation and understanding on the part of our appropriators. So I think a letter would be very advisable.

Mr. LOWE. I agree with those comments, if you were asking.

Chairman SMITH. And Mr. Reaveley, you had a comment.

Dr. REAVELEY. Just to the insurance issue. Heretofore, the insurance industry has been very slow at recognizing the difference between a bad structure and one that might have some resistance. I was in a meeting a week ago where it looks like they are going to start taking that into account in premiums. But if there could be some incentives somehow to get the insurance companies involved with recognizing the difference between buildings, then we would probably put some incentive back into the private sector to do a better job if they could get a break on insurance by doing it right.

Chairman SMITH. Is there enough damage from earthquakes or potential damage for privately owned homes and the information and technology of the potential building type structures that can——

Dr. REAVELEY. Yes.

Chairman SMITH [continuing]. Dramatically improve their resistance to earthquakes?

Dr. REAVELEY. Absolutely. There has just been a project finished in Los Angeles to improve that housing stock. It goes all the way from individual homes to the biggest buildings we have where if we merged at least the basic technologies to address seismically deficient buildings and how to improve them. We don't have all of the answers, and we need an awful lot more work on finding the best and economical ways to do that.

Chairman SMITH. If it is a home loan with HUD or VA or Agriculture, now we require, for example, that if it is an identified potential flood area, we require flood insurance. Do we do any of that with any of our federal loans for home ownership——

Dr. REAVELEY. Not that I know of.

Chairman SMITH [continuing]. To help encourage——

Dr. REAVELEY. And some agencies have stopped writing earthquake insurance in areas, because of the damage and the loss. It may be too big a hit for them to take. I know that Lloyds of London bailed out of the Salt Lake Area years ago when they looked at what it was really going to—what was really going to happen.

Chairman SMITH. How much increase in cost would it take for a private home versus a—I don't know how you categorize different sizes of buildings, if we are retrofitting versus what it takes in initial structure?

Dr. REAVELEY. Two to three percent in a brand new building, at the very maximum. One to two percent, maybe, on the new structure to go from a bad structure to a good structure of building cost. That is all we are talking about. Small, small amounts. When we try to deal with the existing structure to fix it, we are going in—then we run into historical things and that. We can run the cost up between 20 percent of the cost to renew the structure even to 100 percent in the rehab. And there is where the balance is how—to finding out what we can fix economically and that which you should walk away from.

Chairman SMITH. And what are you suggesting that we change it to—what would it be to include tornadoes?

Dr. REAVELEY. Multi-hazard is the term that I think FEMA would use.

Mr. LOWE. Well, it has been, but you know what, I think we should be using the word "all-hazard", and the reason we should be using the world "all-hazard" is we are not dealing in silos of hazards any more. I think we are all saying that you know what, if you do certain things, it is going to protect you from a bunch of different hazards, natural, manmade, whatever. That is all-hazard, not multi-hazard.

Chairman SMITH. Yes.

Mr. LOWE. So I would suggest— —

Chairman SMITH. Representative Lofgren.

Ms. LOFGREN. Thank you. I think this is a very useful discussion. And it is, you know—comparing this discussion with, kind of, what is accepted in California is interesting and forcing me to kind of think through what happens if New Madrid lets loose. You know, we are not ready here in the East or Midwest. And in California, we are readier, although we are never fully prepared. I think that if we were to advocate, I guess this may not be in our Committee's jurisdiction, but loan sources along with the information packets. That would go a long way. I mean, I know, actually, in the San Francisco Bay Area everybody knows there is going to be more earthquakes. And if the faults let loose, you know what is going to fall down. And people go and repair buildings. I mean, the cities have gone on reinforced masonry projects. Individual homeowners are trying to, you know—the structural unsoundness of the California garage under the apartment. I mean, people are attending to that. And I think the people in the Midwest and East aren't familiar with it.

And I think that there are certainly things that can be done that would save lives in addition to ANSS. I mean, you know, to have a little warning does matter. I mean, even a little short warning can mean the difference between whether you die or whether you don't die. And so that is important, but I think it is the ability actually to get this information, these maps and these sensors out across the country and maybe even especially not in California is essential because I—just think what the economic damage to this country would be if we had a large event again, and I think we will. The only question is when. So I don't know if you agree with that, Dr. Reaveley, but— —

Dr. REAVELEY. Let me just say I agree totally with that, but don't think that what you felt in San Jose from Loma Prieta is a big earthquake. It is a moderate earthquake.

Ms. LOFGREN. It got my attention.

Dr. REAVELEY. It absolutely got your attention, but it is not what we are going to see.

Ms. LOFGREN. Right.

Dr. REAVELEY. And in modern time, we haven't had anything— —

Ms. LOFGREN. Right.

Dr. REAVELEY [continuing]. That is going to challenge that built infrastructure the way the big one will.

Ms. LOFGREN. Right. I wonder, Dr. O'Rourke, you had commented on the priorities and what we needed to do. I had a question, really, about another agency that we haven't discussed at all and the role that they might play and that is NIST. I mean, we have talked about needing to get this information out into the public arena. NIST sets standards. Their budget has been devastated in the proposed budget. I don't—maybe—Dr. O'Rourke, maybe that is—you are not the right person to ask this, but——

Dr. O'ROURKE. Well, I think everybody at this table shares that perspective. And there are varying degrees of articulation that we could provide for it. But certainly at the EERI Board of Direction, this has been a concern. As you mentioned, NIST is the national standards developer for this country, and their allocation of resources from the National Earthquake Hazards Reduction Program has been very, very small, almost minuscule in the last several years. If they are to do the things that they are capable of to provide the kind of technical device—advice and development that they are able to do, they need to have an enhanced budget. They need to have enhanced resources and to play a much more significant role through those resources in this program. So you are right, absolutely. And it is part of our common perspective, I am sure, that NIST needs to play a stronger role.

Ms. LOFGREN. Is there a role to play? I mean, building codes are a product of state and local and will remain so and should remain so. But California has dramatically upgraded its building code relative to seismic, and it has shown in terms of our losses. And my sense is that that has not actually happened in other parts of the country who are very much at risk and that there needs to be—I don't know that we need to mandate so much as there needs to be some information flow to the Midwest and to the East about the hazards and risks, because I don't know that the legislators and city council members are even aware of this.

Dr. REAVELEY. The code is out there, and it is a common code that we are all working to, essentially with variations. The difference between the good practice in California, and there is poor practice as well——

Ms. LOFGREN. Yes.

Dr. REAVELEY [continuing]. Is in the enforcement level. It is the will at the local level to do something about it. There are building officials who lose their jobs in other jurisdictions for enforcing what the codes would require. And that is what I am talking about some incentives at the local level to actually use the knowledge we have instead of building more bad buildings.

Ms. LOFGREN. Um-hum. Well, and I guess the insurance issue is—that comes into it. And certainly California has had to take over the insurance, because the loss estimates are so huge that the private market couldn't even cope with it. But I think if insurers took a look at the exposure in the Midwest, it is actually larger than what we have in California under——

Chairman SMITH. Would the gentlelady yield?

Ms. LOFGREN. Certainly.

Chairman SMITH. Do I understand you to say there is, in effect, a federal national building code that can be—that is in place that can be adopted locally by municipalities
or——

Dr. REAVELEY. One of the panel referred to it this morning or this afternoon. The IBC 2000 is a—essentially a national code. And multiple states are adopting it, and it is based upon a very thorough overall look at the country's problem from the mapping program of the USGS. Now——

Chairman SMITH. I was thinking of a building code.

Dr. REAVELEY. It is a building code. The maps are built into the building code, and there is a document available and it is being adopted state by state, which is a uniform look at what is good practice. We have that document. It came, really, out of multiple agencies, but I would, I guess, really have to point to FEMA as the one that pushed, along with ASCE and the building officials. It is a joint effort to make this happen. It was something that we couldn't even think that might happen, but it had converged in this last—for the IBC 2000 from multiple scattered documents where we were conflicting requirements. We pretty well got rid of those.

Chairman SMITH. We have kept these folks for about——

Ms. LOFGREN. Yes.

Chairman SMITH.—4½—let us see, 2½ hours.

Ms. LOFGREN. Thank you very much, though. This has been very helpful.

Chairman SMITH. Do you want to ask——

Ms. LOFGREN. No, I think that, actually, this has been a very useful hearing, because it is really stimulated some ideas and issues that I wasn't thinking about when I walked in here, so——

Chairman SMITH. Well, I am not through yet. I have one more question for——

Ms. LOFGREN. Okay.

Chairman SMITH [continuing]. Mr. Lowe.

Ms. LOFGREN. Well, I will listen to your question and answer.

Chairman SMITH. And that is the—I was told last week that our Emergency Management Program Grants are being transferred—the 4.4 million are being transferred to border security. Are you going to have any input how that is used? I mean, that is part of the NEHRP budget.

Mr. LOWE. Well, as you know, that money was put into the EMPG grants before, and that is—and that whole fund is being transferred over to border security, so there is certainly NEHRP money, as you are referring to, as well as other resources that are being transferred over to border security. We certainly are going to try to make sure that that is done in an orderly way and a sufficient—but once they are transferred into the EMPG pot, it means that states have a flexibility to spend them as they choose, and so——

Chairman SMITH. Well, so you are not going to work with ODP on the——

Mr. LOWE. No, what I am trying to say is there is a certain amount of flexibility that already came from having the money in EMPG. Now with all of that now going over to ODP, that flexibility will remain. We absolutely are going to work with ODP to make sure it works and to try to make sure that we even can have a better job of making sure we know exactly how states are using the money, so——

Chairman SMITH. I hope you were against that transfer, but other than that, give me the general rationale of why that decision was made.

Mr. LOWE. Well, that is a first responder pot that is there. I think it was Secretary Ridge's belief that it—having, kind of, all grants administered and monitored in one place would be a much more efficient way of providing an all-hazard grant. And so that seems to—is the rationale for doing that, as I understand it.

Chairman SMITH. We are going to call this——

Ms. LOFGREN. Could I just do a——

Chairman SMITH. Certainly.

Ms. LOFGREN [continuing]. Quick follow-up on that, because I was actually not aware of that transfer? Will the grants that were—the money that was transferred, are they being treated in the same way using the same formula as the first responder? The reason why I ask is that California is currently receiving, I think it is $3.57 per capita under the First Responder Grants. Wyoming is getting $37 per capita. And——

Chairman SMITH. They live farther apart.

Ms. LOFGREN. Farther from the—and so there is some sense that this is not a good idea in California. And I would be very concerned if these—if this additional money now is morphed into this strange formula. Do you know the answer to that?

Mr. LOWE. As I understand it, the first responder grants are really modeled after the Patriot Act. And so—which is—you know, there is a base level, and then there is some more. So it is a little different in terms of what you are talking about. There is no designation for earthquake funds now or——

Ms. LOFGREN. Okay.

Mr. LOWE [continuing]. Would they be in the future. So I think that kind of answers your question.

Ms. LOFGREN. Thank you.

Mr. LOWE. Can I take a little bit of a liberty to say something about insurance incentives?

Chairman SMITH. Yes, what do you think?

Mr. LOWE. Yes. I just want to say a little bit about it. As you know, I am also the Federal Insurance Administrator and do have the NFIP, which is the National Flood Insurance Program. And one of the things that we thought would be useful is to try to work with the private sector to create an all-hazard insurance policy, which would help spread the risk of, if you will, all of the major hazards across a larger policy base. And so in doing that, it might very well be an earthquake pool, let us say, in California, who would pick up a piece, the NFIP with its 92 insurance companies would pick up the flood piece. We would have a hurricane piece. There would be other pieces. It would also, obviously, create a certain amount of soundness in trying to deal with the terrorism piece.

Now the significance of that is the NFIP, just very quickly, is built on insurance, the promise of insurance if certain mitigation actions occur after the hazard areas are defined. And so ANNS, NEES, all of those are—ANSS, excuse me, are all very critical to such a system. But we think that that is a model that is worth looking at. So we would encourage that and just wanted you to know that those are the sorts of things we were thinking about.

I just want to mention that Executive Order 12699 does say that for federally owned, leased, assisted, or regulated new building construction, it needs to be in accordance with that design standard.

And so in other words—and that is the NEHRP standard. That is the 2000 standard. So that is there. And so it might be a matter of compliance to reach some of what you are talking about.

Chairman SMITH. Let us conclude by, if you wish, maybe taking up to one minute, and I will just raise my hand when your 60 seconds are up, of any last thoughts that you would like to pass on to the Committee as we write the NEHRP reauthorization. And we will start at this end, Mr. Reaveley, with you, and go down the line.

Dr. REAVELEY. Just fund us. And fund the broader program, and make it a focused program. I worry that we have—that we are not focused and coordinated on what our goals and objectives are.

Chairman SMITH. Dr. O'Rourke.

Dr. O'ROURKE. I echo that. I think that this program has done great service and value for the United States, that it is a model for the rest of the world, that it contributes not only to our seismic safety, but, as you have heard in this testimony from all different sources, has had a profound influence on our homeland security and other natural hazards. And so it is—needs support. It needs the funding. And you also asked for priorities. I think ANSS, and also NEES, are two model programs that have terrific opportunity to do the kinds of things you want it to do. They are on the table. They are there. They are well thought out. They are visionary. And with support for those two projects, you will get a lot of leverage.

Chairman SMITH. Dr. Cluff.

Dr. CLUFF. Yes, I support the need to expand the funds, increase the funding in line with what the EERI comprehensive program has called for, at least a three times expansion. When we look at the losses that we certainly can get from earthquakes, on a cost benefit ratio, it is very clear. The Trans-Alaska Pipeline is a good example on the money that was saved from a potential environmental disaster. It was a non-event in the press. When asked—when I had been asked can we afford to increase the budget for the NEHRP program, when I look at the consequences, we can't afford not to.

Chairman SMITH. Thank you. Mr. Olson.

Mr. OLSON. I believe my colleagues have said it all very well. Being educated in political science, I look back and I would like to just suggest that maybe it is time to look back at the chartering legislation that was passed in 1977 and to take a look forward to the next 20 years and see what it ought to say, because that chartering legislation then is what the agencies implement and report to you on. And I think that may be a policy—it might be just time to look at that policy issue. Thank you.

Chairman SMITH. Thank you. Mr. Lowe.

Mr. LOWE. Yeah. I just would want to re-emphasize that the important thing here seems to me to really drive this program toward results, and the results, of course, are saving lives and property. We have all of the makings of that. We have a strategic plan. We are developing an annual plan working with all of our stakeholders and then, of course, the work that will come out of the research coordinating committee. And so we are developing a performance management program. That is vitally important, and so we would like, certainly, the Committee's strong consideration of what we are trying to do here and to give the strategic plan and the structure we have set up along with the management plan, among all the PCC leaders, the NEHRP agency leaders, if you will, to work, because we believe that you will be pleased with the success if you do.

Thank you.

Chairman SMITH. Let me close in saying thank you all very much for the sacrifice of your time being here. Thank you for your expertise and interest and advice. Without objection, the record of this committee hearing will remain open for, how long, 48 hours?

The CLERK. Five days.

Chairman SMITH. Five days in order to have comments from other Members of the Committee and, with the permission of the panelists, to possibly ask you additional questions that haven't been answered. And with that, the Committee is adjourned.

[Whereupon, at 4:33 p.m., the Subcommittee was adjourned.]

Appendix 1:

Additional Statements

PREPARED STATEMENT OF CHARLES G. GROAT
DIRECTOR, U.S. GEOLOGICAL SURVEY
U.S. DEPARTMENT OF THE INTERIOR

INTRODUCTION

The U.S. Geological Survey (USGS) has been an active participant in the National Earthquake Hazards Reduction Program (NEHRP) for twenty-five years. Within NEHRP, USGS provides the fundamental earth sciences information, analyses, and research that form the foundation for cost-effective earthquake risk reduction measures.

Earthquakes are the most costly, single event natural hazard faced by the United States. Twenty-five years of work by USGS, in close cooperation with the three other NEHRP agencies (Federal Emergency Management Agency (FEMA), National Institute of Standards and Technology (NIST), and National Science Foundation (NSF)), has yielded major advances in earthquake preparedness and monitoring, as well as a vastly improved understanding of earthquake hazards, effects, and processes. Through NEHRP, USGS is poised to build on these accomplishments, helping to protect lives and property in the future earthquakes that will strike the United States. In FY 2003, USGS received $46.6 million in appropriated funds to support NEHRP work. The three major activities of USGS within NEHRP and the percentage of funds supporting these activities are given below:

— *Assessment and quantification of seismic hazards*. The USGS produces and demonstrates the application of products that enable the public and private sectors to assess earthquake risks and implement effective mitigation strategies. (40 percent)
— *Operation, modernization, and expansion of real-time earthquake notification and monitoring systems*. The USGS operates the national program in collecting, interpreting, and disseminating information on earthquake occurrences throughout the U.S., and significant earthquakes worldwide, in support of disaster response, scientific research, national security, earthquake preparedness, and public education. (40 percent)
— *Increasing scientific understanding of earthquake processes and effects*. The USGS pursues research on earthquake processes and effects for the purpose of developing and improving hazard assessment methods and loss reduction strategies. (20 percent)

The work of USGS Earthquake Hazards Program is focused on the Nation as a whole and on five broad geographical regions, addressing particular regional needs and problems in areas where the earthquake risk is the greatest. These regions are Southern California, Northern California, the Pacific Northwest (including Alaska), the Intermountain West, and the central and eastern United States (including Puerto Rico).

Approximately one-fourth of the USGS NEHRP funding is used to fund activities, investigations, and research outside USGS. Each year we support approximately 100 research grants at universities, state governments, and in the private sector. The USGS is engaged in some 16 cooperative agreements to support the operations of 14 regional seismic networks maintained by universities. In a cooperative effort with NSF, USGS provides support to the Southern California Earthquake Center, a leading effort in earthquake research at the University of Southern California. By involving the external community, through research grants and cooperative agreements, 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.

USGS NEHRP ACTIVITIES

Earthquake Hazard Assessments. The USGS carries out quantitative earthquake hazard assessments on national and regional scales. The national seismic hazard assessments are used to form the seismic safety elements of model building codes for the United States. These maps integrate results of geologic mapping, field studies of fault locations and slip rates, analyses of seismicity patterns and rates, and crustal deformation measurements. The maps are prepared in digital format and give, at some 150,000 grid points nationwide, the severity of expected ground shaking (in terms of horizontal acceleration and velocity) over exposure times of 50, 100, and 250 years. The maps and their associated databases are used also to predict earthquake losses and to define insurance risks. Periodic review and revision of these maps, as new data become available, is a high priority in the USGS NEHRP program. The latest revision of these maps was completed in 2002.

The national scale earthquake hazard maps do not take into account variations in the amplitude and duration of seismic shaking caused by local geologic structures and soil conditions. For example, artificially filled land and shallow geologic basins filled with loosely consolidated sediments tend to amplify and extend earthquake shaking to dangerous levels. The USGS works in areas of high to moderate seismic risk, such as San Francisco, Los Angeles, Seattle, and Memphis, to produce large-scale maps and databases that show the variations in ground shaking patterns that can be expected from local conditions.

In addition to not taking into account variations in local geology, the national scale assessments do not take into account the time dependence of earthquake occurrence. For example, if a large, magnitude 8 earthquake occurs on the northern San Andreas fault in California tomorrow, is unlikely that an earthquake of similar magnitude will occur on the same fault a year from now, simply because a large portion of the tectonic strain in the region will have be relieved. Studies of the regional "strain budget" result in forecasts of the probabilities of future earthquakes on individual active faults and across the region as a whole. The USGS is in the process of publishing an exhaustive study of the earthquake probabilities in the San Francisco Bay region. This study estimates a 62 percent chance of an earthquake of magnitude 6.7 or greater in the region before 2031.

Earthquake Monitoring and Notification. The USGS is the only agency in the United States responsible for the routine monitoring and notification of earthquake occurrences. The USGS fulfills this role by operating the U.S. National Seismograph Network (USNSN), the National Earthquake Information Center (NEIC), the National Strong Motion Program (NSMP), and by supporting 14 regional networks in areas of moderate to high seismic activity. All of these efforts are being integrated into the Advanced National Seismic System (ANSS). Rapid and reliable information on the location, magnitude, and effects of an earthquake is needed to guide emergency response, save lives, reduce economic losses, and speed recovery. Additionally, the seismic data from routine network operations are essential to define and improve the models of earthquake occurrence, fault activity, and earth structure that underlie earthquake hazards assessments and research on earthquake effect and processes.

The same analysis systems and facilities that process data for domestic earthquakes use data from the Global Seismograph Network (GSN) to monitor foreign earthquakes. Notifications of large foreign earthquakes are provided to the Department of State, the Office of Foreign Disaster Assistance, the Red Cross, and the news media.

The ANSS is an effort to integrate, modernize, and expand earthquake monitoring and notification nationwide. This effort was authorized in the last reauthorization of NEHRP in 2000 (P.L. 106–503). Although appropriations have not reached the authorized level, significant progress has been made in the development of the ANSS. A management structure is in place that includes regional implementation and advisory groups with national level oversight and coordination. By the end of 2003, USGS and its regional partners will have installed some 400 new seismic sensors in urban areas of the United States. These areas include Los Angeles, San Francisco, Seattle, Salt Lake City, Reno, Anchorage, and Memphis. Data from earthquake sensors in urban areas can be used to produce, within a few minutes of an earthquake occurrence, a map showing the actual severity and distribution of strong ground shaking caused by an earthquake. Emergency management officials and managers of transportation, communication, and energy grids use these "ShakeMaps" to direct the response to the earthquake, minimize it effects, and speed recovery. Data from these "Shake Maps" can be imported into FEMA's HAZUS GIS based loss estimation tool to provide extremely reliable results. Some form of ShakeMap capability now exists in Los Angeles, San Francisco, Seattle, and Salt Lake City.

ANSS sensors in urban areas also provide the data necessary to improve earthquake resistant building design and construction practices. These instruments will provide quantitative data on how the ground actually shook during an earthquake. These data will serve as the input to engineering studies to improve site characterization and infrastructure (bridges, buildings, lifelines, etc.) performance, such as the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) sponsored by NSF.

Better Understanding of Earthquake Processes and Effects. With the goal of improving hazard assessments, earthquake forecasts and earthquake monitoring products, USGS conducts and supports research on earthquake processes and effects. This is a effort to increase our understanding of the tectonic processes that lead to earthquakes, the physics of earthquake initiation and growth, the propagation of strong shaking through the Earth's crustal and surficial layers, and the triggering of landslides, rock falls, and other ground failures by seismic shaking. This research is based on theoretical, laboratory, and field studies and addresses many of the fundamental problems of earthquake occurrence and consequences.

Working with User Communities. The USGS believes that all of its work under NEHRP must relate to reducing public risk from earthquake hazards. We make strong efforts to engage the communities of users of our information, assessment products, and research.

The development of the national seismic hazard maps involves an exhaustive process in which we engage seismologists, geologists, and engineers on the regional and national levels. Regional workshops are held at which new data and studies on earthquake hazards are presented and discussed. The changes that will result in incorporating the new results into revised maps are also presented and discussed. Every effort is made to reach a consensus on the validity of the new results and on the resulting changes in the hazard maps. At the national level, we work with FEMA, the National Institute of Building Safety, the Building Seismic Safety Council, the Building Officials Conference of America, and the American Society of Civil Engineers to ensure that the maps are of maximum practical use to the engineering and construction communities.

Our work on regional hazard assessments in northern and southern California, Seattle, and Memphis is carried out in participation and collaboration with regional and local governments and local interest groups. These groups provide essential input on what information is needed and the form in which it is needed to be of greatest practical use.

Within the ANSS management structure, there are six regional advisory committees and a national steering committee. These committees are made up of engineers, seismologists, and emergency management officials. The regional advisory committees ensure that the implementation of ANSS meets regional requirements; the national committee ensures that the program is developed as an integrated system with national operating standards and equipment specifications.

In 2002, under the authority of P.L. 106–505, USGS established a Scientific Earthquake Studies Advisory Committee to advise USGS on its roles, goals, and objectives within NEHRP, to review its capabilities and research needs, and to provide guidance on achieving major objectives and performance goals. Members of this committee have backgrounds in geology, seismology, and engineering and represent academia, State governments, and the private sector. The Committee has met three times during the past year and has provided two reports to this committee on its findings.

The USGS maintains close ties with professional groups such as the Seismological Society of America, the Earthquake Engineering Research Institute, and the American Geological Institute. We also work closely with and support regional groups such as the Central United States Earthquake Consortium, the Western States Seismic Policy Council, the Cascadia Region Earthquake Working Group, and various state geological surveys and seismic safety commissions.

At the federal level, in additional to working with our NEHRP colleagues, we have strong ties to the Tsunami Warning Service of the National Oceanic and Atmospheric Administration, the Nuclear Regulatory Commission, the Bureau of Reclamation, and various elements of the Departments of Defense, Energy, and Transportation.

The USGS has worked with the Red Cross and other agencies to prepare Sunday paper inserts on earthquake awareness for San Francisco and Anchorage. A USGS employee wrote the pamphlet "Putting Down Roots in Earthquake Country" which was published and distributed throughout southern California by FEMA, the State of California, the Red Cross, and the Southern California Earthquake Center.

Promoting the International Exchange of Earthquake Information and Research. Since the beginning of NEHRP, USGS has had formal, active scientific exchange programs with Russia, Japan, and the Peoples Republic of China. In prior years, before development of the Internet and the demise of the Cold War, these exchanges were rather stiff and prescribed with formal annual meetings at which details of joint research projects were negotiated. The annual meetings continue, but in addition to them there is a continual flow of information, ideas, and results between participants on all sides through electronic mail and personal visits. The USGS also has exchange programs with institutes in France, Italy, Turkey, Mexico, and Canada.

In the case of a large, foreign earthquake, when there are lessons to be learned that have applications in the United States or when assistance is requested, the USGS will send teams of scientists to carry out post-earthquake investigations. During the 25 years of NEHRP the USGS has sent teams to investigate earthquakes in dozens of countries including Algeria, Armenia, Australia, Chile, China, Columbia, El Salvador, Guatemala, Italy, India, Japan, Mexico, Turkey, Yemen, and Yugoslavia. Most of these investigations have led to scientific reports that are provided to the host country and many have led to extensive collaborative work between USGS and foreign scientists.

SIGNIFICANT ACHIEVEMENTS OF NEHRP

The USGS has made substantial progress in earthquake awareness, preparedness, and safety during the past 25 years. Immense efforts have gone into planning earthquake emergency response, retrofitting existing structures, and ensuring that new structures are built to withstand expected shaking levels. The USGS has contributed to these efforts through its hazard assessment, monitoring, and research efforts.

Earthquake Hazard Assessment. The flagship product of the USGS under NEHRP is the series of national seismic hazard maps. These seismic hazard maps are the scientific basis of seismic provisions in building codes enacted throughout the U.S. to prevent loss of life and limit damage during large earthquakes. Ten years ago these code maps were based on four broad, qualitative zones that were used to describe the earthquake hazard nationwide. This depiction and classification of the Nation's earthquake hazard was completely inadequate. Today these maps consist of 150,000 grid points each with a quantitative estimate of the expected shaking at each point. The 1996 national seismic hazard maps are directly included in design maps in the *NEHRP Recommended Provisions,* published by the Building Seismic Safety Council and FEMA. In turn, these *Provisions* are used in the 2000 International Building Code (IBC), which is the merging of the three major national model codes. The IBC and the International Residential Code have now been adopted by jurisdictions in 37 states. Thus, this NEHRP product, the set of national seismic hazard maps, is being used to make billions of dollars of new construction each year safer from earthquakes.

The national seismic hazard maps are also used in the FEMA retrofit guidelines, ensuring that older buildings are strengthened so that they withstand future earthquakes. These maps and associated products are also used in the design of highway bridges, landfills under EPA regulation, and dams, as well as the setting of earthquake insurance premiums and the cost of re-insurance. The California Earthquake Authority uses the seismic hazard maps for California, produced by USGS and the California Division of Mines and Geology, to set earthquake premiums for the state earthquake insurance program. Pension funds apply these maps, made under NEHRP, to evaluate the risks to their portfolios of properties. Presidential executive orders specify that new and leased federal buildings must adhere to the *NEHRP Recommended Provisions*. The State of Oregon recently upgraded to seismic zone 4 along the southern part of its coast, largely based on hazard information presented in USGS seismic hazard maps.

Another major advance in hazard assessment work occurred in the 1990's when USGS created formal field offices in Pasadena, Memphis, and Seattle. The purpose of these field offices was to bring our scientists in direct contact with the regional users of the results of our studies. Personnel at these field offices, and at our regional center in Menlo Park, California, have been very successful in working with local interests and creating products that will allow these interests to effectively and efficiently address their earthquake risks.

Earthquake Monitoring and Notification. The USGS has also realized major improvements in its ability to provide timely and informative earthquake reports and information. Twenty-five years ago basic earthquake data processing (location and magnitude determination) was done by hand. Scientists made measurements on paper seismograms with rulers and used slide rules to compute epicenters and magnitudes. Earthquake notification was performed by individually dialed telephone calls. It took at least an hour to develop the photographic paper that recorded the seismic data, make the measurements, analyze the data, and make the phone calls. This was the time required to process one earthquake! Today digital data flows from hundreds of seismometers over dedicated communication links to regional and national data centers. At these centers computers that "read" the seismograms using complex analysis programs process the data. Epicenters and magnitudes are generated automatically and instantaneously and the results are broadcast within seconds.

The concepts underpinning the Advanced National Seismic System are allowing USGS to capitalize on the revolution in information technology of recent decades to achieve dramatic advances in real-time seismic data analysis and rapid earthquake notification. The most noteworthy result of this is the "ShakeMap" product. Complementing ShakeMap is a suite of other real-time earthquake products such as earthquake paging and e-mail services, real-time earthquake location maps, automatic Web pages for significant events, and aftershock probability estimators. Recently we established a Web-based interface to provide Internet users with a means of recording individual earthquakes experiences and compiling these into summary maps of shaking intensity ("Did-You-Feel-It?"). These additional products provide rapid, reliable, and comprehensive information about U.S. and worldwide earthquakes.

Understanding Earthquake Processes and Effects. Progress made in earthquake hazard assessments during the past 25 years have their roots in pioneering USGS field, laboratory, and theoretical research focused on understanding the basic physical processes of earthquakes. Key results include:

— Improved models of seismic energy attenuation as a function of distance from an earthquake;

— Use of the Global Positioning System (GPS) to determine the rate at which faults are being "loaded" (stressed) by the movement of tectonic plates that make up the Earth's outer shell;

— Discovery and documentation of large, prehistoric earthquakes through a new field of study known as paleoseismology through identifying evidence of past earthquakes in trenches dug across faults, in riverbanks, and from drowned coastlines;

— Quantifying the effect of soils and near-surface conditions in amplifying strong ground motion; and,

— Advances in earthquake forecasting through improved understanding of the physics of fracture and friction of rocks in fault zones.

IMPROVING NEHRP

The USGS believes that, although the coordination between NEHRP agencies is good, it could be substantially improved. Coordination between USGS and NSF on NEHRP matters takes place more on a collegial basis, rather than being driven by NEHRP; however, FEMA has recently taken steps to establish a Research Coordination Committee, which may improve the overall coordination. The USGS believes that stronger direction to the overall NEHRP program would be constructive. Because of provisions in the last legislation authorizing NEHRP, USGS now benefits from the advice and guidance of its Scientific Earthquake Studies Advisory Committee. This committee has proven invaluable in providing sound direction to our NEHRP activities. The USGS suggests that a similar advisory body to the entire NEHRP effort would provide the stimulus and guidance to ensure greater coordination, cooperation, and planning.

NEHRP CHALLENGES AND USGS PLANS

Although much has been accomplished under NEHRP, much work remains to be done to ensure safety and reduce economic losses in future earthquakes. The country's population and economy continue to grow in earthquake prone areas. Exposure to earthquake risk continues to increase. Emergency officials, lifeline managers, the news media, and the public expect immediate, reliable, and complete information on the location, magnitude, impact, and effects of any and all earthquakes.

Earthquake hazard information used in model building codes is applied for public safety only; that is to keep the structure from collapsing. The building may be a total loss, but the inhabitants are expected to be safe. Financial and engineering interests are now pursuing the more sophisticated, and more complicated, concept of performance-based design. Under this concept, the structure is designed and constructed so that it will meet a desired performance level during and after an earthquake. For example, the owners and occupants of a structure housing a national corporate headquarters may want it designed so that it will be completely functional immediately after a strong earthquake. Performance based design concepts require more extensive and complete data on the nature and variation of ground shaking and building from earthquakes.

Going forward, USGS will continue to build on existing USGS earthquake monitoring, assessment, and research activities with the ultimate goal of providing the Nation with earthquake products that promote earthquake mitigation and facilitate earthquake response. At the heart of this effort will be a continued emphasis on delivering information that is useful, accessible, and easily understood. By working closely with policy-makers and emergency planners, USGS will ensure that they have the most reliable and accurate information possible about earthquake hazards and that our products are tailored to their needs. The USGS will participate in local and national earthquake mitigation planning exercises and help train emergency responders, contingency planners, risk managers, the media, and others in how to use earthquake hazard assessments and real-time information products. The USGS will also continue to work directly with communities to help them understand their vulnerabilities to earthquakes and to plan mitigation actions. Critical decisions for earthquake preparedness and response, including continued corporate and government operations, are often made far from areas of high seismic hazard. So that informed and appropriate actions can be taken, USGS will continue to work to ensure that earthquake hazard information and products are useful and familiar to decision-makers even in regions of low seismic hazard.

Advanced National Seismic System. The ANSS initiative is intended to contribute to reducing loss of life and property in earthquakes through monitoring actual ground shaking levels in urban areas and the dynamic performance of structures and lifelines in earthquakes. ANSS is intended to collect this information through a nationwide network of sophisticated shaking monitors, placed both on the ground and in buildings in urban areas in seismically active regions. Under the ANSS initiative, USGS had added 400 new seismometers in urban areas and 18 new seismometers to the regional networks it supports.

One component of ANSS is the instrumentation of buildings. To date, two buildings have been instrumented under the ANSS initiative. Currently, the spacing of seismometers is not sufficient to correlate the ground shaking to the performance of specific buildings. If hundreds of buildings in high-risk areas are instrumented with seismometers, engineers can determine how specific types of buildings respond to earthquake shaking. Although model building codes set earthquake resistant standards for broad, general classes of structures (i.e., wood frame, residential) on a generic soil type, these instruments will provide data about how more complicated buildings (i.e., steel-moment frame and non-ductile concrete frame) buildings perform during earthquakes and how to design buildings that will perform well during violent shaking.

The instrumentation of structures in seismically active areas provides engineers with critical information they need to determine how buildings respond to earthquakes. This information includes:

- the coupling between the building foundation and the underlying soils;
- the role of torsion of columns in building shaking;
- the performance of commonly used systems such as shear walls combined with a moment-frame structure; and,
- the ability of mathematical models to predict the performance of buildings during strong shaking.

The closely spaced seismometers could also be used to identify areas of special engineering problems, such as high amplification and focusing, that will require special building design before the destructive earthquake occurs. This in turn will allow identification of locations where seismic strengthening of buildings is needed the most, ensuring the cost effectiveness of the mitigation.

A goal of ANSS is improved reliability, timeliness, and breadth of USGS real-time earthquake products for emergency response purposes. ShakeMap, in particular, requires access to a modern seismic network with digital strong motion recording capabilities and real-time telecommunications feeds. Few U.S. urban areas possess this type of modern technology. For this reason, ShakeMap is currently only available in a handful of cities (Los Angeles, San Francisco, Seattle, and Salt Lake City). We note that the instruments and automatic analysis systems being deployed and developed within the ANSS effort can detect, locate, and determine the severity of large, non-natural events that generate seismic energy, such as explosions and impacts.

Earthquake Warnings. As the ANSS system develops, it will be technically possible, under some conditions, to issue warnings within a few tens of seconds of the initiation of strong ground shaking. The seismic waves that carry strong shaking travel at about two miles-per-second. If an earthquake occurs 100 miles outside of an urban area, data from ANSS sensors near the epicenter can immediately be transmitted over robust communication links to a data analysis center. Here the data can be analyzed automatically to determine that a strong earthquake has occurred. This could be done within a few seconds. A warning could then be issued via radio to the urban area that strong earthquake shaking is imminent. The warning would give school children time to get under their desks, allow surgeons time safely pause their procedures (if possible), and provide time to suspend the pumping of toxic materials and other hazardous activities. The USGS is taking the lead in demonstrating this capability; however its implementation must be done in cooperation with local and regional governments.

Integrating essential data for expanded urban hazard assessments. Most current USGS earthquake hazard assessments are compiled on regional or national scales. These estimates typically are limited to calculating hazards on hard rock conditions as opposed to the actual soil conditions beneath cities and lifelines. At scales needed for urban planning and development, assessments need to account for the amplifying effects of soils and the potential for ground failures, such as liquefaction and landslides.

USGS pilot urban assessments in Oakland, Seattle, and Memphis have shown the usefulness of detailed urban assessments. Central to this effort will be the integration of data on local geology, site conditions, and ground motions needed to produce detailed urban hazard maps. These data integration efforts will require partnerships with state geological surveys and local agencies. As these hazard assessments evolve, they will allow estimates of potential earthquake losses to building stocks and critical lifelines. This is one of the keys to developing cost effective mitigation strategies to reduce future earthquake losses.

Earthquake Hazards in the Eastern United States. The USGS earthquake program devotes approximately 75 percent of its resources to work in the Western United States, primarily because the hazard there is greater. However, history demonstrates that a catastrophic quake could also strike a major city in the Eastern United States. Four damaging earthquakes with magnitudes greater than 7 centered in the New Madrid, Missouri, area struck the Mississippi Valley in 1811–1812. Charleston, South Carolina, was devastated by a magnitude 6.7 shock in1886, and a magnitude 6.0 quake struck the Boston area in 1755.

USGS studies show that urban areas in the Eastern United States will incur far greater damage and far more deaths in a quake of a given magnitude than those in the West for several reasons: (1) for the same magnitude earthquake, shaking affects a much larger area, (2) most structures are not designed to resist earthquakes, and (3) population density is high and residents are not routinely educated about seismic safety.

USGS is developing the methods and understanding that could improve our understanding of the earthquake hazard in the East, where the causative earthquake faults are rarely exposed at the surface and the subsurface conditions beneath major cities are poorly documented. More thorough and accurate assessment of the seismic risk faced by major urban centers in the East will reveal the greatest vulnerabilities and serve as key input to evaluate possible mitigation strategies.

Earthquake Hazards in Alaska. Alaska has the greatest exposure to earthquake hazard of any state. Because of the relatively small urban population, many assume the risk is low compared to the rest of the country. However, the impact of a devastating earthquake in Alaska can extend far beyond its borders, both by generating deadly tsunamis and through economic consequences. Alaska is a major source of natural resources for the rest of the Nation, a major transportation and commercial node of the Pacific Rim being the 5th busiest air cargo airport in the world, and of significant importance to national defense.

Capitalizing on new national facilities. As described in the 2003 National Research Council report, *Living on an Active Earth: Perspectives on Earthquake Science,* continued progress toward evaluating earthquake hazards will increasingly require integrative, physics-based research involving theoretical studies of processes controlling earthquake phenomena, sophisticated numerical modeling, *in situ,* ground-based, and space-based field observations, and laboratory simulations. Research, data collection, and monitoring facilities developed during the first 25 years of NEHRP are aging and becoming obsolete. Recent and proposed U.S. government investments in a number of major earth science and engineering facilities (e.g., ANSS, the NSF-coordinated EarthScope initiative—including the Plate Boundary Observatory, USArray, and the San Andreas Fault Observatory at Depth, the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), and a future interferometric synthetic aperture radar (InSAR) satellite mission) offer, for the first time, the breadth and depth of data required to truly address the physical nature of earthquakes.

The USGS will take advantage of these new data streams to perform earthquake hazard focused experiments on scales never before possible. To improve long-term hazard assessments, USGS will also create region specific earthquake occurrence models that simulate the multiple factors operating in active fault systems. A major goal will be to understand the criteria for the occurrence of earthquakes within a fault system and the impact of one quake on the system through the many processes that transfer stresses. To determine if earthquakes are predictable, USGS will build models of earthquake likelihood, akin to weather forecast models.

Earthquake Prediction. Reliable prediction of the time, place, and magnitude of future earthquake is the "holy grail" of earthquake science. The USGS spent considerable effort on earthquake prediction during the early days of NEHRP (1978–1990). After strong efforts and at least one dramatic failure, based mostly on a phenomenological approach, USGS concluded that earthquake prediction would not be possible without a foundation based on a complete understanding of earthquake physics and processes. During the past decade, we have seen considerable progress in the understanding of earthquake processes. This progress in understanding could contribute to advancing reliable earthquake prediction. But, in order to do so, it would be necessary to review the current state of knowledge, identify the scientific problems that should be addressed, and develop a strategy to address these issues.

CONCLUSION

After 25 years of NEHRP, USGS has become a world scientific leader in seismic hazard studies. In implementing the results of these studies to mitigate the effects of earthquakes, USGS has actively collaborated with state geologic surveys, emergency response officials, earthquake engineers, local government, and the public. This has resulted in dramatic improvement in building safety and earthquake response in the United States. But there is still much to be done. By integrating USGS earthquake information with data from new national initiatives, such as ANSS, USGS will be able to develop a new generation of effective and efficient earthquake hazard assessment and mitigation tools. These tools will be used to further reduce losses of life and property in the future earthquakes that are certain to strike our nation's seismically hazardous regions.

Thank you, Mr. Chairman, for the opportunity to submit this statement.

BIOGRAPHY FOR CHARLES G. GROAT

On November 13, 1998, Dr. Charles G. Groat became the 13th Director of the U.S. Geological Survey, U.S. Department of the Interior.

Groat is a distinguished professional in the earth science community with over 25 years of direct involvement in geological studies, energy and minerals resource assessment, ground-water occurrence and protection, geomorphic processes and landform evolution in desert areas, and coastal studies. From May to November 1998, hie served as Associate Vice President for Research and Sponsored Projects at the University of Texas at El Paso, following three years as Director of the Center for Environmental Resource Management. He was also Director of the University's Environmental Science and Engineering Ph.D. Program and a Professor of Geological Sciences.

Prior to joining the University of Texas, Dr. Groat served asp Executive Director (1992–95) at the Center for Coastal, Energy, and Environmental Resources, at Louisiana State University. He was Executive Director (1990–92) for the American Geological Institute. From 1983–88, he served as assistant to the Secretary of the Louisiana Department of Natural Resources, where he administered the Coastal Zone Management Program, and the Coastal Protection Program.

From 1978–1990, Dr. Groat held positions at Louisiana State University and the Louisiana Department of Natural Resources which included serving as professor for the Department of Geology and Geophysics, and as Director and State Geologist for the Louisiana Geological Survey. He also served as associate professor (1976–78) at the University of Texas at Austin, in the Department of Geological Sciences, and as Associate Director and Acting Director of the Bureau of Economic Geology.

Dr. Groat received a Bachelor of Arts degree in Geology (1962) from the University of Rochester, a Master of Science in Geology (1967) from the University of Massachusetts, and a Ph.D. in Geology (1970) from the University of Texas at Austin.

Among his many professional affiliations, Groat is a member of the Geological Society of America, American Association for the Advancement of Science, American Geophysical Union, and the American Association of Petroleum Geologist. He has also served on over a dozen earth science boards and committees and has, authored and contributed to numerous publications and articles on major issues involving earth resources and the environment.

Dr. Charles G. Groat was born in Westfield, New York, March 25, 1940. He currently resides in Reston, Virginia, with his wife, Barbara. He has two grown children.

PREPARED STATEMENT OF PRISCILLA P. NELSON
SENIOR ADVISOR, DIRECTORATE FOR ENGINEERING,
NATIONAL SCIENCE FOUNDATION

Introduction

Mr. Chairman and distinguished Members of the Subcommittee:

I appreciate the opportunity to submit this testimony from the National Science Foundation (NSF) concerning the Subcommittee's reauthorization of the National Earthquake Hazards Reduction Program (NEHRP). NEHRP was established in 1977 and operates as an effective multi-agency partnership; NSF is privileged to serve as a NEHRP agency. We are confident that NEHRP—in collaboration with other federal agencies, local and state governments, colleges and universities, and private sector organizations throughout the country—will continue to take crucial steps toward meeting the challenge of reducing deaths, injuries and property damage caused by earthquakes in the years to come.

In order to provide context for the NSF involvement in NEHRP, let me first discuss the broader NSF mission in order to place in context my extended discussion of the role of NSF in the NEHRP partnership.

The NSF Mission

Recent years have seen acceleration in rates of change in society and in the world at large. In this era of dynamic change, in which science and technology play an increasingly central role, NSF has remained steadfast in pursuit of its mission: to support science and engineering research and education for the advancement of the Nation's well being. Knowledge is our strongest insurance for preparedness. The Foundation is that main source of funding for the growth in fundamental scientific knowledge and, at the colleges and universities funded by NSF, scientists and engineers are working to provide more effective predictions and to discover ever more effective approaches to prevention and amelioration.

The perspective of each NEHRP agency is critical to creating a complete picture of the Nation's vulnerability to earthquakes—an understanding that leads to effective mitigation and hazard reduction. Collectively, we cover the spectrum from natural and social sciences to engineering, from discovery to implementation, from response to mitigation. With the vulnerability of the Nation to natural hazards growing increasingly complex, we need an integrated, multi-agency perspective to make significant progress.

Role of NSF in NEHRP

NSF supports research and educational activities in many disciplines, and this is reflected in our role within NEHRP. Our role complements the responsibilities assigned to our principal partners in the program: the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS), and the National Institute of Standards and Technology (NIST). NSF is involved in continuing strategic planning with the other NEHRP agencies in order to further interagency coordination and integration.

Legislation authorizing NEHRP called for NSF to support studies in the earth sciences, earthquake engineering, and the social sciences. Since 1977, NSF investments have supported growth of vibrant hazards-related research communities in engineering, geosciences, and in the social sciences. Leadership from the engineering research community has been important to technology transfer of research outcomes into practice and into improvements in codes and standards. NSF's investments in center-based research (the Earthquake Engineering Research Centers—EERCs, and the Southern California Earthquake Center—SCEC) have been very important for the integration of social sciences into engineering and geoscience research questions, and NSF's investments in IRIS (Incorporated Research Institutions for Seismology) have resulted in an effective global network for seismic monitoring. The EERCs are recognized for global leadership in the development of new concepts of performance based earthquake engineering (PBEE), and consequence-based approaches to understanding the performance and vulnerability of complex infrastructure systems. NSF's centers programs provide very useful institutional arrangements for conducting complex holistic research, and this tradition will be carried into the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) project as it becomes fully operational at the end of FY 2004.

During 2002, NSF supported the Earthquake Engineering Research Institute (EERI) to develop a long-term research and education plan to advance the state-of-the-art and the state-of-the-practice in earthquake engineering and earthquake loss reduction. The result is a comprehensive, community-held vision that includes buy-in from all sectors and disciplines including academics, practicing engineers and geoscientists, social scientists, and government employees and regulators. The plan takes advantage of opportunities presented by high performance computing, information systems, simulation and visualization. Integral to the outcome is the commitment by EERI to maintain and update this vision, and to coordinate with other kindred organizations and programs including the Advanced National Seismic System (ANSS, a project of the USGS) and the NEHRP agencies.

Earthquake and hazards-related research and educational activities are supported in many of the programs at NSF, including particular contributions from the Social, Behavioral, and Economic Sciences (SBE), the Geosciences (GEO) and the Engineering (ENG) Directorates. Fundamental seismic research is funded in GEO, while ENG supports fundamental earthquake engineering. Social science research related to earthquake hazard mitigation and preparedness is supported through the SBE and ENG Directorates. Significant progress continues to be made in these programs in understanding plate tectonics and earthquake processes, geotechnical and structural engineering, and the social and economic aspects of earthquake hazard reduction.

In addition to the four NEHRP-funded earthquake centers, numerous individual investigator and small group projects related to earthquakes are also supported by NSF. Other NEHRP-related NSF activities include programs involving earthquake research facilities, post-earthquake investigations, international cooperation, and information dissemination. In the remainder of this testimony, recent highlights of such activities will be discussed briefly.

Research Facilities

NEHRP legislation has reinforced NSF's own expectations regarding the important role for NSF to ensure that U.S. researchers have the required facilities to conduct cutting-edge research well into the next century.

The George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

Previous NEHRP legislation called for NSF, in collaboration with the other NEHRP partners, to develop a comprehensive plan for modernizing and integrating experimental earthquake engineering research facilities in the U.S. That plan was completed and implemented as an NSF Major Research Equipment and Facilities Construction project—the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). In 1999, the NEES project was authorized for NEES construction between FY 2000 and FY 2004. The FY 2004 budget request includes the final increment of $8.0 million for completion of this $81.8 million project.

NEES will be a networked simulation resource of fifteen geographically-distributed, shared use next-generation experimental research equipment sites. The NEES sites were identified through peer-reviewed proposal competitions and include facilities under construction in California, Colorado, Illinois, Minnesota, Nevada, New York, Oregon, Pennsylvania, Texas and Utah.

The NEES experimental capabilities will lead to new tools for modeling, simulation, and visualization of site, structural, and nonstructural response to earthquakes and tsunami effects. NEES will provide an unprecedented engineering capability for attacking major earthquake problems with coordinated multi-organizational teams, producing convincing results that can be adopted into building codes and engineering practice.

- NEES experimental research equipment, located at U.S. universities or off-campus field sites, includes shake tables, geotechnical centrifuges, a tsunami wave basin, large-scale laboratory experimentation systems, and field experimentation and monitoring installations.
- The NEES network links nation-wide users and equipment sites through a high performance Internet system that will include web-based collaborative tools, data and simulation software repositories. The NEES network also provides access to leading edge compute resources.
- Through the network, researchers can remotely interact with each other and with their experimental and simulation tools via "telepresence" tools.

NEES will also serve as a major educational tool. Undergraduate and graduate students throughout the U.S. will be able to access the network for data, information, and course material as well as to participate in various experiments. Involvement with NEES will also enable students to sharpen skills in utilizing modern information technology tools and resources. These learning opportunities could be made available for pre-college students as well as college students, ushering in an unprecedented appreciation for earthquake problems and a new age for earthquake engineering education.

Proposal competitions for all equipment sites and the NEES Internet-based network were completed by FY 2002. All awards are by cooperative agreement and all projects are on schedule and at budget. The sites and the network will be operational by September 30, 2004. Internet sites for NEES are established as http://www.nees.org for the sites and the overall project, and http://www.neesgrid.org for the network.

From FY 2005, the NEES network and facilities will be maintained and operated by the NEES Consortium. The NEES Consortium will provide the leadership, management, and coordination for all the NEES shared-use resources. The NEES Consortium was incorporated on January 31, 2003 and already has more than 250 members in the short 8 weeks since its formation.

The NEES experimental capabilities will lead to new tools for modeling, simulation, and visualization of site, structural, and nonstructural response to earthquakes and tsunami effects. NEES will provide an unprecedented engineering capability for attacking major earthquake problems with coordinated multi-organizational teams, producing convincing results that can be adopted into building codes and engineering practice. NEES experimental resources and data are expected to be used annually by approximately 1,000 U.S. researchers and students, and the Consortium is expected to develop as a broad and integrated partnership in earthquake engineering community, both within the U.S. and abroad, as equipment sites around the world join the NEES network.

We expect NEES to lead to a new age in earthquake engineering research and education. It should be well worth the large investment. We look forward to keeping the Subcommittee informed about its development.

EarthScope

Progress in earthquake prediction and hazard mitigation is critically dependent on results of studies that probe fundamental earthquake processes. Knowledge of regional tectonic conditions enables geophysicists to establish the long-term level of earthquake hazards. Understanding stress accumulation provides the basis for identifying and interpreting earthquake processes. Knowledge of the rupture process, particularly the effects of the local geology on ruptures, provides the basis for estimates of ground shaking. The compelling need for such knowledge has led to the development of the EarthScope project, first authorized and funded in FY 2003.

EarthScope is also an MREFC project, developed with partnership from USGS and NASA. EarthScope will apply modern observational, analytical, and telecommunications technologies to investigate the long-term structure and evolution of the North American continent and the physical processes controlling earthquakes and volcanic eruptions. When fully deployed, EarthScope's components will include modern digital seismic arrays, global positioning satellite receivers, strainmeters and new satellite radar imagery, and an observatory deep within the San Andreas Fault.

The need for knowledge about earthquake processes also explains the intellectual support at NSF for the USGS project—the Advanced National Seismic System (ANSS). ANSS is a permanent national network of shaking measurement systems that will make it possible to provide emergency response personnel with real-time earthquake information, provide engineers with information about building and site response, and provide scientists with high-quality data to understand earthquake processes and solid earth structure and dynamics. ANSS includes a strong emphasis on urban areas and the response of buildings to shaking. Discussions are underway to link the ANSS resource with EarthScope, NEES and the NSF research programs.

NSF expects strong synergy among EarthScope, ANSS and the NEES network, and we will be sure to keep the Subcommittee informed about their progress.

Incorporated Research Institutions for Seismology (IRIS)

In 1984, the seismological community created the IRIS initiative: the Incorporated Research Institutions for Seismology. The IRIS constituency, now at 100 members, includes virtually all U.S. universities with research programs in seismology, plus 44 foreign affiliates. Through IRIS, NSF supports two instrumentation programs that are needed for seismology to take advantage of the many advances in instrumentation and computer technology that have taken place: a permanent network—the Global Seismographic Network (GSN)—in cooperation with USGS; and a portable seismic array—the Program for Array Seismic Studies of the Continental Lithosphere (PASSCAL).

The GSN plan for 120 stations evenly placed throughout the world has been essentially completed. The past two years have seen a number of accomplishments. Use of the GSN seismometers in a rapid analysis of damaging earthquakes has been invaluable. Attention is now being directed toward the much more difficult job of instrumenting the large gaps in the network consisting of the major ocean basins of the world. The IRIS GSN is a founding member of the Federation of Digital Seismographic Networks (FDSN). Other participating networks include Canada, Germany, the French Geoscope, Italy's Mednet, and Japan's Poseidon. FDSN stations worldwide now total about 180.

The PASSCAL plan is for a portable array of 1000 seismic instruments for detailed study of the lithosphere and rapid response to monitor earthquake occurrence or possible earthquake precursors. The PASSCAL Instrument Center is at the University of New Mexico. 600 PASSCAL instruments are now available for fieldwork and they are being used in a number of projects in the U.S. and throughout the world.

The IRIS Data Management Center (DMC) was developed to handle the extremely large volume of digital data that is generated, stored, and accessed by the seismological community. Data is provided through Data Collection Centers in Albuquerque and San Diego to the data archive/mass store in Seattle. Users have network access to the archive and to IRIS headquarters for more general information services. All FDSN data, from 180 stations worldwide, and all PASSCAL project data are available at the DMC, which serves as the first FDSN archive for continuous data. Over 14 terabytes were stored in the DMC at the end of 2002 and it continues to grow at about 3 terabytes per year. A measure of the success of IRIS's effort is the remarkable number of investigators making use of DMC data. In 2002, there were more than 45,000 data requests serviced by the DMC for seismic data.

Global Positioning Systems

NSF has supported development of several GPS networks. The NSF- and USGS-funded Southern California Earthquake Center (SCEC) has provided the impetus for the development of a large-scale permanent GPS geodetic array in southern California focused on earthquake hazard assessment—a new and ambitious concept for the use of GPS technology. SCEC organized the southern California geodetic community through establishment of the Southern California Integrated GPS Network (SCIGN). SCIGN brings together networks and GPS expertise at UC–San Diego, UCLA, MIT, USGS and JPL/NASA. Funding is garnered from many sources, with an implementation plan developed by the SCIGN Steering Committee used to guide resource allocation. The permanent array is now complete at 250 stations.

PANGA is an 18-station permanent GPS network installed in the Pacific Northwest with support of NSF and the Canadian Geological Survey in collaboration with the Central Washington University, University of Washington, and Oregon State University.

The University NAVSTAR Consortium (UNAVCO) has become UNAVCO, Inc., a non-profit membership-governed organization that supports and promotes Earth science by advancing high-precision geodetic and strain techniques such as the Global Positioning System (GPS). UNAVCO, Inc. was formed in response to community support of its role as lead organization for community-based planning and management of new initiatives such as the EarthScope Plate Boundary Observatory (PBO), by establishing corporate oversight, and through the already-established community workshops and working groups.

NSF supports separately a number of investigations utilizing the UNAVCO GPS equipment in crustal distortion areas that are prime candidates for future earthquakes. Seismically active areas occupied to date within or near the U.S. include California, New England, the Caribbean, Colorado, Hawaii, Wyoming, and Montana. Outside the U.S., important distortion areas in Turkey, Iceland, Greenland, Asia, and South America are being monitored.

NSF Research Centers

Southern California Earthquake Center (SCEC)

The Southern California Earthquake Center (SCEC) was founded in 1991 as an NSF Science and Technology Center, and continues under support from NSF and the USGS. The SCEC headquarters are at the University of Southern California, and the Center includes eight core university partners. Other universities, state and local governments, and private companies are participating in the research and outreach activities. The primary science goal of SCEC is to develop a comprehensive, physics-based understanding of earthquake phenomena in southern California through integrative, multidisciplinary studies of plate-boundary tectonics, active fault systems, fault-zone processes, dynamics of fault ruptures, ground motions, and seismic hazard analysis.

Earthquake Engineering Research Centers (EERCs)

NSF funded three new earthquake engineering research centers (EERCs) in October 1997. Each EERC is a consortium of several academic institutions—with an administrative headquarters at a designated campus—involved in multidisciplinary team research, educational and outreaches activities. The EERCs are combining research across the disciplines of the earth sciences, earthquake engineering, and the social sciences, and some of the research conducted at the EERC's is funded by FEMA.

The Mid-America Earthquake Center (MAE) is headquartered at the University of Illinois at Urbana-Champaign. MAE's mission is to reduce losses across societal systems through the development of consequence-based engineering approaches that are founded on advanced technologies for characterizing seismic hazards and the response of the built environment.

The Multi-disciplinary Center for Earthquake Engineering Research (MCEER) has its headquarters at the State University of New York at Buffalo. MCEER's vision is to help establish earthquake resilient communities and its mission to discover, nurture, develop, promote, help implement, and, in some instances pilot test, innovative measures and advanced and emerging technologies to reduce losses in future earthquakes in a cost-effective manner. MCEER places significant emphasis on the seismic response of networks and critical facilities.

With its administrative headquarters at the University of California at Berkeley, the Pacific Earthquake Engineering Research Center (PEER) focuses on earthquake problems in areas west of the Rocky Mountains. The main focus for the PEER Center is performance-based earthquake engineering (PBEE) that includes socio-economic evaluation of whether the seismic performance is cost-effective and suitable to the owner and society.

The three EERCs are not involved only in research and technology advancement for the mitigation of earthquake damages. In order to meet the needs of future professionals in the field, they are educating hundreds of undergraduate and graduate students in the latest analytical, computational and experimental techniques. They also reach out to K–12 students to inspire even younger generations in earthquake engineering: An example is PEER's "Learning with LEGO" Program, which brings annually over 500 K–12 students from socio-economically disadvantaged areas to the campus for an open house and shake-table demonstration.

The EERCs also engage in a variety of outreach activities to the public. Keeping the public abreast of scientific and technological advancements is a continual activity, essential to better understanding of natural hazards, policy issues, and disaster mitigation as it applies to the individual.

- MCEER has worked with the Discovery Channel to develop three programs related to earthquakes.
- The PEER Center worked with the California Academy of Sciences to develop the Academy's *Earthquakes!* Exhibit, which is visited by over one million people annually, and focuses on earthquake preparedness and safety.

Post-Earthquake Investigations

In the wake of the terrorist attacks of September 11, NSF funded quick response research awards that mobilized more than 50 faculty and students to begin the process of observing, recording, and evaluating the impact on the public, the structures, and the organizations involved in response. The National Hazard Research Application and Information Center (NHRAIC) at the University of Colorado at Boulder—a Center funded through NSF with contributions from many federal agencies including FEMA and USGS—coordinated much of the social science research, and the NSF-funded Institute for Civil Infrastructure Systems (ICIS, *http://www.nyu.edu/icis*) provided on-site facilitation and coordination for researchers arriving at the WTC site. It is the mission of ICIS, in addition to its location, that rendered it ideal for coordinating the NSF sponsored research: to focus on developing resources and networks to sustain, renew, and improve the Nation's infrastructure system by integrating different perspectives and disciplines into infrastructure planning, engaging users and communities that host infrastructure services and facilities.

In large part, the reason that NSF could move so fast following the events of 9/11 was that there had been so much practice in multi-agency coordinated post-disaster investigations following major earthquakes in the United States and abroad. Areas struck by major earthquakes represent natural laboratories, offering unusual opportunities to collect time-sensitive information and to learn vital lessons about earthquake impacts. This data importantly serves to test models and techniques derived from analytical, computational and experimental studies, and to observe and document effects on the natural and built environment and resulting social, economic, and policy impacts. For these reasons and for nearly 30 years, NSF has supported post-disaster investigations in conjunction with the Earthquake Engineering Research Institute (EERI) "Learning from Earthquakes" (LFE) project. The post-earthquake investigations involve quick-response teams of researchers, deployed with close coordination to USGS and other NEHRP agency activities. Recent events investigated with NSF support include: the 2001 earthquakes in Nisqually, Washington; Peru; India; the 2002 earthquakes in Italy; El Salvador, and Alaska; and the 2003 earthquake in Colima, Mexico.

The three EERCs are also active in post-earthquake reconnaissance. The Centers initiated their program following the success of the previous MAE Center initiative in sending students to areas around the world hit by earthquakes. Four MAE applicants traveled to Taiwan to engage in a hands-on field assessment exercise. For future events, plans call for a group of EERC faculty and 12 graduate students to spend 10 days visiting earthquake sites to complete hands-on field assessment exercises. Also, MCEER's expertise in earthquake reconnaissance was used to collect and disseminate perishable data in the aftermath of the 9/11 attack for later study to gain a better understanding of how resilience is achieved in physical, engineered and organizational systems.

International Collaborative Earthquake Research

The National Science Foundation aims at nothing less than U.S. world leadership in science, engineering, and technology. Earthquakes are a global hazard. Many countries find collaborative research and the sharing of information essential in meeting this challenge and the U.S. is no exception. Like the other NEHRP agencies, NSF has a long history of cooperating with other countries—such as China, Mexico, Italy and Japan—facing similar seismic risks. There have been some recent developments that serve as excellent examples of how NSF's efforts enable U.S. earthquake researchers to collaborate effectively with international colleagues.

Following the 1999 earthquakes in Izmit, Turkey, and Chi-Chi, Taiwan, NSF made awards to 23 U.S. research teams, each involving collaborators in Turkey and/or Taiwan. In 2002, researchers from the U.S. and other countries gathered in Turkey for a workshop on continuing research needs and opportunities. The research outcomes from this program are providing much needed data on strong ground motion near fault ruptures and attenuation of ground motion with distance from the causative fault. The vast number of recording stations, especially in Taiwan, and the similarity between fault systems in the Western U.S. and those in Turkey and Taiwan will greatly aid seismic code development in the United States. The data base to address the required set-back distances from faults, ground motion estimates close to faults, and similar questions will increase by more than ten times due to the results of research on the Turkey and Taiwan earthquakes.

The response of modern high-rise structures designed under Turkish and Taiwanese codes that are very similar to codes in the United States has been documented through this research, as have the effects of construction quality, code enforcement and specific seismic design. This will directly lead to better design and construction techniques to minimize damage from earthquake loading. In addition, a very important determining factor in loss of life and property during earthquakes is the level of preparedness of individuals, companies, national and international institutions and government agencies prior to the earthquake. Several research projects addressed these issues, and information gathered has proven to be invaluable to emergency planners in the United States.

Individual researchers also engage in international collaboration. For example, an NSF award to Rensselaer Polytechnic Institute and the University of California at San Diego includes a significant international component. The researchers will complete experimental studies on the effect of earthquake-induced lateral ground spreading due to liquefaction on pile foundations, both in full size and centrifuge model conditions. The research will take advantage of the NEES experimental facilities in the United States, and facilities operated by the National Research Institute for Earth Science and Disaster Prevention (NIED) in Japan, including the world's largest shake table (15m by 20m) at Miki City. This research constitutes the first opportunity for direct comparison of results in controlled experimental environments between centrifuge and full size tests to be conducted at NIED. The NEES network will be used both during experiment conduct and collaborative development of engineering interpretations and computer simulations.

NEHRP, Agency Coordination, and the Future

The results of NSF research are carried forward into implementation through the involvement of the researchers themselves in professional organizations, and through activities managed by our three sister agencies. In this respect, NSF funding enables a knowledgeable research community to be prepared to answer questions posed by seismic events themselves, and by observations of the performance of the built environment and socio-political systems during and after earthquake events. NSF-funded research enables changes warranted in engineering practice, and enhances understanding and assessment of risks and uncertainties in natural, physical, and social environments.

NSF-funded fundamental research in base isolation devices was taken up by NIST where methods of test for these systems and provisions for design were developed. NIST's contributions made it possible for the engineering profession to include base isolation in design of new structures and seismic upgrades, and FEMA funds were instrumental in making the early applications of base isolation systems possible. In a similar sequence of knowledge transfer and implementation, NSF-funded research on geographic distributions of hazards, liquefaction potential and ground instability have directly fed into microzonation assessments and the USGS-produced ShakeMaps. These maps are, in turn, used in HAZUS (HAZards United States), a GIS-based (Geographic Information Systems) technology that FEMA developed and that allows users to compute estimates of damage and losses that could result from an earthquake.

The future is bright for the NEHRP agencies, and recent actions have been taken that will enhance coordination of plans and efforts:

- FEMA has set up a Subcommittee on Research that is chartered to identify synergies among research and development programs and to identify ways existing programs can work together more effectively; including enhances linkages between ANSS, NEES, EarthScope and the research programs at USGS and NSF.
- Under USGS leadership, the NEHRP agencies have worked during FY 2002 to create a "Plan to Coordinate NEHRP Post-Earthquake Investigations" that establishes how the agencies will coordinate and share information in the event of a significant national or international earthquake. In FY 2003, the agencies are working to modify this plan to provide clarity concerning how the agencies will interact if/when NIST declares an NCSTA (National Construction Safety Team Act) investigation following an earthquake.
- The NEHRP agencies have the challenge to continue evaluation and updating of the strategic plan, and to maintain the strong ties with stakeholders that were so important to the success in creating the original plan in FY 2001.
- The NEHRP agencies also have the challenge to develop an all-agency Internet portal for dissemination of information about research opportunities and outcomes, news releases, plans and activities in a form that can be easily accessed by the research community, government organizations, and the public at large.

The new research plan of EERI that lays out a road map for research and technology transfer, and with the end of construction for NEES in FY 2004 and the start of grand challenge research projects using this network and equipment, the initiation of the EarthScope project, continued development of ANSS, and with the coordinated NEHRP post-event response plan in-place—NEHRP is poised to accomplish great things.

Mr. Chairman, thank you again for the opportunity to present this testimony. NSF is very excited about what NEHRP has been able to accomplish in the past, and what we expect will be possible to achieve in the future.

BIOGRAPHY FOR PRISCILLA P. NELSON

Dr. Priscilla Nelson is Senior Advisor for the Directorate for Engineering (ENG) at the National Science Foundation (NSF). She has been at NSF since 1994, and has served as Director of the Civil and Mechanical Systems (CMS) Division, Senior Engineering Coordinator, Program Director for the Geotechnical Engineering program, and as Program Manager for the NEES (Network for Earthquake Engineering Simulation) project that represents an $82 million federal investment in cyber infrastructure and earthquake experimentation equipment to be completed between FY 2000 and FY 2004.

Dr. Nelson was formerly Professor of Civil Engineering at The University of Texas at Austin. She has received three earned advanced degrees including Master's degrees in both Geology (Indiana University) and Structural Engineering (University of Oklahoma). In 1983, she received her Ph.D. from Cornell University in Geotechnical Engineering. Dr. Nelson has a national and international reputation in geological and rock engineering, and the particular application of underground construction. She has more than 15 years of teaching experience and more than 120 technical and scientific publications to her credit.

Dr. Nelson is Past-President of the Geo-Institute of the American Society of Civil Engineers (ASCE), a lifetime member and first President of the American Rock Mechanics Association, and currently served on the Executive Committee of the American Geological Institute. In addition to these, she has many other professional affiliations including: the Moles (an organization of the heavy construction industry), the American Underground-Construction Association, the Association of Engineering Geologists, the International Tunnelling Association, and the American Society for Engineering Education. She has served as a member of and liaison to several National Research Council boards and committees. Dr. Nelson has been a part of several major construction projects, including field engineering responsibilities during construction of the Trams-Alaska Pipeline System, and serving as a consultant to the U.S. Department of Energy and the State of Texas for the Superconducting Super Collider project. She is a member of the Nuclear Waste Technical Review Board, appointed by President Clinton in 1997 and reappointed in 2000.

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Introduction

As a representative of one of the four primary federal agencies that comprise the National Earthquake Hazards Reduction Program (NEHRP), I congratulate the earthquake community and our three partners—the Federal Emergency Management Agency as lead, the United States Geological Survey, and the National Science Foundation—as we celebrate the 25th anniversary of the founding of NEHRP.

NEHRP has been an extraordinary, and often exemplary, collaboration between federal agencies, State and local governments, and the private sector.

During its first 25 years, NEHRP has contributed in very significant ways to reduce our nation's vulnerability to earthquakes and NIST is proud to have been a part of that record of accomplishment.

While it is difficult to quantify loss prevention through the adoption of improved mitigation practices, and such measures are very much needed, there is no doubt that NEHRP products and results have contributed in significant ways to reduce the loss of life and economic losses from earthquakes. In addition, the loss of life from earthquakes in the United States has been small compared with similar earthquakes in other countries.

My testimony traces how NIST has contributed to the success of NEHRP. It also reflects upon the broader public safety challenges the Nation now faces and how NEHRP can contribute to meeting those challenges.

Earthquakes and Creation of NEHRP

Earthquakes are among the most frightening and devastating natural disasters. They strike virtually without warning, last only seconds, but can leave death and destruction in their wake.

Seventy-five million Americans in 39 states face significant risk from earthquakes. On an annualized basis, earthquake losses amount to about $4 billion a year, while a single earthquake has a loss potential of $100 billion or more.

For example, the 1971 San Fernando earthquake in California killed 65 people and caused $500 million in damage. The 1994 Northridge earthquake caused losses in excess of $40 billion, with $15 billion in insured property losses alone.

The San Fernando earthquake led Congress to pass the *Earthquake Hazards Reduction Act of 1977* to "reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program." Pursuant to the Act, the Executive Office of the President developed the *National Earthquake Hazards Reduction Program* and issued a program plan in June 1978.

Pre-NEHRP Efforts

Prior to the creation of NEHRP, NIST and many other government, private-sector organizations and universities were conducting research on ways to improve the seismic design of constructed facilities.

NIST began work in earthquake hazards reduction with its organization in 1969 of the U.S.-Japan Panel on Wind and Seismic Effects under the U.S.-Japan Program in Natural Resources. This successful bilateral program continues to this day, with the 35th annual meeting slated to be held next May.

NIST work also included its significant investigation of the performance of structures in the 1971 San Fernando, California, earthquake.

Also, in 1972, the Applied Technology Council, an organization created by the Structural Engineers Association of California, called for a cooperative effort of practice, research, and government to produce up-to-date seismic design and construction provisions. A subsequent ATC study completed in 1978 produced design provisions that were a significant advance on existing provisions.

Role Assigned for NIST in NEHRP

NIST was a natural part of NEHRP because of its long-time role in providing measurements, standards, and technology to help Federal, State, and local government agencies and the private sector protect the Nation and its citizens from natural as well as manmade threats.

As part of NEHRP, NIST took on three assignments:

- First, to develop seismic design and construction standards for consideration and subsequent adoption in federal construction, and encourage the adoption of improved seismic provisions in State and local building codes;
- Second, to assist and cooperate with federal, State, and local agencies, research and professional organizations, model code groups and others that are involved in developing, testing, and improving seismic design and construction provisions to be incorporated into local codes, standards, and practices; and
- Third, to conduct research on performance criteria and supporting measurement technology for earthquake resistant construction.

In addition, as part of the USGS-led Post-Earthquake Investigation Program established by the NEHRP Reauthorization Act of 1990, NIST took on another assignment:

- Fourth, to participate in NEHRP post-earthquake investigations and analyze the behavior of structures and lifelines, both those that were damaged and those that were undamaged, and to analyze the effectiveness of the earthquake hazards mitigation programs and actions and how those programs and actions could be strengthened.

Products and Results from NIST's Problem-Focused R&D

Through laboratory based problem-focused R&D NIST has made important contributions to earthquake safety over the years. Examples include our products and results related to:

- bridge column reinforcing requirements,
- rehabilitation of welded steel moment frame connections,
- test methods for passive and active seismic energy absorption systems, and
- precast concrete frames.

One example is our work with industry and others on precast concrete frames (Attachment A provides summaries of the other examples).

While construction with this type of frame has not been extensive in high seismic regions of the United States, it has enormous benefits in construction speed and quality control.

In 1987, NIST initiated a project to develop a precast beam-to-column connection that was economical, easy to construct, and capable of resisting earthquake loads. A few years later, Pankow Builders, a California general contracting firm specializing in quake-resistant construction, provided funding through the American Concrete Institute (ACI) to further develop the concept. Close collaboration among NIST, Pankow Builders, and the University of Washington resulted in a hybrid connection that combined the use of low-strength reinforcing steel for energy absorption with high-strength pre-stressing steel.

Tests at NIST and on a five-story precast building at the University of California at San Diego demonstrated that the concept worked. NIST-developed guidelines and results were used to obtain approval from a code evaluation service. In addition, the American Concrete Institute issued standards and the International Building Code has adopted provisions that allow use of the system.

Recently, Pankow Builders used the hybrid connection to build a $128 million, 39-story building in San Francisco. Topped out in June 2001, the building is the tallest concrete frame building built in a high seismic region.

Several other structures using the hybrid connection have been built, are underway, or on the drawing board.

We are very proud of our collaboration with Pankow Builders, the University of Washington and others and are gratified that this design innovation and the contributions of its developers have been widely recognized. This work has won numerous awards, most recently the Harry H. Edwards Industry Advancement Award of the Precast/Prestressed Concrete Institute.

Lessons Learned from NIST's Post-Earthquake Investigations

Throughout its history, NIST scientists and engineers have been called in to investigate building failures following fires, earthquakes, high winds, terrorist attacks, construction accidents, and other events.

Tragically, we learn many lessons following an earthquake about what type of design and construction works and what does not. Our goal is to investigate and document building performance and the adequacy of current codes and practices, as well as to identify research needed to mitigate the impact of future earthquakes.

Our investigators have traveled not only to earthquake sites in the United States, including the Loma Prieta earthquake in 1989 and the Northridge earthquake in 1994, but also to those places around the world including Japan, Romania, Nicaragua, Mexico, Armenia, and—most recently—Turkey. The investigation following the 1999 earthquake in Turkey was a cooperative effort led by the USGS, with participation of the U.S. Army Corps of Engineers.

Since NIST is not a regulatory agency and does not issue building standards or codes, the institute is viewed as a neutral, "third-party" investigator. Our investigations are fact-finding, not fault finding. The focus is on improving public safety and on deriving lessons for the future. And, by law, the data, analysis, and reports resulting from NIST investigations may not be used in litigation.

Formation of ICSSC and Federal Construction

One of the early accomplishments of NEHRP was to involve federal agencies with construction responsibilities. Federally-constructed facilities comprise one of our nation's largest building sectors. It was realized early in the NEHRP that it was vital to assist the more than 30 federal agencies that are involved in one way or another in construction to implement earthquake hazards reduction elements into their ongoing programs.

In 1978, the White House directed the Federal Emergency Management Agency to form an Interagency Committee on Seismic Safety in Construction (ICSSC). ICSSC was assigned to develop and implement seismic deign standards for federal construction. NIST, with funding from FEMA, has provided the secretariat for ICSSC since its inception, and the Director of NIST (or the Director's designee) has chaired the ICSSC since 1982.

Not only did the ICSSC provide up-to-date seismic design and construction standards and practices that federal agencies used for their own *new* buildings, but it had a broader effect as well. An executive order issued by the President in 1990 required both federal and federally-assisted homes, such as new homes with FHA or VA mortgages, be designed and constructed using these standards.

This federal mandate was welcomed by the national standards and model building code organizations since it provided incentive for state and local governments to adopt and enforce up-to-date standards and codes to be eligible for federally-assisted construction.

The bottom line result was that NEHRP's broad goal of making adequate seismic resistance available for all new U.S. building construction was achieved. This successful outcome would not have been realized without a NIST study that was crucial to the issuance of the executive order. That study revealed the modest cost implications of the recommended seismic provisions as determined by trial designs.

ICSSC was much involved in support to federal agencies in implementation of the executive order for *new* buildings. It continues today to provide support for the assessment of the equivalency of model building codes to the NEHRP recommended provisions—the most recent assessment was issued in late 2001—and the development of proposed changes to model codes.

The ICSSC turned next to the challenge of evaluating and strengthening *existing* buildings by developing seismic safety standards and assisting federal agencies in implementing a second executive order. That executive order called for agencies to inventory buildings they own or lease and estimate the costs of mitigating unacceptable seismic risks.

The ICSSC developed policies and practices for evaluation and strengthening of existing federal buildings. This included seismic safety standards for existing buildings, which were updated recently; guidance to the federal agencies on implementation of the executive order; assistance with estimating the costs of mitigating unacceptable seismic risks; and extensive review and comment in drafting the resulting report.

Currently, ICSSC is developing a handbook for the seismic rehabilitation of existing buildings. This handbook will facilitate implementation of the seismic rehabilitation plan for federal buildings when a policy decision is made to proceed.

Major Challenges for the Future

NEHRP has come a long way. But, it faces many challenges in meeting its legislative mandate to "reduce the risks of life and property from future earthquakes in the United States."

Four of the key challenges faced by NEHRP are to:

- fill the technology transfer gap between basic research and practice,
- develop and implement seismic safety standards for lifelines,
- develop and implement a multi-hazard approach to risk mitigation, and

- better coordinate post-earthquake investigations.

Challenge #1: Filling the Basic Research to Practice Gap in Earthquake Engineering

Just as NEHRP strives for better ways to improve the performance of construction during an earthquake, NIST and its three NEHRP partners are continually looking for better ways to carry out our mission.

Early in 2001, a NEHRP Strategic Plan was approved by each of the four participating agencies. This plan, developed in partnership with stakeholders, has identified the emergence of a technology transfer gap that limits the adaptation of basic research knowledge into practice. The plan recommends a much-expanded problem-focused research and guidelines development effort:

- to develop future design, construction, evaluation, and upgrade guidelines and standards of practice, and
- to facilitate the development of new mitigation technologies.

It further recommends that NIST, in partnership with FEMA and other NEHRP agencies, should develop a coordinated plan to support this effort.

NIST looks forward to working with its NEHRP agency partners and with industry, academia, and the broader stakeholder community to address this gap.

As a first step, NIST requested the Applied Technology Council, a non-profit corporation to advance engineering applications for natural hazard mitigation, to convene a workshop of national leaders in earthquake design, practice, regulation, and construction in July of 2002.

The purpose of the meeting was to assess the state of knowledge and practice and to suggest an action plan to address the gap between basic research and practice.

Recently completed, the action plan identifies industry priorities in two areas:

- support for the *seismic code development process* through technical assistance and development of the technical basis for performance standards; and
- improved seismic *design productivity* through the development of tools and guidance and evaluation of advanced technologies and practices.

This action plan fits within the broader research and outreach plan developed by the Earthquake Engineering Research Institute titled "Securing Society Against Catastrophic Earthquake Losses." It also incorporates issues raised under Challenge #2 below.

NIST now looks forward to working with the stakeholder community to explore ways to best meet those needs via a public-private partnership. We expect this effort will build on NSF-funded basic academic research, including that conducted as part of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Consortium.

Challenge #2: Developing and Implementing Seismic Safety Standards for Lifelines

While up-to-date seismic provisions for building codes are available today, there are no nationally accepted standards or guidelines for lifelines, except for highway structures and nuclear facilities.

Lifelines include all types of transportation (highways, airports, railways, waterways, ports and harbors), communication, and utility (electric power, gas and liquid fuels, water and wastewater) systems. They provide the physical infrastructure that support most human activities.

The American Lifelines Alliance, with support from FEMA, is working on the development of guidelines and standards for lifelines. Concurrently, the ICSSC has completed an initial survey of lifelines that are the responsibility of federal agencies. It has begun a major effort to identify the needs for standards and guidance for these lifelines, with an initial focus on electric power generation, transmission, and distribution facilities. It is anticipated that implementation of the lifelines plan would be primarily through the existing voluntary standards system with a possible executive order requiring agencies to adopt and use the standards for federal lifelines.

While these initial public and private sector efforts are laudable, I believe NEHRP has much work to do before the Nation will have seismic standards and guidelines for lifelines similar to those we already have for new and existing buildings.

Challenge #3: Developing and Implementing a Multi-Hazard Approach to Risk Mitigation

Seismic hazards are one of many significant hazards that must be considered in design and construction. From the viewpoint of an owner or end-user, a multi-hazard approach to risk mitigation is desirable since it likely will yield more cost-effective solutions. This is especially true for existing construction, where seismic retrofit investments may be better justified when made in conjunction with needed functional and security upgrades.

A careful consideration of regional hazards such as earthquakes and high winds shows that these hazards pose a major risk since they coincide with geographical areas that have seen significant population growth and development in recent years. The risks from fire hazards are spread across the Nation, while the risks from terrorist or technological threats are limited to certain critical facilities or locations.

In comparison with the $4 billion annualized loss estimate for earthquakes, the annualized loss estimate for extreme winds is about $8 B/year and for fire hazards is about $12 billion a year. Similarly, in comparison with the $100 billion loss potential for a major earthquake, a single hurricane event has a loss potential of as much as $50 billion. Major earthquakes, high winds, and other extreme hazards have one thing in common—they are all low probability, high consequence events.

There is significant merit to multi-hazard risk mitigation if practicable tools, practices, and guidance can be developed. Examples include:

- improving overall structural integrity by mitigating progressive collapse, where NIST is already working with the private sector to develop needed tools and guidance;
- conducting multi-hazard vulnerability assessments using an integrated framework based on standard information representation models and interoperable software tools; and
- evaluating the cost-effectiveness of alternate risk reduction technologies and strategies using integrated software tools for making cost-risk trade-offs.

I believe NEHRP has a unique opportunity to provide national leadership in charting the course for a multi-hazard approach to risk mitigation, while continuing with its important risk reduction mission for earthquakes. The development of the HAZUS regional loss estimation model—that now covers earthquakes, wind, and floods—is an excellent example of how NEHRP has already demonstrated this kind of leadership.

Challenge #4: Coordinating Post-Earthquake Investigations

NEHRP has long supported post-earthquake investigations, and in 1990 Congress specifically authorized the establishment of a coordinated program to conduct such investigations with leadership to be provided by the United States Geological Survey. Consistent with this legislation and the recent NEHRP Strategic Plan, an implementation plan has been completed to coordinate future post-earthquake investigations.

In the aftermath of the World Trade Center disaster, Congress has given NIST additional authorities—beyond those NIST already had—through the National Construction Safety Team Act. The legislation, which is modeled in many ways on the National Transportation Safety Board, was introduced by the House Science Committee and signed into law by President Bush on October 1, 2002.

That law, Public Law 107–231, established NIST as the lead agency to investigate building performance, emergency response, and evacuation procedures in the wake of building failures that result in substantial loss of life or that posed significant potential of substantial loss of life. Currently, NIST is conducting two major investigations: a building and fire safety investigation of the September 11, 2001, World Trade Center building collapses; and the February 20, 2003, fire at The Station nightclub in West Warwick, R.I. The act calls for NIST to establish investigative teams including public and private-sector experts.

NIST is developing agreements for future investigations with other federal agencies, and with the private sector so that we can quickly and effectively deploy investigation teams and so that we can share the results of those investigations and related research.

The National Construction Safety Team Act gives NIST the authority to dispatch teams of experts within 48 hours when practicable. The law gives the teams a clear authority to:

- Establish the likely technical cause of building failures;
- Evaluate the technical aspects of procedures used for evacuation and emergency response;
- Recommend specific changes to building codes, standards and practices;
- Recommend any research or other appropriate actions needed to improve the structural safety of buildings, and/or changes in emergency response and evacuation procedures; and

- Make final recommendations within 90 days of completing an investigation.

The act gives NIST and its investigation teams comprehensive authorities to:

- Access the site of a building disaster;
- Subpoena evidence;
- Access key pieces of evidence such as records and documents, and
- Move and preserve evidence.

Congress anticipated the NCST Act to be applicable to building failures caused by earthquakes. The Act specifies that the NIST Director develop implementing procedures that "provide for coordination with federal, State, and local entities that may sponsor research on investigations of building failures, including research conducted under the Earthquake Hazards Reduction Act of 1977." In addition, the Committee Report 107–530 published by the House Science Committee on June 25, 2002, states that "The Director should clearly define how earthquake researchers and Teams will carry out their responsibilities in a coordinated fashion in cases where building failures have been caused by an earthquake."

NIST's responsibilities under the NSCT Act have been incorporated in the recently completed plan to coordinate post-earthquake investigations issued by the four agencies comprising the National Earthquake Hazards Reduction Program. The plan (USGS circular #1242) states that, within 48 hours, NIST will examine the relevant factors associated with building failures that occur as a result of the earthquake and will make reasonable efforts to consult with the other NEHRP agencies prior to determining whether to conduct an investigation under the Act. Any NIST investigation conducted under the authority of the Act will be limited to building failures on one or more buildings or on one or more class or type of buildings selected by NIST.

Conclusion

As we look to the future, I believe NEHRP will continue to play a vital leadership role in making the performance of our buildings and lifelines highly measurable and predictable. This measurement and prediction ability will provide the critical underpinning upon which to achieve specified levels of performance and seismic risk reduction via workable and practicable solutions. Our nation will be safer and more secure for it.

We at NIST look forward to contributing our part to address the challenges that lie ahead.

Attachment A

Products and Results of NIST Problem-Focused R&D

Bridge Column Reinforcing Requirements

Immediately following the 1971 San Fernando earthquake, NIST dispatched a team to document and investigate structural damage caused by the earthquake. In particular, many bridge columns suffered either significant damage or failure. As a result, design requirements for bridge columns in seismic zones were modified. However, the adequacy of these design modifications was not verified.

NIST initiated a project in the 1980s to provide the necessary verification, consisting of two full-scale bridge column tests. The challenges arose from the size of the test specimens and the need to apply horizontal seismic loads in addition to vertical gravity loads. The series of column tests was the first of its kind and as such, provided important benchmark data. The tests also verified the adequacy of the revised design specifications.

In addition, NIST tested companion 1/6-scale bridge columns and the results indicated that the behavior of full-scale bridge columns could be extrapolated from small-scale bridge column tests. This finding suggests that high costs associated with full-scale tests are not always necessary and less expensive small-scale tests may be sufficient.

Welded Steel Moment Frame Connections

Steel framed buildings traditionally have been considered to be among the most seismic resistant structural systems. The January 17, 1994, Northridge Earthquake, however, caused unexpected damage to many welded steel moment frame buildings. In general, the damage was confined to beam-to-column connections that suffered brittle fracture in the flange welds.

In response to these failures, NIST initiated a project to study methods to modify existing buildings to improve their seismic performance, in collaboration with the American Institute of Steel Construction, the University of Texas, the University of California at San Diego, and Lehigh University. Eighteen full-scale tests were conducted on three different methods to reduce the stresses at the beam-to-column connections.

The result of this multi-year effort was the publication of comprehensive guidelines for seismic rehabilitation of existing welded steel frame buildings as an AISC Design Guide. The guidelines provided experimentally-validated response prediction models and design equations for the three connection modification concepts that shift loading from the welded joints into the beams, thus enabling the structure to absorb the earthquake's energy in a non-brittle manner.

Test Methods for Structural Control Devices

Structural control devices, such as seismic isolation and passive energy dissipators, have been installed in numerous structures throughout the world and have proven to be effective in reducing both motions and forces during earthquakes and strong winds. Still these devices are generally produced in small quantities, specifically for each application.

To guarantee that the devices will perform as the designer expected, many building codes and guidelines recommend that the devices be tested before installation. While some of these standards describe a limited number of specific tests, widely accepted test standards do not yet exist. Such standards are useful to designers, manufacturers, and contractors, since they will make the process of validating these devices consistent.

To address the issue NIST has developed two sets of testing guidelines. The *Guidelines for Pre-Qualification, Prototype, and Quality Control Testing of Seismic Isolation Systems* was issued in 1996. ASCE has developed and is currently balloting a national consensus standard based on the NIST-developed isolation device testing guidelines.

While seismic isolation is generally accepted in earthquake engineering practice and recognized in the building codes in high-seismic areas, passive structural dampers are still gaining acceptance and semi-active devices are still in the development phase. NIST has just issued *Guidelines for Testing Passive Energy Dissipation Devices*.

BIOGRAPHY FOR S. SHYAM SUNDER

Dr. Shyam Sunder is Chief of the Materials and Construction Research Division in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST). He is responsible for planning and directing the overall scientific and technical programs, controlling the budget, and recruiting personnel for the Division. The Materials and Construction Research Division provides leadership for BFR's Homeland Security, Advanced Building Materials, and Advanced Construction Technology Goals.

In his current position, Dr. Sunder:

- is working with the BFRL Director Jack Snell to develop and implement the Laboratory's homeland security efforts via a public-private response plan involving a broad coalition of organizations;
- is the lead investigator for the NIST building and fire safety investigation into the World Trade Center disaster;
- is a member of the Executive Group of the Cement and Concrete Reference Laboratory of the American Society of Testing and Materials (ASTM) that is co-located at NIST;
- leads BFRL's Construction Integration and Automation Program in partnership with FIATECH, a consortium established by the Construction Industry Institute (CII) in cooperation with NIST, and is a member of CII's Breakthrough Strategy Committee;
- represents NIST on the four-member Interagency Coordination Council for the National Earthquake Hazards Reduction Program (NEHRP);
- is designated by the NIST Director to chair the Interagency Committee on Seismic Safety in Construction (ICSSC)—a group that recommends policies and practices to its 32 member-agencies on improving the seismic safety of federal buildings nationwide; and
- is U.S.-side chair of the Wind and Seismic Effects Panel established under the U.S.-Japan Cooperative Program on Natural Resources (UNJR).

Dr. Sunder was chief of the Structures Division from January 1998 until June 2002 when the Building Materials Division was merged with the Structures Division and renamed the Materials and Construction Research Division. From June 1996 to December 1997, Dr. Sunder was on assignment to the Program Office, the principal staff office of the NIST Director, first as Program Analyst and later as Senior Program Analyst for NIST. In 1994, Dr. Sunder joined NIST's Building Materials Division as Manager of BFRL's newly created High-Performance Construction Materials and Systems Program and served in that position until June 1996. This program was in support of CONMAT, a public-private R&D program created by the Civil Engineering Research Foundation in partnership with 11 key sectors of the construction materials industry. Dr. Sunder worked with the $100 B/year concrete construction industry to plan an advanced research program and document its economic and commercial benefits. This led to the creation of the Strategic Development Council, bringing together industry executives for the first: time ever to conduct leveraged R&D. He also studied key factors affecting quality, productivity, and innovation among the small firms that make up 85 percent of the more than one million firms in construction.

Dr. Sunder's awards include the Gilbert W. Winslow Career Development Chair (1985–87) and the Doherty Professorship in Ocean Utilization (1987–89) from MIT, the Walter L. Huber Civil Engineering Research Prize (1991) from the American Society of Civil Engineers, and the Equal Employment Opportunity Award (1997) from NIST.

STATEMENT OF THE NEHRP COALITION

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Chairman Smith and Members of the Subcommittee:

The below signed ten members of the NEHRP Coalition, representing the scientific, architecture, design and engineering communities responsible for earthquake hazard mitigation are pleased to offer this testimony on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP).

The earthquake risk to the Nation is unacceptably high and growing daily. We are facing inevitable earthquakes, any one of which alone can cost the Nation $100 to $200 billion. The reauthorization of NEHRP can address this, but it will require additional continuous research, expanded seismic monitoring, and nationwide mitigation. Earthquake occurrence in the United States is not restricted to any single geographical area. All or parts of 39 states are vulnerable to earthquakes.

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

The NEHRP Coalition believes that Congress, in reauthorizing NEHRP, should take the necessary steps to strengthen this critical program. Earthquakes are among the most devastating of all natural hazards. To find ways to reduce the devastation, NEHRP, enacted in 1977, funds earthquake related activities of the U.S. Geological Survey (USGS), National Science Foundation (NSF), National Institute of Standards and Technology (NIST) and Federal Emergency Management Agency (FEMA). Despite continuing need, appropriations for NEHRP have decreased significantly in real dollars since the late 1970's.

Earthquake occurrence in the United States is not restricted to any single geographical area. All or parts of 39 states are within zones where the probability of an earthquake occurring exists. Recent research indicates that areas in the eastern and central United States are at greater risk of earthquake occurrence than earlier evidence indicated.

Recent events substantiate that many public buildings cannot survive a major earthquake. In many cases, federal buildings are less earthquake-resistant than nearby privately-owned buildings.

Because of funding cuts, programs to develop safer buildings and other structures, including lifelines, have been reduced and existing research facilities have been underutilized. In addition, some excellent earthquake researchers have left the field. There is also evidence that much of the engineering research that has been accomplished under NEHRP has not been applied effectively. NEHRP has produced numerous recommendations for standards for new and existing buildings, lifelines and other structures. These provisions have yet to be fully implemented by local governments. As such, there is inadequate transfer of findings to those who help communities prepare for earthquakes. Funds have not been available to help localities improve building codes and zoning provisions in order to improve building safety.

SUCCESSES OF THE NEHRP PROGRAM

Over the past 25 years, NEHRP has provided a wealth of information useful to both the scientific and engineering practice resulting in a significant benefit to the public. The USGS has developed and published uniform earthquake hazard maps that clearly identify the expected earthquake ground shaking at any location in the Nation. NSF, through their grants to university researchers, has funded the development of new engineering analysis and design techniques that allow engineers to make better and more cost effective decisions related to seismic design. FEMA has been able to leverage a small amount of funding into an impressive series of design guidelines, standards and codes that have spread the experience of a few to engineers nationwide. NIST has developed standards for federal buildings that have encouraged owners nationwide to recognize the earthquake vulnerabilities of their communities. It has been a successful program with significant results.

Determining the proper seismic hazard level for a community is still the most consequential information needed for seismic resistant design. The new USGS hazard maps, developed in conjunction with structural engineers, have significantly influenced the engineering community. Some areas in the Nation, such as the Central Valley of California, have learned that the potential earthquake shaking is much lower than traditionally thought. To reduce their vulnerability, some of California's essential business operational facilities have been relocated to these low seismic areas and the need for and cost of seismic rehabilitation in these areas has been significantly reduced. At the other extreme, areas of the Nation, such as the Portland Oregon area, have learned that their seismic exposure is much greater and steps are being taken to increase their resilience to damage through new codes and rehabilitation programs.

Because of the detailed, scientifically based maps, billions of dollars of construction is being spent more wisely, both in terms of reduced initial construction costs and reductions in expected future damage. Similar examples could be cited across the Nation.

Buildings today all over the world are being built on isolation systems or have energy absorbing systems built within their structures. These advanced construction techniques grew out of fundamental NSF research begun in the late 1970's by Professor James Kelly and others at the University of California at Berkeley. Their work was "curiosity based" and not held in high regard at the time. Over the past 30 years it has matured into a commonly used system that protects essential facilities and historic structures in a superior manner. Basic NSF funded research such as this has yielded dozens of analysis and design techniques that are of significant benefit to the public and the Nation.

The Nation's ability to arrest the growth of its seismic vulnerability and reduce it to acceptable levels depends on the efforts of all practicing engineers nationwide. FEMA, recognizing the need for published guidelines and standards, has leveraged the volunteer talents of an army of engineers by providing travel funds, meeting spaces, and publication support. Over the past 20 years, dozens of FEMA "Yellow Books" have been published on various aspects of seismic design and rehabilitation. For example, the American Society of Civil Engineers, has been able to use this material in their standards process to produce state of the art design standards such and as ASCE 7 and ASCE 31. These new standards are used to train engineers nationwide and guide their seismic design and rehabilitation efforts. These efforts, in turn are providing the Nation with a much more reliable constructed environment.

COALITION RECOMMENDATIONS FOR REAUTHORIZATION

The NEHRP Coalition asks that in reauthorizing NEHRP, Congress provide for stronger leadership, increased authorization and improved interagency coordination. In a broad sense, the Coalition supports "Securing Society Against Catastrophic Earthquake Losses," a study recently completed by the Earthquake Engineering Research Institute (EERI) with funding from NSF. The report lays out a vision for the future of earthquake research and outreach focused on securing the Nation from the catastrophic impacts of earthquakes. The report was prepared by a cross disciplinary panel of scientists, engineers and social scientists, and has been endorsed by numerous professional organizations involved in earthquake research.

The report comprises the following five research and outreach programs:

- Understanding Seismic Hazards—developing new models of earthquakes based on fundamental physics.
- Assessing Earthquake Impacts—evaluating the performance of the built environment by simulating performance of structures and entire urban systems.
- Reducing Earthquake Impacts—developing new materials, structural and nonstructural systems, lifeline systems, tsunami protection, fire protection systems and land use measures.
- Enhancing Community Resilience—exploring new ways to effectively reduce risk and improve the decision-making capability of stakeholders.
- Expanding Education and Public Outreach—improving the education of engineers and scientists from elementary school to advanced graduate education, and providing opportunities for the public to learn about earthquake risk reduction.

Success in research will only matter if that research finds its way into practical use. The translation of research knowledge into practice is more than simply disseminating research findings. The report outlines programs to improve the exchange of knowledge and acceptance of new technology and processes during design and construction of new structures as well as in retrofitting older structures.

Technology—ANSS & NEES

Information technologies will play an increasing role in earthquake research in the future. Two applications central to that vision are the Advanced National Seismic System (ANSS) and the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES).

ANSS, authorized by Congress in 2000, is intended to expand the current monitoring system and provide the needed information to maximize our understanding of how specific buildings performed during earthquakes. Strong motion information is critical to making the next quantum leap in understanding how to economically arrest the growth of earthquake risk. ANSS is a critical new program needed by NEHRP and must be funded at an adequate level.

NEES, established by the NSF, will expand knowledge through new methods for experimental and computational simulation. Currently, many new experimental research sites are being put in place around the country, and a system to link into a sophisticated testing and simulation program is being developed. Unfortunately, funds to carry out the research that will make use of this new equipment and simulation technology have not been authorized. Knowledge developed through experiments and simulation methodologies provide the essential scientific knowledge base for improving codes and guidelines. Social science and education research will complement this by helping to better understand and communicate the implications and choices that must be made. An immediate investment in NEES is needed to reduce the cost of seismic design and to strengthen and stimulate significant mitigation activities.

Funding Levels

In order to implement the plan envisioned by the NEHRP Strategic Plan and the EERI report and to increase the effectiveness of NEHRP, it is essential that Congress raise funding levels for NEHRP. The undersigned organizations support increasing funding levels to $358 million a year for the first five years of a twenty-year program. Despite real needs, the funding level for NEHRP has remained flat for many years, which translates into a significant decrease in real funding. This trend must be reversed if we are to reduce our nation's vulnerability to earthquakes to acceptable levels.

Finally, it is important to recognize the immense leverage from NEHRP for improvements in the reliability and security of buildings, transportation systems, water supplies, gas and liquid fuel networks, electric power, telecommunications, and waste disposal facilities. NEHRP provides an enormous return on investment that substantially reduces our nation's vulnerability to earthquakes and, at the same time, improves the performance of its civil infrastructure for both normal operation and extreme events.

CONCLUSION

The first 25 years of NEHRP have proven that limited federal funds, applied to the Nation's earthquake vulnerability, can be leveraged 100 times over in terms of savings in construction and limiting the losses after an earthquake. We believe that the program is just now hitting its stride and reaching full maturity, and is well equipped to handle additional funds that will provide new levels of understanding about the vulnerability and tools for the analysis and design. Significant progress will then be made toward reducing the Nation's vulnerability to an acceptable level.

Thank you for this opportunity to express our views. The NEHRP Coalition is ready to assist in any way we can. If you have questions or need additional information, contact Martin Hight, Senior Manager, Government Relations, American Society of Civil Engineers at (202) 326–5125 or by e-mail at mhight@asce.org.

This statement is endorsed by the following members of the NEHRP Coalition:

American Geological Institute
American Institute of Architects
American Society of Civil Engineers
Earthquake Engineering Research Institute
Mid-America Earthquake Center
National Fire Protection Association
Oregon Department of Geology and Mineral Industries
Portland Cement Association
Seismological Society of America
World Institute for Disaster Risk Management

STATEMENT OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

Washington Office: 1015 15th Street, N.W., Suite 600, Washington, D.C. 20005–2605; (202) 789–2200; Fax: (202) 289–6797; Web: http://www.asce.org

Chairman Smith and Members of the Subcommittee:

The American Society of Civil Engineers (ASCE) is pleased to offer this testimony on the reauthorization of the National Earthquake Hazards Reduction Program (NEHRP).

ASCE was founded in 1852 and is the country's oldest national civil engineering organization. It represents more than 125,000 civil engineers in private practice, government, industry and academia who are dedicated to the advancement of the science and profession of civil engineering. ASCE is a 501(c)(3) non-profit educational and professional society.

NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM

ASCE believes that Congress, in reauthorizing NEHRP, should take the necessary steps to strengthen this critical program. Earthquakes are among the most devastating of all natural hazards. To find ways to reduce the devastation NEHRP, enacted in 1977, funds earthquake related activities of the U.S. Geological Survey (USGS), National Science Foundation (NSF), National Institute of Standards and Technology (NIST) and Federal Emergency Management Agency (FEMA). Despite continuing need, appropriations for NEHRP have decreased significantly in real dollars since the late 1970's.

Earthquake occurrence in the United States is not restricted to any single geographical area. All or parts of 39 states are within zones where the probability of an earthquake occurring is great. Recent research indicates that areas in the eastern and central United States are at greater risk of earthquake occurrence than earlier evidence indicated.

Recent events substantiate that many public buildings cannot survive a major earthquake. In many cases, federal buildings are less earthquake-resistant than nearby privately-owned buildings.

Because of funding cuts, programs to develop safer buildings and other structures, including lifelines, have been reduced and existing research facilities have been underutilized. In addition, some excellent earthquake researchers have left the field. There is also evidence that much of the engineering research that has been accomplished under NEHRP has not been applied effectively. NEHRP has produced numerous recommendations for standards for new and existing buildings, lifelines and other structures. These provisions have yet to be fully implemented by local governments. As such, there is inadequate transfer of findings to those who help communities prepare for earthquakes. Funds have not been available to help localities improve building codes and zoning provisions in order to improve building safety.

SUCCESSES

Over the past 25 years, NEHRP has provided a wealth of information useful to engineering practice and therefore of significant benefit to the public. The USGS has developed and published uniform earthquake hazard maps that clearly identify the expected seismicity of any location in the Nation. NSF, through their grants to university researcher, has funded the development of new engineering analysis and design techniques that allow engineers to make better and more cost effective decisions related to seismic design. FEMA has been able to leverage a small amount of funding into an impressive series of design guidelines, standards and codes that have spread the experience of a few to engineers nationwide. NIST has developed standards for federal buildings that have encouraged owners nationwide to recognize the earthquake vulnerabilities of their communities. It has been a successful program with significant results.

Determining the proper seismic hazard level for a community is still the most consequential information needed for seismic resistant design. The new USGS hazard maps, develop in conjunction with Structural Engineers, have significantly influenced engineering community. Some areas in the Nation, such as the Central Valley of California, have learned that their seismicity is much lower than traditionally held. Some of California's essential business operational facilities have been relocated to these low seismic areas to reduce their vulnerability and the need for and cost of seismic rehabilitation in these areas has been significantly reduced. At the other extreme, areas of the Nation, such as in the Portland Oregon area, have learned that their seismic exposure is much greater and steps are being taken to increase their resilience to damage through new codes and rehabilitation programs. Because of the detailed, scientifically based maps, billions of dollars of construction is being spent more wisely, both in terms of reduced construction costs and reductions in expected damage. Similar example could be cited across the Nation.

Buildings today all over the world are being built on isolation systems or have energy absorbing systems built within their structures. These advanced construction techniques grew out of fundamental NSF research begun by Dr. Jim Kelly at the University of California at Berkeley and others in the late 1970's. Their work was "curiosity based" and not held in high regard at the time. Over the past 30 years it has matured into a commonly used system that protects essential facility and historic structures in a superior manner. Basic NSF funded research, such as this, has yield dozens of analysis and design techniques that are of significant benefit to the public and the Nation.

The Nation's ability to arrest the growth of its seismic vulnerability and reduce it to acceptable levels depends on the efforts of all practicing engineers, nationwide. FEMA, recognizing the need for published guidelines and standards, has leveraged the volunteer talents of an army of engineers by providing travel funds, meeting spaces, and publication support. Over the past 20 years, dozens of FEMA "Yellow Books" have been published on various aspects of seismic design and rehabilitation. ASCE has been able to use this material in their standards process to produce state of the art design standards such and ASCE 7 and ASCE 31. These new standards are used to train engineers nationwide and guide their seismic design and rehabilitation efforts. These efforts, in turn are providing the Nation with a much more reliable constructed environment.

The first 25 years of NEHRP has proven that limited federal funds, applied to the Nation's earthquake vulnerability, can be leveraged 100 times over in terms of savings in construction and limiting the loss after an earthquake. We believe that the program is just now developing its stride and maturity and is ready for additional funds that will provide new levels of understanding about the vulnerability and tools for the analysis and design. Significant progress will then be made toward reducing the Nation's vulnerability to an acceptable level.

ASCE RECOMMENDATIONS

Specifically, ASCE asks that in reauthorizing NEHRP, Congress provides for stronger leadership, increased authorization and improved interagency coordination. Further, ASCE supports changes to NEHRP which:

- Increase applied research, testing, and accelerated technology transfer of research results.
- Adopt and enforce standards for seismic design and construction of new and existing public buildings.
- Adopt and enforce building codes and zoning provisions to incorporate improved seismic design and construction standards of new and existing buildings and lifelines by State and local governments and by industry.
- Improve earthquake preparedness, particularly for building safety, lifeline systems and emergency response.
- Increase public education about earthquakes and engineering concepts for hazard reduction.

Additionally, ASCE supports practices and policies to assist local communities in the use of state-of-the-art performance standards for existing critical, essential, educational and disaster-recovery facilities, such as hospitals, schools and emergency shelters. There needs to be improvements in community preparedness and related civil infrastructure to make them economically resilient to earthquake hazards. Work must continue on development and adoption of nationally accepted, consensus-based standards for evaluation and retrofit of existing buildings. Finally, ASCE supports the development of national seismic standards for new and existing lifelines.

EARTHQUAKE ENGINEERING RESEARCH INSTITUTE REPORT

The Earthquake Engineering Research Institute (EERI), with financial support from the National Science Foundation, recently published a report, "Securing Society Against Catastrophic Earthquake Losses." This report highlights the accomplishments of NEHRP along with the challenges that still must be met. We have an opportunity to build on the existing knowledge gained from past research and to create new knowledge. The report contains a detailed plan, including cost estimates, to meet those remaining challenges.

The report summary concludes that:

> *"The earthquake engineering community is poised for a fundamental shift in the mitigation of earthquake risks by developing new ways of thinking about the performance of structures and new societal choices about seismic safety. The time*

is now to launch a new, bold initiative to provide security for the United States from the effects of catastrophic earthquakes."

ASCE encourages Congress to incorporate the recommendation of the EERI report into the legislation to reauthorize NEHRP. It is time to make a good program a great one.

Thank you for this opportunity to express our views. ASCE is ready to assist in any way we can. If you have questions or need additional information, contact Martin Hight, Senior Manager, Government Relations at (202) 326–5125 or by e-mail at mhight@asce.org.

SEISMOLOGICAL SOCIETY OF AMERICA

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Statement of Support for NEHRP Reauthorization

Earthquakes represent a growing risk to our national security.
We must not wait for a disaster before improving our preparations.

The situation.
Earthquakes are an inevitable hazard that cannot be prevented nor, thus far, predicted; however the risk to our citizens and infrastructure can be greatly mitigated with proper understanding and preparation. Much progress has been made over the past half century but increasing population density and infrastructure complexity means the risks and likely costs due to future earthquakes are increasing at a high rate. A large urban earthquake could cost the nation 100 to 200 billion dollars and cause thousands of fatalities. Information and research is the key to driving effective mitigation efforts.

The National Earthquake Hazard Reduction Program (NEHRP) has proven to be effective for sponsoring data collection, research and engineering practice which decreases our vulnerability to earthquakes. Despite great progress, particularly in California, earthquake risk nationwide continues to grow. A recent NSF sponsored study by the Earthquake Engineering Research Institute, ***Securing Society Against Catastrophic Earthquake Losses*** shows that earthquake risks are increasing at unacceptably high rates. Increased federal funding by a factor of three for hazard mitigation efforts could turn this trend around in less than 20 years. Understanding the hazard in all 39 vulnerable states, communicating that hazard and applying improved and appropriate construction practices is required to actually reduce the earthquake risks.

Needs.
There are three national programs that we feel need continued and strengthened support.

NEHRP - This umbrella program needs to be reauthorized by congress and strengthened for coordinating efforts of its agencies. It needs to implement a balanced and accelerated approach for federal leadership in earthquake monitoring, and research. A strong and expanded NEHRP that provides leadership, funding,, mitigation incentives and requirements must be continued.

ANSS. - The **Advanced National Seismic System** was authorized by Congress in 2000 at $35M per year for 5 years. As of spring, 2003 only $3.9M a year for two years has been appropriated and this year's request is only $1.9M. Funding levels of only 10% of appropriated levels or less will not come close to reaching the systems desired goals. The ANSS is a multipurpose system carefully designed to efficiently provide data and information for the following three primary purposes: 1) monitor earthquake activity to improve our knowledge of faults, seismicity patterns and structure; 2) rapidly provide authoritative information to emergency response and inspection officials immediately following large earthquakes to aid with recovery efforts; 3) to accurately record the strong motions associated with medium to large earthquakes to assist engineers with the design and retrofitting of structures in preparation for future earthquakes. Putting the instrumentation in after the next large earthquake will be too late. **We cannot afford to miss the once in a lifetime opportunity to obtain the strong motion records that explain the damage patterns that will occur during the next major earthquake.**

NEES. The George E. Brown Jr, **Network for Earthquake Engineering Simulation,** was established by the National Science Foundation to expand the state of knowledge in earthquake engineering through new experimental and computational systems. New facilities and interconnections are being established but funds to actually use them for new research is thus far very limited. An immediate investment in NEES is needed to reduce the cost and increase the effectiveness of earthquake design

Thus, we urge that NEHRP be reauthorized, that the ANSS funding be ramped up to its appropriated level and that research support for using NEES be substantially increased.

Appendix 2:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Anthony S. Lowe, Administrator, Federal Insurance Mitigation Administration; Director, Mitigation Division, Emergency Preparedness and Response Directorate (Federal Emergency Management Agency), Department of Homeland Security

Questions submitted by Chairman Nick Smith

Q1. Mr. Lowe noted during the hearing that the Federal Emergency Management Agency (FEMA) has not submitted the coordinated budget request report to the Office of Management and Budget (OMB) as required by Section 206 of Public Law 106–503. The Committee views these reporting requirements essential to ensuring that each agency's National Earthquake Hazards Reduction Program (NEHRP) expenditures are coordinated to create synergy and adequately reflect the Program's objectives. Please explain why this report has not been submitted.

A1. Since the language for Section 206 was included in the authorization of the NEHRP program, FEMA, now part of the Emergency Preparedness and Response Directorate (EP&R), has taken the requirements very seriously. As the NEHRP agencies moved toward completing the NEHRP Strategic Plan, EP&R considered the Plan a surrogate format that would satisfy the requirements of Section 206. Despite the fact that the issuance of the Plan was delayed, EP&R and the other NEHRP agencies were initiating and continuing work pursuant to the Plan within their respective existing resources. The Strategic Plan has served as the platform for compliance with Section 206 and has been a critical linkage in the coordination among the NEHRP agencies. The Strategic Plan created the synergy necessary to adequately reflect the Program's objectives.

EP&R has put into place changes that will allow explicit compliance with Section 206 for the future. Those changes include:

- The other NEHRP agencies have agreed with EP&R's proposal for an overall Management Plan. This Management Plan will articulate NEHRP priorities in the context of the policies of the Administration and will be used to guide the efforts of the senior career levels of the NEHRP, the Interagency Coordinating Committee, or ICC.
- In conjunction with the Management Plan, we will collaborate in the development of an annual Plan of Work, which will lay out each of the proposed activities from the Strategic Plan that we intend to accomplish during the year. This coordinated effort will ensure that activities are complementary. Each of these proposed activities will be justified, using the Strategic Plan, to demonstrate its importance in advancing the stated NEHRP objectives and goals. For each planned activity, we will explicitly identify associated funding requirements that are also represented in each agency's overall request for appropriations.
- The guidance from EP&R to each agency for the preparation of requests for appropriations, as required by Section 206, will occur in the form of our coordination of the development of the annual Plan of Work in concert with the Strategic Plan.
- EP&R will submit the Plan of Work as the overall NEHRP annual budget request to OMB, and this will satisfy our agency requirements, as well as the overall program requirement.

Q2. Section 406 (C) of Public Law 107–296 states that FEMA "shall have the primary responsibility within the executive branch to prepare for and mitigate the effects of nonterrorist-related disasters in the United States." However, the Committee learned on May 2nd that $4.4 million in FEMA Emergency Management Performance (EMP) Grants would be administered from the Office for Domestic Preparedness (ODP) within the Border and Transportation Security Directorate, which is dedicated to protecting the country from acts of terrorism.

Q2a. Given that ODP is not one of the four NEHRP agencies, why are these funds considered part of the NEHRP budget?

Q2b. Please explain how the purpose and structure of ODP grant program that will distribute the $4.4 million is related to the FEMA EMP Grants program.

Q2c. How will FEMA ensure that an appropriate amount of ODP grants are directed toward earthquake hazards mitigation?

A2a,b,c. In FY 2003, $4.4 million of NEHRP funds are provided to States as part of the Emergency Management Performance Grants (EMPGs), along with funds from other programs within EP&R. The EMPG program was created in 1999 to consolidate funding streams to the states and to allow state emergency management directors to direct resources to the risk reduction priorities that they identify for their population at risk from various hazards.

With the creation of the Department of Homeland Security (DHS), EMPGs are being consolidated with other grants, to be managed by the Office for Domestic Preparedness (ODP), beginning in FY 2004. Consolidating the management of grants will provide efficiency and cost effectiveness in grants administration as it has under the EMPG program.

As part of the Administration's effort to increase states' flexibility in FY 2004, there is not explicit funding set aside for this purpose. Of course, states may use the ODP funds for a similar purpose if they so choose.

Q3. How many full-time equivalents within the Department of Homeland Security (DHS) are dedicated to NEHRP activities? How will DHS balance staff-time devoted to carrying out day-to-day NEHRP activities with other emergency needs such as responding to tornadoes and floods?

A3. Within DHS, 46 full-time equivalents (FTEs) are funded with NEHRP funds, 30 FTEs at headquarters and 16 in the regional offices. The headquarters contingent consists of 7 FTEs that are specifically designated to work on NEHRP activities, 11 that are dedicated to multi-hazard initiatives, and 12 support staff and management FTEs. EP&R's staff resources are leveraged among the many programs, and the functional alignment of EP&R's organization allows for the most effective use of resident expertise. There are a number of EP&R employees who work primarily in the NEHRP area, but who are funded from other sources as well.

As with all EP&R programs, NEHRP employees are subject to deployment during disaster situations.

Q4. Please provide written comments on:

Q4a. Witness testimony recommending the designation of a single OMB examiner to review the NEHRP budget.

A4a. The Department of Homeland Security can not comment on the staffing plan of the Office of Management and Budget. The Committee will have to direct those questions directly to OMB.

Q4b. Witness testimony recommending the establishment of an external advisory committee (much like the current USGS Scientific. Earthquake Studies Advisory Committee) to provide recommendations on NEHRP.

A4b. In recent months EP&R has re-energized the high-level Policy Coordinating Committee (PCC) to provide increased direction to the Interagency Coordinating Committee (ICC). This will be accomplished through a Management Plan, which will guide the PCC's oversight of the implementation of the NEHRP Strategic Plan. This Management Plan will articulate NEHRP priorities in the context of the policies of the Administration. In addition, the ICC will develop, each year, a Plan of Work that will contain specific metrics, which will evolve over time and will provide a results-oriented approach. This will assist the PCC in gauging the success of NEHRP initiatives against the metrics, so that the PCC can make decisions about how to effectively allocate NEHRP resources. We believe that this system of oversight by the PCC, previously dormant, will provide excellent support and direction for NEHRP, obviating the need for an advisory committee.

Based on these management initiatives, as well as the newly formed Research Coordination Subcommittee, we feel that an advisory committee is not needed to provide guidance for NEHRP.

Q4c. The five-fold R&D program, priorities, and funding levels detailed in the Earthquake Engineering Research Institute's (EERI) Research and Outreach Plan.

A4c. In the National Science Foundation's (NSF) written testimony, it ". . .supported the Earthquake Engineering Research Institute (EERI) to develop a long-term research and education plan to advance the state-of-the-art and the state-of-the-practice in earthquake engineering and earthquake loss reduction. The result is a comprehensive, community-held vision that includes buy-in from all sectors and disciplines including academics, practicing engineers and geoscientists, social scientists, and government employees and regulators. . ."

EP&R supports the process through which this research and education plan was developed because it represents a consensus of many of the experts in the stakeholder community. EP&R anticipates that the EERI plan will prove beneficial as we implement the NEHRP Strategic Plan, particularly as we integrate components of other research plans, such as the National Institute of Standards and Technology (NIST) research plan (ATC 57), the performance-based earthquake engineering design plan (ATC–58), and the United States Geological Survey (USGS) research plan, into our efforts, through the Research Coordination Subcommittee.

With respect to funding levels, the EERI plan calls for roughly a tripling of the current NEHRP budget over the next 20 years. EP&R will consider EERI recommendations as it develops the FY 2005 budget request,

Q5. The National Science Foundation's written testimony noted the need to develop an "all-agency Internet portal for dissemination of information about research opportunities and outcomes, news releases, plans and activities in a form that can be easily accessed by the research community at large." Is development of such a one-stop shopping website for NEHRP planned for the near future?

A5. EP&R is in the process of developing a NEHRP website that will reside on the EP&R server and will be the primary vehicle to disseminate general NEHRP and EP&R programmatic information relevant to NEHRP. The NEHRP website will provide linkage to other NEHRP information including NEHRP agency websites, state earthquake program websites, earthquake consortia websites, earthquake information research institutions with relevant information or programs, relevant associations and nonprofit organizations, and university programs.

EP&R has also set up a Research Coordination Subcommittee, under the ICC, that is charged with identifying synergies among research programs. This subcommittee is also charged with making research findings more available to the NEHRP stakeholders, as well as to other appropriate audiences. EP&R's NEHRP website will also encapsulate the work of the subcommittee.

Questions submitted by Ranking Member Eddie Bernice Johnson

Q1. Explain how the strategic plan influenced the FY 2004 budget request for the earthquake program.

A1. The NEHRP Strategic Plan lays out the present and future activities of NEHRP and its four agencies and is organized around the four goals of the program, which are:

A. Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation.

B. Improve techniques to reduce seismic vulnerability of facilities and systems.

C. Improve seismic hazard identification and risk assessment methods and their use.

D. Improve the understanding of earthquakes and their effects.

Although this Plan has only recently been approved by OMB and sent to Congress, the four agencies have been operating and reporting according to its draft guidance for two years, while remaining within existing resource constraints. Therefore, each agency's 2004 budget request for NEHRP activities was designed to fulfill the goals of the Strategic Plan, while remaining within the Administration's 2004 budget allowances.

Q2. What level of priority does NEHRP assign to completion of the Advanced National Seismic System (ANSS), and what efforts have been made to get an adequate budget request for ANSS in the President's budget submission?

A2. The NEHRP places the completion and implementation of ANSS among its highest priorities. Specifically, its priority is described in the recently released NEHRP Strategic Plan, *Expanding and Using Knowledge to Reduce Earthquake Losses*. Page 12 of the Plan identifies the need for real-time seismic monitoring and reporting of ground motion intensities that would be provided by ANSS as the first of the program's future challenges, opportunities, and priorities. Under that section, the Plan states that:

> "Recent and unprecedented advances in information technology, telecommunications, and digital electronics now allow for real-time, high fidelity monitoring of seismicity across the Nation. An upgraded seismic monitoring system in the U.S. would enable rapid assessments of the distribution and intensity of earthquake shaking, thereby allowing emergency response officials to assess, within

minutes of an event, where the damage is likely to be concentrated and how emergency resources should be allocated. Someday, the new technology may even allow for a few seconds of warning of impending strong seismic shaking from distant earthquakes already in progress. The USGS funds the Advanced National Seismic System (ANSS), an effort to update current instrumentation and provide this real-time monitoring capability."

Further, the NEHRP Strategic Plan also lists this objective under Goal C: "Provide rapid, reliable information about earthquakes and earthquake-induced damage." Under this objective, NEHRP specifically calls for the implementation of ANSS.

The responsibility for securing adequate funding for ANSS or any other program has historically been with the individual agency—in this case the USGS. In the future, however, we will use the NEHRP Management Plan to submit a coordinated and consolidated NEHRP budget request that fully complies with Section 206.

Q3. Dr. O'Rourke in his testimony indicated that there are insufficient research funds in NEHRP to take full advantage of the new equipment and simulation facilities being made available by the George Brown Network for Earthquake Engineering Simulation. Is this a subject of discussion during the planning process for NEHRP? Explain how program priorities being developed to balance research and research infrastructure needs.

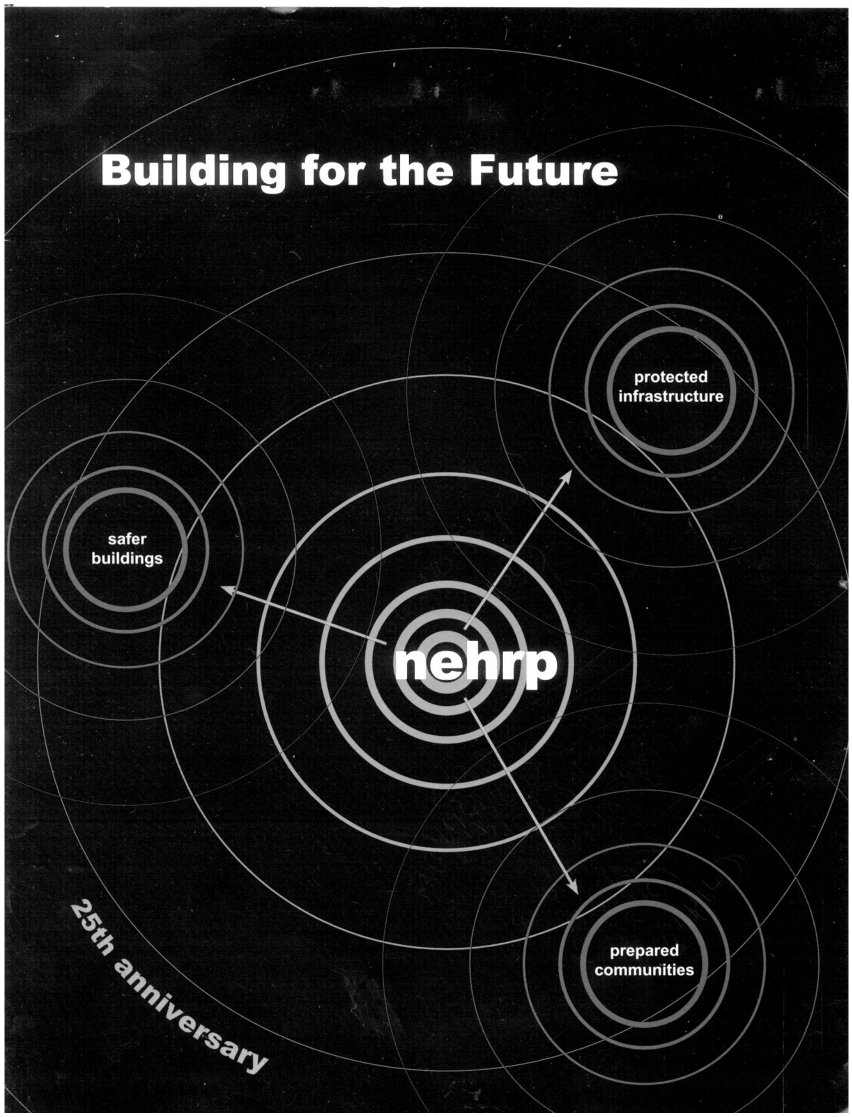
A3. The operation of the NEHRP over the last 25 years has worked within the research community to establish what is essentially a market-driven balance between funded research work and available research infrastructure. With the advent of the first phase of the Network for Earthquake Engineering Simulation (NEES) program, we are presently increasing the available research infrastructure. However, even more important, with the remainder of the NEES program, we will be significantly improving how this expanded research infrastructure can be used through the NEES Co-Laboratory infrastructure. The NEES Co-Laboratory will ultimately allow research to be done much more efficiently, as it will allow researchers to utilize research facilities via the Internet. So, while we are presently expanding the available research infrastructure, we also in effect are lowering the cost of doing research by making it easier for researchers to access that expanded infrastructure.

The expansion of the research infrastructure under the first phase of NEES was called for and directed by the *Assessment of Earthquake Engineering Research and Testing Capabilities in the United States,* a report prepared for NSF and NIST by EERI that was called for under the NEHRP Reauthorization Act of October 1994. That report was published by EERI in September 1995.

NSF has tasked the National Research Council to investigate research needs post-NEES and to prepare a report documenting this issue. This report is due to NSF later this year, and will be used as part of our NEHRP planning process for funding future research. In particular, this report will be utilized by the new Research Coordination Subcommittee of the NEHRP ICC as it moves to improve the coordination of NEHRP-funded research activities.

Appendix 3:

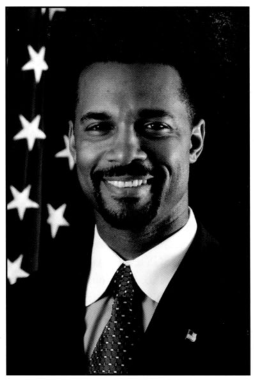
ADDITIONAL MATERIAL FOR THE RECORD


Building for the Future
protected
infrastructure
safer
buildings
nehrp
prepared
communities
25th anniversary

The National Earthquake Hazards Reduction Program: Building for the Future

Anniversaries offer us the opportunity to look back, to evaluate our record, and to plan for the future. As the National Earthquake Hazards Reduction Program (NEHRP) celebrates 25 years, we note the many achievements built on science that have contributed to making our country, our communities, and our citizens safer from the effects of earthquakes.

Some achievements, such as the survival of the Trans-Alaska oil pipeline during a recent earthquake, are based in earth science and earthquake engineering research. Other initiatives, such as the mitigation and outreach work in Los Angeles, Seattle, and numerous other communities, make use of structural and non-structural retrofit, and public awareness to achieve safer homes, schools, and businesses. All of the accomplishments, however, share common features: science and engineering drive the effort, partnerships are established to achieve results, and the public benefits from the synergy.

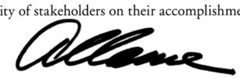


Anthony S. Lowe
Administrator, Federal Insurance and Mitigation Administration

The achievements of the NEHRP over the last 25 years are the basis for innovative initiatives by all of the NEHRP agencies: the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the United States Geological Survey (USGS). Building for the future involves very exciting work that promises to make our country even safer from the threat of earthquakes. Some of the more exciting projects include:

- FEMA will develop performance-based seismic design guidance, building on research funded by NSF, to allow a building owner or community to determine the level of performance they can expect from a building after an earthquake, and will provide a reliable design standards to ensure that performance and further reduce losses.
- The NSF George E. Brown Network for Earthquake Engineering Simulation (NEES) will link 16 distributed earthquake research facilities using high speed internet connections to allow researchers improved access to the nation's best laboratory equipment, and to disseminate research results more efficiently.
- The Advanced National Seismic System (ANSS), a USGS initiative, will provide a much larger array of more reliable instruments across the country for a more accurate and thorough measure of earthquake ground motions. This will improve understanding of earthquakes and how they affect the built environment.
- The National Construction Safety Team Act, recently passed by Congress, will allow NIST to better capture the lessons learned from large-scale building failures after an earthquake.
- The Plan to Coordinate NEHRP Post Earthquake Investigations, developed by the USGS with input from the other NEHRP agencies, will allow the four agencies to better coordinate their activities immediately after the next major earthquake, improving our nation's response and recovery. A key part of this response will be the use of new Internet-based central clearinghouse that includes real-time information and data to better capture important information immediately after an event.
- Recent work by several agencies will demonstrate the benefit of earthquake resistant construction as protection against other man-made hazards, such as blast and fire.

Highlighted here is a cross-section of selected success stories from the NEHRP agencies that illustrate just some of the many benefits that NEHRP has brought to the public over the last 25 years. While the past two and a half decades have seen many accomplishments, the future holds even more promise in the protection of our country from earthquakes and other hazards. I congratulate the NEHRP agencies and vast community of stakeholders on their accomplishments.



Project TriNet Opens a New Era in Earthquake Monitoring

"I just wanted to say thank you for having this web site. We were able to call the nearest maintenance yard, which was near Barstow. We could tell them where to go out to inspect our bridges."

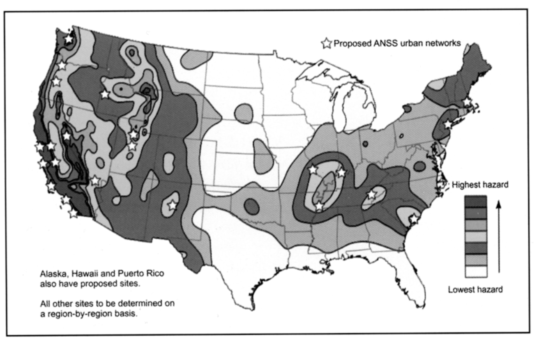
— CalTrans District 8 Bridge Crew

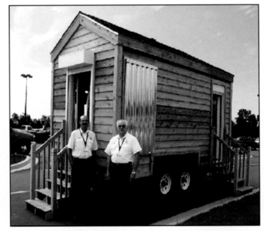
Following the Northridge earthquake in 1994, FEMA provided funding to the California Institute of Technology, the California Division of Mines and Geology, and the USGS to upgrade earthquake monitoring in southern California. The result was project TriNet, a cooperative effort to expand and modernize earthquake monitoring in the region and to provide timely and accurate information on earthquake occurrences. The development of TriNet, which began in 1997, includes:

- Installation of 150 broad-band seismometers by 2002
- Installation of 450 strong-motion sensors by 2002
- Development of a data center to manage and process the information
- Development of new products, especially "ShakeMap"
- The website www.trinet.org

Earthquake shaking is strongly affected by the local geology and soil conditions, and the pattern of the intensity of shaking does not fall in concentric circles about the epicenter. With data from new seismometers available in "real-time," TriNet seismologists realized they could produce realistic contour maps showing the severity and distribution of ground shaking within minutes of an earthquake. This product, called "ShakeMap," was made available at TriNet web sites and has proven immensely useful to emergency management officials and managers of infrastructure and lifeline systems. Now, whenever an earthquake occurs in southern California, there is a regional map available on the web that shows the shaking pattern.

Project TriNet proved so successful that the USGS used it as the pilot model for the Advanced National Seismic System (ANSS). ANSS is an initiative to expand TriNet capabilities to other urban centers in areas of high to moderate seismic risk. Through ANSS, the USGS and regional partners have begun to develop TriNet-like capabilities in the San Francisco Bay region, the Puget Sound region, Salt Lake City, Reno, Anchorage, and the Memphis and St. Louis areas. In addition to providing ground shaking information for emergency response, the engineering community can apply ANSS data in the design and construction of earthquake resistant buildings and critical facilities.





The mobile models educate home-owners to better protect their property their families through Superior Code construction.

Building Beyond Code Requirements in Charleston

"Everyone should be encouraged to build somewhat above code requirements. I don't know of any building official worth his or her salt who builds just to code."

— Carl H. Simmons, Charleston County Building Services

In the fall of 2002, a magnitude 4.32 earthquake was measured in the Charleston area. That earthquake pales in comparison to the magnitude 7.7 earthquake that struck Charleston on August 31, 1886. Could a magnitude 7.7 earthquake strike again? If so, many of those in the building industry in Charleston want to be prepared. The Superior Code Home Standards, which are voluntary standards that go beyond the minimum code requirements for new and existing construction, have been adopted by the Home Ownership Program in the Charleston area, Seabrook Island, South Carolina, and the Habitat for Humanity. The City of Charleston also began enforcing the International Residential Code (IRC) on April 1, 2002, 90 days in advance of any other jurisdiction in South Carolina. "Why would we offer the citizens of Charleston less than the nationally recognized standards for their protection," says Doug Smits, Director of Inspections, Chief Building and Fire Officials for the City of Charleston.

In the City of North Charleston, a non-profit organization established in part with NEHRP assistance will break ground in May 2003 on a permanent home for the organization. It will house an educational center for the community and will feature exhibits on earthquake resistant structural systems, a library, hundreds of safety items and displays, and training programs for a variety of audiences, including architects and engineers, building code officials, contractors, and school children.

The Impact of Model Building Codes

"The development of national model building codes establishing minimum design and construction requirements was one of this country's greatest achievements and will lead to sustainability of our communities."

— James E. Beavers, Director
Tennessee Multihazard Mitigation Center

The nation's model building codes have a greater impact on the quality of construction and how structures will withstand the forces of nature than any other FEMA program. The philosophy is to ensure the quality of construction at the local level before a disaster by making the nation's model building codes adequate for all hazards, and makes FEMA's work much easier, both before and after a disaster.

FEMA's experience with the model code organizations began in the early 1980's. Most notable of FEMA's work with the building codes occurred when the International Code Council (ICC), which was formed from the three original model code organizations, attempted to develop a single International Building Code (IBC). It quickly became apparent that the existence of two sources of seismic code provisions was a serious issue that threatened to derail the entire effort.

FEMA was one of the first outside organizations to meet with the original International Code Council in 1995 to help resolve this issue. FEMA met with the relevant parties, developed a plan that would respond to most of the concerns that had been raised, and managed the Code Resource Development Committee Project. The Committee ultimately developed the provisions that were successfully balloted into the IBC.

This was one of the most critical issues facing the IBC process, and its resolution significantly improved the quality and applicability of the new IBC. FEMA's work was acknowledged in a letter from the ICC.

Shortly after that process was underway, the National Fire Protection Association (NFPA) decided to offer their own building code to complement their wide variety of fire and life safety standards. FEMA worked with the various committees, and FEMA's representative was given a seat on the Technical Correlating Committee, which oversees and resolves conflicts from the other developmental committees. With FEMA's involvement, the NFPA 5000 Building Code adopted the latest version of the ASCE-7 Minimum Design Loads Standards by reference and was published recently.

Solving the Mystery of the Magnitude 9 Earthquake

"The City of Seattle did not suffer major damage from the Nisqually earthquake two years ago based, in large part, on our ability to aggressively explain our improved understanding of earthquake hazards to the structural engineering and community emergency response community to ensure that USGS results are used."

— Craig Weaver, Pacific Northwest
Regional Coordinator, United States Geological Survey

Lewis and Clark didn't reach the coast of Washington State until November 1805. So how do we know that a magnitude 9 earthquake occurred in the Seattle area on January 26, 1700? Amazingly, the remains of dead, saltwater-flooded forests along coastal Washington and widespread deposits of sand high in coastal estuaries suggesting tsunami inundation, along with an analysis of records maintained by the Japanese on tsunamis, presented evidence to geologists that great subduction-zone earthquakes (magnitude 8 to 9) had repeatedly struck the Pacific Northwest in the past thousand years, the most recent earthquake occurring in 1700. Hard detective work by USGS scientists on the Cascadia subduction zone and other crustal faults has helped residents of western Oregon and Washington understand that they live in earthquake country. Particularly in Oregon, where few earthquakes are felt, USGS research helped convince public officials to significantly revise the building codes. Throughout the Portland metropolitan region, new buildings are now designed to resist earthquake forces 50 percent larger than they were under the old code, reducing the risk to life and property in future earthquakes.

Because of NEHRP outreach efforts, individuals are more aware of their personal responsibility for taking risks reduction actions. For example, at The Little Church on The Prairie Learning Center, this awareness played an important part in keeping people safe. Some months before the earthquake, volunteers worked with FEMA hazard mitigation officials to make sure the daycare

Visiting Girl Scouts practice Duck and Cover with 'Terry the Turtle'

– Photo by Lynn Cypher, EMD

center would be safe from shaking effects by bolting cribs to the walls and strapping water heaters, television sets, and computers in place. When the Nisqually earthquake struck, the children and staff at the Center were protected from falling objects. According to Pat Ivy, Director of the Center, "nothing fell over because of our preventative measures. It was amazing."

Business Increases its Involvement in Earthquake Mitigation

"Businesses are more than just buildings."

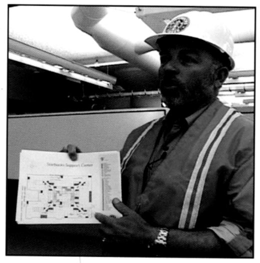
— Robert Freitag, Executive Director, Cascadia Region Earthquake Workgroup

What do Starbucks Corporation, the Boeing Company, and the Friday Harbor Flower Shop have in common? All are businesses, all are located near Seattle, and all are taking an active role in keeping their employees safe and making their businesses more disaster resistant from earthquakes and other hazards.

The Cascadia Region Earthquake Workgroup (CREW) is a non-profit action group on a mission. In 1996, the scientific community established CREW to promote awareness of seismic risk among businesses and emergency managers. The Nisqually earthquake in February 2001 provided CREW and its partners with an important opportunity to assess lessons learned and to take additional steps to mitigate against damage from future earthquakes. Since the Nisqually earthquake, CREW has sponsored conferences and held forums to showcase both successes and failures during the Nisqually earthquake, and how to apply lessons learned to natural and man-made hazards.

In April 2003, CREW will release a 20-minute video directed at small- and medium-sized businesses. Using the lessons learned from Nisqually, the message of the video is "protect your people, your buildings, and your business." The video, which highlights the work of Starbucks, Boeing, and the Friday Harbor Flower Shop, will be distributed along with a tool kit developed in partnership with the Institute for Business and Home Safety (IBHS), and is available at www.crew.org. CREW also plans to meet with the Seattle Chamber of Commerce and other Chambers of Commerce to establish coordinating centers with businesses, and will continue to sponsor its series of business forums.

Starbucks Corporation has taken step at its headquarters facility in Seattle to make the building safer for its employees.



The Trans-Alaska oil pipeline withstood the violent shaking of an 8.0 earthquake in November of 2002.

Survival of the Trans-Alaska Oil Pipeline

"Good science, when applied in the way that the people of Alaska have done, made the difference between an emergency and a tragedy."

— Charles Groat, Director, United States Geological Survey

Each day, the Trans-Alaska oil pipeline carries one million barrels of oil, about 17% of the domestic oil supply for the United States, valued at about $25 million. If the pipeline had ruptured during the recent Denali earthquake, the lost revenue and cost of repair and environmental cleanup would have been incalculable.

When the pipeline was proposed in 1968 to transport oil from producing fields near Prudhoe Bay on the Arctic Ocean to the ice-free port of Valdez, USGS geologists realized that earthquakes on faults along the pipeline route presented a potential threat. In the 1970's, seismologists and geologists commissioned by the Alyeska Pipeline Service Company, in concert with the USGS, studied the likely effects of a magnitude 8.0 earthquake, judged to be the maximum credible earthquake for the Denali fault. The resulting technical requirements for the pipeline stipulated it must be designed to withstand intense shaking levels and up to twenty feet of offset, which proved to be right on target for the magnitude 7.9 earthquake that occurred on November 3, 2002.

Shaking during the magnitude November 3 earthquake was violent and damaged a few of the elevated supports south of the fault zone. However, the pipeline design successfully accommodated the damage and remained adequately suspended between undamaged uprights without rupturing. The Alaska oil pipeline had survived intact, with only nominal damage. "Although considered to be excessively conservative at the time, the USGS design guidance proved to be on target, and the resilience of the pipeline to Sunday's fault rupture is a testament to the importance of science in hazard mitigation and decision-making" says USGS Director, Charles Groat.

Improving the Performance of Steel Moment Frame Connections

"This project was a model of a well-managed program of design guidelines development, with results that have an immediate impact on building construction practices in the U.S. and elsewhere. The seismic safety of steel construction practices has taken a major step forward because of this project."

— Michael D. Engelhardt, Professor of Civil Engineering, The University of Texas at Austin

One of the critical lessons from the 1994 Northridge earthquake was the unacceptable performance of steel moment-resisting frame construction. In response, FEMA established the FEMA/SAC Steel Moment Resisting Frames Project. With this new information, the building code for this type of construction had effectively been invalidated, and there was little idea of how safe existing buildings were or how to repair damaged buildings. Since FEMA funds the repair of publicly owned buildings, this was a crisis for FEMA as well as for building owners. It also quickly became clear that this was not just a California problem but also a national problem. FEMA determined that the first need was for guidance on how to repair damaged buildings. Using the NEHRP Northridge Research Fund, the work was completed in less than a year and its primary product, the *Interim Guidelines for Steel Moment Resisting Frame Construction* (FEMA-267), quickly became the *de facto* standard. To date, FEMA has distributed over 20,000 copies of the *Guidelines*.

FEMA then began the second phase of the project, an effort to study and develop final design criteria for the design and inspection of new construction and upgrading of existing buildings for use by the nation's model building codes and standards. The final products include technical guidance for new construction (FEMA-350), upgrade guidance for existing buildings (FEMA-351), evaluation and repair guidance for damaged buildings (FEMA-352), and a technical specifications and quality control guidance document (FEMA-353). FEMA also published non-technical guidance for building owners and local officials (FEMA-354) and a CD-ROM with all of the publications and a series of background reports (FEMA-355).

This groundbreaking initiative was the first FEMA, if not federal, effort to effectively combine the academic research world and the earthquake engineering design community on a scale never before attempted. As a result of this effort, the building codes and standards for the entire country have been revised to take into account project findings. The quality of steel moment frame construction has been significantly improved because of the project. Both the model code organizations and the industry standards group are now using the final design guidelines as the basis for their products. In fact, the American Institute for Steel Construction is now sponsoring training courses across the country using the FEMA publications and has distributed several thousand copies to date.

FEMA has been widely recognized for its role in organizing and leading the solution to a serious problem for the nation's building codes and standards. The steel industry, through the American Institute for Steel Construction, presented an award to the Director of FEMA for its role in resolving this complex problem.

GPS System Measures Earthquake Potential

"Thanks to SCIGN's sponsors, the southern California scientific community can pioneer the use of the most promising new tool in geophysics since the invention of the seismometer."

— Tom Henyey, Director, Southern California Earthquake Center

The Chinese philosopher Chang Heng invented the first seismoscope in A.D. 132. The instrument was a large urn, on the outside of which were eight dragonheads facing the eight principal directions of the compass. When an earthquake struck, one or more of the eight dragon mouths would release a ball into the open mouth of a toad sitting below. The direction of the shaking determined which of the dragons released its ball. The instrument was reported to have detected an earthquake up to 400 miles away.

Almost 2,000 years later, on July 6, 2001, earthquake scientists unveiled the Southern California Integrated GPS Network (SCIGN), a new type of ground motion monitoring network. Unlike other instrument networks that record shaking, SCIGN tracks the slow motion of the Earth's plates using a Global Positioning System (GPS). With SCIGN, the link between the motions of the plates that make up the Earth's crust and the resulting earthquakes is now being observed by an array of 250 GPS stations operating in southern California and Baja California, one of the world's most seismically active and highly populated areas. Using SCIGN data to measure deformation of the Earth's crust, scientists can determine how strain builds up slowly over time before being released suddenly during an earthquake. These new GPS measurements contribute to improving the region's earthquake hazards assessments that help motivate people to prepare for earthquakes.

Scientists of the NSF-supported Southern California Earthquake Center (SCEC) designed and manage SCIGN. NASA's Jet Propulsion Laboratory (JPL), the Scripps Institution of Oceanography at the University of California at San Diego, and the USGS are the principal SCEC partners in SCIGN, and all data from the array are openly available on the Internet.

Keys View, the 250th SCIGN station, located in Joshua Tree National Park

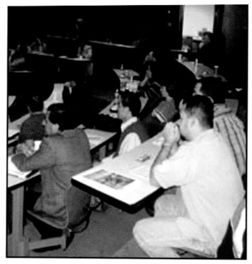
HAZUS, The Standard in Estimating Earthquake Losses

"The success of HAZUS is that it did what is was intended to do, and so much more."
— Bill Holmes, Principal, Rutherford & Chekene

One of the most successful risk assessment tools is HAZUS, or Hazards U.S., a cutting edge software program developed by FEMA with the National Institute of Building Sciences (NIBS). HAZUS uses an engineering-based approach to estimate physical damage, economic losses, casualties, and other societal impacts from earthquakes.

Although originally conceived as a standardized methodology, HAZUS quickly evolved into an easily transportable software program that could be used by earthquake engineers, universities, private industry, and the public for numerous applications. For example, HAZUS estimates provide decision-makers with evidence of the nature and extent of the earthquake risk in a format useful for garnering public support for public policies and actions to reduce future earthquake damage and losses. State and local governments, the private sector, and communities use HAZUS to estimate physical damage and economic loss to their building stock, critical facilities, and lifelines and utility systems, and to determine how potential losses can be avoided or reduced by preventive actions. HAZUS also estimates debris generated, long- and short-term shelter and alternative housing requirements, and indirect economic losses such as unemployment, losses in tax revenue and production, and reduction in the demand for products and spending. HAZUS also can determine the impact of other hazards that may be triggered by the main event, such as ground failure, fire, and inundation from dam failure.

Today, there are a number of HAZUS user groups across the United States supported by FEMA that provide the disaster management community, industry, government, and the public with the resources and knowledge to effectively use HAZUS. FEMA supports HAZUS to demonstrate its use in supporting state and local government implementation of the planning requirements of the Disaster Mitigation Act of 2000 and through pilot projects with the Department of Defense to assess the vulnerability of facilities and infrastructure.



A HAZUS User Group Meeting from Michael Baker Corporation

Significant enhancements have been made to HAZUS since its release in 1997. FEMA is adding the capability to estimate losses from flood and hurricane wind hazards and will also link to models for estimating exposure of people and property to other technological hazards.

The Paramount in San Francisco

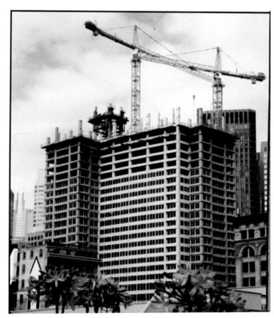
"The application of research results to the building industry is a notable achievement in making our buildings safer."
— Steven Cauffman, Research Engineer, National Institute of Standards and Technology

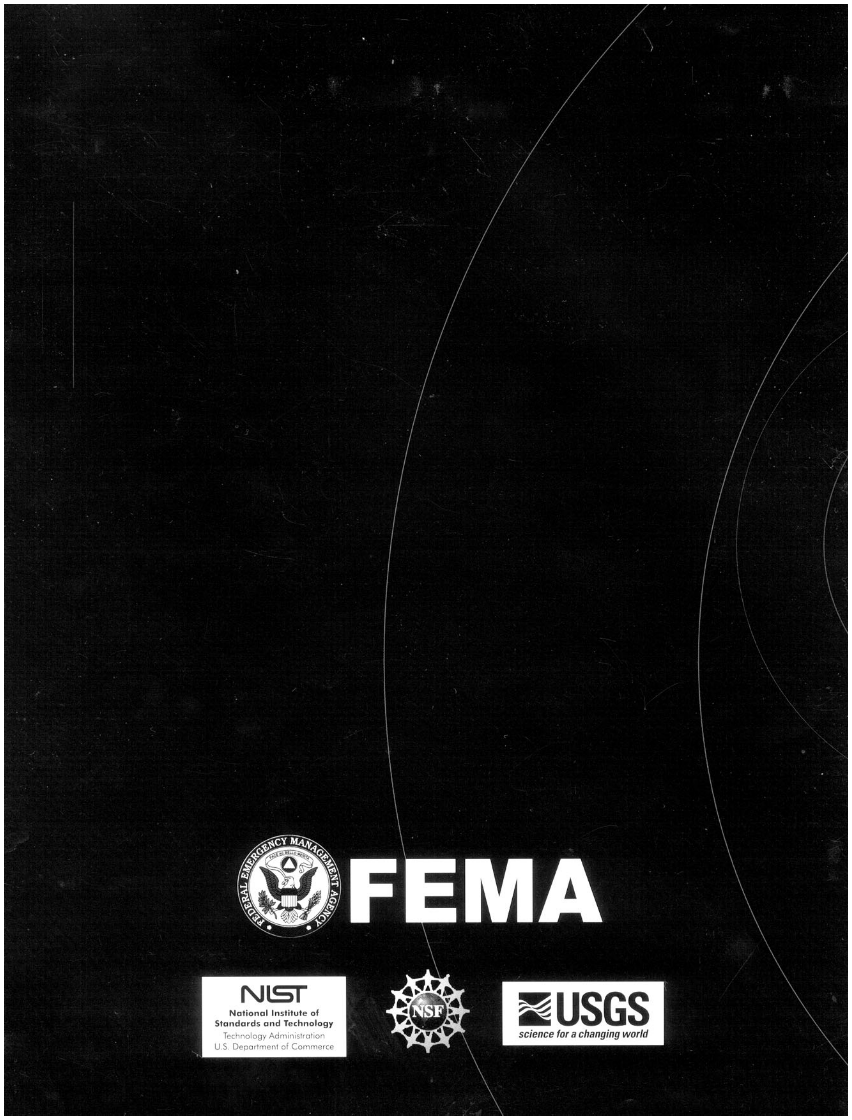
The Paramount, located in the South Market area of downtown San Francisco, is the tallest precast concrete building in a high seismic zone in the United States. The striking 39-story residential apartment tower, completed in 2001 by Pankow Residential Builders II, L.P., includes 486 apartments and parking for 350 cars in a total of 660,000 square feet of building area. The Paramount is also the first significant application of the Precast Hybrid Moment Resistant Frame (PHMRF) System.

The PHMRF is a dramatic new structural building frame system that has been developed over the past decade by leading industry researchers and experts. Although the design approach is innovative, the PHMRF uses existing concrete and steel materials and their properties, but arranges them in a novel way to maximize their benefits. In simple terms, the make-up of the joint using the PHMRF system allows it to work like a shock absorber to accommodate and counter the seismic forces that cause a building to sway when an earthquake strikes. While most modern buildings will withstand a major earthquake if built in accordance with current building code requirements, many of their structural systems will be seriously damaged. The design concept of the PHMRF provides a well-defined joint location to accommodate structure movement, significantly minimizing structural damage during an earthquake.

The development of the PHMRF involved a consortium of industry researchers and experts, including the NIST, the University of Washington, and the Pankow Companies. The NSF-sponsored initial research and testing of the system in the early 1990's. The capabilities of the system have been recognized by building code authorities and have been approved for use by the International Conference of Building Officials (ICBO).

The Paramount Project, utilizing the Precast Hybrid Moment Resistant Frame, under construction in San Francisco.




FEDERAL EMERGENCY MANAGEMENT AGENCY
FEMA
NIST
National Institute of
Standards and Technology
Technology Administration
U.S. Department of Commerce
NSF
USGS
science for a changing world

FEMA 382 / March 2003

Expanding and Using Knowledge to Reduce Earthquake Losses:

The National Earthquake Hazards Reduction Program

Strategic Plan

2001 - 2005

The development and use of this strategic plan will result in a new era of coordination and advancement for the National Earthquake Hazards Reduction Program. It will serve as a mechanism to improve coordination among the agencies, and provide the broad vision that NEHRP will use to move forward boldly into the 21st century. This NEHRP Strategic Plan, respectfully submitted, represents the consensus view of the Policy Coordination Council (PCC).

Anthony S. Lowe (Chair)
Director
Mitigation Division
Emergency Preparedness and
Response Directorate
Department of Homeland Security

Dr. John A. Brighton
Assistant Director
Directorate for Engineering
National Science Foundation

Dr. Arden Bement
Director
National Institute of Standards and
Technology

Dr. Charles Groat
Director
United States Geological Survey

March 1, 2003

Members of Congress:

This Strategic Plan is submitted in response to PL 101-614. It serves as an operational plan for the National Earthquake Hazards Reduction Program (NEHRP) agencies and guides Federal earthquake research, loss reduction, and mitigation efforts in the U.S. The plan articulates the mission and goals of the NEHRP, provides a framework for priority-setting and coordinating activities, and defines priority areas for the future.

The plan was developed jointly among the four NEHRP agencies (FEMA, NIST, NSF, and USGS) and the earthquake stakeholder community. Two workshops, involving over 60 stakeholders, were held in 1999 and 2000 to help identify priority implementation activities (Appendices A and B). The input offered during the workshops has had a significant impact on the overall direction of future earthquake hazard mitigation efforts as identified in the Plan. The stakeholder involvement has assured that Federal efforts are coordinated with state and local governments as well as the private sector.

The plan is also responsive to the desire of Congress that NEHRP emphasize coordination of research activities, speedy transfer of new knowledge, and implementation of the results and technologies by the user community. This plan addresses demands for greater productivity, efficiency, and accountability from the Federal government.

The Government Performance and Results Act of 1993 requires agencies consult with Congress and stakeholders to clearly define their missions, establish long-term strategic goals, and set annual objectives linked to the goals. This Plan is consistent with these requirements.

This is a living document. Factors affecting earthquake risk reduction may change and evolve differently than expected, and therefore goals and objectives, priorities, strategies, and planning contexts may change over the life of this plan. Consequently, the plan will be reviewed biennially by the participating agencies to assess the status of implementation and refine or revise approaches based on experience. The biennial review will coincide with the requirement for a NEHRP report to Congress. A more formal and comprehensive review, to be performed every five years, will involve internal and external stakeholders and may result in more substantive changes.

The NEHRP Agencies

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List Of Acronyms And Abbreviations

Acronym	Definition
ANSS	Advanced National Seismic System
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BSSC	Building Seismic Safety Council
COSMOS	Consortium of Organizations for Strong Motion Observation Systems
CREW	Cascadia Region Earthquake Workgroup
CUREE	Consortium of Universities for Research in Earthquake Engineering
CUSEC	Central U.S. Earthquake Consortium
EERC	Earthquake Engineering Research Centers
EERI	Earthquake Engineering Research Institute
EMPG	Emergency Management Performance Grant
EQNET	Earthquake Information Network
FEMA	Federal Emergency Management Agency
GPS	Global Positioning System
HAZUS	Hazards U.S.
IBC	International Building Code
ICC	Interagency Coordination Council
ICSSC	Interagency Committee on Seismic Safety in Construction
InSAR	Interferometric Synthetic Aperture Radar
IRC	International Residential Code
IRIS	Incorporated Research Institutions for Seismology
MAE	Mid-America Earthquake Center
MCEER	Multidisciplinary Center for Earthquake Engineering Research
NASA	National Aeronautics and Space Administration
NEES	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
NISEE	National Information Service for Earthquake Engineering
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
NSMP	National Strong Motion Program
PCC	Policy Coordination Council
PEER	Pacific Earthquake Engineering Research Center
SAFOD	San Andreas Fault Observatory at Depth
SCEC	Southern California Earthquake Center
USGS	U.S. Geological Survey
WSSPC	Western States Seismic Policy Council

Executive Summary

Earthquakes represent an enormous threat to the Nation. Although damaging earthquakes occur infrequently, their consequences can be staggering. As recent earthquakes around the world have demonstrated, high population densities and development pressures, particularly in urban areas, are increasingly vulnerable. Unacceptably high loss of life and enormous economic consequences are associated with recent global earthquakes, and it is only a matter of time before the United States faces a similar experience.

Earthquakes cannot be prevented, but their impacts can be managed to a large degree so that loss to life and property can be reduced. To this end, the National Earthquake Hazards Reduction Program (NEHRP) seeks to mitigate earthquake losses in the U.S. through both basic and directed research and implementation activities in the fields of earthquake science and engineering. This program is authorized and funded by Congress and is managed as a collaborative effort among the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the United States Geological Survey (USGS). These four Federal organizations work in close coordination to improve the Nation's understanding of earthquake hazards and to mitigate their effects. The missions of the four agencies are complementary: FEMA, a component of the Department of Homeland Security, works with states, local governments, and the public to develop tools and improve policies and practices that reduce earthquake losses; NIST enables technology innovation in earthquake engineering by working with industry to remove technical barriers, evaluate advanced technologies, and develop the measurement and prediction tools underpinning performance standards for buildings and lifelines; NSF strives to advance fundamental knowledge in earthquake engineering, earth science processes, and societal preparedness and response to earthquakes; and USGS monitors earthquakes, assesses seismic hazard for the Nation, and researches the basic earth science processes controlling earthquake occurrence and effects.

Mindful of the increasing threat posed by earthquakes, NEHRP initiated a review of the scientific goals and strategies of the Program and a discussion of the opportunities and priorities for the five-year interval 2001-2005. This review and discussion culminated in the new strategic plan presented here. Shaping the plan are four goals that represent the continuum of activities in the Program, ranging from research and development to application and implementation. These four goals are as follows:

A. Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation.

B. Improve techniques to reduce seismic vulnerability of facilities and systems.

C. Improve seismic hazard identification and risk assessment methods and their use.

D. Improve the understanding of earthquakes and their effects.

For each of these goals and their underlying objectives, specific implementation activities are identified. Taken together, these activities do not represent a dramatic redirection of the program, but instead serve to emphasize the importance of continued investment in several well-established focus areas complemented by directed growth into a few new strategic areas of opportunity. The latter represent areas where compelling, fundamental issues in earthquake hazard reduction overlap with emerging technological opportunities, resulting in unprecedented potential to make rapid advances in our knowledge and our implementation of such knowledge, leading to the reduction of vulnerability. Six especially promising opportunities stand out:

- Upgrading seismic networks to allow for real-time notification of earthquake activity and intensity of ground shaking,
- On-scale recording of strong motion to facilitate prediction of ground motion and its effects,
- Simulation and testing of earthquake engineering design parameters,
- Development of performance-based seismic design methods,
- Monitoring of active fault zones to constrain the conditions that prevail prior to, during, and after an earthquake, and
- Improving the effectiveness of earthquake risk mitigation efforts through utilization of both existing and new research in the social, behavioral, and economic sciences

In addition to these challenges, NEHRP must also invest in the development of enhanced loss-reduction policies and practices; increased use of research findings by the building science, earth science, and social science communities; improved technology transfer; expanded education on earthquake issues; and increased incentives for earthquake mitigation. These product-oriented activities are essential if the research and development efforts of NEHRP are to be translated in to real progress in earthquake loss reduction.

Management of this Plan is shared by the NEHRP agencies. Each agency brings its strengths and organization to bear in support of the NEHRP mission, and is committed to developing the coordinated and cooperative actions identified in this strategic plan. Joint action of the agencies and interagency coordination at all levels will be important including:

- Post-earthquake coordination
- Information dissemination
- Interagency Internet resources
- Coordinated project activities across agencies

- Coordination with external stakeholders
- Coordination of transfer of research into practice and technology

Strategic planning is a continuous process that flows from conception to planning, implementation, assessment, improvement, and reporting. A biennial review will be carried out by the participating agencies to assess the status of implementation and to refine NEHRP's focus based on experience. In addition, a comprehensive review of the NEHRP Strategic Plan will be performed every five years, which may result in substantive changes in NEHRP's activities.

Introduction

Earthquakes represent the largest single potential source for casualties and damage from a natural hazard facing this country. Although the location varies, the pattern is the same: an earthquake strikes without warning, leaving cities in rubble and killing tens to hundreds of thousands of people. Worldwide during the 20th century, there were ten earthquakes that each killed in excess of 50,000 people, and over 100 earthquakes that killed in excess of 1000 people.

The U.S. has been fortunate in recent years in that its urban centers have largely avoided a direct hit from a "major" (M7.0 or greater) earthquake. Since the great Alaska earthquake of 1964, there have been twenty-six major earthquakes in the U.S. and none has claimed more than 65 lives. One reason for this low impact is that most of these events occurred in remote areas such as the Aleutian Islands or the Mojave Desert. Even the two most noteworthy events—the M7.1 Loma Prieta earthquake of 1989 and the M6.7 Northridge earthquake of 1994 (both with significant damage costs—occurred along the fringes of major metropolitan areas and struck during off-hours when impact was reduced.

It is only a matter of time before one or more large earthquakes strike the U.S. in a densely populated region. All but seven states in the U.S. are exposed to significant earthquake risk, including many large metropolitan areas. FEMA, a component of the Department of Homeland Security, estimates that the current annualized earthquake loss for the U.S. is $4.4 billion per year (*HAZUS 99 Estimated Annualized Earthquake Losses for the United States,* FEMA #366, Sept. 2000). This estimate, however, represents the expected loss averaged over many years. If a large-magnitude earthquake strikes a major metropolitan area, the actual loss will be significantly larger.

One only needs to look to Japan's experience during the 1995 Kobe earthquake to appreciate the catastrophic potential of even a moderate urban earthquake. The M6.7 Kobe earthquake—similar in size and duration to the Northridge earthquake—caused $100-200B in damage and approximately 5500 fatalities. The earthquake's impact was significantly larger than that of the Northridge earthquake ($40B and 57 lives lost), which ranks as the costliest natural disaster to strike in the U.S. The high price tag of the Kobe earthquake is due principally to its location—the event was centered beneath a highly urbanized region whereas Northridge was positioned beneath the northern edge of the Los Angeles metropolitan area. The U.S. was lucky.

Vulnerability to earthquakes in the U.S. is growing at an alarming rate. Population growth, urbanization, and infrastructure expansion are all contributing to this trend. In addition, a large inventory of existing structures lack earthquake-resistant design and have not been retrofitted to meet current design codes. A large-magnitude earthquake near one of several urban regions could cause thousands of deaths and financial losses approaching $100-200 billion. Bold action must be taken today to counter this trend and to develop effective, long-term, sustainable strategies for building earthquake-safe communities. An action plan to achieve this goal is the focus of this document.

Background

Responsibility for reducing earthquake risks is shared by Federal, state, and local governments and the private sector. The National Earthquake Hazards Reduction Program (NEHRP) is the Federal government's coordinated approach to addressing earthquake risks. NEHRP was established by Congress in 1977 as a long-term, nation-wide program to reduce the risks to life and property in the U.S. resulting from earthquakes. NEHRP comprises the Federal Emergency Management Agency (FEMA), the National Institute of Standards and Technology (NIST), the National Science Foundation (NSF), and the United States Geological Survey (USGS). The premise of the Program is that while earthquakes may be inevitable, earthquake disasters are not.

The NEHRP agencies work jointly and in cooperation with other Federal and state agencies; local governments; private companies; academic institutions; and regional, voluntary, and professional organizations to improve the Nation's understanding of earthquake hazards and to develop methods to reduce their effects. Underpinning earthquake risk reduction is research that develops new knowledge about, and understanding of, 1) the earthquake hazard, 2) the response of the natural and built environment to that hazard, and 3) techniques to mitigate the hazard. The foremost challenge facing NEHRP is encouraging the use of knowledge to foster risk reduction among local and state agencies and private entities.

Statement of the program's mission provides strategic guidance:

> *The mission of the National Earthquake Hazards Reduction Program is to develop and promote knowledge and mitigation practices and policies that reduce fatalities, injuries, and economic and other expected losses from earthquakes.*

The four NEHRP agencies each contribute their own unique set of skills and capabilities to the combined NEHRP mission:

FEMA has primary responsibility for overall planning and coordination of the NEHRP program. FEMA works to translate the results of research and technology development into effective earthquake loss reduction measures at state and local levels of government. It supports public-private partnerships to develop disaster-resistant 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, 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. FEMA also develops and supports public education to increase awareness of earthquake loss reduction measures.

NIST is responsible for problem-focused research and development in earthquake engineering aimed at improving building codes and standards for both new and existing construction and advancing seismic practices for structures and lifelines. This work is focused on removing technical barriers, evaluating advanced technologies, and developing measurement and prediction tools underpinning performance standards needed by the U.S. design and construction industry.

NSF supports a broad range of basic research covering the geoscience, engineering, economic, and social aspects and impacts of earthquakes. NSF supports basic research into the causes and dynamics of earthquakes, plate tectonics, and crustal deformation. It funds research on geotechnical, structural, architectural, and lifeline systems and expands the Nation's earthquake engineering research capabilities. NSF supports research on the social, behavioral, and economic aspects of earthquake hazard mitigation. It also supports the education of new scientists and engineers, the integration of research and education, and outreach to professionals and the general public.

The USGS conducts and supports basic and applied earth science investigations that increase knowledge about the origins and effects of earthquakes, produces national and regional assessments of seismic hazards, and carries out engineering seismology studies of ground shaking. USGS also has primary responsibility for monitoring earthquake activity in the U.S. and for coordinating post-earthquake reconnaissance investigations. USGS supports an external research program and works with a number of partners and stakeholders to transfer its earthquake-related products into practice.

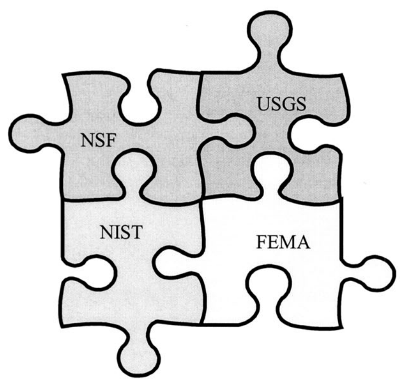

Figure 1. Interconnection of the four NEHRP agencies

The activities of the NEHRP agencies form a complementary program that has the ultimate aim of reducing earthquake losses across the Nation. At its foundation is research, which underpins nearly all of NEHRP's activities. The basic research supported and conducted by NSF and USGS extends across a number of earthquake-related disciplines including earthquake engineering, seismology, geology, and the social sciences. The knowledge gained from this basic research is utilized by NIST to help industry adopt and use innovative technologies through problem-focused research and development aimed at removing technical barriers, evaluating advanced technologies, and developing measurement and prediction tools underpinning performance standards for buildings and lifelines.

Similarly, an improved understanding of earthquake processes is utilized by the USGS to develop long-range earthquake probability forecasts, hazard assessments, and ground motion maps. FEMA then synthesizes the NIST and USGS applied research results into useable loss-reduction tools and methods. It also uses the research results to guide policy and practice in seismic risk reduction. Feedback loops at every step in the process stitch these separate program pieces—and the stakeholder community—together, so that results are shared, product needs are communicated back to the researchers, and program priorities are revised as needed.

An example of how this coordinated process has been effective in the past is presented here as insight into the way in which NEHRP expects to operate in the future. This example describes the research-to-practice pipeline that has been the lifeblood of NEHRP.

Example of NEHRP Coordination: State-of-the-Art Building Codes
An excellent example of the success of the NEHRP process is the incorporation of seismic provisions into the International Building Code (IBC), International Residential Code (IRC), and the codes being developed by the National Fire Protection Association (NFPA). Building codes have been recognized as one of the most effective tools for mitigating earthquake losses, and NEHRP activities have had a direct effect on the building code process in the United States, even though NEHRP has no regulatory authority. This process shows the success of both long term and short-term efforts on the part of NEHRP.

Over the past 20 years, a significant body of basic research work has been accomplished by NSF and the USGS in the areas of earthquake engineering, geoscience, and seismology. This fundamental research work, and the use of the earthquake monitoring networks by USGS, has allowed the development of detailed seismic hazard maps by USGS, and the development of significant earthquake engineering knowledge by NSF.

In parallel, FEMA, with the assistance of NIST, has developed and continued to refine the *NEHRP Recommended Provisions*, a guidance document for the seismic design of structures; directly incorporating the results of scientific advances of both NSF and USGS. The seismic hazard maps developed by USGS are directly referenced in the *Provisions*, and NSF research results are used throughout the document. In addition, during the periodic revisions of the *Provisions*, numerous unresolved issues have been forwarded back to USGS and NSF for their attention in future research. This guidance document within the engineering profession is regarded as the state-of-the-art in earthquake design guidance.

National implementation of new design standards is done through the adoption and enforcement of building codes. FEMA and USGS work with state and local governments and multi-state consortia to improve hazard identification and to promote the adoption of the building codes in seismically at-risk communities and states. In addition, the *NEHRP Recommended Provisions* was selected by model code organizations to be the basis for the seismic design provisions of the IBC and IRC, and will also be the basis of the codes being developed by NFPA.

This example clearly shows the significant and direct impact that NEHRP activities and coordination have had on the seismic safety of citizens, and the critical need to continue to invest in, and strengthen, the NEHRP partnership.

Future Challenges, Opportunities, And Priorities

As we begin the twenty-first century, the estimated impact of a major urban earthquake is increasing dramatically as urban growth and capital investment in earthquake-prone areas continue.

In particular, NIST currently occupies a critical niche in the Program: mining the basic earthquake engineering research of NSF and developing applied products and engineering guidelines that can be implemented by FEMA to reduce earthquake risk. Historically, the relative breakdown in funding among the agencies has been as follows:

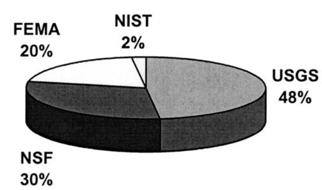

Figure 2. Relative Funding Levels of NEHRP Agencies

NEHRP has made substantial progress in hazards reduction since its inception in 1978. NEHRP has succeeded in establishing regional and national seismic networks that provide reliable, rapid information on recent earthquake activity for decision makers and the public. NEHRP has integrated 20 years of seismological, geophysical, and geological research into national seismic hazard maps that portray seismic hazards in a probabilistic sense and which quantify expected ground motions. These hazard assessments and their underlying databases are now being used in conjunction with NEHRP-developed loss-estimation tools to assess earthquake risk and to design strategies to mitigate it. From an engineering perspective, NEHRP has succeeded in providing improved design guidance for new and existing buildings, and in working with local governments, advocacy groups, and professional engineering associations to see that these guidelines are adopted and incorporated into building codes. NEHRP researchers continue to advance earthquake-engineering technology while working closely with industry to translate this new technology into practice. NEHRP has also excelled at translating the technical research results from the earth and engineering sciences into tools, guidelines, and informational products that are distributed to state and local governments, emergency managers, professional societies and other stakeholders to elevate the state of knowledge on earthquake issues across the country. The overall success of NEHRP is reflected in the resilience of communities that have been tested by significant earthquakes during the past decade. But these same communities also demonstrate that there is still progress to be made.

Looking forward, a number of compelling issues confront NEHRP. These issues occur on multiple time lines: some are more immediately addressable (10-15 years), while others may not deliver a payoff for many years. The most noteworthy challenges are as follows:

- Providing real-time reports of seismic activity and associated shaking intensity,
- Predicting ground motions in at-risk urban areas and determining how these ground motions interact with structures,
- Understanding performance of structural systems,
- Designing structures to explicitly reduce financial losses,
- Predicting earthquakes and their magnitude, and
- Improving the effectiveness of earthquake risk mitigation efforts through utilization of both existing and new research in the social, behavioral, and economic sciences.

In this report we propose several new or expanded research and development activities specifically designed to address these future challenges. Each of these proposed activities is a high priority for NEHRP and each is designed to complement ongoing NEHRP activities. Because of the scope and magnitude of these proposed activities, however, the ability of the NEHRP agencies to implement them is limited under existing funding. We summarize these proposed activities as follows:

Real-Time Seismic Monitoring and Reports of Ground Motion Intensities

Recent and unprecedented advances in information technology, telecommunications, and digital electronics now allow for real-time, high fidelity monitoring of seismicity across the Nation. An upgraded seismic monitoring system in the U.S. would enable rapid assessments of the distribution and intensity of earthquake shaking, thereby allowing emergency response officials to assess, within minutes of an event, where damage is likely to be concentrated and how emergency resources should be allocated. Someday, the new technology may even allow for a few seconds of warning of impending strong seismic shaking from distal earthquakes already in progress. The USGS funds the Advanced National Seismic System (ANSS) an effort to update current instrumentation and provide this real-time monitoring capability.

Prediction of Strong Ground Motion and Its Effect on Structures

The first step to predicting ground motion is to expand the observational database of strong motion recordings. Few if any complete recordings of strong motion near an earthquake's source have ever been recorded. Typical seismic networks are composed of sensors designed to record earthquakes at great distances from an earthquake; these sensors go off scale when strong shaking occurs at distances near the instrument. With improved recordings and more detailed information on geologic structures and near-surface physical properties, it will soon be possible to compute synthetic time series that contain all of the critical information on the expected ground shaking, in addition to its duration. These synthetic time histories are needed by engineers if they are to determine how ground motion interacts with structures and consequently, how to improve engineering design standards. The ANSS, described above, calls for instrumentation that would permit on-scale recording of seismic shaking at over 7000 ground-based sites and structures. ANSS expands the observational database of ground motion recordings, thereby providing data that are critical to improving design standards and building practices.

Earthquake Engineering Simulation and Testing

Improved engineering design standards have traditionally followed from observational testing, where the observation was made from testing on-scale models and structural components in an experimental facility or observed during post-earthquake reconnaissance. However, dynamic testing of full-scale structures subjected to strong shaking is both logistically difficult and prohibitively costly. Fortunately, increased computational capabilities now allow for a new means of engineering design testing through computer simulation. The latter can be directed at both individual structural components and at integrated systems. Testing of complex structures and processes can be performed with real-time coordination at several facilities with enhanced capabilities and information stored and shared on-line, using Internet technology to integrate and interconnect nationally distributed facilities. The resulting information would then be integrated into improved guidelines for practice and activities that include NIST and FEMA. The NSF has secured funding to develop such a facility, referred to as the Network for Earthquake Engineering Simulation (NEES), which is expected to be on-line in 2004. The facility will include linkages to observational data acquired by USGS through ANSS, thereby allowing calibration of simulation results with observed strong motion recordings from structures and lifelines.

Performance-Based Seismic Design

Building codes have traditionally been designed to limit loss of life, not to guarantee a specific level of structural performance. In principle, however, it is possible to design for a range of performance objectives (i.e., "damage states") for a given seismic event. This concept, known as performance-based design, represents the next generation of code development and is a high priority for NEHRP. In addition to the need for performance-based designs for buildings, there also is a need to develop performance-based standards for lifelines. Lifelines include transportation systems (bridges, highways, railroads, airports), water and sewerage, electric power, communication systems, and gas and liquid fuel pipelines. With the exception of bridges and large buildings, most lifelines are constructed without any special codes or guidelines for seismic resistance. The production of performance-based design codes for buildings and lifelines would allow the owner and builder to design a structure to an acceptable damage state, i.e., they could explicitly design for reduced financial losses. The end result would be a better understanding of the economic implications of the seismic risk and the ability to manage that risk. A NEHRP effort to develop performance-based codes is proposed herein and would be lead by FEMA and NIST, with support from NSF and USGS.

Monitoring of Strain and Physical Properties Within and Across Active Fault Zones

The ultimate goal for earthquake seismologists is the prediction of earthquakes. Currently it is not clear that earthquake prediction is realizable; earthquake nucleation may be an inherently unstable process that does not lend itself to prediction. However, it is possible to monitor active fault zones to diagnose their strain state and to capture the conditions that prevail when an earthquake initiates. New technologies utilizing advanced drilling techniques and satellite-based geographic positioning systems (GPS) now afford unprecedented opportunities to measure strain accumulation and the physical conditions under which earthquakes occur.

As part of a new initiative known as EarthScope, NSF is proposing to develop four new earth science facilities that will contribute to NEHRP goals: USArray, the San Andreas Fault Observatory at Depth (SAFOD), the Plate Boundary Observatory (PBO) and the Interferometric Synthetic Aperture Radar (InSAR) satellite. Multi-agency partnerships will be necessary to accomplish the construction of EarthScope including USGS and NASA. USArray will determine the detailed 3-dimensional structure of the earth's crust, which will be necessary to develop estimates of earthquake ground motion. SAFOD is designed to monitor physical properties *within* the earthquake zone of the San Andreas Fault. This observatory will revolutionize the understanding of earthquake processes by enabling, for the first time, direct measurement of the physical conditions under which earthquakes occur and will allow for direct observation of the processes of earthquake ruptures. Both PBO and InSAR permit measurement of the rate and distribution of strain buildup and release before, during, and after earthquakes. PBO will consist of high precision, continuously recording GPS receivers and strain meters that will permit measurement of the rate and distribution of strain buildup. InSAR also measures crustal distortion but with revolutionary spatial resolution. All elements of EarthScope are designed to complement each other to provide an integrated picture of the structure and dynamics of the earth's crust. Collectively these facilities are essential if NEHRP is to advance the physical understanding of the mechanics of earthquakes and determine whether earthquake prediction will ever be possible.

Improved Use of Social Sciences to More Effectively Mitigate Earthquake Risks

One of the historic problems in successful implementation of earthquake risk reduction efforts has been the lack of understanding of factors that motivate action. A considerable body of knowledge in the areas of social, behavioral, and economic science exists that can provide great insight into the nature of decision making, risk communication, and the human dynamics involved in hazard mitigation. In addition, there is a need for both continued focused research and transfer of research results into practice in this area. FEMA and NSF will work together to identify and transform existing research into practice, and to identify topics where further research is needed.

Each of the topics discussed above represent scientific and technologic growth areas that have the potential to deliver dramatic advances in our understanding of earthquake processes and our ability to mitigate their effects. As such, these new growth areas symbolize new lifeblood for NEHRP's research-to-application pipeline, which is the foundation of the Program's success. Support for research in science and technology alone, however, is not sufficient. Success cannot be achieved without the effective and timely transfer of information to the myriad of potential users, ranging from the general public to engineers, planners, government officials, business leaders, and many others.

In the pages that follow, the NEHRP agencies outline a bold action plan for developing effective, long-term, sustainable strategies for building earthquake-safe communities. This plan provides the necessary balance among the research, development, and implementation activities of NEHRP and is structured around four main goals. These goals do not stand alone, but instead are strongly linked such that knowledge gained under one goal feeds research, development, and implementation efforts in the other goals. For this reason, overall success in earthquake mitigation requires that efforts in the four programmatic areas be appropriately coordinated. Specific implementation activities are discussed separately for each of the four goals. In addition, a philosophy is also presented that will guide how the NEHRP agencies implement Program management and coordination, and how they will measure program performance.

Goals And Objectives

Goals

The goals and objectives of NEHRP lay a foundation on which the program builds its mission to reduce earthquake losses. The goals are of equal priority and are mutually dependent:

A. **Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation.** *Promote earthquake loss-reduction activities and support those who adopt, implement, and enforce such policies and practices.*

B. **Improve techniques to reduce seismic vulnerability of facilities and systems.** *Develop, improve, and disseminate products that guide design and construction practices and land-use planning, and improve professional practice.*

C. **Improve seismic hazards identification and risk-assessment methods, and their use.** *Develop, improve, and disseminate products that portray earthquake-related hazards accurately and quantify seismic risk.*

D. **Improve the understanding of earthquakes and their effects.** *Support research to understand the processes that lead to earthquakes and associated hazards and to advance engineering, social, behavioral, and economic knowledge.*

Objectives

The following objectives indicate how the NEHRP agencies will achieve each goal:

Goal A. Develop effective practices and policies for earthquake loss-reduction and accelerate their implementation.

1. Develop and provide information on earthquake hazards and loss-reduction measures to decision-makers and the public. NEHRP will develop information to increase knowledge about earthquake hazards, to understand the risks, and to assist decision-makers in evaluating loss reduction alternatives. NEHRP will also foster development and dissemination of knowledge and tools that are formulated to meet user needs.

2. Promote incentives for public and private sector loss-reduction actions. NEHRP will support community-based efforts to develop and implement economic and other incentives that promote loss-reducing actions, and create disaster-resistant and sustainable communities.

3. Advocate state and local government practices and policies that reduce losses in the public and private sectors. NEHRP will collaborate with state and local government officials, associated advisory bodies, and regional earthquake consortia to provide technical and other assistance for developing, adopting, and evaluating earthquake loss-reduction measures in at-risk states and communities.

4. Implement policies and practices that reduce vulnerability of Federal facilities. NEHRP will support the Interagency Committee on Seismic Safety in Construction (ICSSC) and its member agencies in developing and implementing practices and policies for earthquake risk reduction for buildings and lifelines that are owned, leased, assisted, and regulated by the Federal government.

5. Develop the Nation's human resource base in the earthquake field. NEHRP will support education and training for engineers, practicing design and construction professionals, planners, facility managers, and emergency managers through continuing education programs. NEHRP will also support educational activities for university students, K-12 school children, and the general public to facilitate a broader, informed understanding of earthquake hazard, risk, and mitigation.

Goal B. Improve techniques to reduce seismic vulnerability of facilities and systems.

1. Facilitate technology transfer among standards organizations, state and local governments, and private-sector professionals. NEHRP will support development and publication of design, construction, evaluation, and upgrade guidelines and pre-standards for consideration by national organizations that develop codes and standards for buildings and lifelines. NEHRP will also develop tools to assist in the use of those guidelines. NEHRP will work with professional and trade associations to promote the use of new technology.

2. Improve earthquake loss-reduction knowledge and the quality of practice. NEHRP will support problem-focused and fundamental research by academia and the private sector to fill knowledge gaps and provide the technical basis for design, construction, evaluation, and upgrade guidelines and pre-standards. NEHRP will also support the exchange of information to maintain awareness of national and international developments in earthquake mitigation technology.

3. Support efforts to improve seismic standards and codes and improve design and construction practices for buildings and lifelines. NEHRP will support periodic revision of the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures*, application of the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, and development of design and construction criteria for lifelines, including utility and transportation systems. NEHRP also will support post-earthquake investigations to identify knowledge gaps and will conduct studies to address special problems identified after major earthquakes.

Goal C. Improve seismic hazards identification and risk assessment methods, and their use.

1. Provide rapid, reliable information about earthquakes and earthquake-induced damage. NEHRP will continue to support the operation of regional data centers, the National Earthquake Information Center (NEIC), the Global Seismic Network (GSN), the International Seismic Centre (ISC), and the IRIS Data Management Center (DMC). In addition, NEHRP will deliver rapid, accurate reports on the intensity and distribution of strong ground shaking in urban areas following damaging earthquakes. NEHRP will also propose to implement the ANSS.

2. Improve seismic hazard characterization and mapping. NEHRP will improve hazard assessment methods and produce updated national-scale ground-shaking maps and related products on a regular basis. NEHRP will also work with cooperators to develop a standard methodology for production of large-scale seismic hazard maps for urban regions.

3. Support development and use of risk and loss assessment tools. NEHRP will support improvement of loss estimation and risk assessment tools and the development of next generation databases. Testing and dissemination of the nationally applicable loss-estimation model will continue. States and communities will be encouraged to provide detailed data on local geology, building inventories, and utility and transportation systems to enable more accurate planning and establishing of priorities.

Goal D. Improve the understanding of earthquakes and their effects.

1. Improve monitoring of earthquakes and earthquake-generating processes. NEHRP will continue to develop improved seismic monitoring capabilities geared toward full-waveform recording, real-time reporting, and improved network integration. NEHRP also will continue to support and expand other monitoring systems and the use of satellite-based observational systems for monitoring the deformation of the earth's crust due to earthquakes and earthquake-generating processes.

2. Improve understanding of earthquake occurrence and potential. NEHRP will support research into the processes by which earthquakes occur, including studies of how large earthquakes initiate and grow, the role of fault zone geometry and mechanical properties, and the effect of changes in earth stresses.

3. Improve earthquake hazards assessments and develop earthquake-potential estimates as planning scenarios. NEHRP will support a broad-based research program on earthquakes and ground failure by improving quantification and understanding of the extent of hazards and by encouraging use of that knowledge for planning purposes.

4. Improve fundamental knowledge of earthquake effects. NEHRP will support research on the nature of strong ground shaking from earthquakes, how it is affected by seismological and geological factors, and how its characteristics are related to permanent ground deformation and damage. These efforts will include investigations of damage from domestic and foreign earthquakes and collaboration with non-U.S. research programs.

5. Advance earthquake engineering knowledge of the built environment. NEHRP will implement the Network for Earthquake Engineering Simulation (NEES) to improve the seismic design and performance of U.S. civil and mechanical infrastructure systems through collaborative and integrated experimentation, computation, theory, databases, and model-based simulation.

6. Advance understanding of the social and economic implications of earthquakes. NEHRP will support earthquake-related social science and policy research to advance understanding of the social and economic impacts of earthquakes, determine levels of risk deemed acceptable by various groups in society, and reduce the social, economic, and political barriers to effective earthquake risk reduction.

Implementation

The following sections describe, by goal and objective, specific NEHRP priorities and activities that the agencies intend to pursue in the near term. Because the amount of available resources has a distinct bearing on the scope and breadth of activities, the discussion has been framed to reflect what can be accomplished at current funding levels.

Goal A. Develop Effective Practices and Policies For Earthquake Loss-Reduction and Accelerate Their Implementation

Through Goal A, NEHRP seeks to reduce the seismic vulnerability of the built and social environments by disseminating earthquake hazard and risk information and advocating risk reduction techniques. Activities identified under Goal A are designed to accelerate earthquake loss reduction in the public and private sector by engaging and supporting partners at the local, state, and national levels. FEMA is the primary agency carrying out Goal A efforts, with NIST, NSF, and USGS playing important supporting roles.

NEHRP will continue to use existing resources to develop partnerships as described in the sections below to provide risk assessment and risk reduction tools to local business and government leaders, to provide training to design and construction professionals, and to advocate the adoption and enforcement of state-of-the-art codes and land-use practices for buildings and lifelines.
The following sections address current and future NEHRP activities under each of the five objectives of Goal A.

1. Develop and provide information on earthquake hazards and loss-reduction measures to decision makers and the public.

NEHRP will develop information to increase knowledge about earthquake hazards, to understand the risk, and to assist decision-makers in evaluating loss reduction alternatives. NEHRP will also foster development and dissemination of knowledge and tools that are formulated to meet user needs.

Under Objective 1, NEHRP's priorities are to:

- Promote the use of NEHRP resource materials to evaluate seismic risk and mitigation alternatives.

- Work with professional organizations, universities, and local and national partners to distribute NEHRP products and promote adoption of risk reduction measures.

NEHRP and its partners generate a large range of products that address earthquake hazards, document the associated seismic risk, and provide loss-reduction alternatives. These products are largely the outgrowth of activities in Goals B, C, and D of the program. Successful mitigation requires that these products be effectively understood, distributed, accepted, and used, and that a broad base of earthquake-aware individuals be developed and nurtured at all levels. To accomplish these goals, NEHRP pursues a variety of different means to distribute its tools and products so that they can be utilized effectively. Publications, press releases, web sites, and symposia are some of the traditional means of information dissemination. FEMA-supported multi-state consortia (CREW, CUSEC, NESEC, and WSSPC) are utilized as coordinators and policy centers for states and communities with similar seismic risk characteristics. Additionally, NEHRP works with its grantees in the regions, such as the three NSF-supported earthquake engineering research centers (MCEER, MAE, PEER) and the NSF/USGS supported multidisciplinary Southern California Earthquake Center (SCEC), to provide local outreach programs designed to educate the public, promote earthquake awareness, and develop strategies to transfer research findings into implementation.

NEHRP and its partners also work with professional organizations and multi-state consortia to develop the most effective means to communicate seismic hazard and risk issues and to better determine the needs of NEHRP audiences. This approach enables NEHRP to reach potential mitigation advocates effectively while also establishing a feedback loop to assure that projects are optimized to meet user needs. NEHRP provides the seismic expertise, while the professional organizations and regional consortia provide translation of the needs of their constituencies, such as the insurance industry, utility operators, facilities managers, design and construction professionals, and land-use planners. Funding for these collaborative efforts is often shared, thereby leveraging the ability of NEHRP to provide crucial knowledge transfer activities. In order to increase the promotion of risk reduction measures, NEHRP will increase its efforts to work with professional organizations to promote the use of risk-reduction tools by their members.

One professional group that receives special focus from NEHRP is the structural engineering community. NEHRP utilizes university-based earthquake engineering centers (MAE, MCEER, PEER) and related Internet distribution channels (e.g., EQNET, CUREE, and NISEE) as a means of disseminating earthquake information to the professional community and the general public. NEHRP also works directly with engineering-based professional organizations (EERI, BSSC, ASCE, ATC, COSMOS) to promote guidelines development, to coordinate post-earthquake activities, and to translate and disseminate research results to practicing engineers. In the future, the NSF-funded Network for Earthquake Engineering Simulation (NEES) project will be an increasingly important nexus for information flow from the experimental research community to practicing professionals, with translation of the research results to local decision makers and the public.

As the need for reducing risks becomes more urgent in increasingly developed, at-risk communities, NEHRP must reach beyond traditional end-users. State-of-the-art resources must be provided to a larger group of design professionals and those in the construction trades, as well as land-use planners, emergency managers, and public administrators. Products must be specially crafted to meet the needs and backgrounds of individual audiences. NEHRP will work with researchers in the behavioral, policy, and social sciences to determine the most effective means to communicate seismic hazard and risk-reduction messages to these target audiences. NEHRP will also expand its use of the Internet as a medium for product distribution and hazard awareness.

2. Promote incentives for public and private sector loss-reduction actions.

NEHRP will support community-based efforts to develop and implement economic and other incentives that promote loss-reducing actions, and create disaster-resistant and sustainable communities.

Under Objective 2, NEHRP's priority is to:

- Promote seismic risk reduction through partnerships with local communities and businesses. Advocate the use of incentives as a means of improving disaster resistance.

Mitigation is accomplished locally, and thus a successful earthquake mitigation program requires the involvement and commitment of local communities and businesses. Recognizing this, FEMA has established a nation-wide initiative to build disaster-resistant communities through local partnerships. This initiative is based on three principles: 1) preventive actions must be decided at the local level, 2) private sector participation is vital, and 3) long-term efforts and investments in prevention measures are essential. FEMA provides incentives for risk reduction activities within these communities, including small start-up funding as well as technical assistance through its National Earthquake Technical Assistance Program. FEMA, together with other NEHRP agencies, also works with communities to identify risks, prioritize needs, and develop long-term plans to protect each disaster-prone community. Increasingly, communities are using means such as the transfer of development rights into less hazard-prone areas to mitigate their risk. An essential element in the crafting of these mitigation strategies is the use of NEHRP tools and products (such as seismic hazard maps and HAZUS loss estimation software) to identify areas of a community that are most vulnerable to seismic hazards. FEMA also engages local and national businesses to promote disaster prevention efforts. One example is the promotion of low-interest loans—established in partnerships with banks doing business in the community—for mitigation of existing buildings. These activities are not only a good source of public relations for companies, they also result in more resilient communities, which improve the economic viability of the business over time. Finally, FEMA works with its NEHRP partners to promote the adoption of state-of-the-art building codes in communities and to insure access to, and use of, the latest seismic engineering design and retrofit techniques.

3. Advocate state and local government practices and policies that reduce losses in the public and private sectors.

NEHRP will collaborate with state and local government officials, associated advisory bodies, and regional earthquake consortia to provide technical and other assistance for developing, adopting, and evaluating earthquake loss-reduction measures in at-risk states and communities.

Under Objective 3, NEHRP's priorities are to:

- Promote seismic risk reduction at the state and local government level through partnerships with seismic advisory boards and multi-state earthquake consortia.

- Promote adoption of updated building codes by states and local governments to enhance seismic risk reduction.

- Encourage mitigation during disaster recover efforts.

The primary step that NEHRP advocates for at-risk states to achieve earthquake mitigation is to establish a seismic safety advisory board to serve as the statewide authority for seismic hazard identification and risk reduction. Currently 13 states and territories have established seismic safety advisory bodies. These boards provide advice to elected officials, develop seismic risk mitigation programs, and sponsor legislation directed at improving seismic safety. A goal of NEHRP is to expand this to all of the 45 states and territories that have been identified as having moderate to very high earthquake risk.

NEHRP also places a high priority on working with states and local governments to promote seismic risk reduction through the adoption of building codes with up-to-date seismic provisions. The first International Building Code (IBC) and International Residential Code (IRC), which include state-of-the-art seismic components, were released in 2000. NEHRP will increase its efforts to actively promote the adoption of this code by at-risk states and communities, as well as other seismic-resistant codes such as those recommended by the National Fire Protection Association (NFPA). (For a discussion of the NEHRP's building code role, see Goal B.) The enforcement of codes with seismic components that states and communities have adopted will be promoted through existing public and private-sector partnerships.

Through FEMA, NEHRP also provides financial and technical support on an annual basis to states and territories at moderate and high seismic risk as an incentive for these states and territories to work with their most vulnerable jurisdictions. Multi-state consortia (e.g., CREW, CUSEC, NESEC, and WSSPC) are also funded to serve as coordinators and policy centers for states with similar seismic risk characteristics. Lastly, FEMA uses the Emergency Management Performance Grant (EMPG) program to urge at-risk states to assess the vulnerability of their facilities, and to develop plans to reduce the identified risks.

A final area where NEHRP can work to reduce earthquake vulnerability is to encourage mitigation practices after natural disasters occur. After a disaster, affected citizens as well as local decision makers are frequently more receptive to mitigation, and this represents a tremendous opportunity to introduce earthquake mitigation measures. FEMA will therefore increase efforts to develop and provide earthquake mitigation tools and practices designed to be introduced into local disaster recovery efforts.

4. Implement policies and practices that reduce vulnerability of Federal facilities.

NEHRP will support the Interagency Committee on Seismic Safety in Construction (ICSSC) and its member agencies in developing and implementing practices and policies for earthquake risk reduction for buildings and lifelines that are owned, leased, assisted, and regulated by the Federal government.

Under Objective 4, NEHRP's priorities are to:

- Reduce the risk to existing and future Federal facilities through partnerships with Federal agencies.
- Provide state-of-the-art risk-reduction standards to all affected Federal agencies.

The Federal government must set an example for both the public and private sectors, including the implementation of effective hazard mitigation measures for more than 500,000 buildings that it owns, leases, assists, and/or regulates throughout the country. The ICSSC was established as part of NEHRP by the Earthquake Hazards Reduction Act of 1977 to assist Federal departments and agencies in developing and incorporating earthquake hazard reduction measures into each organization's ongoing facilities management program. The chair of the ICSSC is the Director of NIST or his designee, who reports to FEMA leadership. FEMA, NIST, NSF, and USGS are ICSSC member agencies. Twenty-eight other Federal departments and agencies are also members of the ICSSC, which recommends uniform practices and policies to reduce earthquake risk at both new and existing Federal facilities, including buildings and lifelines. These ICSSC recommendations are primarily embodied in two Executive Orders: *EO 12699, Seismic Safety of Federally Assisted or Regulated New Building Construction,* and *EO 12941, Seismic Safety of Existing Federally Owned or Leased Buildings.* FEMA has overall responsibility for carrying out Executive Orders, and provides progress reports to Congress; FEMA and NIST share responsibility in providing technical assistance to ICSSC member agencies in implementing the Executive Orders. To assure compliance with the requirements of the Executive Order, the ICSSC conducts periodic studies to compare the equivalence between the model building codes and standards issued by the private sector and the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures.*

In the future, as NEHRP develops performance-based standards for buildings and lifelines under Goal B, the ICSSC will disseminate these next-generation materials to all Federal agencies and support implementation.

5. Develop the Nation's human resource base in the earthquake field.

NEHRP will support education and training for engineers, practicing design and construction professionals, planners, facility managers, and emergency managers through continuing education programs. NEHRP will also support educational activities for university students, K-12 school children, and the general public to facilitate a broader, informed understanding of earthquake hazard, risk, and mitigation.

Under Objective 5, NEHRP's priorities are to:

- Develop and use partnerships to provide training in the use of NEHRP technical resource materials developed under Goals B, C, and D.

- Advocate the inclusion of seismic hazard and risk reduction information into curricula at K-12 schools and higher education institutions.

Because seismic risk-reduction activities are best carried out by local professional and construction trade organizations and by state personnel who are familiar with local issues and needs, NEHRP will increase its ongoing efforts to develop audience-specific risk-reduction tools, publications, and programs to meet the needs of these users. NEHRP will pursue this in cooperation with professional and trade membership organizations so that these organizations take a leadership role in training and educating their members. Similarly, as states and communities adopt seismic codes, NEHRP will work with code groups to support training and enforcement activities.

The education of the next generation of seismic risk reduction advocates and professionals is important to the continued success of NEHRP. This education must begin at an early age, so that a basic understanding of earthquakes and their consequences is broadly established. For this reason, FEMA, NSF, and USGS have participated in partnerships with other Federal agencies and non-governmental organizations to develop and advocate curricula for K-12 school children and university students on earthquakes and their effects. Universities also are supported by NSF to educate researchers and other earthquake professionals in all aspects of seismic issues (i.e., engineering, seismology, geology, social sciences, and public policy). These efforts will continue and will focus on promoting the use of these curricula and related educational activities in areas of very high to moderate seismic risk.

Goal B. Improve Techniques to Reduce Seismic Vulnerability of Facilities and Systems

The Goal B activities assure the availability of improved techniques to reduce the seismic vulnerability of facilities and systems. These improvements are achieved through several means, including: publication of design, construction, and evaluation guidelines for buildings and lifelines; development of tools to assist in the use of those guidelines; problem-focused research and development to fill knowledge gaps; execution of coordinated post-earthquake investigations; publication of associated longer-term studies to address special problems identified after major earthquakes; cooperation with professional and trade associations to improve the use of technology; advocacy to include research results in curricula and continuing education for practicing professionals; and international exchange of information on earthquake mitigation technology.

The following is a discussion of NEHRP activities supported under Goal B.

1. Facilitate technology transfer among standards organizations, state and local governments, and private-sector professionals.

> *NEHRP will support development and publication of design, construction, evaluation, and upgrade guidelines and pre-standards for consideration by national organizations that develop codes and standards for buildings and lifelines. NEHRP will also develop tools to assist in the use of those guidelines. NEHRP will work with professional and trade associations to promote the use of new technology.*

Under Objective 1, the NEHRP's priorities are to:

- Support strong model building codes; and

- Encourage technology transfer through professional organizations.

NEHRP supports the development and periodic revision of model building codes. The current trend is toward unified national codes for both new and existing buildings, such as those developed by the International Code Council and those being developed by the National Fire Protection Association (NFPA). These codes are replacing the three regionally based model codes and are expected to be implemented throughout the Nation. The *NEHRP Recommended Provisions* serve as the resource documents for these model building codes for new buildings, while the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* serve as the resource documents for code development for existing buildings. FEMA is the lead agency supporting the model building code efforts. The USGS' probabilistic seismic hazard maps define the level of seismic hazard as a function of geography, and are thus the basis for applying the seismic design criteria contained in the model codes. The USGS also produces interactive tools that enable determination of location-specific seismic design parameters that can be used with the model building codes and standards. The basic and applied research performed by NSF and NIST, respectively, directly supports the development of the technical provisions of NEHRP guidelines. In addition, the ICSSC conducts periodic studies to compare the equivalence between the model codes and the *NEHRP Recommended Provisions* and issues consensus recommendations based on its findings for adoption by Federal agencies. In the future, this level of effort will be sustained using existing program funds.

A second activity under Objective 1 is the dissemination of information and transfer of earthquake-resistant design and construction technology to users. These users include design and construction professionals, trade schools, and developers, among others. FEMA will be the lead agency in this effort, but will work in coordination with USGS and NSF efforts in science education. A baseline of activity directed at these audiences will proceed using existing funds.

2. Improve earthquake loss-reduction knowledge and the quality of practice.

NEHRP will support problem-focused and fundamental research by academia and the private sector to fill knowledge gaps and provide the technical basis for design, construction, evaluation, and upgrade guidelines and pre-standards. NEHRP will also support the exchange of information to maintain awareness of national and international developments in earthquake mitigation technology.

Under Objective 2, NEHRP's priorities are to:

- Expand the use of problem-focused research and development to support codes and standards improvement.
- Carry out international exchange of information to keep abreast of state-of-the-art technology in earthquake mitigation.

NEHRP currently supports a modest program of problem-focused research and development to fill knowledge gaps and provide the technical basis for improved design, construction, evaluation and upgrade guidelines and pre-standards for buildings and lifelines. NIST is assigned lead responsibility for this activity, with supporting efforts from FEMA and NSF. NIST's research program, focused on the structural performance of buildings within a multi-hazard context, includes studies of: new performance-based seismic design approaches, evaluation of advanced structural control technologies, structural performance of housing systems, and strengthening and rehabilitation of structures. FEMA also contributes to studies of design and rehabilitation of welded steel-frame buildings and supports problem-focused research at university-based research centers and at the National Research Council.

This strategic plan includes a provision for increased emphasis of problem-focused research that will alleviate the "technology transfer gap" that is noted to exist for research outcomes. The current level of support in NEHRP for problem-focused research is insufficient to leverage the wealth of information emerging from basic research activities. As a result, a technology transfer gap has emerged which limits the adaptation of basic research knowledge into practice. This gap is expected to widen as NEHRP embarks on a new generation of performance-based provisions and guidelines for buildings and lifelines. A much-expanded problem-focused research and guideline development effort is critically needed for future design, construction, evaluation, and upgrade guidelines and pre-standards, and to facilitate the development of new mitigation technologies. NIST, in partnership with FEMA and the other NEHRP agencies, will develop a coordinated NEHRP plan to support an expanded level of problem-focused R&D. Recognizing that the U.S. is not the only developed country with an active earthquake engineering community, NEHRP must maintain awareness of international developments in earthquake mitigation technology and enhance learning through participation in international post-earthquake investigations and international information exchanges. Post-earthquake investigations in other countries provide rare opportunities to obtain important information on the performance and vulnerability of buildings and lifelines in major earthquakes. Similarly, formal and informal exchange mechanisms with the international community allow for enhanced sharing of research results and more rapid advancement of the science. These efforts, albeit modest, will continue as an integral part of NEHRP's strategy to reduce seismic vulnerability of facilities and lifelines.

3. Support efforts to improve seismic standards and codes and improve design and construction practices for buildings and lifelines.

NEHRP will support periodic revision of the NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures, *application of the* NEHRP Guidelines for the Seismic Rehabilitation of Buildings, *and development of design and construction criteria for lifelines, including utility and transportation systems. NEHRP also will support post-earthquake investigations to identify knowledge gaps and will conduct studies to address special problems identified after major earthquakes.*

Under Objective 3 NEHRP's priorities are to:

- Maintain the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures.*

- Support *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* and other tools related to existing buildings.

- Support development of guidelines and pre-standards for lifeline systems.

- Start development of next generation performance-based codes.

- Improve coordination of post-earthquake investigations.

The *NEHRP Recommended Provisions* and the related *Commentary* present criteria for designing and constructing buildings subject to earthquakes throughout the U.S. They are resource documents widely used by practicing professionals and building officials. Periodic updates of these documents are critical in order to incorporate results from NEHRP-funded research for immediate use by practicing engineers. FEMA will provide lead support for these periodic revisions, while USGS will support the revision of the underlying probabilistic seismic hazard maps and NIST and NSF will continue to support research and development efforts leading to new cutting-edge methodologies and technologies. NEHRP experts from all four agencies will participate in technical committees responsible for updating the *NEHRP Recommended Provisions* and will work in close coordination with the ICSSC.

The *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* and related *Commentary* are first-of-their-kind, performance-based, nationally applicable design and engineering documents. They contain new approaches, new analytical techniques, choices as to seismic safety levels, and acceptability criteria for upgrading all major types of existing buildings and construction materials. FEMA led the development of this document and will continue to ensure these documents are kept current. This work, and the updates to the *NEHRP Recommended Provisions* discussed above, will be accomplished with existing funding.

Lifelines are another high priority area for NEHRP. FEMA, in partnership with non-governmental organizations and the private sector, has initiated the processes of developing consensus guidelines for lifelines. The goal of this effort is to achieve an acceptable level of seismic performance for these structures, building upon current seismic provisions, as appropriate. To date, efforts to develop the technical basis for performance-based standards, codes, and practices for infrastructure lifeline systems pale in comparison to similar efforts directed at guideline development for new and existing buildings. NEHRP therefore recognizes the need to significantly expand efforts in this area. FEMA will lead this effort and will be assisted by NIST.

Looking to the future, NEHRP supports the need to develop a new generation of performance-based provisions for new buildings and lifelines. Performance-based provisions will encourage/permit competition through value-added products and services, adoption and use of innovative technologies, selection of design or rehabilitation performance level based on owner/user needs, and setting of risk-adjusted insurance premiums commensurate with the chosen performance level. FEMA will lead this effort, and NIST will assist FEMA with problem-focused R&D in developing the technical basis for performance-based standards, codes, and practices for buildings. NIST work will include application of probabilistic and reliability analysis methods underpinning performance-based provisions in coordination with the risk analysis and loss estimation work under Goal C. NSF will continue to support basic research in performance-based earthquake engineering and probabilistic methods through its existing programs.

Major earthquakes provide a unique source of information on the performance of the built environment and failure mechanisms at full scale. Post-earthquake investigations are thus critical for documenting structural performance, examining the adequacy of current standards and practices, and identifying research needs to mitigate the impacts of future earthquakes. NEHRP has long supported post-earthquake investigations, both in the engineering and earth science disciplines. However, improved coordination is necessary if these investigations are to maximize learning through the sharing of information. Therefore, NEHRP, under the leadership of the USGS, will spearhead an examination of the roles and responsibilities of the various groups involved in post-earthquake investigations and will develop a NEHRP protocol action plan for investigations following major national and international earthquakes. This protocol action plan will detail the degree of coordinated learning desired and how it will be achieved and how findings can be most effectively disseminated to all stakeholders (e.g., in a comprehensive, multidisciplinary NEHRP report). The plan will improve coordination during post-earthquake investigation efforts, minimize duplication, and provide safety training for participants.

Goal C. Improve Seismic Hazard Identification and Risk Assessment Methods, and Their Use

Seismic hazard identification and risk assessment are critical components of NEHRP's earthquake mitigation strategy. Under this goal, NEHRP agencies identify and quantify seismic hazards through improved seismic monitoring and through detailed geological and geophysical characterization of regions of active faulting. The seismic hazard information then becomes the foundation upon which subsequent risk assessment models are based. NEHRP will continue to emphasize geological, geophysical, and seismological research activities that improve the state of knowledge of seismic hazard identification. NEHRP will also continue to develop and improve the HAZUS loss estimation tool and work with state and local governments to ensure that this tool is used effectively to guide pre-earthquake mitigation efforts.

1. Provide rapid, reliable information about earthquakes and earthquake-induced damage.

NEHRP will continue to support the operation of regional data centers, the National Earthquake Information Center (NEIC), the Global Seismic Network (GSN), the International Seismic Centre (ISC), and the IRIS Data Management Center (DMC). In addition, NEHRP will deliver rapid, accurate reports on the intensity and distribution of strong ground shaking in urban areas following damaging earthquakes. NEHRP will also propose to implement the ANSS.

Under Objective 1 NEHRP's priorities are to:

- Continue support for global, national, and regional seismic monitoring networks and associated data centers.
- Propose implementation of the Advanced National Seismic System (ANSS).
- Develop improved algorithms for rapidly determine earthquake source parameters (e.g., location, size, type of faulting, direction of fault rupture) and estimating earthquake damage patterns through the production of shaking intensity maps (ShakeMaps).

Seismic monitoring serves as a primary source of information necessary for seismic hazard assessments. USGS has the assigned Federal responsibility to monitor seismic activity in the U.S. The USGS fulfills this role by operating the U.S. National Seismograph Network (USNSN), the National Earthquake Information Center (NEIC), the National Strong Motion Program (NSMP), and by supporting sixteen regional networks in areas of moderate to high seismic activity. Additionally, NSF and USGS operate the Global Seismic Network, which provides the main source of worldwide earthquake information, and NSF also operates archival and distribution centers: the International Seismic Center and the IRIS Data Management Center. NEHRP will continue to maintain and operate these networks and data centers and will improve their integration and real-time reporting capabilities.

Traditionally earthquake monitoring in the U.S. has focused on the identification of areas of active faulting. Recent technological advances, however, are contributing to a broadening in emphasis to include strong motion recording of ground shaking and building response in seismically active urban areas. The data resulting from these efforts are critical to engineering research directed at improving design standards so that structures and systems are better able to withstand the effects of earthquakes. To provide useful, high quality data that meet the needs of engineers, a significant upgrade of the current networks as well as a major expansion of new instrumentation in urban areas is required. The specifications of such a system, referred to as the Advanced National Seismic System (ANSS), have been developed through discussions with the engineering community and summarized in USGS Circular 1188 at the request of Congress. The report calls for over 6000 new instruments in at-risk urban areas, including 3000 strong motion instruments on the ground and an additional 3000 instruments in structures. In addition, the report calls for 1000 broadband stations in regional networks across the Nation. ANSS has received widespread endorsement in the earthquake community and is a high priority for NEHRP.

An important new earthquake-reporting tool that builds on ANSS is ShakeMap. ShakeMap utilizes network recordings of seismic energy to portray the intensity of ground shaking in the region surrounding a significant earthquake. It can thus provide an estimate of earthquake damage patterns and impact within minutes of an event. This information, in turn, can be used by emergency managers to speed earthquake disaster relief. ShakeMap is now being implemented in networks across the country, but for it to be truly effective, it must be supported by a modern seismic network with real-time, high fidelity recordings of the type envisioned in ANSS. Currently the only regional network in the U.S. that offers this capability is in southern California.

Another, longer-range research effort that builds on the technological capabilities of ANSS is the development of an early warning capability for earthquakes already in progress. Specifically, USGS scientists are now exploring the possibility of developing faster means of detecting and characterizing large earthquakes. If large earthquakes can be discriminated from small earthquakes at the onset of rupture, it might be possible—in the special case where the earthquake source is distant to an urban center—to provide an alert of imminent strong ground shaking. Although such a system would offer only a few seconds to tens of seconds of early warning, this brief period may be sufficient to secure critical facilities and prepare for the arrival of strong ground shaking.

2. Improve seismic hazard characterization and mapping.

NEHRP will improve hazard assessment methods and produce updated national-scale ground-shaking maps and related products on a regular basis. NEHRP will also work with cooperators to develop a standard methodology for production of large-scale seismic hazard maps for urban regions.

Under Objective 2, NEHRP's priorities are to:

- Maintain and update national hazard maps through the collection and integration of geologic, geophysical, and seismological data, including prehistoric earthquake chronologies, location of active faults, determination of 3-D velocities and geologic structure, and wave propagation and attenuation parameters.

- Improve probabilistic methods for quantifying seismic hazards, including formally incorporating uncertainty into hazard estimates, especially for areas of relatively low seismicity, such as the East and Intermountain West.

- Produce prototype urban seismic hazard maps for select major metropolitan areas.

The USGS, with support from NSF, has lead NEHRP responsibility for the production of probabilistic seismic hazards maps in the U.S. The first generation of these maps, released in 1996, has been incorporated into updates of the International Building Code, and the information is used by numerous consulting companies to estimate earthquake losses for insurance companies, pension funds, and other clients. Going forward, the USGS will produce an updated set of these maps and associated databases for the contiguous U.S. and will develop new maps for U.S. Trust territories, including American Samoa, Guam, the Northern Mariana Islands, and Puerto Rico/Virgin Islands. The revised national maps will incorporate an updated earthquake catalog with consistent magnitudes, improved ground-motion attenuation relations for the Central and Eastern U.S., and improved knowledge of earthquake source zones and recurrence rates. This work will be completed with existing funds.

Concurrent with the updating of the hazards maps, USGS- and NSF-supported scientists will conduct research on ways to improve probabilistic and scenario methods for quantifying seismic hazards, including identifying and testing alternative methodologies for earthquake-potential estimates. Research efforts will also be directed at formally incorporating uncertainty into hazard estimates. Using existing funding, efforts in this area will be focus on areas of relatively low seismicity, such as the East and Intermountain West.

Another key focus area of NEHRP is urban seismic hazard mapping. The increasing valuation of building stock and infrastructure assets, combined with demographic shifts toward earthquake-prone cities, are combining to increase loss potential dramatically for the next urban earthquake. To aid metropolitan areas in evaluating and mitigating this risk, USGS will work with local communities in three test areas (Oakland, Seattle, and Memphis) to develop a standard methodology for urban hazard mapping in three contrasting tectonic environments (strike-slip, subduction, and intraplate faulting, respectively). In these regions, the USGS will collaborate with state geologists, state agencies, and local committees to compile digital surficial geology maps, ground shaking amplification maps, and liquefaction, lateral spreading, and landslide susceptibility maps. The USGS will also determine priorities for subsequent studies in other seismically active urban areas.

3. Support development and use of risk and loss assessment tools.

NEHRP will support improvement of loss estimation and risk assessment tools and the development of next generation databases. Testing and dissemination of the nationally applicable loss-estimation model will continue. States and communities will be encouraged to provide detailed data on local geology, building inventories, and utility and transportation systems to enable more accurate planning and establishing of priorities.

Under Objective 3, NEHRP's priorities are to:

- Provide HAZUS training and support for users.
- Devise standards and protocols that can be implemented to aid in data base enhancements and data collection efforts.
- Continue to improve the usability, functionality, and accuracy of HAZUS. Calibrate and refine HAZUS loss-estimation models following actual damaging earthquakes.
- Integrate ShakeMap with HAZUS to allow for rapid loss estimations.

The main NEHRP focus under Objective 3 is the continued development and promotion of Hazards U.S. (HAZUS), a FEMA GIS-based loss estimation tool designed to aid in mitigation planning and disaster response activities. HAZUS provides a standardized approach to estimating losses from earthquakes and other hazards and utilizes the national seismic hazard maps developed by the USGS as well as complementary information on the built environment to assess risk. Although HAZUS has been used by FEMA to estimate annualized earthquake losses nationally across the U.S. (FEMA #366, Sept. 2000), it also offers the capability of computing more detailed loss estimates for major urban centers. Communities across the country are anxious for this capability; however, additional developmental components must be completed before use will be widespread.

First, there is a universal need for additional training and guidance in the use of HAZUS. This is a high priority for NEHRP and FEMA will lead in this effort. Second, there is a need for development of data collection standards, tools, and storage formats to enable consistent, accurate, and effective augmentation of the national data-bases with more detailed local information such as building inventories, lifeline inventories, and local site response estimates. The USGS and FEMA will cooperate with local users to establish these standards and protocols. It is important to note, however, that NEHRP is not capable of performing detailed data acquisition efforts at a local scale. This will be the responsibility of states and local communities. Third, there is a general need to improve the usability, functionality, and reliability of HAZUS and to calibrate with post-earthquake assessments following major damaging earthquakes. Finally, if HAZUS is to be used in a rapid response mode, it must be modified to incorporate the near real-time intensity ground shaking information portrayed in the USGS's ShakeMap routine. The USGS and FEMA are working on adding this capability, thereby permitting rapid, automatic calculations of loss estimation to aid in both the response and recovery processes. Widespread use of such features, however, will ultimately require modern seismic monitoring instrumentation of the type envisioned by ANSS. Use of these features, in coordination with local and federal GIS capability, has the potential to significantly move the state of the practice forward.

Goal D. Improve The Understanding Of Earthquakes and Their Effects

Activities under Goal D comprise the basic research component of NEHRP and cover a range of disciplines from geology and seismology, to earthquake engineering and structural engineering, to the behavioral and economic sciences. USGS and NSF are the two primary NEHRP agencies supporting Goal D efforts, with USGS emphasizing the geologic and seismologic disciplines and NSF also supporting these areas in addition to studies of the built environment and the behavioral and economic impact of earthquakes. Activities in Goal D are inherently intermediate- to long-term research efforts that may not yield immediate payoffs. Past experience suggests, however, that these efforts will contribute significantly to future risk mitigation efforts.

The following sections address current and future NEHRP activities under each of the six objectives of Goal D.

1. Improve monitoring of earthquakes and earthquake-generating processes.

> *NEHRP will continue to develop improved seismic monitoring capabilities geared toward full-waveform recording, real-time reporting, and improved network integration. NEHRP also will continue to support and expand other monitoring systems and the use of satellite-based observational systems for monitoring the deformation of the earth's crust due to earthquakes and earthquake-generating processes.*

Seismicity and crustal deformation monitoring provides a wealth of critical information for research into fault identification, slip rate estimates, and hazard assessments. Earthquake monitoring also contributes to engineering investigations of building and infrastructure response and soil-structure interactions for earthquake design purposes. NEHRP is continually seeking ways to improve monitoring and reporting technologies and thereby enhance real-time reporting efforts while delivering ever-improving information for downstream research efforts into hazard assessments and earthquake engineering. (Note that seismic monitoring activities are presented in detail under Goal C.1. We thus incorporate that section by reference and limit this discussion to crustal deformation monitoring.)

Under Objective 1, NEHRP's priorities are to:

- Maintain crustal deformation monitoring in active seismic areas of California, the Pacific Northwest, the Central U.S., Nevada, Utah, and Alaska for understanding the strain fields associated with earthquakes.

- Establish a Plate Boundary Observatory consisting of a network of GPS, and deformation sensors (GPS, strain meters) across the Western U.S.

- Investigate Interferometric Synthetic Aperture Radar (InSAR) techniques for providing map images of fault slip, areal crustal deformation associated with earthquakes, and rapid post-earthquake damage assessment.

Even in the most seismically active parts of the U.S., aseismic movements account for the majority of crustal deformation. For this reason, USGS and NSF-supported researchers monitor crustal deformation across seismically active regions using a range of instrumentation (e.g., leveling and laser-ranging surveys, strain meters, and Global Positioning System (GPS) sensors). The measurement of aseismic deformation includes determination of the plate motion rates that drive earthquakes in California, Oregon, Washington, and Alaska, of strain rates in interplate areas of the U.S., as well as the recording of small transient strain signals associated with fault motion that may be related to earthquake generation.

Recent advances in technology and large decreases in the cost of instrumentation have enabled continuous determinations of positions at fixed GPS sites, providing a practical way to continuously track crustal deformation. A number of continuous GPS monitoring stations currently exist in concentrated areas of study across the western U.S., and NSF is now proposing to expand and integrate these networks into a single strain observatory that extends across the entire North American–Pacific plate boundary (i.e., from the Rocky Mountains to the Pacific Ocean). This Plate Boundary Observatory (PBO) will permit NEHRP scientists to measure the rate and distribution of strain buildup and release before, during, and after earthquakes, and determine how deformation is accommodated three-dimensionally within the plate boundary zone.

In addition to GPS-based deformation monitoring, NEHRP is supporting research into new technologies for satellite-based monitoring of crustal deformation. In particular, both NSF and USGS are working cooperatively with NASA to explore the capabilities of satellite-based InSAR techniques in mapping small changes in ground deformation. Large areal maps of the ground deformation will give clear images of deformation accompanying and following large earthquakes. The technology may also elucidate regional strain accumulation around faults between earthquakes.

Funding for PBO and InSAR are being proposed under NSF's EarthScope initiative, which was advanced in FY 2002 as a Major Research Equipment and Facilities Construction Project (MREFC).

2. Improve understanding of earthquake occurrence and potential.

NEHRP will support research into the processes by which earthquakes occur, including studies of how large earthquakes initiate and grow, the role of fault zone geometry and mechanical properties, and the effect of changes in earth stresses.

Seismic hazard assessments rely upon estimates of the locations, sizes, and probabilities of future earthquakes. These estimates, in turn, require identifying the physical variables that govern where and how often earthquakes occur and how large they will be. NEHRP supports a range of studies directed at understanding these variables through investigations into earthquake rupture, recurrence, stress transfer, aftershock activity, and remote triggering.

Under Objective 2, NEHRP's priorities are to:

- Investigate the rupture process of large earthquakes, including the initiation, propagation, and arrest of seismic rupture and test the resulting hypotheses by geologic, geodetic, seismological, and other relevant field observations, laboratory experiments, and numerical simulation.

- Use geodetic and geologic techniques to determine crustal strain rates, compare these strain rates with long-term seismic moment release, fault slip rates, and modeled plate rates, and investigate how all of these quantities are related to future earthquake potential. Evaluate the validity of the "characteristic earthquake" model.

- Acquire laboratory measurements of physical properties, rock/fluid compositions, temperature, stress, and pore pressure in active fault zones under *in situ* conditions.

- Establish the San Andreas Fault Observatory at Depth (SAFOD) and use it as an *in situ* laboratory for measuring and monitoring fault zone properties at depth across the San Andreas Fault.

Research into the fundamental physics of large earthquakes is being supported by NSF and USGS through an array of laboratory, field, and theoretical investigations of seismicity, fault zone properties, and crustal strain. These studies are directed at understanding earthquake nucleation, propagation, arrest, and recurrence and include research into fault zone geologic or geometric heterogeneity, frictional properties, deformation rates, rupture histories, wave propagation, fault segmentation, measured strain rates, stress concentrations, and mechanical and chemical effects of pore fluids. These studies will continue to be supported at current levels.

A future priority for NEHRP is the creation of the San Andreas Fault Observatory at Depth (SAFOD), an *in situ* laboratory for measuring and monitoring the San Andreas Fault. SAFOD is designed to facilitate direct measurements of fault zone properties where aseismic creep and small earthquakes occur. By monitoring the fault zone prior to, during, and after an earthquake, SAFOD will provide answers to a number of fundamental questions about the physical and chemical processes responsible for earthquake generation. Funding for SAFOD is being proposed under NSF's EarthScope initiative, which was advanced in FY 2002 as a Major Research Equipment and Facility Construction Project.

3. **Improve earthquake hazards assessments and develop earthquake-potential estimates as planning scenarios.**

   NEHRP will support a broad-based research program on earthquakes and ground failure by improving quantification and understanding of the extent of hazards and by encouraging use of that knowledge for planning purposes.

National and regional hazard assessments require integration of information from nearly all aspects of earthquake hazards research as well as the information collected by the seismic and crustal strain monitoring networks. These activities are described under Goal C. Future improvements in the quality of hazard assessments depend on new insights derived from these seismological and geological research efforts.

Under Objective 3, NEHRP's priorities are to:

- Enhance modeling of large earthquakes to incorporate realistic physical constraints and fault behavior.

- Model the likely impact of anticipated great earthquakes on large urban regions, using realistic scenarios. Validate results from earthquake studies with results from structural and engineering investigations.

While peak accelerations in great earthquakes are not expected to be significantly larger than they are in the near-source region of moderate-to-major earthquakes, great earthquakes cause very long duration shaking (several minutes) and very large long-period ground motions. Neither long shaking durations nor large long-period ground motions have been experienced by modern U.S. cities, and their effects are poorly understood. Although the likelihood of a great earthquake in an urban center is certainly much smaller than a moderate earthquake, there is precedent for such events (e.g., 1906 San Francisco and 1923 Tokyo earthquakes) and scenario models are needed to assess their potential impact.

New research results from these fundamental earthquake studies can have enormous benefits in better understanding the response of structures and lifelines to the large ground motions of big earthquakes. It is therefore essential that results of these fundamental earthquake studies be shared with the geotechnical and engineering communities. The information provided by large earthquakes elsewhere in the world in various tectonic settings provides results that are valuable for validation and improvement of design and planning standards in the U.S.

4. Improve fundamental knowledge of earthquake effects.

NEHRP will support research on the nature of strong ground shaking from earthquakes, how it is affected by seismological and geological factors, and how its characteristics are related to permanent ground deformation and damage. These efforts will include investigations of damage from domestic and foreign earthquakes and collaboration with non-U.S. research programs.

Among the most important contributions of NEHRP to reducing earthquake losses in the U.S. are improving the understanding and modeling of damaging earthquake effects. These effects include strong ground shaking, failure and deformation of unstable ground, and the impact of these geologic effects on the built environment. NEHRP research into earthquake effects is thus directed at both the geophysical parameters controlling ground shaking and ground deformation and their relationship to structural damage through studies of soil-structure interaction.

Under Objective 4, NEHRP's priorities are to:

- Develop improved methods to generate synthetic seismograms for expected future earthquakes, incorporating improved understanding of the rupture process and information about the fault and the properties of the surrounding earth's crust. Test 3-D numerical simulations of basin response to strong shaking.
- Record strong seismic shaking for large earthquakes and develop synthetic models that match the observed. Acquire recordings by implementing a national strong motion instrumentation program for structures and ground-based sites, and by conducting post-earthquake investigations.
- Identify the parameters of ground motion that cause liquefaction and slope instability and damage to structures (such as acceleration, velocity, shaking duration, and spectral content). Develop techniques to estimate the permanent ground deformation and displacement resulting from earthquake-induced landslides and liquefaction. Improve understanding of soil-structure interaction and examine the response of structures and lifelines.

Studies of strong ground shaking and earthquake effects require knowledge of the earthquake source, the propagation of seismic energy from the source to the site, and the local geologic conditions that characterize the site. For this reason, USGS and NSF support a broad spectrum of research ranging from studies of earthquake source properties to near-field effects, wave-propagation effects, local site effects controlling ground failure, and correlation of ground motion parameters to structural and lifeline response. NSF also supports research on engineering methods to mitigate the effects of the ground motion on new and existing structures and lifelines. Collectively these research activities address the primary factors controlling the magnitude of earthquake losses and casualties through their effects on structures and lifelines.

Synthetic seismograms are an outgrowth of these studies and are used to model building and lifeline response and guide their design. A priority for NEHRP is the development and refinement of synthetic seismogram modeling techniques to produce more accurate ground motion time histories. The seismograms must accurately simulate a number of parameters used by structural and geotechnical engineers, including peak acceleration, ground velocity and displacement, response spectra, and shaking duration.

Large and destructive earthquakes provide the best opportunities to substantially advance the understanding of earth science and engineering issues associated with earthquake effects. But to capitalize on this learning opportunity, instruments capable of capturing the complete seismic signal must be in place. This is one of the reasons NEHRP is proposing to implement an Advanced National Seismic System, which would include approximately 3000 strong motion instruments capable of full-waveform recording in critical structures, facilities, and buildings across the Nation. These instruments will provide heretofore unavailable data on structural response to strong shaking that is absolutely essential for advancing earthquake-engineering practices.

The other means of obtaining strong motion recordings is through post-earthquake investigations. NEHRP will thus continue to respond to damaging domestic earthquakes with portable seismic instrumentation, geodetic measurements, geologic field investigations, and damage evaluations. USGS will take the lead in coordinating these post earthquake response efforts, following the guidelines outlined in the post earthquake response action plan called for under Goal B. In the case of foreign earthquakes, NEHRP will cooperate with U.S. and foreign institutions in focused investigations directed at filling critical knowledge gaps in fault behavior, site effects, and soil-structural interaction.

Landsliding, liquefaction, and lateral spreading are major contributors to earthquake destruction. An improved understanding of subsurface conditions and ground failure mechanisms is necessary if losses in this area are to be reduced. Advances in this area require improved measurements and instrumentation. Monitoring of physical properties, pore pressure, acceleration, and other transient parameters are all necessary to characterize the ambient physical properties of the soils in which failure occurs. Such measurements will enable NSF-supported researchers and USGS scientists to develop techniques designed to estimate earthquake-induced permanent ground deformation and displacement.

Studies of nonlinear soil response are critical for assessing site-specific shaking hazards. The NSF earthquake engineering research centers actively support research in this area, and there are ongoing projects by other NSF-funded investigators that are focused on the prediction of site response under large earthquakes for which soil behavior may not be elastic. The NEES equipment portfolio will include experimentation equipment that will extend our knowledge in this area.

5. Advance earthquake engineering knowledge of the built environment.

NEHRP will implement the Network for Earthquake Engineering Simulation (NEES) to improve the seismic design and performance of U.S. civil and mechanical infrastructure systems through collaborative and integrated experimentation, computation, theory, databases, and model-based simulation.

NEHRP supports research in earthquake engineering through NIST and NSF. The problem-focused research and development conducted by NIST to improve codes, standards, and practices for buildings and lifelines is discussed under Goal B. The NSF-supported research is directed at developing new knowledge derived from fundamental research on buildings, lifelines, geologic materials, and geotechnical construction. NSF research activities also address the impacts of seismic events on the physical infrastructure systems that serve the public and societal institutions.

Under Objective 5, NEHRP priorities are:

- Improve the understanding of existing materials and develop new materials and technologies for earthquake resistant structures. Develop and validate new structural systems and new methods of structural control.

- Improve the understanding of collapse mechanisms of various classes of structures. Enhance the understanding of fragility curves for various classes of buildings and utility and transportation lifelines to improve performance-based earthquake engineering methodologies.

- Focus research efforts on theoretical simulations of building and lifeline "systems" through the implementation of NEES. Research how structure and component integration change the performance of the overall structure. Conduct post-earthquake investigations to validate and calibrate research results.

A new facet of earthquake engineering research now being launched by NSF is theoretical studies of the structural response of the built environment to earthquakes based on computer simulations. This effort, known as the Networked Earthquake Engineering Systems (NEES), will transform earthquake engineering research from its current reliance on physical experiments to investigations based on integrated experimentation, computation, theory, databases, and model-based simulation. Research areas to be supported under NEES include: structural control, composite and hybrid seismic structural systems, smart materials and structures to develop new building systems, advanced technologies for seismic response reduction and control, and health monitoring. NSF also supports experimental and model-based research projects in these areas. The NEES project will exploit Internet technology to integrate and interconnect nationally distributed facilities. NEES will also provide a curated data repository for easily accessible information, and the managing NEES consortium will develop outreach, educational, and experimental opportunities for the professional community.

As the network of NEES facilities comes on line in FY 2004, university-based research is important to provide maintenance and operation support for the NEES facilities and to support the expanded research opportunities made possible by the NEES project.

6. Advance understanding of the social and economic implications of earthquakes.

NEHRP will support earthquake-related social science and policy research to advance understanding of the social and economic impacts of earthquakes, determine levels of risk deemed acceptable by various groups in society, and reduce the social, economic, and political barriers to effective earthquake risk reduction.

The social science community has the potential to make vital contributions to NEHRP as it moves forward. Social scientists can, for example, research effective ways to involve communities in risk identification, prevention, and mitigation; communicate earthquake risks to targeted audiences; evaluate the effectiveness of existing and proposed programs and policies; and assess and improve the design and operations of organizations and institutions whose job it is to prepare for, respond to, mitigate, and aid in recovery from earthquakes. This work can serve to increase the pace and overall success of NEHRP risk-reduction measures. Currently NSF provides funding for interdisciplinary university-based research conducted in the social, economic, policy, and decision sciences, in addition to research contributions from engineering and natural sciences. In addition, the NSF-funded earthquake engineering research centers develop strategic research agendas that include interdisciplinary research framed to integrate contributions from social and natural sciences and engineering, with applications to performance-based earthquake engineering, seismic risk mitigation, pre-earthquake preparedness, and post-earthquake response and recovery. This work will continue and will be more directly integrated into the NEHRP activities outlined in other portions of the plan.

Under Objective 6, NEHRP priorities are to:

Analyze how incentives influence risk-reduction behavior under the conditions of uncertainty inherent with earthquake predictions. Research ways to expand and improve incentives to promote earthquake mitigation.

- Analyze risk perceptions and their effects on decision making in order to develop a common framework for discussing risk with engineers, building owners, occupants, and public officials. Improve techniques for explaining risk under conditions that have varied degrees of uncertainty.

- Research effective means to communicate real-time warnings to various intended recipients so that appropriate responses are elicited. Incorporate research results into the development of earthquake early notification systems.

Improving earthquake risk communication requires continued investment in both fundamental research and translation of that research into risk communication and management policies and practices. While we now understand a good deal more about risk perceptions than we did several decades ago, research on the relationship between risk perceptions and mitigation decisions, and on risk communication and management, may enable risk reductions as large as or larger than equal investments in physical and engineering sciences.

NSF supports research by social and behavioral scientists that will improve our understanding of how different incentives influence behavior under conditions of uncertainty. Research should be supported on the direct and indirect effects of a range of incentives for hazard mitigation, including taxes and other financial incentives, social and legal sanctions, and land-use based incentives. NSF also supports research on risk analysis and management as well as on the design of effective institutions, which can help to identify potentially effective policies and organizational strategies for achieving risk reduction. The policy implications of the results of this research should be identified and evaluated. If, for example, specific kinds of financial incentives are identified by researchers as potentially effective at encouraging large and small businesses, organizations, government agencies, and individuals to implement mitigation programs, FEMA could support Federal and state tax consultants to identify the specific changes in existing Federal and state tax policies that would accomplish this.

We are not currently able to measure and quantify risks and discuss them within a common framework used by engineers, building owners, occupants, and public officials. Early work was conducted in the field of risk perception and communication, however, further research in the decision sciences field is needed to enable policy makers to communicate relative risks under conditions that have varied degrees of uncertainty in terms of time, place, magnitude, and frequency, while taking into consideration the limitations of engineering knowledge.

Technological developments have made real-time warning systems a potential tool to communicate warnings to affected groups: the general public, large and small businesses, emergency responders, hospitals, and schools systems. However, we do not have an adequate understanding of how best to communicate these warnings in a way that is fast, reliable, and generates the appropriate response from each recipient. NSF supports research by social scientists to understand how warning information is processed and acted upon and how transmission modes and messages are linked to behavioral response. USGS will such research results into the development of earthquake early notification systems.

Implementation Summary

The table below summarizes the range of implementation activities proposed under this strategic plan. NEHRP program managers will work with agency policy officials through the NEHRP Policy Coordination Council, and with the Office of Management and Budget and Congress to develop detailed plans and budget justifications for these projects.

Table 1. Summary of planned implementation activities.

Goal A. Develop effective practices and policies for earthquake loss reduction and accelerate their implementation.

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

Goal and Objective	NEHRP Activity	Lead Agency	Support Agencies
A.1	Distribute NEHRP resource materials and provide technical advice to promote adoption of risk reduction measures to decision makers and the public.	FEMA	NIST NSF USGS
A.2	Promote loss reduction actions through development of partnerships and incentives with local communities and businesses.	FEMA	NSF USGS
A.3	Advance seismic risk reduction at the state and local government level through interaction with, and support of, state-based advisory bodies.	FEMA	USGS NSF
A.3	Promote the adoption of building codes at the state and local levels.	FEMA	USGS NSF
A.4	Reduce the risk to existing and future Federal facilities, in cooperation with the ICSSC, through development and adoption of risk-reduction standards for Federal agencies.	FEMA NIST	USGS NSF
A.5	Support curricula and education programs for K-12 and university students.	FEMA NSF	USGS NIST
A.5	Provide training and continuing education through partnerships for the use of NERHP technical resources developed under Goals B, C, and D.	FEMA USGS	

Goal B. Improve techniques to reduce seismic vulnerability of facilities and systems.

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

Goal and Objective	NEHRP Activity	Lead Agency	Support Agencies
B.1	Support development of improved building codes and encourage technology transfer through consortia and professional trade associations.	FEMA	NIST
B.2	Expand the use of problem-focused research to support a new generation of codes and standards for buildings and lifelines.	NIST	FEMA NSF
B.3	Maintain NEHRP guidance documents for new and existing buildings.	FEMA	USGS
B.3	Develop performance-based codes for buildings and lifelines.	FEMA NIST	NSF USGS
B.3	Improve coordination of post-earthquake investigations.	USGS	FEMA NIST NSF
B.3	Develop integrated, comprehensive NEHRP post-earthquake reports and databases.	USGS	FEMA NIST NSF

Goal C. Improve seismic hazards identification and risk assessment methods, and their use. 1. Provide rapid, reliable information about earthquakes and earthquake-induced damage. 2. Improve seismic hazard characterization and mapping. 3. Support development and use of risk and loss assessment tools.			
Goal and Objective	**NEHRP Activity**	**Lead Agency**	**Support Agencies**
C.1	Operate national, regional, and global seismic networks and associated network information centers.	USGS NSF	
C.1	Upgrade seismic monitoring networks through the implementation of the ANSS.	USGS	
C.2	Update and expand national seismic hazard maps, including U.S. trust territories. Incorporate new earth science data and improve probabilistic methods.	USGS	NSF
C.2	Develop prototype urban seismic hazard maps for select major metropolitan areas.	USGS	
C.3	Expand access to HAZUS and provide necessary training.	FEMA	
C.3	Support development of standards for database management and data collection efforts.	FEMA	NSF USGS
C.3	Refine HAZUS earthquake model to incorporated new research findings and database developments and calibrate with post-earthquake studies.	FEMA	USGS

Goal D. Improve the understanding of earthquakes and their effects.

1. **Improve monitoring of earthquakes and earthquake-generating processes.**
2. **Improve understanding of earthquake occurrence and potential**
3. **Improve earthquake hazards assessments and develop earthquake-potential estimates as planning scenarios.**
4. **Improve fundamental knowledge of earthquake effects.**
5. **Advance earthquake engineering knowledge of the built environment.**
6. **Advance understanding of the social and economic implications of earthquakes.**

Goal and Objective	NEHRP Activity	Lead Agency	Support Agencies
D.1	Expand and advance crustal deformation monitoring, including investigation of GPS and Interferometric Synthetic Aperture Radar techniques.	NSF	USGS NASA
D.1	Establish and support Plate Boundary Observatory in western U.S.	NSF	USGS
D.2	Continue earth science studies and research related to earthquake potential and earthquake occurrence.	USGS NSF	
D.2	Establish and support the San Andreas Fault Observatory at Depth (SAFOD).	NSF	USGS
D.3	Model the likely impact of anticipated large earthquakes on urban regions and refine results using structural and engineering investigations.	NSF	USGS
D.4	Develop improved methods to predict ground shaking and structural damage. Evaluate effect of nonlinear soil response on urban areas. Calibrate results through post-earthquake investigations.	USGS NSF	
D.4	Develop techniques to estimate ground deformation from landslide and liquefaction.	NSF USGS	
D.5	Improve knowledge of structural characteristics and system performance of constructed facilities.	NSF	NIST
D.5	Advance earthquake engineering knowledge of the built environment through implementation of NEES.	NSF	
D.6	Support interdisciplinary research that involves engineering, natural science, and social, economic, and decision sciences.	NSF	FEMA USGS NIST

Program Management / Agency Coordination

Program management requires a programmatic agenda, or implementation plan, that identifies the projects, schedules, responsible agencies, and resource commitments and that describes the involvement of each agency. Management of this Plan is shared by the NEHRP agencies on a collegial basis. Each agency represents its own interests and remains responsible for its own programs, but recognizes the value of cooperative actions. As the lead agency, FEMA is ultimately responsible for program and policy matters but solicits advice from the Interagency Coordination Council (ICC). The ICC is responsible for writing, adopting, and implementing this Strategic Plan, and for integrating agency programs to accomplish the Plan's goals and objectives. Periodic meetings provide a forum for discussing common activities, exploring crosscutting issues, collaborating on joint projects, identifying and resolving conflicts, and seeking support and cooperation. The ICC also provides a mechanism for revising the Strategic Plan.

The ICC will conduct an annual program review at which the project managers will present achievements and reports on their projects. This meeting will have two purposes. The first is to permit the ICC to assess progress and to redirect efforts to take advantage of new results. The second purpose is to allow the agency representatives to gain insight into the work of the other agencies and to facilitate collaboration among them.

The NEHRP agencies have identified several explicit areas where resources and funding will be specifically coordinated:

- Meetings of Policy Coordination Council (PCC)
- Meetings of Interagency Coordination Council (ICC)
- Developing an explicit research implementation process
- Post-earthquake coordination
- Coordinated audience identification/information dissemination/Internet presence
- Coordination of EERCs and multi-state consortia activities and funding
- Guidelines for external partnering

The following discussions outline in more detail the specific areas of coordination listed above.

The PCC, consisting of the head of FEMA's Mitigation Division, and the directors of NIST, NSF, and USGS, will meet on at least a bi-annual basis. The focus of their meetings will be high-level policy issues that concern strategic NEHRP direction and liaison with the Office of Management and Budget and Congress.

The ICC, chaired by the Director of FEMA's Engineering and Technology Unit, and populated with a representative from NIST, NSF, and USGS, will meet on at least a quarterly basis throughout the year. The key focus of the ICC will be interagency coordination of projects, programs, plans, budgets, and operational NEHRP issues. Some of the key purposes of these regularly held meetings are for each of the program agencies to present their NEHRP-related budget and expense figures and to have a better understanding of what activities each agency is emphasizing. These meetings also will act as a catalyst for spurring interagency cooperative projects.

An extremely high priority in the short term for NEHRP is the improvement of the "research to practice to implementation" cycle, especially in the building sciences area. There currently exists a fundamental disconnect in that there is not a clear link for research results to be incorporated into codes and standards development and implementation activities. The result is that relevant research activities take longer to get translated into practice. Similarly, research needs identified by guideline development and implementation activities are not being communicated to research organizations; hence, these items are not being investigated in a timely manner. An exception has been the incorporation of USGS and NSF data on the national hazard maps into the model building codes. This is an example where the cycle appears functional and has worked well. The NEHRP agencies need to develop and agree on a conceptual flowchart and process to close this loop. This will be accomplished by a NEHRP research issues ad hoc working group that will have the responsibility of designing mechanisms and processes that assure proper information transfer and coordination.

Another area that requires attention is post-earthquake investigations. Following an earthquake, there is a tremendous opportunity to both learn and to transmit findings. Following the 1964 Alaska and 1971 San Fernando earthquakes, significant government efforts produced comprehensive reports on the respective earthquakes. Since that time, the scientific landscape has changed. A large number of groups now embark on post-earthquake reconnaissance and data collection efforts and produce reports. However, there is insufficient coordination or synergy to these efforts. By creating a pre-earthquake action plan for post-earthquake coordination, NEHRP's goal is to produce a framework, with stakeholder input, that maximizes the efficiency and minimizes the overlap of these efforts.

Coordinated audience identification is a key component of any effective effort by the NEHRP agencies to raise earthquake awareness and encourage mitigation activities. It is critical for NEHRP to coordinate internally so that it speaks to the community in a common voice. This is especially important during post-earthquake response efforts and requires improved coordination among the various field offices of FEMA, NSF, and USGS.

The NEHRP agencies will form an ad hoc information dissemination working group that seeks to eliminate overlap in agency dissemination efforts and to better coordinate resources in existing efforts. One area of immediate focus will be the development of a NEHRP web site that serves as an information source about NEHRP agency activities and other program information. FEMA will assume the lead for this effort.

The NEHRP agencies provide significant funding to the EERCs (MAE, MCEER, and PEER) through NSF. In addition, FEMA and USGS fund multi-state consortia such as the Central US Earthquake Consortium (CUSEC), the Western States Seismic Policy Council (WSSPC), the New England States Emergency Consortium (NESEC), and the Cascadia Region Earthquake Workgroup (CREW). Historically, each of the NEHRP agencies has funded these entities separately, presenting a challenge to coordinate the efforts of these groups to meet NEHRP objectives. The NEHRP agencies will promote the joint coordination of the activities of these groups and will develop coordination in annual reviews. This will help avoid duplicative efforts. It will also force better coordination between the centers and consortia in meeting NEHRP objectives.

Finally, as an aid to Plan revisions, NEHRP will convene an ad hoc stakeholder group comprised of a balanced and representative sampling of NEHRP stakeholders. This group will have a revolving membership and will aid the ICC in revising the Strategic Plan by providing opinions and firsthand observations of what is needed on the ground to ensure more efficient earthquake loss reduction.

Measuring Performance

Measuring the progress of earthquake mitigation is inherently problematic. Those who seek to quantify the value of mitigation efforts face a frustrating dilemma—it's the actions that aren't taken that lead to measurable consequences, while the actions that are taken are subject to ambiguity. Did the structure survive because of retrofitting, or because the shaking intensity and duration of the earthquake were not sufficiently strong to cause damage? If the building codes had not been strengthened, what would have been the impact of an event? It is extremely difficult to measure events that have not yet occurred, but that is nevertheless the challenge.

The Earthquake Hazards Reduction Act of 1977 and the NEHRP mission statement contain two complementary, fundamental goals: 1) to develop knowledge and, 2) to promote practices and policies to reduce fatalities, injuries, and economic and other losses. As they are distinctly different tasks, different methods of measuring performance need to be employed.

Developing Knowledge

Evaluating the *outcomes* of the research component of NEHRP requires a science-sensitive approach. Research under NEHRP is intended to fulfill program goals as well as to address a national goal of leadership in scientific knowledge. Basic research is intended to advance knowledge—it is not required that it produce tangible, immediately useful results, although this often happens. NEHRP activities are focused to expand fundamental understanding of earthquake processes, engineering, and social and economic impacts. This knowledge is further developed through applied research and development activities that enable effective transfer of the new applications, methods, and technologies to those who will use it in reducing earthquake losses.

A performance assessment for research and development activities should include continuous self-assessment and periodic external independent review of the outcomes and quality of research. Of importance to the NEHRP mission, the review should: 1) evaluate the excellence of the research methods and products; 2) determine how rapidly research results are translated for use in reducing risk; 3) assess how effectively earthquake scientists, engineers, and practitioners learn from other areas of research and from other nations; 4) assess how investigators apply new knowledge and use it in advancing their own research and development efforts; and 5) analyze the effectiveness and appropriateness of allocation of research resources by discipline and NEHRP priorities. Recommendations from such evaluations can be used to improve the effectiveness of the research, development, and implementation programs in meeting the Nation's science objectives and the NEHRP goals and objectives. Conclusions from such reviews should be included in NEHRP reports to Congress.

Reducing Losses

The second component of measuring performance is measuring the effectiveness of the program in the reduction in earthquake losses. Damaging earthquakes occur only infrequently, which makes difficult the validation of the predicted or expected reductions in earthquake losses as a result of NEHRP activities. NEHRP could work to develop HAZUS loss estimates over 5-year time intervals to estimate the likely reductions in earthquake losses in selected areas of the country. However, the logistical difficulties required to assemble this data make this path impractical. An alternative approach is the development of risk indicators that can serve as proxy measures of the success of loss-reduction activities. Input will be required from the stakeholder communities to identify meaningful metrics, and to evaluate the usefulness of candidate metrics. Program metrics developed should be subjected to periodic review to ensure that the target indicator is being accurately represented, and should incorporate the results of continuing research in the field.

Next Steps

Development of metrics for a program as diverse and difficult to measure as the NEHRP program will require careful thought and effort. It is critical that metrics be designed that are meaningful, that will accurately reflect the performance measures of interest, and that will actually measure the two key program objectives, developing knowledge and reducing losses. To develop the desired metrics, the NERHP agencies will commit resources in FY03 to developing a series of metrics consistent with each NEHRP agencies' GPRA reporting requirements for both the developing knowledge and reducing losses missions of NEHRP.

Appendix A. Development of Implementation Plan

The development of the implementation sections of this strategic plan began with a stakeholder workshop in September of 1999. Workshop participants were identified by goal so that broad representation was assured. Discussion of implementation activities occurred in four concurrent discussion sessions corresponding to the four NEHRP Goals. Discussion leaders were appointed, and these same leaders were responsible for producing summary reports of recommended implementation activities following the meeting discussion.

The next step in the process was for a working subgroup of the ICC to categorize the existing NEHRP activities by goal and objective. This list was then compared to the list of proposed implementation activities generated from the September 1999 workshop. Areas where suggested implementation activities were matched by ongoing activities within the agencies were left alone, while gaps (i.e., those areas where suggested activities represented new or expanded efforts not currently being addressed within NEHRP) were specifically identified. The agencies then prioritized these proposed activities on the basis of perceived value and need, and on the fit with stated NEHRP goals and objectives. These recommendations were then summarized by goal and objective into a draft document that was distributed to all the participants of the September 1999 workshop.

The distribution of the draft plan was followed by a second workshop in September 2000. At this meeting, a summary of the major changes to the document was presented. Breakout sessions corresponding to the four Strategic Plan goals were again assembled to discuss in detail the recommendations under each goal contained in the latest version of the plan. Also, topical discussions on stakeholder involvement and program metrics were undertaken in the breakout groups. Comments were collected in the breakout groups and presented in a general plenary session. A considerable question and answer period was also employed as a feedback mechanism. The ICC Working group then took the feedback from the second workshop and incorporated relevant comments into the plan. At this juncture, the document was reformatted to reflect the forward-looking nature of NEHRP and to sharpen the focus of the Plan's message. The Working Group prepared final revisions, and the plan was submitted to the agencies for formal internal review in early November 2000.

Appendix B. List Of Workshop Participants

<u>September 1-2, 1999</u>	
Daniel P. Abrams	Mid-America Earthquake Center
Jim Ament	State Farm Fire and Casualty Co.
Jill Andrews	University of Southern California
Walter Arabasz	University of Utah
Michael Armstrong	FEMA
James E. Beavers	Mid-America Earthquake Center
Richard Bernknopf	USGS
Ann Bostrom	NSF
Jawhar Bouabid	Durham Technologies, Inc.
James Buika	FEMA
Arrietta Chakos	City Managers Office, Berkeley, CA
Harish Chander	Department of Energy
Karen Clark	Applied Insurance Research
Craig Comartin	Comartin-Reis
James Davis	California Division of Mines & Geology
Gregory Deierlein	Stanford University
Claire Drury	FEMA
Charles D. Eadie	University of California
Donald Eggleston	SERA Architects PC
Richard Eisner	Office of Emergency Services, CA
Steven P. French	Georgia Institute of Technology
John Filson	USGS
Arthur D. Frankel	USGS
Edward S. Fratto	NESEC
Ian Friedland	MCEER
Marjorie R. Greene	EERI
John Gross	NIST
Robert Hanson	FEMA, University of Michigan
Ronald Hamburger	EQE International
James R. Harris	JR Harris & Company
Jack Hayes	US Army Construction Engineering
Thomas Heaton	CALTECH
Gregory L. Hempen	USACE, St. Louis District
Gil Jamieson	FEMA
Arch Johnston	CERI, University of Memphis
Rob Johnson	Cascadia Region Earthquake Workgroup
Gerald H. Jones	National Institute of Building Sciences
John D. Kiefer	Kentucky Geological Survey
Anne S. Kiremidjian	Stanford University
Elizabeth Lemersal	FEMA
H.S. Lew	NIST
Theodore Litty	FEMA

Sue Luebbering-Evers	FEMA
Edgar V. Leyendecker	USGS
Ronald Lynn	Clark Co. Nevada Bldg. Dept.
George Mader	Spangle Associates
Stan Mahin	University of California, Berkeley
Mike Mahoney	FEMA
Bob McCluer	BOCA International
Thomas R. McLane	ASCE
Mike Mehrain	Dames & Moore
Ugo Morelli	FEMA
Sam Morton	The Morton Company
Priscilla Nelson	NSF
Joanne Nigg	University of Delaware
Stuart Nishenko	FEMA
Robert A. Olson	Robert Olson Associates, Inc.
Ronald Padgett	Kentucky Division of Emergency Management
Joy Pauschke	NSF
Milo Pearson	California Earthquake Authority
Chris Poland	Degenkolb Engineers
Jonathan G. Price	Nevada Bureau of Mines and Geology
Joseph Rachel	FEMA
Robert Reitherman	CUREe
Michael Riley	NIST
Christopher Rojahn	Applied Technology Council
Paul Senseny	Factory Mutual Insurance
Daniel Shapiro	SOHA Engineers
Haresh Shah	Stanford University
Tim Sheckler	FEMA
Paul G. Somerville	URS Greiner Woodward Clyde
Shyam Sunder	NIST
Bruce Swiren	FEMA
Alex Tang	Nortel
Mary Taylor	FEMA
Thomas Tobin	Tobin and Associates
Susan K. Tubbesing	EERI
Jerry Uhlmann	Missouri State Emergency management Agency
Anita Vollmer	FEMA
Yumei Wang	Oregon Dept. of Geology and Mineral Industries
James Whitcomb	NSF
Stephen Weiser	Idaho Bureau of Disaster Services
Stuart Werner	Seismic Systems and Engineering Consultants
Soy Williams	International Code Council, Inc.
Craig Wingo	FEMA
Cecily Wolfe	NSF
T. Leslie Youd	Bringham Young University

Eugene Zeller	Long Beach Department of Planning
Robert Zimmerman	Boeing Company

<u>September 6-7, 2000</u>

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Ian Buckle	University of Nevada, Reno
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Charles D. Eadie	University of California
Donald Eggleston	SERA Architects PC
John Filson	USGS
Edward S. Fratto	NESEC
Jayanta Guin	Applied Insurance Research
Marjorie R. Greene	EERI
Robert Hanson	FEMA, University of Michigan
James R. Harris	JR Harris & Company
Jack Hayes	US Army Construction Engineering
Thomas Heaton	CALTECH
Gregory L. Hempen	USACE, St. Louis District
Jon Janowitz	FEMA
Rob Johnson	Cascadia Region Earthquake Workgroup
Gerald H. Jones	National Institute of Building Sciences
John D. Kiefer	Kentucky Geological Survey
Anne S. Kiremidjian	Stanford University
Elizabeth Lemersal	FEMA
Mark Leonard	California Earthquake Authority
Theodore Litty	FEMA
Sue Luebbering-Evers	FEMA
Edgar V. Leyendecker	USGS
George Mader	Spangle Associates
Mike Mahoney	FEMA
Jill McCarthy	USGS
Thomas R. McLane	ASCE
Mike Mehrain	Dames & Moore
Jack Moehle	PEER, University of California, Berkeley
Ugo Morelli	FEMA
Priscilla Nelson	NSF
Stuart Nishenko	FEMA
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Robert A. Olson	Robert Olson Associates, Inc.

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Michael Riley	NIST
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Richard Roths	FEMA
William U. Savage	Pacific Gas & Electric Company
Paul Senseny	Factory Mutual Insurance
Daniel Shapiro	SOHA Engineers
Tim Sheckler	FEMA
Howard Simpson	Simpson Gumpertz & Heger, Inc.
Paul G. Somerville	URS Greiner Woodward Clyde
Shyam Sunder	NIST
Craig Taylor	Natural Hazards Management, Inc.
Susan K. Tubbesing	EERI
Jerry Uhlmann	Missouri State Emergency management Agency
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