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Introduction

Mr. Chairman and distinguished members of the Subcommittee:

I appreciate the opportunity to discuss the National Earthquake Hazards Reduction Program (NEHRP) with the Subcommittee, and the role of NSF in this effective multi-agency partnership that was established in 1977. NSF is privileged to serve as one of the principal agencies in NEHRP. Our participation in NEHRP is consistent with our policy of integrating NSF's activities with those of other agencies when it will facilitate the achievement of national goals, which in the case of NEHRP involves the goals of reducing deaths, injuries and property damage caused by earthquakes. We are confident that NEHRP - in collaboration with other Federal agencies, local and state governments, and private sector organizations throughout the country - will continue to take crucial steps toward meeting this challenge in the years to come. Among other functions, NSF is involved in enabling knowledge creation and the education of future professionals, activities which make possible effective earthquake hazard mitigation in the nation.

I will initially put our involvement in NEHRP in perspective by saying a few words about the broader NSF mission. Then I will discuss the role of NSF in the NEHRP partnership.

The NSF Mission

Recent years have seen acceleration in the rate of change in society and the world at large. In this era of rapid change, in which science and technology play an increasingly central role, NSF has remained steadfast in pursuit of its mission. That mission is to support science and engineering research and education for the advancement of the nation's well being.

At NSF, we believe that federally funded research should have economic and social benefits for society, as well as represent excellence in science and engineering. We also see the necessity for and benefits from integrating research and education, which can most effectively be done at academic institutions.

NSF makes its investments in science and engineering with the recognition that there is a need to maintain excellence across the frontiers of scientific and engineering disciplines. In order to significantly enhance the return on such investments, we actively seek partnerships with other Federal agencies as well as other entities.

Finally, NSF places significant emphasis on the diffusion of knowledge and technological innovations that are relevant to such national goals as education, environmental sustainability, and the development of reliable and safe civil infrastructure systems. This requires an appreciation of a broad range of research and educational contexts, including the recognition that research centers, consortia, and individual investigator projects all contribute to the advancement of needed scientific and engineering knowledge.

Role of NSF in NEHRP

NSF supports research and educational activities in many disciplines, and this is reflected in the role we are assigned under NEHRP. Our role complements the responsibilities assigned to our principal partners in the program: the Federal Emergency Management Agency (FEMA), the US 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. NSF is also a frequent collaborator with the other NEHRP agencies. This collaboration includes co-funding research, educational and outreach activities.

Previous legislation reauthorizing NEHRP calls for NSF to support studies in the earth sciences, earthquake engineering, and the social sciences. Since an integrated body of knowledge is needed to understand earthquake problems and to develop effective solutions for dealing with them, such as innovative building designs and control technologies, NSF encourages cross-disciplinary research. The NSF-supported earthquake centers, which I will discuss later, provide one of the most useful institutional arrangements for conducting complex holistic research.

Earthquake research and educational activities are supported at NSF in the Geosciences and Engineering Directorates. Fundamental earthquake research is funded in the Geosciences Directorate, while the Engineering Directorate supports earthquake engineering and social science research related to earthquake hazard mitigation and preparedness. 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.

NSF supports numerous individual investigator and small group projects, two university consortia, and four earthquake centers that advance NEHRP goals. Other NEHRP-related

NSF activities include programs involving earthquake research facilities, post-earthquake investigations, international cooperation, and information dissemination. I will briefly discuss some of the highlights of such activities since the last time that NSF and the other NEHRP agencies appeared before the Subcommittee on April 10, 1997.

Research Facilities

NSF has long recognized that its mission to advance science and engineering in the U.S. includes providing the academic community with requisite resources for developing world-class research facilities and equipment. And NEHRP legislation has reinforced our own expectations regarding this important role for NSF. Let me provide some examples of our efforts to ensure that U.S. researchers have the required facilities to conduct cutting-edge research well into the next century.

Network for Earthquake Engineering Simulation (NEES)

In response to a congressional mandate, NSF and NIST supported a study that was coordinated by the Earthquake Engineering Research Institute to assess earthquake engineering experimental research resources in the U.S. Recommendations from this study, which identified the need to upgrade the earthquake engineering experimental research infrastructure in the U.S., were published in a comprehensive 1995 report entitled Assessment *of Earthquake Engineering Research and Testing Capabilities in the United States*.

The 1997 NEHRP reauthorization 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. I am happy to report that such a planning process was successfully undertaken involving the NEHRP agencies and relevant stakeholders in the earthquake field, including academic researchers, practitioners in the public and private sectors, and suppliers of earthquake research equipment. Consultations with representatives from these groups occurred on numerous occasions over the past two years and included in-depth discussions at seven meetings and workshops. I am pleased to say that this process has resulted in a plan for significantly improving the earthquake engineering experimental research infrastructure in the U.S.

The plan involves the creation of a Network for Earthquake Engineering Simulation (NEES) over the next five years. In November 1998, the National Science Board gave its approval to NSF to include the cost of initiating the development of NEES in the agency's FY 2000 budget. An estimated investment of nearly $82 million will be required to develop NEES over the next five years.

When completed, NEES will involve a networked system of upgraded and new experimental research facilities for testing full size structures and their components as well as partial scale physical models. The components of the system will be distributed at various sites around the country and will include such facilities as: (1) shake tables used for earthquake simulations; (2) large reaction walls for pseudo-dynamic testing; (3) centrifuges for testing soils under earthquake loads; and (4) field testing facilities, such as mobile shakers.

In recent years, rapid advances have occurred in information technology, and NEES will reflect new developments in the Internet and computer software. For example, despite their geographic dispersion, the various components of NEES will be interconnected with a computer network, allowing for remote access, the sharing of information, and collaborative research. Also, this system will be integrated through networking software so that integrated models and databases can be used to create model-based simulation. NEES will leverage public and private investments in the $100 billion-a-year information technology industry by using existing software and making effective use of the high-speed networking infrastructure that is one of NSF's most successful investments. We believe that this utilization of advanced IT will enable the earthquake engineering research field to move from a reliance on physical testing to model-based simulation. If this occurs as expected, this will be a major transition for earthquake engineering research and lead to results that rapidly help advance earthquake hazard reduction in the nation.

NEES will also serve as a major educational tool. For example, 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. Such 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.

NEES, then, promises 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.

<u>EarthScope</u>

An important new research facility, EarthScope, is under consideration by NSF. EarthScope is an integrated, multi-purpose geophysical instrument array that has the potential for making major advances in our knowledge and understanding of the structure and dynamics of the North American continent. This knowledge is not only important scientifically, but is needed for use in mitigating the impact of disasters caused by earthquakes and volcanic eruptions. This will provide a significant enhancement of NSF's contribution to NEHRP goals.

One of the principal goals of Earthscope is to estimate realistic strong ground motions from different types of faults and within different types of geologic structures. Thus, Earthscope directly complements the NEES effort in that it is intended to provide realistic earthquake strong motion data for the engineering simulations.

Incorporated Research Institutes in Seismology (IRIS)

NSF supports the Incorporated Research Institutes in Seismology (IRIS) consortium in order to provide the seismographic facilities necessary to monitor earthquakes worldwide, study the tectonic structure of active seismic zones, and provide emergency seismographic response to aftershock zones of major earthquakes.

IRIS's Global Seismographic Network (GSN), operated in partnership with the U.S. Geological Survey, is the primary means of locating, in near-real time, seismic events around the world to provide emergency and policy planners information with which decisions on responses can be made. The GSN is nearly complete on land with over 100 stations worldwide, most of which are accessed in near-real time, and all of which are available over the Internet through the IRIS Data Management Center. The Data Management Center now stores over 8 terabytes of data and is growing at a rate of 2 terabytes per year. Tests are now being conducted on the deep ocean floor to determine the best technology with which to instrument the vast oceanic areas of the Earth.

IRIS maintains a ready array of advanced, portable seismic systems for rapid deployment in the aftershock region of major earthquakes. This array is also used to map the tectonic structure of active seismic regions. With knowledge of the tectonic structure, scientists can better understand the geometry of potential earthquake rupture zones and compute their associated destructive strong motions, especially close to the earthquake source.

Global Positioning System (GPS)

The Global Positioning System (GPS) was initially developed by the Department of Defense in order to provide location accuracies of a few meters. However, the differential use of GPS with two or more receiving systems can achieve sub-centimeter accuracy and this fact has revolutionized the science of earthquake tectonics. The distortion of the earth's surface is an essential measure of the potential for earthquakes in a given region. This distortion can be monitored with GPS and other space-based positioning systems. NSF supports facilities that use GPS to monitor crustal distortion in both campaign and fixed-network modes.

The University Navstar Consortium (UNAVCO), supported by NSF in partnership with NASA, was formed to support scientific campaigns that monitor crustal distortion in active tectonic areas. UNAVCO provides instrumentation, training and logistics support to individual scientists who have been funded to study specific tectonic areas throughout the world.

The Southern California Integrated GPS Network (SCIGN) is the most ambitious U.S. GPS fixed-network to date and is under construction with support of NSF in partnership with NASA, the USGS, and the Keck Foundation. SCIGN, now almost one-half complete, will consist of 250 fixed GPS stations in southern California. It will be linked with less dense networks in Nevada, northern California, and the Pacific Northwest. The SCIGN data is available on the Internet in near-real time, and has already provided significant new discoveries and constraints on our ideas of the tectonics of the San Andreas Fault plate-boundary zone.

Research Centers

NSF established the Southern California Earthquake Center (SCEC) in 1991 as a Science and Technology Center for the purpose of promoting and integrating science related to earthquake hazard estimation and reduction in the southern California region. The USGS is a partner in SCEC, which also receives support from FEMA, the State of California, the City of Los Angeles, County of Los Angeles, industry and private foundations. Such broad funding is an example of how NEHRP agencies leverage funds and indicates that SCEC truly is seen as an activity that cuts across the concerns of the NEHRP program. SCEC is a consortium of institutions and is administered through the University of Southern California. It continues to contribute significantly to a new understanding of the earthquake hazard in southern California by combining insights from seismicity, new geodetic technology, new geologic discoveries, and local site conditions in an innovative framework of earthquake hazard evaluation. Recent examples of SCEC findings include a) the discovery that magnitude 7 earthquakes have occurred on at least one local thrust fault in the Los Angeles metropolitan region, b) a determination that one major thrust fault discovered beneath the region is currently inactive, and c) a suggestion that north-south strain across the Los Angeles region may be partially accommodated by east-west crustal extension. SCEC advances are being effectively communicated to professionals, students and the public through a very active education and outreach program.

NSF funded three new earthquake engineering research centers (EERCs) in October 1997. Representing a new generation of such institutions, these recently funded EERCs build on the experience of the first such center that was funded by NSF in 1986, the National Center for Earthquake Engineering Research (NCEER).

Each EERC is a consortium of several academic institutions involved in multidisciplinary team research, educational and outreach activities. 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 and emphasizes performance-based design in its research and educational programs. The Mid-America Earthquake Center (MAE) is headquartered at the University of Illinois at Champaign-Urbana and focuses on hazards in the Central and Eastern U.S. and emphasizes research related to critical facilities. The Multi-disciplinary Center for Earthquake Engineering Research (MCEER), which is the successor to NCEER, has its headquarters at the State University of New York at Buffalo and emphasizes research related to advanced technologies that are applicable to earthquake problems throughout the U.S.

The EERCs are combining research across the disciplines of the earth sciences, earthquake engineering, and the social sciences. And in order to meet the need for future professionals and assure continuing U.S. leadership in the field, they are educating hundreds of undergraduate and graduate students in the latest analytical, computational and experimental techniques. Additionally, even though it is early in their tenure, the EERCs have established major partnerships with industry, government, and foreign research organizations, which should also help advance earthquake hazard reduction in the nation in the years ahead.

The three EERCs have developed significant collaborative efforts in their research, educational and outreach programs. And they are developing similar ties to SCEC.

Post-Earthquake Investigations

Actual earthquake events provide a wealth of knowledge relevant to earthquake hazard mitigation. Areas struck by such events represent natural laboratories, offering unusual opportunities to learn vital lessons about earthquake impacts and to test models and techniques derived from analytical, computational and experimental studies. For this reason, NSF continues to support post-disaster investigations, often in conjunction with the Earthquake Engineering Research Institute. The post-earthquake investigations involve quick-response teams of researchers visiting impacted sites to collect information that remains available only up to the time that full-scale community restoration and reconstruction commence. The events investigated with NSF support since the last NEHRP reauthorization hearing include the tsunami that followed an earthquake in Papua New Guinea on July 17, 1998, the aftershocks following the earthquake in northwestern Pennsylvania on September 25, 1998, and the earthquake that struck Columbia on January 25, 1999.

The catastrophic Papua New Guinea tsunami resulted in an official death toll of over 2,000, making it one of the deadliest such events this century. The NSF- funded team of four researchers, which included geophysicists and engineers, spent a week in Papua New Guinea to perform a survey of the devastation in order to obtain sufficient data to model the event and determine the potential for such an event striking the U.S. coast. Upon completion of their work, the team briefed Papua New Guinea authorities, made recommendations for tsunami hazard mitigation, and addressed local hospital staff and high schools regarding tsunami warning signs and appropriate response actions.

Additional data on the tsunami were collected by a follow up team. Further work will continue to model the source and determine the potential for future tsunamis from the same subduction zone. One of the goals of this continuing work is to more clearly define the tsunami risk to the shorelines of the United States.

Aftershocks from the September 25, 1998, magnitude 5.2 Pymatuning earthquake, named for a nearby reservoir in a northwestern corner of Pennsylvania, were investigated by means of the IRIS portable seismometer array. Earthquakes of this size can be very destructive if centered at a shallow depth under a populated area. Seismicity is much lower in the eastern U.S. than in the West, but the relatively large population and the vulnerability of buildings and infrastructure counteract the benefits of lower seismicity. This vulnerability is compounded by our lack of understanding as to why earthquakes occur in the eastern U.S., which is a relatively stable tectonic plate interior. These factors point out the difficulty in estimating the seismic hazard, which is very real, in the eastern half of the U.S.

A multi-disciplinary team of six researchers carried out the post-disaster investigation of the Colombia earthquake, which caused a total of over 600 deaths in the cities of Armenia and Pereira. This team, which spent a week in Colombia gathering data on the disaster, was assembled by the Earthquake Engineering Research Institute through its "Learning from Earthquakes" project, which is funded by NSF. The focus of the investigation was on the geotechnical aspects of the event, including soil characteristics and strong ground motion features; structural aspects, including damage to various types of buildings; the performance of lifelines, including electric, water and telecommunications systems; and socioeconomic aspects, including casualty patterns and emergency response.

The Colombia earthquake team is preparing a final report on the implications of this event for earthquake hazard reduction and research, which will include recommendations for follow up research. A preliminary report is available to the public on the Web.

Collaborative Earthquake Research

As indicated by the above discussion, earthquakes are a global hazard. For this reason, many countries find collaborative research and the sharing of information essential in meeting this challenge; the U.S. is no exception. Similar to 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. Let me briefly mention some recent developments with regards to NSF's efforts to enable U.S. earthquake researchers to collaborate with their Japanese counterparts.

In 1993, the US/Japan Common Agenda for Cooperation in Global Perspective was established by President Clinton and the Prime Minister of Japan to facilitate cooperation in addressing pressing global problems, including natural hazards. In 1998, a new joint earthquake research program, called the US/Japan Cooperative Research in Urban Earthquake Disaster Mitigation, emerged out of this broad agreement. Under this five-year program, NSF provides funding for U.S. researchers, while collaborating Japanese researchers are being supported principally by the Japanese Ministry of Education, Science, Sports and Culture.

NSF has made fourteen awards under the program thus far, and others will be made over the next four years. The current set of projects is multidisciplinary, and has a significant educational component. Numerous research topics are being studied during this early phase of the program. They include, for example, studies of the effects of near-field ground motions, earthquake resistant design for lifelines and foundations, performance-based design, perceptions of earthquake impacts and loss-reduction preferences of citizens, and disaster mitigation for urban transportation systems. These projects involve significant interaction between U.S. and Japanese researchers and are enabling researchers from both countries to accomplish goals together that they could not accomplish separately.

Information Network

The NEHRP agencies, along with academic institutions, professional organizations and many other types of organizations, continue to engage in and support a variety of information dissemination and technology transfer activities, including workshops, information clearinghouses, and educational programs for practitioners. The plethora of information providers offer the promise of meeting the critical need for the timely distribution of seismic risk information to potential users throughout the nation. However, this also presents the challenge of developing better ways to coordinate the activities of these groups and of leveraging their scarce resources so that they will be more effective as a totality.

A new mechanism has been recently established with NSF and FEMA support to further coordination between seismic information providers. This mechanism is an umbrella organization called the Earthquake Information Providers Group (EqIP), which has been made possible because of the development of new electronic technologies. EqIP is comprised of thirty organizations that attempt to disseminate seismic information to the research community, practitioners, policy makers and the public in a more coordinated fashion. During its two-year existence, EqIP participants have exchanged ideas and technical information and implemented collaborative projects. Also, a web site called EQNET has been created to link the individual web sites of the various participant organizations. Thus EqIP has positioned itself to enhance the cooperation between earthquake information providers and thereby offer better information services to the nation and help further earthquake hazard reduction.

Mr. Chairman, this completes my remarks. I will be happy to answer any questions that the Subcommittee might have about NSF's participation in NEHRP.