Report of the
Eighth Planning Meeting of NEES/E-Defense
Collaborative Research on Earthquake Engineering

Held in Miki, Hyogo, Japan
September 17–18, 2010

Convened by
Hyogo Earthquake Engineering Research Center (NIED)
NEES Operation Center (NEEScomm)
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These research programs aim to identify and reduce the risks from major earthquakes to life safety and to the economy by including research in a wide variety of disciplines including structural and geotechnical engineering, geology/seismology, lifelines, transportation, architecture, economics, risk management, and public policy.

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ISSN 1547-0587X
Report of the Eighth Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering

held at

Hyogo Earthquake Engineering Research Center of the National Research Institute for Earth Science and Disaster Prevention and Hyogo Prefectural Emergency Management and Training Center in Miki, Hyogo, Japan

during

September 17 and 18, 2010

convened by

Hyogo Earthquake Engineering Research Center, NIED and NEES Operation Center, NEEScomm

September 2010
Preface

Following an agreement between the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the U.S. National Science Foundation (NSF), the First Planning Meeting for NEES/E-Defense Collaboration on Earthquake Engineering Research was held in 2004. This meeting laid the groundwork for a joint research program related to improving understanding of seismic effects and thereby reducing the seismic vulnerability of buildings and civil infrastructural systems. The emphasis of the program is to conduct experimental research using the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) equipment sites and the three-dimensional full-scale earthquake testing facility (E-Defense) of the National Research Institute for Earth Science and Disaster Prevention (NIED). To formalize the collaboration, two Memorandums of Understanding (MOU) were executed, one between NSF and MEXT in September 2005 and one between the NEES Consortium Inc. (NEES Inc.) and NIED in July 2005. In order to continue the collaboration to the “second phase” that began in 2010, the latter MOU was updated in May 2010 by the NEES Operation Center (NEEScomm) and NIED.

Before updating the MOU between NEEScomm and NIED, two meetings were held to prepare for the second-phase collaboration. The First Planning Meeting for the Second Phase of the NEES/E-Defense was held in January 2009 to discuss the need for and benefits of continued NEES/E-Defense collaboration. This meeting identified a number of important topics of mutual interest to the U.S. and Japan that would benefit from continued research collaboration and sharing of NEES and E-Defense resources. In addition, a follow-up meeting to discuss details of the next phase of collaboration was recommended. In response, the Seventh Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering was convened in September 2009 to review the efforts and accomplishments of the past four and one half years and to discuss specific opportunities for continued and hopefully stronger collaboration for the coming years.

Following these two meetings, the Eighth Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering was convened during September 17 and 18, 2010. The meeting was attended by leading researchers from both countries as well as representatives from NSF, MEXT and other government agencies. In the plenary and breakout sessions of the meeting, thirty-two participants from the U.S. and forty participants from Japan discussed NEES/E-Defense collaboration in the second phase that started in 2010.

This report contains a summary of the Eighth Planning Meeting along with the recommendations and resolutions reached by the participants. The appendices contain the list of participants, the meeting agenda and schedule, the materials presented during the plenary sessions, and summaries of the recommendations developed by individual breakout sessions where participants discussed in detail various scientific and engineering challenges that should be addressed during the second phase of the NEES/E-Defense collaboration.
Acknowledgements

The Joint Technical Coordinating Committee for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering would like to thank the meeting participants for making the meeting a success by generously sharing their time, experience and ideas. The participants agree that the cordial and harmonious atmosphere at the meeting, and the candid and thoroughgoing discussions signal an outstanding future for NEES/E-Defense Collaboration.

The meeting was held at the Hyogo Earthquake Engineering Research Center, NIED, and at the Hyogo Prefectural Emergency Management and Training Center in Miki, Hyogo, Japan. The participants would like to express their gratitude to NIED and Hyogo Prefecture for opening their facilities for the meeting.

The Hyogo Earthquake Engineering Research Center hosted the meeting, including making local arrangements. The support of the center’s staff contributed greatly to the success of the meeting.

Many participants from the U.S. and Japan attended the meeting using their own travel funds. Travel support for a significant number of the U.S. participants was made possible by the U.S. National Science Foundation though Award No. CMMI-0958774 (Coordinating Workshops for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering (Phase 2). This support is greatly appreciated.

The findings, recommendations and conclusions contained in this report are the consensus views of the meeting participants, and do not necessarily reflect opinions of any one individual or the policy or views of the National Science Foundation, the National Earthquake Hazards Reduction Program, the NEES Operation Center or other organization in the U.S., nor of the Ministry of Education, Culture, Sports, Science and Technology, National Research Institute for Earth Science and Disaster Prevention or the Hyogo Earthquake Engineering Research Center in Japan.
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Summary and Resolutions

Background

The U.S.-Japan Joint High Level Committee (JHLC) on Science and Technology emphasized, in the Joint Communiqué of the Ninth Meeting, which the two countries should cooperate on multiple aspects of earthquake-related research. During the first Japan-U.S. Workshop on Science and Technology for a Secure and Safe Society held in February 2004, the Japan Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the U.S. National Science Foundation (NSF) agreed to discuss opportunities for cooperative activities related to earthquake research, citing NEES/E-Defense collaboration as a specific example of such cooperation.

To realize the cooperation, the First Planning Meeting for NEES/E-Defense Collaboration was held in 2004, and the basic scheme for a five-year joint research was established. Two thrust areas, i.e., steel buildings and bridges, were given highest priority for the joint research. To formalize the collaboration, two Memorandums of Understanding (MOU) were executed, one between NSF and MEXT in September 2005 and one between NEES Consortium Inc. (NEES Inc.) and the National Research Institute for Earth Science and Disaster Prevention (NIED) in July 2005.

In order to examine the need and benefits of continuing NEES/E-Defense collaboration into a “second phase,” the First Planning Meeting for the Second Phase of the NEES/E-Defense was held in January 2009 at NSF in Arlington, Virginia, U.S.A. The participants unanimously recommended the second-phase collaboration be carried out, and recommended a number of high priority research needs to be discussed in future planning meetings. In response, the Seventh NEES/E-Defense Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering was held in September 2009, reviewing the efforts and accomplishments made during the past four years and discussing possibility of collaboration beyond March 2010 in which the first-phase NEES/E-Defense collaborative research expired. To secure the implementation of the “second-phase” collaboration, NEES Operation Center (NEEScomm) and NIED updated their MOU in 2010.

Issues discussed

This Eighth Planning Meeting was organized to discuss in detail continuing collaboration in the second phase beyond March 2010. The following six topics were chosen as the targets of collaboration based on the discussions during the First Planning Meeting for the Second Phase (January 2009) and the Seventh Planning Meeting (September 2009).

(a) High performance R/C structures,
(b) Base-isolation and vibration control,
(c) Geotechnical engineering,
(d) Energy facilities,
(e) Numerical simulation, and
(f) Monitoring.

In this two-day meeting, progress on both the Japanese and U.S. sides related to the above topics since the last meeting were reported, and six breakout sessions related to these topics were organized to facilitate in-depth discussion on the type and organization of collaboration between the U.S. and Japan. The agenda of the meeting and the list of participants are shown in Appendices I and II.
materials presented during the two plenary sessions are presented in Appendices III and IV, while the detailed breakout session discussions are summarized in Appendix V.

**Resolutions and Recommendations**

Based on the presentations, discussions and deliberations, the participants of the Eighth Planning Meeting of the NEES/E-Defense Collaborative Research on Earthquake Engineering formulated and unanimously adopted the following specific resolutions and recommendations:

(1) Collaborative research should proceed without delay. The participants reaffirmed that the six topics chosen for NEES/E-Defense collaboration are very timely, and that collaboration will accelerate scientific and engineering advances of great importance to the U.S. and Japan. The proposed collaborative research on these topics leverages important intellectual, laboratory, computational and other resources available in each country.

(2) Task Groups working on each topic should meet/communicate frequently. Annual planning meetings to review overall progress and to refine overall strategic goals are essential. However, the success of research programs on the topics selected depends on extensive discussion and detailed planning. To achieve the desired benefit of collaboration, and maximize the outcomes from the research, frequent meetings (2-4 times a year) are required for planning and preparation of test programs and for interpreting and analyzing results. To facilitate planning, funding is needed to allow Task Group members to carry out necessary exploratory design studies and analyses. Adequate resources are needed to enable a broad range of participants to participate in these activities.

(3) Payload opportunities should be sought more comprehensively to maximize the benefit of large-scale tests. The large-scale tests utilizing E-Defense or NEES facilities provide a useful test bed for others to explore their own research objectives or to contribute to the specific goals of the NEES/E-Defense tests. Payload projects might range from the addition of sensors for health monitoring and nonstructural elements and contents to assess their seismic performance, to the addition of extra test days to study modified structures. Such payload projects need to be sought out and incorporated early in the test planning process.

(4) Exchange of human resources, particularly young researchers and graduate students, should be promoted to strengthen the conditions needed for a vigorous continuing program of US-Japan collaboration.

(5) Funding agencies are encouraged to provide needed resources.

**Closure**

The participants believe that the Eighth Planning Meeting of the NEES/E-Defense Collaborative Research Program on Earthquake Engineering was highly successful, and that NSF and MEXT should be congratulated for providing the earthquake engineering community with cutting-edge tools that will substantially accelerate progress towards the important goals of earthquake loss reduction. The attendees agree that the cordial and harmonious atmosphere at the meeting and the candid and thoroughgoing discussions signal an outstanding future for NEES/E-Defense Collaboration.
The participants also appreciate and heartily thank the Hyogo Earthquake Engineering Research Center for its efforts in hosting this successful meeting.
# Appendix I: List of Participants

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<th>First Name</th>
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<tr>
<td>Tracy</td>
<td>Becker</td>
<td>University of California, Berkeley</td>
<td>PhD Student</td>
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<tr>
<td>JoAnn</td>
<td>Browning</td>
<td>University of Kansas</td>
<td>Professor</td>
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<td>Ian</td>
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<td>Professor</td>
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<tr>
<td>Shin-Ho</td>
<td>Chao</td>
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<td>Nhan</td>
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<td>PhD Student</td>
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<td>Shideh</td>
<td>Dashti</td>
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<td>Gregory</td>
<td>Deierlein</td>
<td>Stanford University</td>
<td>Professor</td>
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<td>Shirley</td>
<td>Dyke</td>
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<td>Professor</td>
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<tr>
<td>Catherine</td>
<td>French</td>
<td>University of Minnesota</td>
<td>Professor</td>
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<td>Wassim</td>
<td>Ghannoum</td>
<td>University of Texas at Austin</td>
<td>Assistant Professor</td>
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<tr>
<td>John</td>
<td>Hayes</td>
<td>National Institute of Standards and Technology</td>
<td>Director, National Earthquake Hazard Reduction Program</td>
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<tr>
<td>Peter</td>
<td>Lee</td>
<td>Skidmore Owens Merrill LLP</td>
<td>Associate Director</td>
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<tr>
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<td>Assistant Professor</td>
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<td>Mahin</td>
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<td>Director, Pacific Earthquake Engineering Research Center and Professor</td>
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<td>Manos</td>
<td>Maragakis</td>
<td>University of Nevada, Reno</td>
<td>Professor and Dean of Engineering</td>
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<td>Morgan</td>
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<td>Khalid</td>
<td>Mosalam</td>
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<td>Professor and Vice Chair</td>
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<td>Mosqueda</td>
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<td>Farzad</td>
<td>Naeim</td>
<td>John A. Martin &amp; Associates, Inc.</td>
<td>Vice President and General Counsel</td>
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<td>Narutoshi</td>
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<td>Gordon</td>
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<td>Kentaro</td>
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## LIST OF PARTICIPANTS (CONTINUED)

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<td>Keiichi</td>
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<td>Susumu</td>
<td>Yasuda</td>
<td>Tokyo Denki University</td>
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## Appendix II: Agenda of Program

### Friday, September 17, 2010

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<th>Time</th>
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<td>10:00</td>
<td><em>Gather at Crowne Plaza Hotel Lobby and Ride on Limousine</em></td>
<td>Crowne Plaza Hotel</td>
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<tr>
<td>10:45</td>
<td><em>Arrive at Hyogo Prefectural Training Center Registration</em></td>
<td>Hyogo Prefectural Training Center</td>
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<tr>
<td>11:00-11:20</td>
<td><strong>Opening Session</strong></td>
<td>Auditorium</td>
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<td></td>
<td>Chair: Stephen Mahin (UC Berkeley) &amp; Masayoshi Nakashima (NIED)</td>
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<td></td>
<td><strong>Welcoming Remarks</strong></td>
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<td></td>
<td>- Yoshinori Suzuki (MEXT)</td>
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<td>- Joy Pauschke (NSF)</td>
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<td></td>
<td>- Jack Hayes (NIST)</td>
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<td>- Yoshimitsu Okada (NIED)</td>
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<td>- Julio Ramirez (Purdue University)</td>
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<tr>
<td>11:20-12:15</td>
<td><strong>Plenary Session 1</strong></td>
<td>Auditorium</td>
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<td>Chair: Farzad Naeim (JAMA) &amp; Kazuhiko Kawashima (Tokyo Tech)</td>
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<td>(11:20-12:15)</td>
<td><strong>NEHRP Research Goals</strong> (15 minutes)</td>
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<td>- Jack Hayes (NIST)</td>
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<td><strong>Overview of NEES Research Program</strong> (15 minutes)</td>
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<tr>
<td></td>
<td>- Joy Pauschke (NSF)</td>
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<tr>
<td></td>
<td><strong>Introduction to NEEScomm</strong> (15 minutes)</td>
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<td></td>
<td>- Julio Ramirez (Purdue University)</td>
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<td></td>
<td><strong>Summary of 7th NEES/E-Defense Planning Meeting</strong> (10 minutes)</td>
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<tr>
<td></td>
<td>- Masayoshi Nakashima (NIED)</td>
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<td></td>
<td>- Stephen Mahin (University of California, Berkeley)</td>
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<tr>
<td>(12:15-13:00)</td>
<td><strong>Outline of NIED Research Projects</strong> (10 minutes)</td>
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<tr>
<td></td>
<td>- Taizo Matsumori (NIED)</td>
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<td></td>
<td><strong>High Performance R/C Structures</strong> (25 minutes)</td>
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<td></td>
<td>- Takuya Nagae (NIED)</td>
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<td></td>
<td><strong>Base-Isolation &amp; Vibration Control</strong> (10 minutes)</td>
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<td></td>
<td>- Eiji Sato (NIED), Taichiro Okazaki (NIED)</td>
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<tr>
<td>13:00-13:50</td>
<td><em>Lunch</em></td>
<td>Cafeteria</td>
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<tr>
<td>13:50-14:55</td>
<td><strong>Plenary Session 2</strong></td>
<td>Auditorium</td>
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<tr>
<td></td>
<td>Chair: Ian Buckle (Univ. of Nevada, Reno) &amp; Kohji Tokimatsu (Tokyo Tech)</td>
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<tr>
<td></td>
<td><strong>Geotechnical Engineering</strong> (20 minutes)</td>
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<td></td>
<td>- Kentaro Tabata (NIED)</td>
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<td></td>
<td><strong>Energy Facilities</strong> (10 minutes)</td>
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<td></td>
<td>- Izumi Nakamura (NIED)</td>
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<td></td>
<td><strong>Numerical Simulation</strong> (30 minutes)</td>
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<td></td>
<td>- Takuzo Yamashita (NIED)</td>
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<tr>
<td></td>
<td><strong>Monitoring &amp; Data Archival System</strong> (5 minutes)</td>
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<td></td>
<td>- Kentaro Tabata (NIED), Hisanobu Sakai (NIED)</td>
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<tr>
<td>14:55-15:00</td>
<td><em>Move to Breakout Session Rooms</em></td>
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<tr>
<td>15:00-16:20</td>
<td><strong>Breakout Sessions #1</strong></td>
<td></td>
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<tr>
<td>(a)</td>
<td><strong>Numerical simulation</strong></td>
<td>(a) Auditorium</td>
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<tr>
<td></td>
<td>Moderator: Gregory Deierlein (Stanford University)</td>
<td>(b) Lecture room 1</td>
</tr>
<tr>
<td></td>
<td>- Muneo Hori (ERI, University of Tokyo)</td>
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<tr>
<td>(b)</td>
<td><strong>Monitoring</strong></td>
<td>(c) Director room</td>
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<tr>
<td></td>
<td>Moderator: Shirley Dyke (Purdue University)</td>
<td>of E-Defense</td>
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<tr>
<td></td>
<td>- Akira Nishitani (Waseda University)</td>
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<tr>
<td>(c)</td>
<td><strong>JTCC Meeting</strong></td>
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<td></td>
<td>Moderator: Stephen Mahin (University of California, Berkeley)</td>
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<td></td>
<td>- Masayoshi Nakashima (NIED)</td>
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<tr>
<td>16:20</td>
<td><em>Leave Hyogo Prefectural Training Center for E-Defense by Limousine</em></td>
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</tbody>
</table>
16:25  Arrive at E-Defense
16:30-16:50  Introduction of Test on Isolated R/C Hospital Building (20minutes)
             Eiji Sato (NIED), Takahito Inoue (NIED)
17:00  Test Observation
17:30  Leave E-Defense for Crowne Plaza Hotel by Limousine
18:10  Arrive at Crowne Plaza Hotel
19:00-21:00  Banquet

Saturday, September 18, 2010

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>9:00</td>
<td>Gather at Crowne Plaza Hotel Lobby and Ride on Limousine</td>
<td>Crowne Plaza Hotel</td>
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<tr>
<td>9:45</td>
<td>Arrive at E-Defense</td>
<td>E-Defense</td>
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<tr>
<td>9:50-15:00</td>
<td>Breakout Sessions #2</td>
<td>(a) Meeting room 3</td>
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<tr>
<td></td>
<td>(a) High performance R/C structures</td>
<td>(b) Meeting room 2</td>
</tr>
<tr>
<td></td>
<td>Moderator: John Wallace (University of California, Los Angeles)</td>
<td>(c) Meeting room 1</td>
</tr>
<tr>
<td></td>
<td>Hitoshi Shiohara (University of Tokyo)</td>
<td>(d) Reception room</td>
</tr>
<tr>
<td></td>
<td>(b) Base isolation &amp; vibration control,</td>
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<td></td>
<td>Moderator: Keri Ryan (University of Nevada, Reno)</td>
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<td></td>
<td>Kouichi Kajiwara (NIED)</td>
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<td></td>
<td>(c) Geotechnical engineering</td>
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<td>Moderator: Nick Sitar (University of California, Berkeley)</td>
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<td></td>
<td>Ikuo Tohwhata (University of Tokyo)</td>
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<td></td>
<td>(d) Energy facilities</td>
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<td>Moderator: Khalid Mosalam (University of California, Berkeley)</td>
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<td></td>
<td>Tomohiro Ito (Osaka Prefecture University)</td>
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<td>(12:15-13:00)</td>
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<td>(14:00-14:45)</td>
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<td></td>
<td>Lunch</td>
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<tr>
<td></td>
<td>Summarize breakout sessions</td>
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<tr>
<td>14:45-15:00</td>
<td>Afternoon Break</td>
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<tr>
<td>15:00-16:00</td>
<td>Closing Session</td>
<td>Meeting room 3&amp;2</td>
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<tr>
<td></td>
<td>Chair: Julio Ramirez (Purdue University) &amp; Masayoshi Nakashima (NIED)</td>
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<tr>
<td>16:00</td>
<td>Leave E-Defense by Limousine</td>
<td>Shin-Kobe Station</td>
</tr>
<tr>
<td>16:40</td>
<td>Arrive at Shin-Kobe Station</td>
<td>Crowne Plaza Hotel</td>
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<tr>
<td>16:45</td>
<td>Arrive at Crowne Plaza Hotel</td>
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</tr>
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</table>
Appendix III: Plenary Session - Introduction
NEHRP Research Goals: Jack Hayes

Overview

- National program first authorized by U.S. Congress in 1978.
- Overall purpose: ‘... to reduce the risks of life and property from future earthquakes in the United States.’
- NEHRP has been re-authorized on 2 – 5 year cycles following formal U.S. Congressional hearings. New re-authorization now in process (HR 3620). Meanwhile, agencies continue their Program activities.
- Program has no authority to establish or enforce codes and regulations, or to conduct post-earthquake response and recovery operations.

Major Statutory NEHRP Activities

- Conduct interdisciplinary research on earthquakes and earthquake effects on communities, structures, buildings, homes, and lifelines. (NSF, USGS, NIST)
- Monitor earthquake activity and characterize hazard. (USGS)
- Develop earthquake-resistant design and construction practices. (NIST, FEMA)
- Develop and promote adoption of effective model building codes and practices for earthquake resilience. (FEMA, NIST)
- Public education on earthquake risks and mitigation. (All)

2005-2011 NEHRP Agency Budgets

<table>
<thead>
<tr>
<th>FY</th>
<th>FEMA</th>
<th>NIST</th>
<th>NSF</th>
<th>USGS</th>
<th>NEHRP Total</th>
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<td>2005</td>
<td>14.2</td>
<td>0.9</td>
<td>55.1</td>
<td>55.4</td>
<td>127.7</td>
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<tr>
<td>2006</td>
<td>9.5</td>
<td>0.9</td>
<td>51.8</td>
<td>64.4</td>
<td>118.7</td>
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<tr>
<td>2007</td>
<td>7.2</td>
<td>1.7</td>
<td>54.2</td>
<td>55.4</td>
<td>118.3</td>
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<tr>
<td>2008</td>
<td>6.1</td>
<td>1.7</td>
<td>53.6</td>
<td>58.1</td>
<td>118.9</td>
</tr>
<tr>
<td>2009</td>
<td>9.1</td>
<td>1.1</td>
<td>55.5</td>
<td>61.2</td>
<td>129.4</td>
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<tr>
<td>2010</td>
<td>8.0</td>
<td>1.1</td>
<td>55.1</td>
<td>63.3</td>
<td>131.3</td>
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</table>

<table>
<thead>
<tr>
<th>Requested Agency NEHRP Budgets (Million)</th>
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<tbody>
<tr>
<td>FY</td>
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<tr>
<td>2011</td>
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</tbody>
</table>
NEHRP Research Goals: Jack Hayes

NEHRP Strategic Plan

Outline
- Executive Summary
- Introduction - Background (History, Prior Accomplishments)
- Vision / Mission / Strategic Planning Principles
- Goals / Objectives / Outcomes
- Strategic Priorities
- Summary
- Appendices

A nation that is earthquake-resilient in public safety, economic strength, and national security.

This vision gives rise to the NEHRP Mission Statement (see next slide).

NEHRP Mission Statement

To develop, disseminate, and promote knowledge, tools, and practices for earthquake risk reduction – through coordinated, multi-disciplinary partnerships among the NEHRP agencies and their stakeholders – that improve the nation’s earthquake resilience in public safety, economic strength and national security.

Strategic Planning Principles

- Program impact through effective development and transfer of knowledge, tools, and practices
- Program revision – not reinvention
- Interagency coordination / cooperation / synergy
- Close partnerships with stakeholder communities
- Exploitation of ANSS, GSN, IRIS, NEES
- Multi-disciplinary approach
- Multi-hazard leveraging awareness
- Linkages with broader federal policies, plans, and priorities (e.g., SDR Grand Challenges for Disaster Reduction)
- Increased international cooperation

Adoption of nine Strategic Priorities that support Program goals and objectives

Goal A: Improve understanding of earthquake processes and impacts

Objective 1: Advance understanding of earthquake phenomena and generation processes

Objective 2: Advance understanding of earthquake effects on the built environment

Objective 3: Advance understanding of social, psychological, and economic factors linked to implementing risk reduction and mitigation strategies in the public and private sectors

Objective 4: Improve post-earthquake information management
**NEHRP Research Goals: Jack Hayes**

**NEHRP Strategic Plan**

**Goal B: Develop cost-effective measures to reduce earthquake impacts on individuals, the built environment, and society at large.**

- Objective 5: Assess earthquake hazards for research and practical application
- Objective 6: Develop advanced loss estimation and risk assessment tools
- Objective 7: Develop tools to improve the seismic performance of buildings and other structures
- Objective 8: Develop tools to improve the seismic performance of critical infrastructure

**Goal C: Improve the earthquake resilience of communities nationwide**

- Objective 9: Improve the accuracy, timeliness, and content of earthquake information products
- Objective 10: Develop comprehensive earthquake scenarios and risk assessments
- Objective 11: Support development of seismic standards and building codes and advocate their adoption and enforcement

---

**Goal C: Improve the earthquake resilience of communities nationwide (continued)**

- Objective 12: Promote the implementation of earthquake-resilient measures in professional practice and in private and public policies
- Objective 13: Increase public awareness of earthquake hazards and risks
- Objective 14: Develop the nation’s human resource base in earthquake safety fields

---

**Strategic Priorities**

Describes 2006 ICC examination of “gaps” & emphasizes 9 strategic priorities (presented in order of first association with goals and objectives):

- Fully implement Advanced National Seismic System (ANSS)
- Improve techniques for evaluating & rehabilitating existing buildings
- Further develop Performance-Based Seismic Design (PBSD)
- Increase consideration of socio-economic issues related to hazard mitigation implementation

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**Strategic Priorities (continued)**

- Develop a Post-Earthquake Information Management System (PEMS)
- Develop advanced risk mitigation technologies & practices
- Develop earthquake-resilient lifecycle components and systems
- Develop & conduct earthquake scenarios for effective earthquake risk mitigation
- Facilitate improved earthquake mitigation at state & local levels

---

**Thank You!**

www.nehrp.gov
Overview of NEES Research Program: Joy Pauschke

NEES Program at NSF

NEES Research Directions (1 of 2)

- Vision 2020: An Open Space Technology Workshop on the Future of Earthquake Engineering, St. Louis, Missouri, January 2010
  http://www.nsf.gov/awardsearch/showAward?doi=NSF100120

- US-Japan Workshop on Future Directions for Earthquake Engineering Research, Japan, March 2010
  http://www.nsf.gov/awardsearch/showAward?doi=NSF100120

- Coordinating Workshops for the NEES/E-Defense Collaborative Research Program in Earthquake Engineering (Phase 2)
  http://www.nsf.gov/awardsearch/showAward?doi=NSF100120

- Research Needs Emerging from the 2010 Haiti and Chile Earthquakes
  http://www.nsf.gov/awardsearch/showAward?doi=NSF100120

- Haiti Earthquake Workshop, September 20, 2010, at NSF
  - Workshop results to be posted at http://www.nsf.gov

NEES Research Directions (2 of 2)

- Tsunami Research Colloquium, Chapel Hill, NC, sponsored by DHS S&T, October 19-20, 2009
  http://hazardscenter.unc.edu/diem/News_Events.php

- Geotechnical Earthquake Engineering Research Colloquium, RPI, Sponsored by DHS S&T,
  Proceedings of the Geotechnical Engineering Workshop, Rensselaer Polytechnic Institute, July 29, 2009
  http://hazardscenter.unc.edu/diem/documents/DIEm geotech_proc_FINAL July09.pdf

NEES for the Engineering Community

NSF 10-071 Dear Colleague Letter
Future of Earthquake Engineering Research Infrastructure Support beyond FY 2014

- Fall 2010 – Spring 2012: Two studies underway
  - National Academy of Sciences, CUMB-10459, Fall 2010 Workshop
    - Grand Challenges in basic earthquake engineering research require a network of earthquake engineering experimental facilities and cyberinfrastructure
    - Researcher and cyberinfrastructure needed to address the Grand Challenges
    - Focus on an requirements, rather than reference to existing or anticipated specific facilities
    - Workshop report completed early 2011
  - Science and Technology Policy Institute, AST-1045173
    - Priorities and scenario for integrated experimental and cyber facilities needed to address the Grand Challenges in basic earthquake engineering research
    - Community input: https://xloci.doe/engforum
    - Study to be completed by spring 2012

- Fall 2012: NSF informs the earthquake engineering community of its plans beyond 2014 for multi-user earthquake engineering research infrastructure
New NSF/ENG Policy on Data Management Plan
(to be included in all Proposals ~Jan 2011)


Beginning in January 2011 (actual implementation data to be announced), a Data Management Plan (DMP) will be required for all new NSF proposals. FastLane will be updated to enable its upload as a separate Supplementary Document. Proposals that do not include the requisite DMP will be stopped from submission. Specific guidance will be included in an upcoming revision to the NSF Proposal & Award Policies & Procedures Guide. Please note, the Engineering Directorate (ENG) will have additional guidance for proposals submitted to ENG programs, http://nsf.gov/eng/general/ENG_DMP_Policy.pdf. Detailed instructions, including responses to Frequently Asked Questions will be provided at the time of implementation. In the meantime, questions and/or suggestions about this new requirement may be addressed to Dr. Maria K. Burka at mburka@nsf.gov.

Some NSF Funding Opportunities

- NEES Research (NEESR) – Under Revision for FY 2011
- NSF 10-609: Broadening Participation Research Initiation Grants in Engineering (BRIGE)
- NSF International Opportunities (planning, workshops, students, etc.)
Introduction to NEEScomm: Julio Ramirez

Outline
- NEEScomm Center
- NEES Collaboratory
- NEEShub Release 1
- NEEScomm Outreach

NEEScomm on September 2010
- Focused on enhancing network infrastructure and building community

NEES an Essential National Resource

NEES IMPACT
Reduce impact of earthquakes and tsunamis on society by supporting efforts to (a) improve Performance Based Design Procedures, evaluation methods & strengthening techniques; and (b) develop the next generation of researchers, educators, scientists and engineers

NEEShub (R.1 July 31, 2010)
Introduction to NEEScomm: Julio Ramirez
Tools and Resources

- Simulation tools
  - Run on NEEShub

Resources
- Reports, Papers, Ppoint

Facilitates research dissemination

Engaging Researchers and Practitioners

- Communications
  - NEEScomm monthly update

- NEES/PEER Annual Meeting
  - Sessions dedicated to NEEScomm activities
  - NEEScomm committee meetings

- Partnerships
  - Research: International MoUs (NIED & PARI in Japan)
  - Practitioner: EERI collaborative agreement

http://nees.org/
Summary

Second Planning Meeting
Phase 2 NEES/E-Defense Collaborative Earthquake Engineering Research Program

Held at E-Defense, September 18-19, 2006

Third Planning Meeting, E-Defense, Miki & Kobe, Japan September 17-18, 2010

First Planning Meeting*

- Discuss desirability of a second five-year phase of NEES/E-Defense Collaborative Research Program on Earthquake Engineering
- Identify high priority research topics of mutual interest to the US and Japan that:
  - Utilize the unique capabilities of the E-Defense and NEES facilities
  - Lead to major new discoveries, solve important scientific challenges and result in innovative and transformative approaches to earthquake loss reduction
  - Provide opportunities for solid collaboration and synergy

* For Phase 2

Observations from First Planning Meeting

Contemporary urban society in US and Japan
- Are recognized to be more vulnerable to earthquakes due to complex interaction and interdependency of engineered structures and systems
- Have higher expectations for safety and continuity of normal social, cultural and business operations

- US & Japanese research communities each working to address these issues
- NEES and E-Defense provide uniquely complementary tools to address engineering and science challenges.

Phase 2 Recommendations

By concentrating on different aspects of a common meta-theme, rapid progress possible

Enabling the Earthquake Resilient City
- Provides a strong framework for addressing all of the high priority topics identified
- Provides life safety, while minimizing damage and speeding recovery
- Many new and exciting engineering and scientific challenges addressed

Need research on:
- Building systems utilizing high performance and sustainable materials
- New protective systems and advanced technologies
- Lifelines
- Underground structures
- Includes:
  - Numerical and experimental simulation
  - Health monitoring and prognosis
  - Protecting contents and nonstructural components

Resolutions

Strong collaboration is desired among projects and disciplines to achieve overall goal of meta-theme

Recommended that
- "Theme Structures" be devised to focus efforts by different groups
- Joint Japan-US "capstone" experiments be considered

Implementation actions
- Joint Technical Coordinating Committee
  - Steve Martin, Berkeley
  - Parzad Naeimi, JAMA
  - Masayoshi Nakashima, E-Defense
  - Yoshimizu Okada, NIED
  - Julio Ramirez, Purdue
  - Yoshinori Suzuki, MEXT
- Technical Subcommittees on each major theme area
- Planning meetings needed to define needs and scope of work

Proceedings

Contains:
- White papers
- Plenary papers on past and possible future research
- Breakout session reports
- Workshop resolutions
- Participant list
- Agenda
Mechanism established for coordinating US side of program

NSF has funded four-year coordination effort
- Publicizing opportunities, activities and outcomes in conjunction with NEESCoMM and NSF
- Encouraging broad participation by various means, including:
  - Funding travel to meetings by investigators having a diversity of interests, gender, ethnicity and age, engineering practitioners, specialized experts, and students.
- Annual NEES/E-Defense planning and coordination meetings in Japan
- Periodic Technical Subcommittee Meetings in the US
- Technical support for managing theme structures
- Facilitate communications
  PI: Stephen Mahin

Opportunities

- Develop effective overall research and work plan for capstone tests being conducted on E-Defense
- Future planning meetings
  - NEESR solicitation
    - Full projects collaborating with Japanese counterparts on one of the four thrust areas
    - Payload projects
  - Sensors, monitoring and health assessment
  - Nonstructural issues
  - Computational Simulation

A Summary of Seventh NEES/E-Defense Planning Meeting

by Masayoshi Nakashima
E-Defense
National Research Center for Earth Science and Disaster Prevention (NIED)

NEES/E-Defense Collaboration Memorandum of Understanding (MOU)

MEXT & NSF (National Science Foundation):
Research Collaboration on Disaster Mitigation
NIED & NEES (J. Brown Jr. Network for Earthquake Engineering Simulation):
Collaboration on Joint Research Using NEES/E-Defense

MEXT-NEES: August 3, 2005
MEXT-NSF: Sept 13, 2005

A History of Planning and JTCC Meeting

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<tr>
<th>Planning Meetings</th>
<th>First</th>
<th>April 6 to 8, 2004 at Kobe</th>
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<tr>
<td>Second</td>
<td>July 12 to 13, 2004 at Washington DC</td>
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<td>Third</td>
<td>January 17, 2005 at E-Defense</td>
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<td>Fourth</td>
<td>August 2 to 3, 2005 at E-Defense</td>
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<td>Fifth</td>
<td>September 27 to 29, 2006 at E-Defense</td>
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<td>Sixth</td>
<td>September 28 to 30, 2007 at E-Defense</td>
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<tr>
<td>(First for Second Phase of NEES/E-Defense)</td>
<td>January 12 to 13, 2009 at Washington DC</td>
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<tr>
<td>Seventh</td>
<td>September 18 to 19, 2009 at E-Defense</td>
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<tr>
<td>Second</td>
<td>April 17, 2006 at San Francisco</td>
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<tr>
<td>Third</td>
<td>June 24, 2009 at Honolulu</td>
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Resolutions Adopted in First Joint Planning Meeting for Second Phase of NEES/E-Defense Collaborative Research
Washington DC, USA
January 11 to 12, 2009

Resilient City as a Common Meta-Theme

The three meta-themes discussed in the meeting, i.e., "Disaster Resilient Communities", "Preparing for the Big One", and "Low-Probability, High-Consequence Events" are linked in many ways. The fundamentals of the first meta-theme are the damage reduction and quick recovery. These require developments of new materials and technologies that would enhance the performance of various components that form the urban area. Methods to detect the damage quickly and systems that can be repaired (or re-built) with minimal interruption of life and business are also the important topics to consider. In the second meta-theme, developments of new materials and technologies are the key to the prevention of a downward spiral of deterioration. The third meta-theme has much in common with the preceding two in light of the specific scientific challenges to be pursued. Thus, it was agreed that the 'Resilient City' provided a mutually important goal upon which members of the US and Japanese earthquake engineering communities could work and that US-Japan collaboration would accelerate realization of this goal and leverage the resources available in both countries.
Summary of 7th NEES/E-Defense Planning Meeting: Masayoshi Nakashima and Stephen Mahin

**Seventh NEES/E-Defense Planning Meeting**

*32 participants from the US*
*29 participants from Japan*

**Agenda**

**September 17**
Overview, NEEScomm, Japanese Proposals, Test Observations,

**September 18**
Six Breakout Sessions, Plenary, Closure

Japanese Proposals for Phase II
Project (a) New Materials and Technologies
Project (b) Base-Isolation and Structural Control
Project (c) Lifelines and Geotech
Project (d) Energy Facilities
Project (e) Monitoring
Project (f) Numerical Shaking Table (Data Repository)

**Interaction Between “Resilient City” Approach and NIED EE Project**

**Resilient City**
- Buildings
- Nonstructural Elements
- Transportation Systems
- Lifelines & Geotech
- Computational Simulation
- Monitoring

**NIED EE Project**
- New Materials and Technologies
- Base-Isolation and Structural Control
- Geotechnical Engineering
- Energy Facilities
- Numerical Shaking Table
- Monitoring

**Resolutions**

Pages 6 – 8 of Report of the Seventh Joint Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering

- NEES/E-Defense Collaboration should continue without interruption into Phase.
- Projects (a) to (f) are suitable for NEES/E-Defense Collaboration.
- Theme structure concept is most preferable.
- Respective task teams should be established as soon as possible.
- Funding agencies are encouraged to provided needed resources.
Appendix IV: Plenary Session - Japanese Proposals
Outline of NIED Research Projects: Taizo Matsumori

Taizo Matsumori
National Research Institute for Earth Science and Disaster Prevention

Four Experimental Studies

- High Performance R/C Structures
- Geotechnical Engineering
- Base Isolation & Vibration Control
- Energy Facilities

Timetable of E-Defense Large-Scale Shaking Table Tests

Plan as of September 2009

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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Plan as of September 2010

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<th>Fiscal Year</th>
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Discussions in Breakout Sessions

Breakout Sessions from 3:00 PM until 4:20 PM on Friday, September 17
(a) Numerical Simulation (at Auditorium)
   Moderator: Gregory Deierlein
   Researcher: Hidetomo Kato
   Discussion: Use of numerical simulation for evaluating the performance of structures

(b) Monitoring (at Lecture room No. 1)
   Moderator: Shirley Dyke
   Researcher: Akinori Hayashi
   Discussion: Development of monitoring systems for structural health monitoring

Breakout Sessions from 9:40 AM until 2:45 PM on Saturday, September 18
(a) High Performance R/C Structures
   Moderator: John Wallace
   Researcher: Hidetomo Kato
   Discussion: Challenges in designing high performance R/C structures

(b) Base Isolation & Vibration Control
   Moderator: Kenji Ryo
   Researcher: Keiichiro Kijima
   Discussion: Innovations in base isolation and vibration control systems

Suggested issues to discuss:
1. Comments and suggestions to Japanese projects from the US
2. Research plans in the US and comments from Japan
3. Possible issues for collaboration
4. Complementary research strategies
High Performance R/C Structures: Takuya Nagae

The 2009 first day’s options

The 2009 second day’s discussion

San Francisco, 16 Oct.

Revisions after the second meeting:
(a) To make the test concept clearer;
   (i) Cb for the allowable stress design is set as 0.15 for both directions
   (ii) Walls become thinner and wider
   (iii) Beams connected to the walls become thinner
(b) To show and make the post-tensioned system more reasonable;
   (i) X frames become two bays of 7.2 m
   (ii) Internal frames in Y direction become weaker
High Performance R/C Structures: Takuya Nagae
High Performance R/C Structures: Takuya Nagae
Base-Isolation and Vibration Control: Eiji Sato and Taichiro Okazaki

Background and Motivation
- Increasing popularity of isolation systems following 1995 Kobe Earthquake
  - 2000 condominium, office, and hospital buildings, 9000 residential buildings constructed to date
- Characteristic frequency is 2 sec for earlier systems, 3 to 5 seconds for later systems. Consider horizontal motion only.
- Partial isolation (isolated floors, equipment isolation) is used frequently.
- Need to address vertical motions
  - Vertical motion exceeding 1G recorded from 2004 Chuetsu EQ
  - 3D isolation is becoming reality (planned for at least one project), but verification has not been performed.
  - Little verification data available for partial isolation.
- Concern for long-period ground motions
  - Limited verification
  - Elongating the characteristic period is not the solution for long-period ground motions — What is needed is absolute isolation.

Objectives
- Adjust characteristic period and damping to the ground motion → “Active (semi-active) isolation” (1), (2)
- “Absolute isolation” — Elongating the characteristic period is not enough (2)
- Address vertical motions (3)
- Validate cost-effective, high-performance solutions (e.g., floor isolation, equipment isolation) (2), (3)

Basic Concept
- Hybrid Systems employing TMD or AMD
- 3D Systems

Expected Outcomes
- Solutions against long-period motions
  - Isolation systems tuned/adjusted for various ground motions (both long and short-period motions)
- Solutions for 3D vibration
- Improvement of floor isolation systems

Impact on Society
- Collaboration with industry (Japan Society of Seismic Isolation, construction industry, device manufacturers) to develop guidelines
- Wider acceptance of isolation technology
- Active (semi-active) isolation systems for important structures and facilities
- Establish 3D limit states
- Benchmark for isolation systems applied to residential buildings
E-Defense Geotechnical Test Project

**Underground Structures in Urban Areas**

Kentaro Tabata
Senior Researcher
Hyogo Earthquake Engineering Research Center
National Research Institute for Earth Science and Disaster Prevention

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**Reviews of geotechnical projects at E-Defense**

- FY2005-06: Dai-Dai-Toku project years
  - Four tests performed = soil-pile-foundation interaction, liquefaction-induced lateral spreading phenomenon

<table>
<thead>
<tr>
<th>Test Date</th>
<th>Location</th>
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<tbody>
<tr>
<td>Feb 14-24, 2006</td>
<td>Non-liquefiable deposits</td>
</tr>
<tr>
<td>Mar 23, 2006</td>
<td>Sheet pile-type quay wall</td>
</tr>
<tr>
<td>Aug 22-25, 2005</td>
<td>Liquefiable deposits</td>
</tr>
<tr>
<td>Dec 15, 2006</td>
<td>Cartoon-type quay wall</td>
</tr>
</tbody>
</table>

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**E-Defense geotechnical testing**

- Through the two-year process, the E-Defense testing capability had been verified:
  - Reproduction of ground motion records on the table
  - Simulation of liquefaction and liquefaction-induced phenomena such as lateral spreading
  - Simulation of failures on structures (e.g., piles and caissons)
  - Preparation and installation of soil, structure models and sensors
- Two unique advantages of the E-Defense testing:
  - Large-scale model
    - Observe "more realistic" situations and phenomena
    - Record "more detailed" behavior placing more sensors
  - Performance to produce earthquake disaster
    - Obtain the case histories of an "artificial" disaster

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**"Resilient City" as a common meta-theme**

- Achieve a disaster resilient city:
  - Maintaining function of lifelines including supply of water and electricity, and transportation system during and even after a large earthquake
  - Recovering damaged function quickly
- To fulfill the above, define target structures for the E-Defense geotechnical test project:
  - Lifeline structures in focus = transportation systems in urban areas
  - Tunnels for subways, underground expressways...
  - Underground structures such as subway stations
  - Access structures to subway stations
  - Neighboring underground structures

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**Targets of the geotechnical research**

- In urban areas, widespread networks of buried, underground lifelines exist:
  - Technology innovations, effective usage of land, landscape preservation...
- Complex structures, complicated distribution of structures, structures placed into heterogeneous soil strata, deeper locations...
  - Behavior during earthquake?
  - Interaction between neighboring structures?
  - Evaluation method of their seismic capacity?

Need to investigate seismic behavior of underground structures mentioned above...
**Underground space in mega-cities**

- Exchanging ideas with practitioners, define research targets:
  - Damage development at a joint
  - Effect of neighboring structures on seismic behavior of structure
  - Seismic behavior of vertical underground structures

( Courtesy: MIT, Vision of technology development for usage of deep underground)

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**Draft of test setup**

- Highway
- Subway
- Shopping Center
- Entrance
- Cement mixed sand
- Shopping Mall
- Station Bldg
- Subway Station
- Foundation
- Highway
- Subway

---

**Testing schedule**

- FY 2010: Preliminary studies
  - Perform a series of small-scaled model centrifuge and shaking-table tests; element tests of geo-material and numerical simulations to obtain fundamental data
- FY 2011: Large-scaled model test at E-Defense
- FY 2012: Evaluation of the test results
- FY 2013-2016: Another series of preliminary studies and large-scaled model test
  - Based on the results from the first series of the tests, define target structures for the second series
Research project plan
- Energy facilities

Izumi Nakamura
National Research Institute for Earth Science and Disaster Prevention

Background

- Components of energy facilities need to remain in safety at seismic events.
  > Need to raise the leakage of high-energy content in these components.
  > To keep the function of the facilities.
  > The energy plants are expected to resume operations after the seismic events, provided the safety of the facilities are assured.
- The safety margin and structural integrity of the components is not clear which are struck by unexpected input motions.
- The integrity of the components with aging degradation under the seismic events is also an important issue.

Objective

- To clarify the seismic safety margins and structural integrity of components of energy facilities under large seismic motions, especially over the design level.

Energy facilities
- Power generation structures
- Oil and natural gas processing and storage facilities
- Chemical facilities, etc.
- Components of energy facilities
- Piping systems and supports
- Containers
- Tanks, …etc.

Past studies in NIED

- Several shake table tests on piping system models with and without aging degradation have been conducted.
  One-directional shake table test (1998-2005)
  Three-directional shake table test (July 2010)
- Behavior and failure mode beyond design basis input were obtained for piping system itself (with and without degradation).
- FEM analysis is well estimated the piping systems behavior and failure mode.

Seismic reliability of steam cycle

- To clarify the behavior of steam cycle systems with piping and other components, like supports, tanks, pumps, etc.
  > The past tests are focused on the behavior of the piping system itself, and the test model configuration is relatively simple.
  > It is known that there is a certain level of the seismic margin of the piping itself until it loses its function, but the seismic margin including other components is not clarified.

Failure process of piping systems

- From the several experimental studies, the failure mode of the piping system under high-stress level cyclic load is mainly the fatigue failure.

As supports, the high stress is applied locally to the piping system.
- The plastic region is extended.
- Stressed deformation is occurred.
- Coating part is damaged.
- Fatigue failure

When and how can we detect the damage before failure?
Are NDI or other inspection method useful to find the damage by seismic events?
How to approach the tasks

- Shake table test (E-Defense Shake Table Test)
- Non destructive inspection (NDI) during the test
- Numerical Analysis

Test model and contents of the experiment

- Among the components of energy facilities, a piping system with some supports will be tested at the first year (2011).
- Three dimensional shake table test on a piping system model.
- Some containers or tanks may be included.
- Ultimate strength and failure mode will be obtained by increasing the input motion levels and repeated shaking.
- At several input levels, to detect the damage on the test model before failure.
- NDI such as visual check and ultrasonic test will be attempted.

Following topics may be included in 2011 tests

- Seismic behavior of the piping systems under operation
- With high-pressure / With flow velocity

Future tasks

The following items are not in scope in 2011 shake table test

- Aging problem
- Seismic reliability of the components with degradation by aging
- Interaction with other structures
- Interaction of the soil foundation, structures which include the energy facilities' components

These research items will be treated in the future shake table test.
Numerical Simulation: Takuzo Yamashita

Large-Scale Numerical Simulation for Seismic Failure of Structures by E-Simulator

Takuzo Yamashita
Research Fellow
Hyogo Earthquake Engineering Research Center
National Institute for Earth Science and Disaster Prevention

What’s “E-Simulator”?

• Developed at Hyogo Earthquake Engineering Research Center (E-Defense) of NIED
• Virtual shaking table: Large-scale seismic response analysis using mesh with solid elements
• Final force software environment to simulate global and local seismic responses of buildings and civil structures (and city)
• Platform: ADVENTURE/ADVENTURECluster (parallel finite element analysis software for large-scale analyses)
• Developing constitutive equations and method to model fractures of buildings, bridges etc.

Advantages to Use Solid Elements

• Macro constitutive equations are not necessary.
  → Implementation of constitutive equation for materials is easy.
• Consideration of discontinuity (contact, fracture, rupture etc.) is easy compared with shell elements.
• Both local and global collapse behaviors can be simulated simultaneously.

Section Meeting of E-Simulator
Charperson: Prof. Muneo Hori (Univ. of Tokyo)
Vice-Chairperson: Prof. Makoto Ohsaki (Hiroshima Univ.)

Working Group
• Civil Engineering (RC structure)
  → RC Pier
• Building (Steel structure)
  → 4-story steel building
• Computational Engineering
  → fast solver
• Facilities
  → seismic response on facilities in buildings
• Urban Disaster
  → Integrated earthquake simulation
• Geotechnical Engineering (from 2011)
  → Underground Structure

Topic 1

Failure Analysis of Reinforced Concrete Pier subjected to Seismic Loading

E-defense Experiment to be Analyzed
Difficulties in Numerical Analysis

- Crack propagation: dominant phenomena
  - Crack = discontinuities in displacement
  - Difficult (impossible) to analyze using existing methods
- Details of crack propagation: ultra-high resolution model
- Requires massive computation
- (reinforcement, aggregates?)
- Complicated mechanical behavior of Reinforced Concrete (RC)
  - Nonlinear, history-dependent constitutive relation
  - Hysteresis due to the accumulation of damage.
  - Earthquake: Cyclic loading

PDS: Particle Discretization Scheme

\[ u(x) : \text{Voronoï} \]
\[ u_f(x) : \text{Delaunay} \]

\[ \dot{u}_e(x) = \sum_i^n u_i e_i(x) \]
\[ \dot{u}_f(x) = \sum_i^n u_i f_i(x) \]

PDS: Conjugate geometry for discretization of a function and its derivative

FEM-like continuum
Uniquely determined spring constants
DEM-like failure treatment: Cut the spring

PDS-FEM/ADVENTURE Cluster

- ADVENTURE Cluster
  - FEM platform for dynamic Elasto-Plastic problems
  - Fast solver based on COCCG (Coarse Grid Conjugate Gradient)
- ADVENTURE
  - FEM platform for static Elasto-Plastic problems
  - ADVENTURE Cluster is based on ADVENTURE

Analysis: Failure of RC pier
Static and dynamic Elasto-Plasticity + Failure

<table>
<thead>
<tr>
<th>Model Size</th>
<th>concrete</th>
<th>steel</th>
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<tr>
<td>total</td>
<td>601,137</td>
<td>599,993</td>
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<tr>
<td>node</td>
<td>104,577</td>
<td>97,223</td>
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</table>

Material Properties

- Concrete
  - Young's modulus: 25,000.0
  - Poisson's ratio: 0.2
- Steel
  - Young's modulus: 200,000.0
  - Poisson's ratio: 0.2
- Tensile strength: 1000.0
- Yield stress: 30.0
- Density (ton/m³): 2.30.0
Numerical Simulation: Takuzo Yamashita

**Failure by Static Load: Bending**
Change in Stress Distribution
- Fracture surface propagates through the area with stress concentration
- Rebars carry large tensile stress

**Failure by Seismic Load: Bending**

**Constitutive Relation of Concrete**
- Elastic-Plasticity+Damage Accumulation
- deformation=Damage accumulation
- Change in slope
  - The slope is a complicated function of damage
  - Plastic strain is a complicated function of elastic strain

- Total Strain VS. Total Stress
- The slope is always positive

**Concrete Constitutive Relation for Massive Computation**
- Want to make it a Positive Definite Matrix
  - Ordinary incremental form: negative slope requires special care
  - Positive slope + Additional terms
  - Slope never becomes negative

**Constitutive Relation of Concrete (problem setting)**
- Boundary Condition:
  - Y-Z plane fixed in X-direction
  - Z-X plane fixed in Y-direction
  - X-Y plane fixed in Z-direction
  - Z=200mm: displacement (~2mm) as shown in the graph

**Constitutive Relation of Concrete (Stress-Strain curve)**

Applied Displacement vs. Stress}

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Numerical Simulation: Takuzo Yamashita

**Analysis of Simple Model (PDS-FEM+Concrete)**

**Conditions for Analysis**
- Machine: SG Altix 4700 Intel Itanium 1.66GHz
- Cores: 256(1 node x 256cores)
- Convergence Parameters:
  - cg_nr_tol = 1.0e-5
  - cg_nr_sloptol = 1.0e-5
  - newton_disp_tol = 1.0e-4
  - newton_tol = 5.0e-4

- Computation Time:
  - Static Self Weight: 4,146 s
  - Dynamic (Earthquake): 25 s/step
  - # of steps before abortion: 21003
- Nodes, Elements:
  - Nodes: 1,298,661 (3,895,883 DOF)
  - Linear tetrahedron element: 7,647,069

**1 week computation gives this...**

**Fracture Parameter**

**Fracture Parameter (Close-up)**
Numerical Simulation: Takuzo Yamashita

### Conclusion of Topic 1
- Implementation to ADVENTURECluster
  - PDS-FEM
  - Crack propagation
  - Constitutive Relation for Concrete
    - Complicated mechanical behavior of RC
- Failure Analysis of simple RC pier model
- Ultra-high resolution model

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### Topic 2
Collapse simulation of full-scale 4-story steel frame

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### Purpose of This Analysis
- Elasto-plastic time-history analysis for the 4-story steel frame using mesh with hexahedral solid elements using the prototype of E-Simulator
- Compare the results with those of shaking table test

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### 4-Story Steel Frame Model
- **Steel material**
  - Piecewise linear isotropic hardening
  - Parameters identified by uniaxial test results
  - Mass density: $7.86 \times 10^3$ kg/m$^3$
- **Concrete material for slab**
  - Bilinear elastoplastic material
  - Mass density: added equivalent density for nonstructural components and retaining members to the density of concrete, $23 \times 10^3$ kg/m$^3$.
- **Damping**
  - Rayleigh damping of 0.02 for 1st and 4th modes
  - (two lowest translational modes in X-direction)
Numerical Simulation: Takuzo Yamashita

**Details of FE-Mesh (1)**

- **Hexahedral solid elements**

**Details of FE-Mesh (2)**

- Slabs and plates such as flanges and webs of beams are divided into, at least, two layers of solid elements.

**FE-Models**

- Three column-base models are examined.
- Spring model for exterior wall.

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of elements</th>
<th>Number of nodes</th>
<th>Number of dof</th>
<th>Column base</th>
<th>Exterior wall</th>
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<td>4,005,682</td>
<td>14,717,076</td>
<td>FE-model</td>
<td>Spring</td>
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**FE-Model of Column Base**

- Connections of anchor bolts: distributed nodes connected by rigid beams to prevent stress concentration.
- PRINTLESS connector between base plate and base.
- MPC (horizontal dir.)
- Rigid plate modelled by rigid beams.
- Anchor bolt (stress element).
- Correct base and upper face of base plate.
- Axial force: 100 kN.

**Eigenvalue Analysis**

- Computers: 16 cores of HP ProLiant BL465 2.6 GHz dual core.
- Computation time for the four lowest modes: 5,471.6 s (1.5 hours).

<table>
<thead>
<tr>
<th>Natural Period</th>
<th>1st mode</th>
<th>2nd mode</th>
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<tbody>
<tr>
<td>Case 1</td>
<td>0.3480</td>
<td>0.9144</td>
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<tr>
<td>Case 2a</td>
<td>0.6003</td>
<td>0.5760</td>
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<tr>
<td>Case 2b</td>
<td>0.7047</td>
<td>0.5372</td>
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</tbody>
</table>

**Time-History Analysis**

- Table acceleration record for 80% Takahata wave (20 s).
- Computers: SGI Altix 4700 (SPU Intel Xeon 1.66 GHz) at NIED.
- No. of cores: 1 node=256 core/node = 256 cores.
- Elapsed time.
  - Static analysis (self-weight): 2.414 s = 40 min.
  - Dynamic analysis: 1.106 s/step (t=0.01 s, 20060 steps).

Input Acceleration (the first half)
Numerical Simulation: Takuzo Yamashita

4-Story Frame (Movie, Case 1, Scale = 20)

Story Drift Angle of 1st Story

Max and Min Values of Story Drift Angle of 1st Story (Case 2a)

- Simulation
  X-direction: 0.01089 rad and -0.01397 rad
  Y-direction: 0.00865 rad and -0.007946 rad

- Experiment
  X-direction: 0.0121 rad and -0.0142 rad
  Y-direction: 0.0130 rad and -0.00933 rad

Story Shear Force of 1st Story

Max and Min Values of Story Shear Force of 1st Story (Case 2a)

- Simulation
  X-direction: 1142 kN and -1153 kN
  Y-direction: 1385 kN and -1229 kN

- Experiment
  X-direction: 1169 kN and -1173 kN
  Y-direction: 1423 kN and -1058 kN

Deformation (Time: 6 s, Scale = 10)

Column-base model: Case 2b
Time: 6 s (nearly the maximum deformation)
Rotation response around Z-axis is observed due to effect of exterior wall.

Equivalent Stress at the Maximum Deformation (Case 1)

Approach to improve calculation accuracy for 4-story steel frame model

1) model accuracy of component:
   - column-base
   - exterior wall
   - composite beam

2) constitutive equation for steel material

Whole frame Close view around the 2nd floor and the 1st story
Large stress is observed around the column base and beam-column connections.
Simulations of Component tests (1)
Column-Base
- FE Model
- Detachment of mortar and base plate is simulated

Simulations of Component tests (2)
Exterior wall
- FE Model
- Plasticity due to contact of panel and steel is simulated
- Further examination
  - Generating precise FE model of bolt and angle member
  - Identification of Material constant of Drucker-Prager model for ALC panels
  - Contact model considering friction
  - Quantitative evaluation of absorbing plastic energy

Simulations of Component tests (3)
Composite beam
- FE Model
- Wire mesh layer
- Stud: Spring element considering Young's Modulus for concrete contacted to stud
- Asymmetric bending stiffness due to contact of slab and column

Constitutional equations for steel material
- Low-carbon steels used for buildings have yield plateau
- Hardening characteristic at initial yielding is different from that at second and subsequent yielding
- Multi-linear mixed hardening law with implicit rule
  - What is implicit rule?
  - Stress-Strain curves for initial loading and second and subsequent loadings are prepared; these curves are automatically chosen.
  - Uniaxial cyclic loading
  - Cyclic loading to beam
  - Experiment is simulated with high accuracy

Conclusion of Topic 2
- FE-analysis for full-scale 4-story steel frame using prototype of E-simulator
- Good estimation of collapse test of 4-story frame
- Simultaneous simulation of local and global collapse behaviors without macro models such as plastic hinges and composite beams
- Further improvement of computational accuracy of this analysis
  - Model accuracy of component
  - Constitutive equation for steel materials
Monitoring and Data Archival System: Kentaro Tabata and Hisanobu Sakai

Monitoring & Data Archival System

Kentaro Tabata
Senior Researcher
Hyogo Earthquake Engineering Research Center
National Research Institute for Earth Science and Disaster Prevention

Data Archival System

- Archives of shaking-table experimentation database and information – “ASEBI”
- Web-based system to share and publish data obtained from E-Defense tests
- Archival system built on ZOPE/Plone (contents management system)
  - Reducing development and operation costs
- Open in 2009

Data Archival System

- As of June, 2010:
  - Publishing 9 E-Defense tests through the system
  - 211 users registered
  - Approx. 450 PV/month accesses
  - Currently available for users in Japan

Monitoring

High Performance R/C Structures
Geotechnical Engineering
Base Isolation & Vibration Control
Energy Facilities

- Practical application of structural health monitoring
- Storage identification from video or expensive data
- Indentation indentation-based damage detection
- Development and application of smart sensors
- Measuring distribution of ground deformation
- Visualizing distribution of earth pressure on a structure’s surface
- Monitoring over water pressure in silos, embankments, etc.
- Monitoring contamination in susceptible ground
- Feedback reaction control
- Record and store damage history of isolated level
- Detection of the initial damage condition
- Application of AE method for damage detection
- Development and validation of the seismic damage indicator

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Appendix V: Breakout Session Summaries
**Session Summary Report**

**Breakout Session 1(a) Numerical Simulation**

**Moderators:** Muneo Hori (University of Tokyo) and Greg Deierlein (Stanford University)

**Recorders:** Tony Yang (University of British Columbia)

**Members** (in alphabetical order of last names): Tracy Becker (University of California, Berkeley), JoAnn Browning (University of Kansas), Nhan Dao (University of Nevada, Reno), Hideo Fujitani (Kobe University), Tatsuhiko Ine (NIED), Manos Maragakis (University of Nevada, Reno), Taizo Matsumori (NIED), Keisuke Minagawa (Tokyo Denki University), Khalid Mosalam (University of California, Berkeley), Minehiro Nishiyama (Kyoto University), Taichiro Okazaki (NIED), Sri Sritharan (Iowa State University), Kentaro Tabata (NIED), Ikuo Towhata (University of Tokyo), Zeynep Tuna (University of California, Los Angeles), Takuzo Yamashita (NIED)

**Background:**

As described in reports from previous NEES/E-Defense coordination meetings (January 2009 at the U.S. NSF and September 2009 at E-Defense), modern computational tools offer unprecedented capabilities to simulate earthquake and tsunami effects on buildings, bridges, distributed lifelines, and other facilities. However, research in earthquake engineering is generally not making full use of the available computing capabilities of modern multi-processor supercomputers and supporting massive data storage, networking and modern information technologies. Without sufficient research and development on new computational simulation methods that utilize today’s state-of-the-art peta-scale computing capabilities, future generations of earthquake engineering researchers and practitioners will be without the necessary technologies to make effective use of advanced computing. Moreover, given the inherent limitations of physical testing, many important earthquake risk assessment and mitigation problems facing society can only be addressed through computational simulations.

Many of the computational methods that have become routine nowadays, such as nonlinear dynamic analyses that utilize interactive graphic pre- and post-processing, trace their development to pioneering research of the 1960’s and 1970’s, when access to computers were limited to leading research universities and a few major corporations. At the time of their development, many of the computational methods seemed impractical for earthquake engineering practice, owing to the prohibitive cost of computing and lack of data to calibrate and validate the models. But without such visionary research, the computational tools that are used routinely today would not exist. Looking ahead, this begs the question as to whether sufficient attention is being given to develop computational models and technologies that utilize most powerful supercomputing power of today, which will provide the tools for computing that will be routine 10 to 20 years from now.

In Japan, E-Defense is conducting research on advanced computation through the “E-Simulator” initiative that uses the “Kei-Soku-Keisanki” supercomputer (a cluster-type computer with 10 peta-flops performance). The Kei-Soku-Keisanki computer center hosts several major computing initiatives, one of which concerns natural hazards. The computational mechanics research component of the natural hazards initiative is built upon the ADVENTURECluster system, which is a parallel finite element software system for large-scale analyses. The ADVENTURECluster (http://www.alde.co.jp/english/advc/index.html) software is a commercial platform that is based on the ADVENTURE Project at the University of Tokyo (http://adventure.sys.t.u-tokyo.ac.jp). During the NEES/E-Defense meeting, Dr. Yamashita provided an overview of some of the advanced simulation research that is organized into six working groups: civil engineering (RC structures), buildings (steel...
structures), computational methods, facility condition and operation, urban disasters, and geotechnical engineering (underground structures). Apart from the challenges of creating and analyzing very large models with millions of finite elements and degrees of freedom, a key focus of the research is the development of appropriate constitutive and failure models to simulate local material response. These engineering-focused projects have links to earth science projects dealing with earthquake, tsunami and flood simulations.

In the U.S., a major new peta-scale computing effort is getting underway at the NCSA facility at the University of Illinois, which is constructing the “Blue Waters” computer - an IBM machine that is expected to have a calculation speed of 10 peta-flops. The Southern California Earthquake Center (SCEC) has initiated a project called “preparing for the big one” to conduct coupled seismic-geotechnical-structural simulations on the Blue Waters machine. This project proposes linking codes for earthquake source modeling with ones for site response, soil-structure interaction, and structural modeling. The OpenSees software framework is proposed for the local site, soil-structure interaction and structure modeling. A related peta-scale computing project is one by Bielak, Fenves, and Elgamal, who are performing soil-structure-interaction analyses of a highway interchange that incorporates a site model measuring 0.5 x 1.0 km with a source-to-site transmitting boundary and uses OpenSeesPL (the parallel version of OpenSees). This project embraces the goal described in the summary report of the January 2009 NEES/E-Defense meeting “to develop the capability to simulate the full range of damage mechanisms of structure-foundation-soil systems all the way to collapse under a wide range of earthquakes, including the uncertainties associated with the design, construction, and health of the structure in addition to the inherent uncertainty of the hazard”.

**Specific Research Needs:**

Many challenges remain for to predict the realistic behavior of structures (including buildings, bridges and distributed infrastructure) under extreme earthquake motions. While progress is being made, such as through the peta-scale computing initiatives mentioned previously and other computational research, significant challenges remain to achieve high-performance models that can simulate accurately the fundamental behavior of structural materials (including soils) over the range of response that may occur in earthquakes. The following specific research and development needs were identified during the breakout meeting discussion:

- **Material constitutive models and damage models that capture accurately both the local and global behavior and failure modes in structures:** Several examples were cited of situations where localized softening behavior is critical to the overall response, such as the fractures in steel structures in the Northridge and Kobe earthquakes, or concrete spalling and lap splice failures in concrete structures. Thus, research and model development must strive to represent fundamental behavior at scales that appropriately capture significant effects. This will require development and validation of constitutive and damage models to improve simulation under complex stress states and loading conditions.

- **Modeling and analysis tools and services to facilitate the creation and processing of detailed models:** Owing to the large size of peta-scale problems (e.g., models with millions of elements and degrees of freedom), new technologies are needed to create and manage the models with reasonable levels of effort. The required technologies include user-friendly graphical interfaces, database management and query tools, strategies to facilitate translation between physical and idealized models, automated meshing facilities, parallelized codes for fast computations, and tools for rapid data visualization.
• Advanced computational methods for solving large-scale problems: Improvement of computational solution and numerical integration techniques are needed to simulate large structures more efficiently, and to achieve more robust solutions for highly nonlinear systems exhibiting degrading behavior. In particular, improved algorithms are necessary to capture post-peak response and guarantee uniqueness of solutions for softening structures.

• Model validation through blind predictions and benchmark studies: Compare and validate results predicted by computational models with observed behavior in physical tests, including material, component, sub-assemblage, shaking table and field tests. Carryout challenging testbed applications to evaluate and improve the simulation tools. Candidates for testbeds include: structural systems constructed from reinforced concrete, steel and other materials, soil and soil/structure interaction problems (underground structures), distributed electrical systems, and fluid and fluid/structure interaction problems. Validation case studies should also be conducted, including consideration of the effects of uncertainties. These studies should include experiments conducted on sub-assemblies, shaking tables (NEES and E-Defense) and in the field (NEES facilities at UC Santa Barbara, UCLA, and the University of Texas).

• On-line grid computing technologies: Continue to extend, validate and deploy high performance simulation platforms such as ADVC, OpenSees, and others. NEES has made progress in this area through the OpenSees Lab, whereby OpenSees can be accessed and run using tera-grid resources. In Japan, ADVC is available on the Kei computer. Efforts should be continued to make these tools available to a larger population of researchers.

• Leverage research approaches in hybrid simulation and monitoring/sensing to facilitate digital communication and information management between (a) various analysis software systems or models, (b) analysis platforms and databases of computational and experimental results, and (c) analyses with data from proprietary databases (e.g., simulation tools of distributed networks with proprietary/confidential data on utility networks).

• Multidisciplinary approaches: Further emphasis should be given toward research that embraces the strengths of multi-disciplinary teams, including expertise areas in engineering, earth science and seismology, physics and material science, computational science, and social sciences.

• Multi-scale research that spans length-scales and physics from detailed response of structures, to buildings and infrastructure systems, to earthquake effects on urban regions: The "resilient city" theme introduced in previous meetings requires simulations that can encompass very localized behavior up through large geographically distributed systems. Additionally, to assess system effects, simulation tools should extend beyond modeling of structural behavior (calculation of engineering demand parameters) to simulate other contributors to earthquake losses and disruption (e.g., calculation of monetary losses, facility downtime, injuries and fatalities). Whereas current performance-based tools tend to model losses through empirical relationships, further research is needed to develop fundamental models of these effects (e.g., development of models to simulate egress from a city, disruption to utility or traffic systems, facility repair and recovery operations).

Desired Collaborations and Suggested Initiatives:

The following are proposed as steps to take to increase collaborations between the US and Japan that will contribute to the advancement of high-performance simulations for earthquake engineering:

a. Direct collaboration between NEEScomm (OpenSees, NEEShub, etc.) and E-Defense (KEI computing) groups developing, deploying and maintaining high performance computational simulation capabilities and information exchange and database systems is desirable to leverage resources and knowledge and to promote sharing of critical information and technologies.

b. It is believed that advanced computational simulation should be an integral part of all
NEES/E-Defense projects, and that payload and other efforts to apply specialized computational simulation tools and models to these projects should be encouraged.

c. Beyond the current research activities and collaboration mechanisms, a large concerted initiative is required to provide the critical mass of expertise and effort that is necessary to achieve substantive advancements in peta-scale computing to simulate the realistic response of buildings, bridges and other civil infrastructure.

d. In addition to regular NEES/E-Defense planning meetings, it would be useful to establish a website to facilitate communication and collaboration.

e. It is recommended to explore opportunities for graduate research student exchanges that can nurture US-Japan research collaboration.

Finally, given the anticipated gains to earthquake engineering through high-performance simulation, it is recommended that groups in both countries pursue planning and funding opportunities to support development of advanced peta-scale simulation. In Japan, some funding mechanisms are already in place through the KEI E-Simulation initiative. In the US, some modest support for basic software infrastructure is available through NEES; however, more substantial dedicated funding is required to engage multidisciplinary research from the earthquake engineering, computational mechanics, computer science and other communities. Possible opportunities may exist through the NSF-EFRI (Emerging Frontiers in Research Innovation) program, the NSF-CDI (Cyber-enabled Discovery and Innovation) program, or other programs at the NSF. Other support for fundamental advancements in large-scale simulations may be possible through the U.S. Department of Energy or other government agencies.
Session Summary Report
Breakout Session 1(b) Monitoring

Moderators: Shirley Dyke (Purdue University) and Akira Nishitani (Waseda University)
Recorder: Naru Nakata (Johns Hopkins University)
Members (in alphabetical order of last names): Shin-Ho Chao (University of Texas, Arlington), Shideh Dashti (University of Colorado, Boulder), Catherine French (University of Minnesota), Satoshi Fujita (Tokyo Denki University), Yohsuke Kawamata (NIED), Susumu Kono (Kyoto University), Peter Lee (Skidmore Owens Merrill LLP), Anne Lemnitzer (California State University, Fullerton), Manos Maragakis (University of Nevada, Reno), Khalid Mosalam (University of California, Berkeley), Takuya Nagae (NIED), Izumi Nakamura (NIED), Manabu Nakayama (NIED), Hidekazu Nishimura (Keio University), Isao Nishiyama (NILIM), Yoshihiro Nitta (Ashikaga Institute of Technology), Gustavo Parra-Montesinos (University of Michigan), Zeynep Tuna (University of California, Los Angeles), Gordon Warn (Pennsylvania State University), Susumu Yasuda (Tokyo Denki University)

Background:
The user of monitoring systems may play a key role in bringing the concept of “resiliency” to fruition. There are numerous reasons to monitor a system; for example, for model identification, model updating, characterization of loading, damage detection, etc. To achieve the various goals involved in the monitoring of structural systems, the two of the main questions that need to be answered are: What do we need to measure? And how do we accomplish it?

The E-defense and NEES collaboration offers the opportunity to consider very realistic engineering systems and situations/earthquakes. The experiments performed will provide the community with information and data for research in monitoring. However, the researcher trying to add a payload experiment will typically need to be involved in the planning and execution of the main experiment. It is unlikely that the data acquired for the main experiment will happen to acquire the appropriate data for most monitoring purposes. Thus, it is best for the payload team to establish a good relationship with the main experimental team and get involved during the early planning stages. Mechanisms for such planning are needed.

Discussions:
The discussion revolved around two questions:
• HOW to utilize efficiently a variety of data from the experiments conducted at NEES/E-Defense from the SHM point of view?
• HOW to put WHAT additional sensors WHERE in the structure for the purpose of conducting monitoring, etc.

Use of Data from Experiments
• Issues in Global Sensing / Local Sensing?
• Unprocessed data is necessary for users who are interested in signal processing.
• Need to specify a signal to noise ratio for each sensor to find out reliability of data
• Any standard format of data in NEES/E-Defense for others to use
• How many years until data is released after the experiments?
• Centralized or distributed data collection
• Synchronization of data from different data acquisition systems
• Comparison of data from different tests and sites
Technical Challenges in Monitoring

- Data aggregation / reduction
- Centralized vs. distributed methods
- Global behavior/ local behavior
- Synchronization of data sources
- Number of sensors needed
- Data fusion methods
- Important indicators of damage

Mechanisms for Monitoring Projects

- How to add new sensors in NEES/E-Defense?
- Ask personnel in NEES/E-Defense to add sensors?
- Can we borrow sensors from different sites?
- Users guide of NEES and E-Defense facilities for users in terms of monitoring
- Planning monitoring has to be done prior to the experiment.
- Monitoring teams need to join the main project teams for the testing in the planning stage
- What will be the mechanism to monitor the type of data that the main team is not intended to monitor?

Opportunities and Funds

- Recommendation to NSF to encourage payload projects in monitoring
- Better way to allocate funds for payload in monitoring projects
- ‘EAGER’ style proposal?
- NIST funds to develop new sensors and instrumentation

Development of New Sensors

- Use NEES/E-Defense experiments to validate new sensors in full/large-scale tests
- Data fusion from different sensor types and sources for validation
- Accuracy of sensors: Do we know sensors are already working fine?
- How is data from new sensors used? Is the date from the new sensors used by the other users?

Monitoring in Geotech Applications

- Monitoring in Geotech systems is different than in structures.
- Geotech monitoring is complicated. Interested in deformation of ground, pressure changes, etc.
- We still do not know how to measure may quantities of interests
- Monitoring in Centrifuge Tests should also be considered

Specific NEES/E-Defense projects discussed include:

- RC structures tested in December, teams may consider the energy dissipation by rocking motion, other aspects
- Three monitoring teams participated in the RC test at E-Defense
- Energy dissipation capabilities in Base Isolation Projects
- Thermo-couple for rubber bearing

Several Key Ideas Resulted from the Discussion:

- Need a discussion forum (perhaps using existing NEEShub functionality) to discuss experiment plan, instrumentation, etc. and facilitate discussion of small steps or sensors to add to the usefulness of the data from the experiments
- Develop blind monitoring competitions / benchmark problems to compare algorithms, validate sensors, etc.
• Standard data formats and need for unprocessed data should be agreed upon
• Shared “monitoring kit” should be developed for research teams to borrow including various sensors & DAQ to supplement laboratory equipment perform monitoring, including accelerometer, displacement, gap, pressure, force, Krypton, etc.
Session Summary Report

Breakout Session 2(a) High Performance R/C Structures

**Moderators:** John Wallace (University of California, Los Angeles) and Hitoshi Shiohara (University of Tokyo)

**Recorder:** Wassim Ghannoum (University of Texas at Austin)

**Members** (in alphabetical order of last names): Shih-ho Chao (University of Texas, Arlington), Greg Deierlein (Stanford University), Cathy French (University of Minnesota), Jack Hayes (National Institute of Standards and Technology), Toshimi Kabeyasawa (University of Tokyo), Yoshio Kai (NIED), Susumu Kono (Kyoto University), Taizo Matsumori (NIED), Farzad Naeim (John A. Martin & Associates, Inc.), Takuya Nagae (NIED), Isao Nishiyama (NILIM), Minehiro Nishiyama (Kyoto University), Gustavo Para-Montesinos (University of Michigan), Julio Ramirez (Purdue University), Sri Sritharan (Iowa State University), Kenichi Tahara (NIED), Zeynep Tuna (University of California, Los Angeles), Tony Yang (University of British Columbia)

**Visit Construction Site:**

The group started the meeting by touring the construction site of the two RC structures being prepared for testing in December 2010. The group had the privilege of witnessing the casting of the 2nd floor.

**Presentations:**

1- Takuya Nagae:  Overview of RC structure test specimen being prepared
   - Designed to satisfy most requirement for minimum Japanese practice
   - No joint requirement in Japanese code
   - Rectangular walls not currently allowed in Japanese code – shape was determined with US input

2- Hitoshi Shiohara:  Beam/column connections
   - Shiohara presented some of his research on RC joints
   - Shiohara raised concern of joint performance in RC test structure

3- Wassim Ghannoum:  Modeling of RC structure
   - A 3D analytical model of the RC structure was presented (developed in OpenSees)
   - Results for the Kobe – Takatori motion were presented
   - Very large drifts are anticipated for that motion
   - Results compare well with Kenichi Tahara model results
   - Further development of model is planned

4- Zeynep Tuna:  Modeling of RC structure
   - Zeynep Tuna and John Wallace from UCLA will work with Wassim Ghannoum on improving 3D model of RC structure

5- Takuya Nagae:  Overview of PT structure test specimen being prepared
   - PT wall has twice the capacity of the RC wall but significantly less energy dissipation
   - Wall post-tensioning is unbonded, while beam and column PT is bonded
   - Beam and column details already in use in Japan, whereas the unbonded wall details are new to Japanese practice
   - Mild steel is used at wall base for energy dissipation

6- Kenichi Tahara:  Response analysis of RC and PT test structures
   - 2 ground motions considered:  JMA Kobe, Takatori Kobe
   - Non-linear rotational spring models for both RC and PT
Takatori drifts very large → decided to use only JMA Kobe
Analyze structures with 4 rotation variants for the bi-directional motion: 0, 45, 90, 135 degrees
Recommend using JMA Kobe, with 0 degrees for wall direction and 90 degrees for frame
Scale of motions: 10%, 40%, 70%, 100%

7- Susumu Kono: PT structure analysis by Richard Sause
Brief look at Prof. Sause’s analytical work on PT specimen

8- Sri Sritharan: New NEESR project: Rocking walls (collaborating with Japanese)
Overview of recently awarded NEES project
NEES team amenable to collaboration with Japanese researchers

9- Shih-ho Chao: New NEESR project: collapse of ductile columns
Overview of recently awarded NEES project
NEES team amenable to collaboration with Japanese researchers

10- John Wallace: NEES/E-Defense collaboration efforts (see next section)

**Collaborative Effort:**

1- Test Schedule (Nagae)
   - December 15th +/- 2 days
   - JCI-ACI workshop group will join the tests

2- Component Tests
   - Shiohara asks if there is budget for component tests on US side
   - Only two projects funded that have some relation to Japan tests – projects have limited budget for component testing directly related to Japan tests

3- High-rise RC project for 2013 – Format not known from Japan side
   - US side asks if plans can be made earlier so that proposals can be submitted earlier to NEES prior to E-Defense tests
   - Need to meet often and early to continue the collaboration
   - Good communication is essential
   - As early as March 2011 planning and coordination should commence

4- Monitoring of RC and PT specimens
   - Discussed potential for US researchers to bring own instrumentation and additional channels to 2010 or 2013 tests. Japan side amenable.

5- Blind Analysis or Prediction Contest (Wallace & Shiohara)
   - US side could organize semi-blind contest
   - Details to be finalized by US side prior to December tests
   - Deadline for submissions about June 2011
   - Report results perhaps at NEES/PEER annual meeting
   - Need some support for a couple of students to organize the contest
   - NEEScomm may be able to fund such effort through high impact EOT

6- Other
   - Organizing yearly workshop to present collaboration work is proposed by Wallace and Kabeyasawa.
   - Workshop to focus on RC testing related to collaboration effort.
   - Possibly can be opened to international collaborators
   - Should involve participation from practicing engineers

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Resolutions:

1- COLLABORATION MEETINGS
• The group gave top priority for scheduling and conducting future meetings. They should be conducted often (2-4 times a year) and early (prior to Japanese initiatives) to build on the fruitful collaboration. Good communication is essential for this effort. In-person meeting is preferred but WebEx could be used when in-person meeting is not possible or convenient.

2- WITNESSING TESTS (Education)
• US to pursue funding to send as many researchers and students to December 2010 Japan tests
• Longer term: student and researcher exchanges should be encouraged

3- INSTRUMENTATION
• Discussed potential for US researchers to bring own instrumentation and additional channels to 2010 or 2013 tests. Japan side amenable.

4- SIMULATION CHALLENGE
• US will pursue organization and funding of prediction challenge. Japan side agrees to share limited data for competition.
• Time frame: US to finalize details by December, submissions by June, results announced in NEES annual meeting. Continue effort for 2013 tests.
• Consider doing this contest as a multi-site high-impact NEES EOT activity

5- NEW KNOWLEDGE AND TRANSFER
• Group wants to draw knowledge from simulations and chart new research in analytical tools
• Important to share new knowledge at venues with practicing engineers. EERI will present collaboration efforts in newsletter.
• Data sharing with Japan. Standard time lapse is 24 months for Japan data to become public. Similar time frame for data exchange exists in NEES. Need to reduce time delay from both sides.

6- WORKSHOP
• There is interest in starting workshops and perhaps open them to international participation to discuss experimental work
• Workshops should be focused on topics of relevance to RC collaborative tests
• Workshops should bring in practicing engineers

7- POTENTIAL FUNDING FOR 2013 TESTS
• The group think it would be useful to submit for NEESR funding (this March) for preliminary analyses to develop concepts for 2013 tests
Session Summary Report

Breakout Session 2(b) Base isolation & vibration control

Moderators: Keri Ryan (University of Nevada, Reno) and Kouichi Kajiwara (NIED)
Recorder: Gordon Warn (Pennsylvania State University)

Members (in alphabetical order of last names): Tracy Becker (University of California, Berkeley), Ian Buckle (University of Nevada, Reno), Nhan Dao (University of Nevada, Reno), Shirley Dyke (Purdue University), Hideo Fujitani (Kobe University), Masahiko Higashino (Takenaka Corporation), Muneo Hori (The University of Tokyo), Peter Lee (Skidmore Owings Merrill LLP), Stephen Mahin (University of California, Berkeley), Manos Maragakis (University of Nevada, Reno), Troy Morgan (Tokyo Institute of Technology), Gilberto Mosqueda (University at Buffalo), Narutoshi Nakata (Johns Hopkins University), Akira Nishitani (Waseda University), Yoshihiro Nitta (Ashikaga Institute of Technology), Yoshimitsu Okada (NIED), Taichiro Okazaki (NIED), Joy Pauschke (National Science Foundation), Hisanobu Sakai (NIED), Eiji Sato (NIED)

Specific Research Needs:

The discussions held during the breakout session demonstrated unanimous agreement between the Japanese and US participants that protective systems, including base isolation, are an essential component to achieve the ‘Resilient City’ meta-theme adopted for the second phase of the NEES/E-Defense collaboration. Key challenges that remain and the research needed to address these challenges were identified and are summarized as follows:

Challenge 1: Vertical earthquake motion

Participants are concerned that “traditional” base isolation hardware might not provide effective protection for nonstructural components and essential equipment housed within an isolated structure from the high frequency, vertical component of excitation that can be significant relative to the horizontal motion. Damage to nonstructural components (e.g., ceiling systems, piping systems, etc.) or essential equipment (e.g., computer servers, medical imaging devices, etc.) during severe earthquake shaking could disrupt, or prevent, post-event operation of critical facilities that contribute to the resiliency of the community and economy.

Specific research needs to address Challenge 1:

1. Full scale testing of isolated structures outfitted with nonstructural components: The E-Defense shake table provides a unique opportunity to test structures and components at full-scale under three components of earthquake ground shaking. Tests conducted on structures isolated with “traditional” hardware would provide new data of the response of nonstructural components housed within isolated structures so that the efficacy of traditional hardware and current design procedures could be evaluated.

2. Three-dimensional (3D) isolation: Both the US and Japanese participants are interested in developing and experimentally validating new and innovative isolation system or combinations of protective systems that effectively provide three-dimensional (3D) isolation. Efforts are underway in Japan to develop such 3D systems and to explore combinations of base isolation and floor isolation to achieve 3D isolation; however, these systems have not been validated experimentally at reduced or full-scale.

Challenge 2: Long period/long duration earthquake ground motion

Long-period, long-duration ground motion produced by earthquakes in subduction zones are considered to be a serious concern for base-isolated buildings. The concern stems from the
predominant frequency content of this type of ground motion that is in the range of the effective period of traditional isolation systems (typically between 3 and 5 seconds). This type of ground motion could lead to a resonant condition with unbounded displacements in the isolation system. This resonance, coupled with the long-duration, could place extreme demands on the bearings; for example, heating in a lead-rubber bearing that would reduce the effectiveness of the lead-core to dissipate energy and therefore control displacements.

Specific research needs to address Challenge 2:
1. Development of new and innovative isolation systems that adjust to the incoming ground excitation: Potential innovative isolation systems include active, semi-active and hybrid systems, that are able to adjust the period of the system and damping properties based on the characteristics of the earthquake ground motion. These innovative systems are needed to address concerns related to the long-period, long-duration motions as well as achieving specific local and global system performance objectives. Participants agree that the availability of a versatile testbed structure that would allow for rapid specimen assembly and reconfiguration, and direct evaluation of one isolation/control strategy against another would accelerate the development of innovative systems and enhance collaboration.

2. Damage detection and health monitoring: There is concern that isolation systems subjected to the extreme demands associated with large amplitude, short-duration as well as long-period, long duration ground motions might sustain damage that is difficult to detect following a major earthquake event. Participants from both sides are interested to pursue the development of damage detection and health monitoring methodologies for these devices to aid in post-event replacement decision-making.

Research need to address Challenges 1 and 2
Absolute/Perfect isolation grand challenge: The US and E-Defense researchers identified the grand challenge of achieving “absolute” or “perfect” isolation using base isolation and seismic protective systems. This research would require the development of innovative hardware and control algorithms so that the structures could remain inert (zero absolute accelerations) under any earthquake ground motion. An “absolute” isolation system would provide maximum protection of the structure and its contents from the damaging effects of earthquake ground shaking, thus contributing to the realization of the “resilient city.”

 Desired Collaborations and Benefits of Collaboration:

NEES-TIPS project
The planned NEES-TIPS testing of a base isolated five-story steel structure on the E-Defense shake table provides an opportunity for collaboration in the following areas:

1. Nonstructural component and contents payload
   At present, sufficient funds are available to the NEES TIPS project only to test the bare structural frame. However, given the considerable costs associated with the test program, not adding nonstructural components and contents to the test setup would be a missed opportunity. Testing ceiling systems under 3D excitation is seen to be especially compelling.

2. Damage detection payload

3. Blind prediction contest
   Utilizing the data for the previous blind prediction contest on the same specimen, a parallel contest for the isolated building would test the hypothesis that the design community can collectively predict the demands in an isolated building with greater accuracy and less variance than in a fixed-base building.
Test-bed structure for innovative seismic isolation systems and control strategies

The participants of the breakout session expressed a deep interest and desire for the collaborative development of a test-bed structure that would enable: rapid specimen assembly; accelerated testing and development of innovative systems and control algorithms; full-scale verification; and comparative evaluation of newly developed systems. As envisioned, the test-bed structure should be: modular; reconfigurable steel or concrete segments; capable of three-dimensional loading; and provide ease of hardware replacement. The test-bed structure would also need to be able to accommodate mass dampers, either active or passive, at the isolation level or in the upper levels of the test-bed structure. Two possibilities exist for the test-bed:

1. E-Defense previously constructed eight isolated mass pieces, which, when assembled with linear sliders, function as a gravity load carrying system. Four pieces can be stacked vertically for testing. The linear sliders can be arranged to achieve planar motion (as done in all previous projects) or they can be arranged differently to permit motion in both translational directions. The pieces can be assembled with lateral framing in either direction to act as a complete system. The pieces can also be reconfigured, for instance, with isolation and control systems at different interstory levels. The pieces have been used in the NEES/E-Defense Self Centering Rocking Steel Frame project and two other E-Defense projects. However, currently, E-Defense has no specific plan to utilize the test-bed pieces for Phase 2 research on isolation and control.

2. E-Defense plans to design and build a full scale realistic building specimen to test innovative isolation and control strategies for the Phase 2 research projects. The design concept of the specimen is expected to be complete by about March 2011. US researchers planning collaborative NEESR projects at E-Defense could therefore propose to utilize this specimen. Both US and E-Defense participants are enthusiastic to contribute to the design of this planned full-scale, non-symmetric building specimen, and tentative plans were made to establish a NEEShub group for online communication. The specimen is envisioned to be non-symmetric, perhaps containing both horizontal and vertical irregularities. Collaboration on the design of the non-symmetric building specimen would ensure maximum versatility for future collaborative and independent testing. The key benefits of this collaboration would be a consistent specimen for comparative evaluation of new systems and new design procedures. The collaboratively designed non-symmetric building specimen would also enable further joint investigations of the performance of nonstructural components and essential equipment housed within seismically isolated buildings.
Session Summary Report
Breakout Session 2(c) Geotechnical Engineering

Moderators: Nick Sitar (University of California, Berkeley) and Ikuo Towhata (University of Tokyo)
Recorder: Shideh Dashti (University of Colorado, Boulder)

Members (in alphabetical order of last names): Youssef Hashash (University of Illinois, Urbana-Campaign, in WebEx), Munee Hori (University of Tokyo), Tatsuhiko Ine (NIED), Takahito Inoue (NIED), Yohsuke Kawamata (NIED), Anne Lemnitzer (California State University, Fullerton), Manabu Nakayama (NIED), Kentaro Tabata (NIED), Keiichi Tamura (PWRI), Takuzo Yamashita (NIED), Susumu Yasuda (Tokyo Denki University)

Background:

As large numbers of people live and work in mega cities, they depend on various lifeline systems, including transportation systems, such as subways, and water and power supply systems. In most mega cities around the world, the availability of land above the ground surface level for lifeline systems is very limited; therefore, these lifeline systems tend to be constructed underground. Accordingly, mega cities often have spatially complicated underground corridors composed of the various lifeline systems and other structures, such as building foundations.

In terms of earthquake engineering, many mega cities exist in seismically active regions in Japan as well as in the U.S. In design practice, seismic performance is generally evaluated on the basis of a single structure. There is no or few assessments of accounting for possible interaction between multiple neighboring structures and soil during strong earthquake motions.

In light of this, a series of large-scale model tests are planned at E-Defense in 2011 and 2014 to obtain better understanding of the seismic behavior of complicated underground systems. Based on ideas exchanged with practitioners and discussions by a technical advisory board, target structures are have been selected to address the following conditions: (1) effect of neighboring structures, (2) seismic behavior of vertical structures and (3) damage development at joints.

Review of the Draft of the Test Plan:

Based on the research background above, the draft of the large-scale model test at E-Defense (Figure 1) was prepared prior to the breakout session of the meeting. In the session, the participants reviewed and discussed the draft. During discussions in the session, a number of areas that need to be clarified before finalizing the test specifications were identified as follows:

1. Scaling issues in terms of similitude between the structure and soil
2. Scaling of the mass of the tunnel structure in order to adequately represent the length of the tunnel structure
3. Properties of model structures (e.g. stiffness)
4. Spacing of the structures showing significant interaction
5. Properties of structural joints between vertical and horizontal components
6. The issue of sand density and settlement
7. Characteristics of input ground motions for the test specimen on the shaking table
8. Instrumentation options, especially for the area of contact pressures (tactile sensors) and deformation measurements (fiber optic)
It is essential that details of the test plan need to be finalized by February 2011.

![Diagram](image)

**Figure 1 Draft of test setup plan**

**Possible Collaborations:**

The sophisticated nature of this research project presents a number of areas for potential U.S. and Japan research collaboration. Specifically, the following areas have been identified as areas of opportunity for future collaboration:

1. Performance of centrifuge tests for baseline data and to provide independent verification of the consistency of test results
2. Calibration of numerical modeling and parameters, especially for dry sand
3. Comparison of possible instruments to establish the best sensing plan for the large-scale model test (e.g. tactile sensor, fiber optic sensor)
4. Collaboration with NEES for data simulation and visualization
5. Development of an environment for more frequent exchange of data and opinions

Possibilities of such collaboration work needs to be carefully considered considering policies for NEES/E-Defense research projects.

Specifically, the following steps will be carried in close collaboration in order to help in the development of the detailed test plan:

1. A preliminary elastic analysis will be performed to assess the issues of horizontal spacing of tunnel structures and their interaction with vertical shafts.
2. The proposed centrifuge test and 1-g shaking table test will be used to perform a baseline physical model study.
3. The potential use of tactile and fiber optic sensors will be further explored.
4. Further material characterization will be performed.
5. The current status of the project will be presented to interested potential NEES participants at the Quake Summit in San Francisco at 11 am-12:30 pm, Saturday October 9th.
6. The time of the next planning meeting will be established as soon as possible to assure maximum participation.
Session Summary Report
Breakout Session 2(d) Energy Facilities

Moderators: Khalid Mosalam (University of California, Berkeley) and Tomohiro Ito (Osaka Prefecture University)
Recorder: Khalid Mosalam (University of California, Berkeley)
Members (in alphabetical order of last names): Keisuke Minagawa (Tokyo Denki University), Izumi Nakamura (NIED), Masayoshi Nakashima (NIED)

Background:
Our modern way of life in both Japan and the US depends on an uninterrupted supply of electric energy. Electricity permeates not only industry, transportation and communications, but also conduct of business, education and social functions in our societies. Insuring uninterrupted production and supply of electricity is, therefore, a task of the utmost importance for the structural engineers in Japan and in the US. The NEES/E-Defense meeting focused on the seismic hazard exposure of electricity transmission and production facilities.

The discussion in the meeting was mainly focused on the electric facility, but the energy facility components present a special case of the general class of high-importance infrastructure facilities. These include natural gas energy generation facilities, liquid natural gas storage facilities, petrochemical refineries, storage and transportation facilities, and water purification, transportation and storage facilities.

Discussions:
In the meeting, we were reminded that the prior research activities were limited in this field and the community of researchers was small. The seismic issues for the energy facilities were less understood compared with other structures, though the structures had a high impact on society when they were damaged by earthquakes. Therefore, it was agreed that the Japanese and the US sides should made an effort to gather more participants in the next year meeting with possible representatives from the industry and practitioners to identify key problems related to the seismic performance of energy facilities.

The rough plan of the shake table test on piping system models was proposed by the Japanese side, and we agreed that the test objectives are suitable for the large scale shake table test as the first stage of the experimental study in the field of the energy facilities. This is indeed the case since the piping system is generic and the knowledge from the study would be useful to many plants and facilities. The example of the structural damage in the Kobe earthquake and the outline of the multiple input simulators for the piping system model were also introduced by Professor Ito. Based on the proposed tests and the related discussion, the following effects or problems were agreed as essential ones to consider in conjunction with the planned seismic performance of the piping system.

1. High fidelity simulation
2. Aging
3. Fatigue
4. Effect of high pressure / flow velocity, i.e. involving multi-physics problems
5. Different support conditions
6. Non-destructive inspection and monitoring systems
7. Connecting isolated to non-isolated structures, e.g. nuclear reactor to turbine building
8. Multiple input to the system using the hybrid simulation framework
9. Multi-directional excitation, especially including vertical acceleration (evidence from the Kobe earthquake observations)

From the US side, the shake table test and hybrid simulation on the porcelain insulators were introduced by Professor Mosalam. We agreed to promote the development and validation of hybrid simulation framework for energy facilities, because it is a natural approach, from practicality and accuracy points of view, given by the segmented nature of these facilities.

**Desired Collaborations and Benefits of collaboration:**

It was concluded that Japan and the US should collaborate in characterizing the general and common features for a large benchmark shake table test for energy facilities. The benchmark test would be an effective vehicle to identify and tackle the unique seismic issue in the energy facilities. Moreover, other researchers can utilize the data to validate and improve analytical structural models for energy facilities. Both sides will greatly benefit from a coordinated research approach in the important area of energy facilities.

The following topics, which were discussed in the 2009 NEES/E-Defense meeting, should also be promoted at every chance for collaboration between the Japanese and the US sides.

1. Integrate equipment qualification test data from tests already conducted in the US and Japan with the newly conducted beyond-design-basis tests planned at E-Defense.
2. Conduct complementary large-scale tests using E-Defense for large and US shaking tables for comparatively smaller equipment. Use US shaking tables to conduct tests under differential support motions.
3. Conduct complementary and cooperative computational simulations to calibrate the numerical models using large-scale test data on the response of components, systems and structures.
4. Integrate response modification devices into the design of electric power facilities.
5. Develop fragility data with the common performance basis.
6. Develop design guidelines, assessment tools and practical recommendations based on the E-Defense and NEES data sets.
7. Enable fast dissemination of results at an international level and promote international collaboration in the field of critical infrastructure.
8. Educate younger generations of structural engineers to specialize in critical infrastructure facilities.
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These research programs aim to identify and reduce the risks from major earthquakes to life safety and to the economy by including research in a wide variety of disciplines including structural and geotechnical engineering, geology/seismology, lifelines, transportation, architecture, economics, risk management, and public policy.

PEER is supported by federal, state, local, and regional agencies, together with industry partners.

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ISSN 1547-0587X
Report of the Eighth Planning Meeting of NEES/E-Defense Collaborative Research on Earthquake Engineering

Held in Miki, Hyogo, Japan
September 17–18, 2010

Convened by
Hyogo Earthquake Engineering Research Center (NIED) and NEES Consortium, Inc.