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Achieving the Grand Challenge: A Research Plan for NEES

BASIS FOR PLANNING

In formulating a research plan for NEES, the committee was guided by the vision that earthquake disasters ultimately can be prevented. However, this cannot be achieved immediately. Therefore the committee has chosen to focus on a series of progressive research needs to mitigate the effects of earthquakes. Cumulatively, and over the next two to three decades, the complete vision can become a reality. To provide strategic direction, objectives were established by the committee for coordinated and integrated progress in a number of interrelated areas. These include (but are not limited to) the following:

- Lower-cost but higher-resolution techniques for the identification of earthquake hazards,
- New construction materials and design techniques (e.g., performance-based seismic design) for earthquake-tolerant facilities,
- Lower-cost techniques and materials for retrofitting existing facilities that have unacceptably high seismic risk,
- Automated tools for the injury prediction and emergency response needs of an affected community following an earthquake,
- Validation of models for loss-estimation for insurance, land planning, and emergency response needs, and
- Demonstration tools to better communicate earthquake risk and potential preventative actions to the general public, students, and government officials.

Objectives of NEES Research

- Lower cost techniques and materials
- Higher resolution analysis
- Increased validation of design
- Enhanced visualization and communication of effects

To accomplish this, the committee developed a research plan for the seven topical areas discussed in Chapter 2 of this report. The plan offers short-term (fewer than 5 years), medium-term (5 to 10 years), and long-term (10+ years) goals for addressing the challenges presented by seismology, tsunamis, geotechnical engineering, buildings, lifelines, risk assessment, and public policy. However, these are not stand-alone issues to be resolved on a narrow, discipline-oriented basis. NEES offers the earthquake engineering research community the opportunity to simulate complex problems of seismic excitation and system response and to couple the results with their social, economic, and political implications through multidisciplinary collaboration with the social and policy sciences. The knowledge gained from these interdisciplinary efforts can underpin an entirely new generation of analytical and predictive tools for improving building and lifeline performance, loss estimation, emergency preparedness and response, and risk assessment and management.

These new tools will support the two types of investments in earthquake hazard mitigation that are needed to prevent disasters. The first is the relatively modest but sustained investments that must be made for seismically resistant new buildings, lifelines, and communities. These investments are more often incurred for informing and educating decision makers than for the technology per se—in many cases actions to address seismicity cost little more to implement than actions taken without considering seismic vulnerability. The second category consists of the larger investments necessary to increase the resistance of existing buildings, lifelines, and communities. Often, because of cost, only the most critical vulnerabilities can be addressed, but when major retrofits are planned for other reasons, adequate seismic resistance often can be obtained for only modest additional cost.

THE RESEARCH PLAN FOR NEES

The committee did not interpret its charge to develop a research plan that could only be accomplished through NEES. The committee has identified what it believes to be the significant issues in earthquake engineering and the research that will be needed to address them over the next several years. Although the NEES equipment will undoubtedly facilitate heretofore impractical or impossible experiments and make possible new lines of research, the committee believes that it is the connectivity and multidisciplinary cooperation embodied in NEES that will most benefit earthquake engineering research. Research proposals to address specific problems through NEES should demonstrate the connections with geoscience on one end and the potential benefits of loss reduction and disaster mitigation on the other. At the same time, potential investigators should be expected to take a multidisciplinary approach to the problem and to demonstrate how the results will be shared broadly throughout the earthquake engineering community. This will require the active collaboration of earth scientists, engineers, social and policy scientists, and education and communication specialists.

The committee's research plan anticipates that all research should have as an underlying objective the development of innovative new approaches that will lead to the construction and retrofit of safe, economical facilities, lifelines, and communities that perform acceptably during earthquakes. This research will be in critical areas such as foundation systems, structural and nonstructural building components and systems, and site treatment approaches. Research conducted through NEES should foster ancillary breakthrough technologies such as new imaging tools and site and condition-assessment tools that can be used rapidly and economically to identify and evaluate site hazards or to reveal hidden flaws in structural components. Particularly needed is information that can be used as input for the emerging performance-based approach to the seismic design of constructed facilities and lifelines.

NEES will also play an important role in illustrating the effects of preventive measures such as zoning practices, building code modifications, and other loss mitigation strategies. For example, to avert a catastrophic tsunami loss in a coastal community, NEES research could provide local government with a series of practical options, such as

- Requiring structures to resist the wave impact
- Constructing an offshore deflection structure

- Modifying existing zoning and land use within the run-up area
- Undertaking a community education and awareness program.

Similarly, it is crucial to proactively increase capabilities for preparedness and emergency response, including more advanced simulation, instrumentation, and communication capabilities. Finally, education and the dissemination of policy information are key to creating public awareness and achieving policy objectives, and the dissemination component of the research should provide the necessary simulations, demonstrations, and curricular materials for this effort.

All of these efforts will require multidisciplinary collaboration between the scientists and engineers who will develop and test new theories on earthquakes, earthquake damage, and its mitigation, and the social and political scientists who will use the science and technology that will come from NEES to develop better risk assessment tools, loss estimation models, and communication and teaching strategies to help enact and implement more enlightened policies on earthquake loss mitigation.

The remainder of this chapter describes the committee's stakeholder involvement process, research needs within the seven topical areas, the expected benefits of research in these areas, and a business plan that integrates the needs, interests, and abilities of government, academia, and industry.

STAKEHOLDER INVOLVEMENT IN DEVELOPING THE RESEARCH PLAN

Since its inception, NEES has been envisioned as an inclusionary process that would address the needs and expectations of myriad stakeholders for earthquake engineering research. A specific objective of the committee was "…to articulate a dynamic, stakeholder-inclusive process for determining research needs for NEES and for changing the paradigm for earthquake engineering research."

This process began with the selection of the committee members who themselves represent, and further interact with, a broad range of stakeholders—graduate students, current and former professors and federal research managers, earth scientists, engineers, and an information specialist who represent practitioners and researchers. Committee members are deeply involved in the activities of the major organizations of the earthquake risk reduction community such as the Earthquake Engineering Research Institute, Seismological Society of America, and the American Society of Civil Engineers. Many have had leading roles in the National Earthquake Hazards Reduction Program since its inception in 1978, and they personally participate in the major national and international conferences on earthquake risk reduction.

To gain further insight into the needs of the stakeholder community, during its deliberations, the committee interacted with:

- leaders of the National Science Foundation's Division of Civil and Mechanical Systems
- the directors of the three NSF Earthquake Engineering Research Centers
- leaders of the NEES Consortium Development group, the System Integration group, and the NEES equipment sites
- leaders from industry and professional practice representative of the end users of NEES research results;

- researchers working on advanced sensing and information technologies, which will be exploited by NEES, and on collaborative efforts, which will exemplify NEES

The committee meeting agendas are included in Appendix D and identify specific individuals with whom the committee interacted in its data-gathering sessions. In addition to this direct outreach, the committee initiated an electronic mailbox from September 1 through October 18, 2002 to solicit input from individuals with whom the committee could not interact directly. The mailbox format entailed the posting of the committee's Statement of Task to a National Academies' website and requesting comments. The results of the electronic forum are summarized in Appendix E.

GOALS FOR RESEARCH

Seismology

A fundamental challenge to earthquake engineering is predicting the level and variability of strong ground motion from future earthquakes. Improving this predictive ability requires a better understanding of the earthquake source, the effects of the propagation path on the seismic waves, and basin and near-surface site effects. Seismologists, geologists, and engineers base their understanding on a knowledge of the dynamics of earthquake fault rupture, the three-dimensional elastic and energy-dissipation properties (anelastic structure) of the earth's crust, modeled nonlinearities that occur in the shallowest parts of the earth's crust during strong earthquakes, and the complex interactions between structures and the seismic wavefield.

Challenge

Predicting the level and variability of strong ground motion from future earthquakes requires a combination of improved observations and large-scale simulation; simply extrapolating attenuation relations to larger magnitude earthquakes will not suffice

Short-Term Goals

- Develop ground motion simulations from scenario earthquakes as input for engineering design.
- Integrate seismic ground motion excitation with the dynamic coupling of the soil in soil-foundation-structure interaction studies.
- Incorporate the effects of the spatial variation of ground motion into the design of large structures or lifelines.

Medium-Term Goals

- Map the three-dimensional velocity and attenuation structure of the earth's crust in major earthquake-threatened urban areas for ground motion modeling.

- Based on seismic observations, develop stochastic descriptions of the crustal heterogeneity in order to model ground motion at frequencies of greatest engineering interest.
- Develop measures of ground motion intensity that better predict the damage potential of strong ground motions.

Long-Term Goals

- Adopt simulation-based seismograms based on a properly validated fundamental understanding of the physics of earthquakes, wave propagation, and soil behavior, for performance-based design.
- Perform fully coupled soil-foundation-structure interaction analysis based on a fundamental understanding of the physics of soil nonlinearity.

Tsunamis

Tsunamis are generated by seismic fault displacements of the seafloor, landslides triggered by earthquakes, volcanic eruptions, or explosions. All of these generation mechanisms involve a displacement of the ocean boundary, either at the seafloor, at the shoreline, or at the water surface. Tsunamis can be generated in many locations, including oceans, harbors, lakes, reservoirs, and rivers. The run-up and inundation associated with tsunamis causes loss of life, destruction, and economic losses. Coastal areas, which are often preferred sites for residences, industry, and ports, are vulnerable to seismically generated sea waves from near and distant sources.

Challenge

A complete numerical simulation of tsunami generation, propagation, and coastal effects should be developed to provide a real-time description of tsunamis at the coastline for use with warning, evacuation, engineering, and mitigation strategies.

Short-Term Goals

- Investigate the run-up of both breaking and large, nonbreaking nonlinear transient translatory long waves at the shoreline.
- Answer questions related to the resonant excitation of harbors and embayments by tsunamis.
- Determine how nearshore bathymetric features control the focusing and defocusing of breaking and near-breaking nonlinear waves.
- Study the propagation of waves generated by aerial, partially aerial, and submarine landslides in offshore, onshore, and alongshore directions and the associated run-up.
- Develop a better understanding of transient sediment transport in the direction of, and orthogonal to, the direction of wave propagation of transient translatory long waves.

- Quantify the impact forces on structures owing to objects (e.g., cars, trees, and poles) transported by tsunami-like waves as well as the forces imposed by the wave and the run-up tongue on coastal structures.
- Determine the effect of tsunamis on individual buildings and groups of buildings.
- Work with the National Tsunami Hazard Mitigation Program, a three agency/five state partnership led by the National Oceanic and Atmospheric Administration (NOAA) to define research needs, so the NEES program can best support NOAA's mission realizing that NOAA is responsible for the Nation's tsunami warning system.

Medium-Term Goals

- Verify and validate the numerical models used for defining inundation limits for design and planning purposes in tsunami-prone areas-for example, the West Coast of the United States (including Alaska), Puerto Rico and Hawaii.
- Work with the geotechnical community and centrifuge facilities to study the mechanics of aerial, partially aerial, and submarine landslides.

Long-Term Goals

- Develop comprehensive, interactive scenario simulations that integrate the physical aspects of the problem—tsunami generation, propagation, run-up, and structure interactions—with societal issues, such as the transmission of warnings to the public, evacuation, environmental impacts, rescue tactics, and short-term and long-term recovery strategies.

Geotechnical Engineering

Subsurface soils are one of the primary factors affecting the performance of constructed facilities and lifelines during earthquakes. Yet these soils are typically the most variable and least controlled and understood of all materials in the built environment. As historical earthquakes have repeatedly borne out, greater damage occurs in areas of weaker soil, and significant losses are often associated with soil amplification and soil-related failures such as liquefaction, landslides and slope failures, fault displacement/offsets, and seismically induced instability of geotechnical structures (e.g., earthen dams, embankments, waste fills). It is instructive and encouraging to note that recent experience shows that proper engineering procedures, especially ground improvement, can mitigate earthquake-related damage and in reduce losses. Although great strides have been made in the past two decades to improve predictive capabilities and seismic engineering design practices, there remains an urgent need for improved modeling procedures and predictive tools, more powerful site-characterization techniques, and more quantitative guidelines for soil-improvement measures.

Challenge

Improved modeling procedures and predictive tools are needed along with more powerful site-characterization techniques, and more quantitative guidelines for soil-improvement measures.

Short-Term Goals

- Improve understanding of soil-foundation-structure interaction due to seismic shaking.
- Develop a better understanding of how local soil conditions modify seismic shaking and how these conditions can be identified and designed or zoned for, especially in regions that contain deep, soft soil deposits that can amplify ground motions.
- Improve in situ testing of soil properties to achieve a three-dimensional understanding of soil and site conditions and a quantification of parameters that directly relate to the engineering performance of soils.
- Develop detailed and curated databases on the performance and soil characteristics of sites subjected to strong earthquakes (i.e., liquefied and nonliquefied free field areas, improved zones, and buildings, structures, and lifelines where soil failure or amplification contributed to damage).

Medium-Term Goals

- Develop new ground-improvement technologies, as well as more quantitative guidelines for existing ground-modification and foundation-retrofitting practices.
- Improve the ability to predict liquefaction-related deformations and responses of level and gently sloping ground and their effects on facilities and lifelines.
- Improve prediction of ground rupture patterns and structural interactions along faults.
- Improve geotechnical modeling procedures, both physical and numerical, and develop parameters that can be used for performance-based seismic engineering analyses.
- Validate methods for strengthening waste containment facilities, reinforcing slopes, and identifying potentially hazardous landslide areas
- Expand and validate estimating tools for liquefaction triggering and permanent deformation so that they consider the influence of foundation and structural elements on the sequence, timing, and location of liquefaction and resulting deformations

Long Term-Goals

- Predict earthquake-induced deformations and the response of natural slopes and earthen structures such as dams, dikes, levees, waste containment facilities, highways, and bridge approaches, with an emphasis on post-liquefaction-related deformations and failure phenomena.
- Produce three-dimensional, real-time simulations and visualization of soil, foundation, and structure deformations under conditions of liquefaction, soil amplification, or fault offset.
- Develop simplified procedures for use by practicing engineers based on a comprehensive understanding of the seismic behavior of the site-structure system.

Buildings

Damage to buildings in recent earthquakes illustrates that despite advances in the design and construction of seismically resistant buildings, a significant increase in the knowledge and understanding of building performance is needed to ensure people's safety and to limit economic losses during earthquakes. This will require an understanding of variations in building types nationally as well as the variation in the adoption and enforcement of local building codes to address earthquake hazards. Performance assessments of the complete structural system rather than just individual components are of particular interest. Predicting the performance under extreme earthquake loads of existing buildings with little seismic resistance, of structures retrofitted to current standards, and newly built structures continues to be a major challenge to structural engineers. This is particularly true when deformations are large and do not follow conventional linear deformation theory.

Challenge

There is a need to predict and improve the performance of existing buildings without seismic resistance, retrofitted buildings, and newly built structures when they are subjected to the extreme loads imposed by earthquakes.

Short-Term Goals

- Develop analytical models that can predict the seismic performance of existing buildings.
- Develop repair and retrofit technologies for existing high-risk structural systems such as unreinforced masonry buildings, concrete wall tilt-up industrial buildings, and many pre-1975 structures, including wood-framed houses, apartments, and commercial buildings.
- Develop retrofit strategies for historical buildings and structures that do not sacrifice historical integrity for seismic resistance.

Medium-Term Goals

- Validate the behavior of buildings having smart materials and structural systems. Perform analyses to fully illustrate the ability of smart technologies to achieve various performance objectives and evaluate their benefits and costs.
- Develop a curated data repository that contains information on experimental models, and test results for structural components, nonstructural components, and foundations.

Long-Term Goals

- Using a suite of integrated sensors, obtain diagnostic information on the condition of both structural and nonstructural components.
- Implement practical and economical smart structural systems.

- Make performance-based seismic design the standard of practice for the design of new buildings and the renovation of existing buildings. Buildings will be rated and designed for specific performance levels under various levels of earthquake input.

Lifelines

The mitigation of earthquake hazards for lifeline infrastructures presents a number of major problems, primarily because of the vast inventory of facilities and their broad spatial distribution. Lifelines are typically more vulnerable than conventional facilities to earthquake hazards, because there is less opportunity to avoid these hazards through prudent site selection or site improvement. Although much has been done since the San Fernando earthquake of 1971 to increase our understanding of lifeline vulnerability to earthquake hazards, to improve the engineering and construction of new or replacement facilities, and to retrofit existing facilities, much remains to be done, especially in seismic areas of the United States outside California.

Challenge

Technologies must be developed to protect the vast inventory of lifeline facilities (complex transportation and utility infrastructure, which includes highways, railroads, ports, airports, electric power transmission and distribution, communications, gas and liquid fuel pipelines and distribution systems, and water and sewage systems) despite their wide spatial distribution and interdependencies.

Short-Term Goals

- Develop analytical models that can predict the seismic performance of existing lifeline systems.
- Improve the seismic resistance of porcelain insulators.
- Mitigate damage to rigid bus bars as a result of differential displacement of heavy equipment components.

Medium-Term Goals

- Develop performance-based design requirements that can guide the economical improvement of the nation’s vast network of lifelines and facilities.
- Develop a fuller understanding of the impacts of complex infrastructure system failures on our social, economic, and political institutions.
- Improve our ability to predict liquefaction-related deformations and responses of level and gently sloping ground, and their effects on facilities and lifelines.
- Improve the ability to predict and characterize liquefaction-induced ground movements at bridge abutments (river crossings).
- Improve methods for assessment of liquefaction and liquefaction-induced ground movements.
- Develop ground-improvement strategies for liquefiable marine deposits.
- Determine postbuckling compressive strain limits for pipe.

- Improve methods for analyzing strain localization in pipe resulting from upheaval buckling.

Long-Term Goals

- Improve characterization of soil-pipe interaction and validate with full-scale testing for various types of ground deformation.
- Predict earthquake-induced deformations and the response natural slopes and earthen structures such as dams, dikes, levees, waste containment facilities, highways, and bridge approaches, with an emphasis on post-liquefaction-related deformations and failure phenomena.

Risk Assessment

The challenge in communicating risk is having the tools to adequately assess and convey hazard, exposure, vulnerability, and loss in a clear and quantitative manner to a nontechnical audience. Although damaging earthquakes are rare events in any particular community, their impact has the potential to change that community forever. Many people (citizens, business owners, government officials, elected representatives) are totally unaware of their potential exposure to a damaging earthquake or, if aware, of how devastating the consequences could be. Risk assessment and its widespread dissemination are a vital component of earthquake disaster prevention.

Challenge

Decision makers should be given information to reduce risk exposure and improved loss estimation and risk mitigation alternatives and tools that enable them to make better decisions to reduce risk than are currently possible.

Short-Term Goals

- Plan with FEMA's Natural Hazard Loss Estimation Methodology (HAZUS) and private-sector risk assessors for NEES contributions to improved risk-assessment technologies.
- Review loss models, including direct and indirect losses, to identify gaps and define research needs.
- Develop improved decision-support and risk-management models and tools for use in policy and financial decisions.

Medium-Term Goals

- Develop improved structural performance and vulnerability models and data for important building and lifeline types for use in risk assessments.
- Develop improved site hazard data and models for risk assessments.
- Develop improved models and data for building and infrastructure inventories.

- Develop simulation and visualization models and tools for consequence analysis and risk assessments for individual structures.
- Develop regional simulation and visualization models and tools for consequence analysis and risk assessment to study the interactions of buildings, lifelines, society, and economies.
- Develop improved cost models for existing and new seismically resistant buildings and lifelines.
- Develop advanced loss estimation models exploiting NEES capabilities.

Long–Term Goals

- Expand performance and vulnerability models and data to exploit advancing knowledge and innovative materials and systems.
- Incorporate advancing knowledge from site hazard models and data.
- Advance simulation and visualization techniques as user needs evolve and technical capabilities improve.
- Continually update cost and loss estimation models to incorporate new knowledge and experience.

Public Policy

Unless NEES research results are adopted into public law, local ordinance, or building, fire, and zoning codes, earthquake disaster reduction efforts are unlikely to progress fast enough to truly prevent disasters. One of the major measures of NEES long term success will be the maintenance of earthquake hazard mitigation as a public and governmental priority. The timely adoption of policy measures will be the path to the committee's vision of earthquake disaster prevention.

Challenge

The general public, local governments, and legislative bodies must raise their awareness and acceptance of earthquake hazard mitigation.

Short-Term Goals

- Increase the awareness of earthquakes and earthquake hazard mitigation across the spectrum of society: government officials, business leaders, private citizens, and students.
- Generate sufficient public support for the adoption and enforcement of current building codes in all communities that have more than a 1 percent per year risk of a damaging earthquake.
- Generate sufficient public support for structural retrofit programs for high-risk structures in all earthquake-prone communities.
- Persuade public opinion that seismically hazardous structures should be prominently labeled as such.

Medium-Term Goals

- Generate cost-effective techniques to retrofit existing structures to resist damage.
- Provide validated, quantitative loss-estimation methods that are not only specific to a local area but also can be generalized to a regional scale.
- Require performance-based design for all structures occupied by more than 100 people.
- Generate sufficient political support to fund predisaster mitigation grants.
- Generate sufficient public opinion that many communities begin to undertake coordinated, community-wide programs to reduce their earthquake vulnerability.
- Develop statistically reliable estimates of earthquake probability and scenario-based damage.

Long-Term Goals

- Provide information to support programs requiring retrofit or phase out of all structures at risk of collapse in earthquakes above a predetermined magnitude.
- Reduce the risk of damage in structures constructed after 2010 to a small fraction of that for then existing structures.
- Provide information to support programs requiring structural reinforcement or replacement of all public buildings that have excessive risks of earthquake damage.

EXPECTED BENEFITS OF THE NEES RESEARCH PLAN

Seismology

NEES research in engineering seismology will result in more accurate and reliable knowledge of earthquake ground motion in seismic regions. Knowledge of the anticipated ground motion is necessary in order to determine the inertial forces that a structure must withstand during an earthquake. Predicting the ground motion to which structures will be exposed during their lifetimes is a crucial first step in designing earthquake-resistant facilities and retrofitting existing structures.

Tsunamis

Tsunami simulation models developed through NEES research will serve as the real-time element of a nationwide tsunami warning system and will be helpful in the design of tsunami-resistant structures and facilities and the development of mitigation strategies. Some of the investigations, such as the scour and structural studies related to wave-induced impact forces, will ultimately be used to produce engineering design manuals for tsunami-resistant structures.

Geotechnical Engineering

There are many potential benefits from NEES research efforts in geotechnical engineering. A better understanding of slope and soil deformation and liquefaction under earthquake loadings will lead to improved methods for soil treatment to improve its performance. There are multiple benefits from this area alone—namely, better performance of foundations, buildings, and lifelines, which will result in reduced losses. At the same time, increased knowledge will permit the design of more economical foundations and earthen structures tailored to the specifics of geology and seismic risk. NEES will also support the development of advanced numerical models that should lead to more robust analyses and reduced testing costs.

Buildings

The results of the research produced by NEES will increase our understanding of the behavior of buildings and their structural and nonstructural systems and how to simulate their response to seismic loads on both structure and system levels. This understanding will include not only new construction but also the many at-risk structural types requiring retrofit. Historical structures pose particular challenges in this regard, because care must be taken so they do not lose their historical significance in the process of retrofitting them. NEES will provide the validation testing necessary for design engineers to incorporate new materials and smart systems into structures both new and old.

Lifelines

Because it has much in common with the preceding issues, NEES research into lifeline behavior will build on the work done in engineering seismology, geotechnical engineering, and buildings and structures. For example, high-reaction testing frames could be used in the bending test of pipe to calibrate finite element models, liquefaction studies would be applicable to lifelines as well as foundations; and shake-table studies could test many systems and components at full and reduced scales. This research would lead to mitigation strategies for the huge inventory of vulnerable capital assets throughout the country as well as standards for the development of performance-based design criteria. The ultimate outcome will be improved seismic performance at lower life-cycle cost.

Risk Assessment

Risk assessment provides the quantitative information needed to guide rational investments that will reduce the vulnerability both of new and existing facilities. Presentation of the results of risk assessments that are based on improved loss estimation models in an appropriate decision-support framework can assist facility owners and government officials in evaluating risks and selecting alternatives that are consistent with their tolerance for risk exposure and available resources. NEES research will support the loss estimation and risk assessment activities that are critical to insure the implementation of cost-effective mitigation strategies.

Public Policy

NEES research will provide key information and tools to facilitate policy decisions based on hazard and risk exposure for a specific region or the entire nation. Risk management strategies will need to consider the ability of a community to enact proposed legislation in the face of financial constraints and recognition of land use rights. Simulation models based on NEES research on analyzing losses from scenario earthquakes and policy options for mitigating them will help legislators assess the effectiveness and benefits of proposed policies. Success in this area will facilitate more rapid and widespread implementation of proactive seismic mitigation policy.

IMPLEMENTING THE RESEARCH PLAN

The NEES Business Model

The committee discussed at some length the potential for NEES to become self-sustaining as a research and testing enterprise in earthquake engineering. Initially, and for the foreseeable future, the committee foresees the majority of funding being provided by NSF and other NEHRP agencies. This position is based on historical funding patterns for earthquake engineering research in the United States. However, as the program matures, the NEES Consortium becomes firmly established as an operating entity, and a track record is established for producing results needed by the private sector, support from the private sector and other governmental agencies should be pursued. The committee believes that there are many potential relationships to involve individual NEES sites and other investigators in the research plan. They may help attract needed funding and provide for the effective involvement of the entire earthquake community of educators, graduate students, researchers, and practitioners, as well as for the effective transfer of research results to practice. These relationships include the following:

- The planned NEHRP research program
- Cooperative research with federal and other public agencies
- Cooperative research with industry and industry associations
- Serving as a user facility for academic researchers
- Serving as a user facility for industry researchers
- Collaborative research with international research institutions that have similar and complementary experimental facilities
- Serving as an information source for researchers, practitioners, educators, government, industry, and the media.

The list of potential projects that can be undertaken by NEES to implement the research plan is extensive. NSF should make every effort possible to encourage the involvement of multiple equipment sites and many investigators in these research efforts. NSF should also take advantage of the research capabilities available through the existing earthquake engineering research centers as well as small teams or single investigators at universities and other laboratories by actively encouraging their participation. The unprecedented connectivity provided by NEES can bring these seemingly disparate elements to bear on major issues. NSF should strongly consider formulating future solicitations to encourage proposals that address these broad, multidisciplinary challenges.

- Single Investigator Grantees (SIGs) are the traditional heart of NSF's programs. Their unsolicited proposals are the means for support of unexpected good ideas for the advancement of knowledge and practice. NEES needs to be open to SIGs for its own health (to involve the best research and researchers) and for the public benefits of making the NEES resource available to exploit unplanned inspirations.
- Potential investigators, including SIGs, need continuing good access to information on NEES programs, capabilities, and accessibility. Accessibility to NEES facilities should be easy, economical, and timely. Investigators and students using a NEES facility should find good living and working conditions for both on-site and remote access. Both technical and human support will be needed. It is particularly important that participating investigators become an integral part of the intellectual community of the NEES.
- To ensure that the research is driven for practical applications, cooperation and partnerships with federal agencies should be a critical component of NEES. This can have particular benefit when considering the transfer potential of earthquake disaster procedures for similar emergency situations involving national security.
- To increase cost-effectiveness and promote collaboration, there should also be an effort to involve other large laboratories and other laboratory equipment that are not NEES equipment sites..
- NEES needs an intellectual environment celebrating and recognizing diverse contributions to work done in or with NEES. For instance, sharing best practices in instrumentation can greatly advance many investigators' work and reduce the slope of the learning curve for graduate students.
- Standard software applications will be required that can be used systemwide for data acquisition, processing, storage, display, and Web-based networking among participants and users of data. Ideally, these software applications should be developed using commercial off-the-shelf software platforms. Widely used software applications have the advantages of being upwardly compatible and supported by operating system managers, as well as offering new releases of their own applications. The development of custom applications by the NEES system integrator or individual laboratories will probably have high maintenance requirements. For the efficient use of funds, the goal should be to minimize software maintenance.
- Protection of intellectual property rights will be a challenge for NEES. Commercial sponsors will need to protect their intellectual property rights to profit from their investments in research, and clear guidance in this area is important to encourage effective marketing and exploitation of knowledge gained in NEES.

The development and funding of a NEES research program provides the opportunity to identify and address significant goals that will reduce the consequences of earthquakes on the nation's citizens.

A Stakeholder Inclusive Process for Guiding NEES Research

It is essential that the talents of the earthquake community be used both for the continuing evolution of these program topics and in prioritizing them. However, the type of progress promised by NEES cannot rely on the serendipitous submittal of appropriate proposals. The committee believes that unlike traditional NSF research initiatives, strategic guidance must be provided from within NSF itself. It is for this reason that the committee believes that a strategic advisory group to engage the entire community of interest for earthquake engineering research should be established. The mission of this group would be to assess, on a periodic basis, the state of progress in resolving critical issues and to outline promising areas for NEES to pursue as research results become available. These periodic assessments would provide a framework for identifying and prioritizing new research directions and also establish performance objectives for new lines of inquiry.

Some of the responsibilities and authority of the strategic advisory group might include the following:

- To recommend to NSF the short- and long-term goals of the program and relative funding levels
- To recommend to NSF topical goals, prioritization of these goals, and allocation of funds to achieve them
- To assist in identifying opportunities for the implementation of NEES results.

Securing Society Against Catastrophic Earthquake Losses

The Earthquake Engineering Research Institute (EERI), with an NSF grant, recently released a 20-year research and technology transfer plan for earthquake engineering (EERI, 2003). The plan, *Securing Society Against Catastrophic Earthquake Losses*, identifies basic and applied research that can substantially reduce losses from earthquakes and also help protect the built environment from the devastating effects of disasters caused by wind, flood, fire, and terrorist bombings. The plan builds on the accomplishments of the past 25 years of research in earthquake engineering, while taking advantage of breakthrough opportunities that are presented by advances in computing, information processing, engineering, and understanding human behavior in earthquakes. The EERI plan is not presented simply as a research vision but as a vision for an entire society shocked into awareness of some of the catastrophic risks that it faces. The plan states that earthquakes are catastrophic risks that need to be addressed in a more concerted way than they have been to date and that doing so will have enormous benefits for society as a whole.

The recommended distribution of costs among the various activities of the EERI research and action plan for fiscal years 2004 through 2023 are summarized in Figure 5.1. Although the estimated annual cost of $325 million to carry out this research and action plan is significant, it amounts to less than one-thirtieth of the annualized U.S. earthquake risk of $10 billion estimated by EERI and 14 per cent of the $4.4 billion annual loss calculated by FEMA. The total cost of $6.5 billion over the twenty-year program life is less than one-fifteenth of the potential cost of a single catastrophic earthquake ($100 billion).

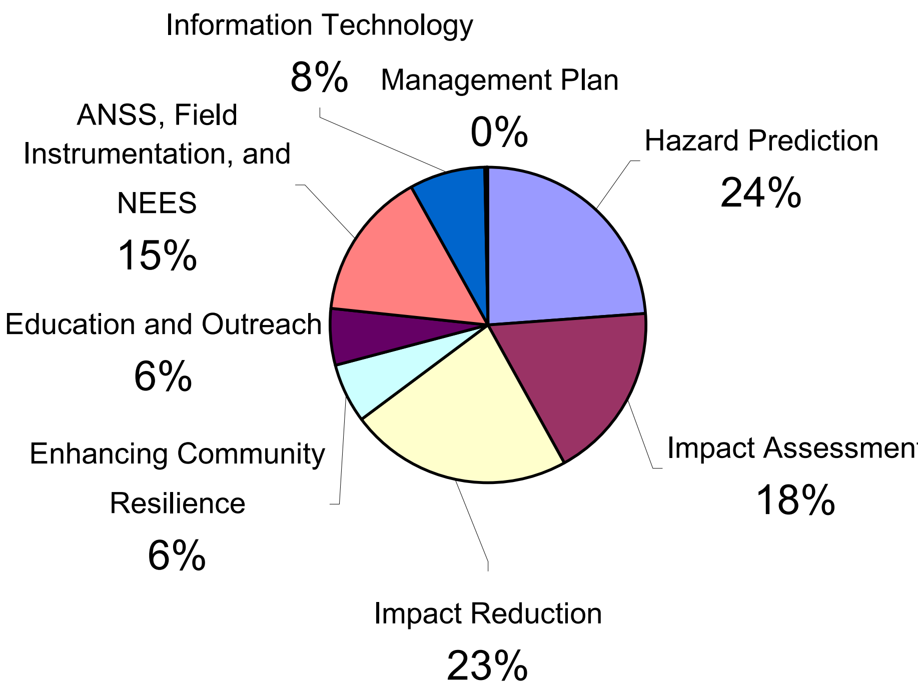

FIGURE 5.1 Distribution of costs in the EERI research and Action plan budget for fiscal years 2004 TO 2023. SOURCE: EERI, 2003

Funding for NEES

On the matter of an appropriate level of funding for NEES, the committee offers several observations. First and foremost, the committee notes that the various NEES equipment sites will provide the core of NEES research activities. In addition to the testing equipment, this extensive research infrastructure will include many educators, researchers, graduate students, and technicians. Fully developing the capabilities of NEES will require that at each equipment site, the various players involved in a project function as a team and learn to work together to produce the best results possible. To do this will require that the equipment and the research team be continuously engaged in testing and experimentation—and have adequate resources to do so. It is the committee's carefully considered opinion that high quality research cannot be produced consistently if the equipment is not fully utilized so that the research staff can learn its capabilities and limitations and maximize their skills. Second, NEESgrid is more than just a systems integration project. It encompasses the co-development of new collaboration technologies and data standards and is being constructed on information technologies that are new and evolving rapidly. Although there may be some expectation that the foundational information technologies are similar to the fixed investments of the NEES equipment sites, they are not the same. Once NEESgrid, the initial system integration project is complete in 2004, a substantial foundation will be in place, but many problem-specific applications and capabilities will still need to be developed. Dedicated funding will be required to continue the development of the information technology components of NEES and to realize the research goals.

The committee is aware that there will never be enough money to fund everything that is important and regardless of how much funding is provided, there will always be more needs than resources to address them. For this reason, an effort was made to develop a convergent solution. The committee identified the research needs and then, based on its collective experience, determined the basic amount necessary to operate and maintain a research program using the NEES infrastructure investment. The collective experience of the committee members suggests that the annual operating costs of large engineering research machines are on the order of fifty per cent of the capital cost. In the case of NEES, this would be somewhat more than $40 million. The committee did not try to determine the level of investment in NEES research that was justified by the expected benefits; the long term payoff is so great as to justify almost any investment level. The EERI research plan recommends funding in the amount of $325 million for fiscal years (FY) FY2004 through FY2008. This amount is for the entire earthquake program and includes earthquake prediction, engineering research, technology transfer, and education. Approximately $240 million, or an additional $48 million per year for the next 5 years, would be applicable to research that could be conducted through NEES and the committee selected this as a baseline amount. This amount is of the same magnitude as the committee's empirical estimate, and on this basis, the committee believes that NSF should be prepared to provide this general level of funding ($40 to $50 million per year) as a minimum to support the NEES initiative. This amount is consistent with an earlier report on earthquake engineering research and testing capabilities in the United States (EERI, 1995). In light of this, the committee strongly recommends that NSF initiate whatever actions are necessary to ensure that this level of additional funding is available so that NEES can meet the grand challenge of ultimately preventing earthquake disasters. Should more funding be made available, the pace of research could be accelerated and the benefits of that research realized sooner.

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