

Preventing Earthquake Disasters: The Grand Challenge in Earthquake Engineering

A Research Agenda for the Network for Earthquake Engineering Simulation (NEES)

Committee to Develop a Long-Term Research
Agenda for the Network for Earthquake Engineering Simulation (NEES)

Board on Infrastructure and the Constructed Environment

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
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THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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This study was supported by the National Science Foundation under Grant No. 0135915. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations that provided support for the project.

International Standard Book Number 0-309-0XXXX-X
Library of Congress Control Number 97-XXXXX

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Preface

BACKGROUND

The George E. Brown, Jr., Network for Earthquake Engineering Simulation (NEES) is a collaboratory for integrated experimentation, computation, theory, databases, and model-based simulation in earthquake engineering research and education intended to improve the seismic design and performance of the U.S. civil and mechanical infrastructure. Administered by the National Science Foundation (NSF), NEES is mandated to be operational by September 30, 2004.

The NEES collaboratory will include 16 geographically distributed, shared-use, next-generation earthquake engineering experimental research equipment installations, with teleobservation and teleoperation capabilities networked through the Internet. (Appendix A in this report provides information about the equipment installations.) In addition to providing access for telepresence at the NEES equipment sites, the network will use cutting-edge tools to link high-performance computational and data-storage facilities, including a curated repository for experimental and analytical earthquake engineering data. The network will also provide distributed physical and numerical simulation capabilities and resources for the visualization of experimental and computational data. Through NEES, the earthquake engineering community will use advanced experimental capabilities to test and validate analytical and computerized numerical models that are more complex and comprehensive than ever. When the results of the NEES effort are adopted into building codes and incorporated into existing and new buildings and infrastructure, they will improve the seismic design and performance of our nation's civil and mechanical systems. The NEES equipment includes new and upgraded shake tables, centrifuges, an enlarged tsunami wave basin, large-scale laboratory experimentation systems, and field experimentation and monitoring installations.

NEES is envisioned as a new paradigm for earthquake engineering research. To take advantage of NEES's unique capabilities, NSF requested the assistance of the National Research Council (NRC) in developing a long-term research agenda. The purpose of the NRC effort was both to develop a process for identifying research needs and to consult stakeholders in framing the important questions to be addressed through NEES. The long-term research agenda will guide the next generation of earthquake engineering research and shape the conduct of a program of great national and international importance.

THE INVOLVEMENT OF THE NATIONAL RESEARCH COUNCIL

In response to the request to review the NEES program and to offer recommendations for conducting a long-term research program, the NRC assembled an independent panel of experts, the Committee to Develop a Long-Term Research Agenda for the Network for Earthquake Engineering Simulation (NEES), under the auspices of the Board on Infrastructure and the Constructed Environment. The 14 members of the committee have expertise in seismology, earthquake engineering, theoretical structural dynamics, computer modeling and simulation, experimental methods for structures, soil dynamics, coastal engineering, behavior of lifeline infrastructure, group facilitation and consensus building, technology applications for distance

learning and remote collaboration, research management, risk assessment, and loss estimation. Members are involved in the major U.S. organizations of the earthquake risk-reduction community (e.g., the Seismological Society of America, the Earthquake Engineering Research Institute, the American Society of Civil Engineers, and the Association of Engineering Geologists). They have had leading roles in the National Earthquake Hazards Reduction Program since its inception in 1978 and attend the major national and international conferences on earthquake risk reduction. (Biographical information about the committee members is provided in Appendix B.)

THE STATEMENT OF TASK

The committee was asked to perform the following tasks:

1. Articulate a dynamic, stakeholder-inclusive process for determining research needs that is capable of utilizing the multi-modal research capability embodied by NEES and assess how NEES might fundamentally change the paradigm for earthquake engineering research.
2. Identify the principal issues in earthquake engineering (e.g., structural [connections, soil/structure interaction, lifeline dynamics, tsunami effects, materials, reinforced concrete, steel, masonry, wood], appropriate investigative techniques), and possible synergies arising from an integrated research approach that incorporates analysis, computational modeling, simulation, and physical testing.
3. Assess and comment on the possible roles of information and communication technologies for collaborative on-site and remote research, the sharing of data (including the need for standardization in data reporting), metadata, and simulation codes, and identify additional research resources that are not currently available.
4. Produce a long-term (at least 10 years) research plan based on the short-, intermediate-, and long-term goals developed through the research needs process; identify general programs to achieve them, the estimated costs and benefits, and a business model for the involvement of industry, government (at all levels), and academia in the program.

Task 1 is addressed in Chapter 5 and by Recommendation 4. In addition, stakeholder involvement in the committee's process for determining research needs is described in Chapter 5 and Appendix E. Tasks 2 and 3 are addressed in Chapters 2 and 4, respectively. Task 4, the research plan and business model, are presented in Chapter 5.

ORGANIZATION OF THIS REPORT

Chapter 1 provides a brief overview of the threat posed by earthquakes, the contributions of earthquake engineering research to reducing that risk, a brief description of NEES, and the role anticipated for NEES in future research. Chapter 2 discusses research issues in the seven topical areas (seismology, tsunamis, geotechnical engineering, buildings, lifelines, risk assessment, and public policy) that the committee believes are key to achieving the prevention of earthquake disasters. Chapter 3 discusses the role of NEES in grand challenge research, outlines several grand challenge research ideas, and presents several examples of how NEES equipment sites could be configured to carry out collaborative research proposals. Chapter 4 discusses the

potential impact and possible roles of new information and communications technologies with respect to earthquake engineering research and how these new and evolving technologies will affect NEES. Chapter 4 also considers the issues associated with teleobservation and teleparticipation in research, as well as sharing, archiving, and mining data. Chapter 5 presents the committee's research plan. Chapter 6 presents the committee's overall conclusions and specific recommendations on the role of NSF and NEES in preventing earthquake disasters.

ACKNOWLEDGEMENTS

This report represents the efforts of many individuals and organizations. On behalf of the Committee to Develop a Long-Term Research Agenda for the Network for Earthquake Engineering Simulation (NEES), I would like to acknowledge and thank all the engineers and scientists who made presentations to us both in person and via teleconferencing as well as the organizations that supported them. These presentations were informative, understandable, and concise.

I want to express my appreciation to members of the committee for candidly expressing their opinions and views. Composed of engineers and scientists interested in earthquake engineering research generally and in the Network for Earthquake Engineering Simulation specifically, the committee truly represents a cross section of the earthquake engineering profession. The members made substantial contributions to this report and gave unselfishly of their time to ensure its timely completion.

Lastly, I want to thank Richard G. Little and other members of the National Research Council staff for their hard work and conscientious efforts on behalf of the committee.

William. F. Marcuson III

Chairman

Committee to Develop a Long-Term Research Agenda

for the Network for Earthquake Engineering Simulation (NEES)

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Jill H. Andrews, California Institute of Technology,
Eddie Bernard, NOAA-Pacific Marine Environmental Laboratory,
Susan Cutter, University of South Carolina,
William J. Hall, University of Illinois at Urbana-Champaign,
James O. Jirsa, The University of Texas at Austin,
Chris D. Poland, Degenkolb Engineers,
Robert V. Whitman, Massachusetts Institute of Technology, and
Mary Lou Zoback, U.S. Geological Survey.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Clarence Allen, California Institute of Technology. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Acronyms

ANSS	Advanced National Seismic System
AG	AccessGrid
CISN	California Integrated Seismic Network
COSMOS	Consortium of Organizations for Strong-Motion Observation Systems
EERI	Earthquake Engineering Research Institute
FEMA	Federal Emergency Management Agency
GIS	geographic information system
IPR	intellectual property rights
IRIS	Incorporated Research Institutions for Seismology
IT	information technology
MAST	multiaxial subassemblage Testing
MBS	model-based simulation
MEMS	microelectromechanical system(s)
MRE	major research equipment
MUST-SIM	multiaxial full-scale substructures testing and simulation
NEES	Network for Earthquake Engineering Simulation
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSF	National Science Foundation
PBSD	performance-based seismic design
PEER	Pacific Earthquake Engineering Research Center
PITAC	President's Information Technology Advisory Committee
SCEC	Southern California Earthquake Center
SFSI	soil–foundation–structure interaction
SIG	single investigator grantee
SUNY	State University of New York
UCLA	University of California, Los Angeles