

# Hybrid Simulation Workshop: Review and New Directions

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**nees@berkeley**

The George E. Brown, Jr. Network for Earthquake Engineering Simulation



# Hybrid Simulation

- ◆ Hybrid simulation is an experimentally based method for investigating the response of structure to dynamic excitation using a hybrid model
- ◆ A hybrid model is a an assemblage of one or more physical and one or more numerical, consistently scaled, substructures
- ◆ The equation of motion of a hybrid model under dynamic excitation is solved during a hybrid simulation test

# We Talked About...

- ◆ The basics
- ◆ Sub-structures and sub-structuring
- ◆ Similitude relations
- ◆ Errors and accuracy
- ◆ Integration algorithms
- ◆ OpenFRESCO implementation
- ◆ OpenSees Navigator user interface
- ◆ OpenSees (Silvia Mazzoni and Frank McKenna)
- ◆ Examples (by Tony Yang, Andreas Schellenberg)
- ◆ MTS hardware implementatin (Scott Jiran)
- ◆ Use of video and data

# We Could Have Talked About...

- ◆ Force and mixed DOF control
- ◆ Varieties of predictors and correctors
- ◆ More integration algorithms
  - Explicit, but stable
  - Fancy implicit algorithms
- ◆ Real-time testing
  - Modern servo-hydraulic controllers
  - Fast hardware
  - Different configurations and data flow
  - Analog feedback and open-loop tests
- ◆ New developments in the framework
- ◆ New frameworks being developed
- ◆ Complex non-linear multi-sub-structured hybrid models and simulations all over the world

# New Directions: For Hybrid Simulation Developers

- ◆ To achieve widespread adoption:
  - Develop stable and portable implementations
  - Develop good user interfaces
- ◆ Develop measures of test quality:
  - On-line indicators of simulation error
  - Post-experiment evaluation tools
- ◆ Improve simulation methods:
  - Better algorithms and models
  - Better communication protocols and faster data flow
  - Better integration of physical and computer worlds
  - Go faster! (maybe faster than real-time?)
- ◆ Make hybrid simulations acceptable as benchmark tests
  - Develop a portfolio of proof-of-concept simulations

# New Directions: For Hybrid Simulation Users

## ◆ Adopt hybrid simulation:

- Plan and conduct research using it in combination with other experimental and analytical tools
- Use the rigor required to design hybrid models to elevate the quality of research
  - ◆ Similitude, error analysis, result interpretation

## ◆ Boldly go where no one has gone before:

- Develop new structural concept
- Investigate complex interaction

where hybrid simulation may be the only experimental method that can provide an answer

# Is Hybrid Simulation Good for ME?

## ◆ Hybrid models enable:

- Investigations at large scale for realistic excitations
- Integration of sub-structures to achieve high levels of complexity at (hopefully) a fraction of the cost
- Control of scale, time, interactions and accuracy

## ◆ Hybrid simulation:

- Gives a better view on the response of structures
- Enables a rigorous examination of the value of an experiment with respect to research goals
- Makes small laboratories look big!

# Follow-up: <http://opensees.berkeley.edu>

The screenshot shows the OpenSees website homepage in Internet Explorer. The browser title is "Open System for Earthquake Engineering Simulation - Home Page - Windows Internet Explorer". The address bar shows "http://opensees.berkeley.edu/index.php". The website has a dark blue header with the "OpenSees" logo and navigation tabs for "HOME", "USER", "DEVELOPER", "PROJECTS", "SUPPORT", and "SITE MAP". Below the header, there are links for "About", "News", "Calendar", and "Registration". The main content area is divided into three columns. The left column contains links for "MESSAGE BOARD", "USER DOC", "DOWNLOAD", "SOURCE CODE", and "BUG REPORT", along with a search box and a "Site Map" link. The middle column features a "Welcome" section with a paragraph about the software's purpose, a paragraph about the development goal, a paragraph about continual development, and a paragraph about sponsorship by the Pacific Earthquake Engineering Research Center through the National Science Foundation. The right column has a "Register" section with information about new releases and a "News" section with a list of recent updates from 2005 to 2006, including "New Examples Manual released", "Version 1.7.3 Released", "Workshop Presentation Material Node Available", "Version 1.7.2 Released", "Copyright Revised", "Version 1.7.1 Released", and "Server Running Again". At the bottom of the right column, there is a "Calendar" section with an entry for "2006-09-16 OpenSees Symposium". The footer of the browser shows "Done" and "Internet" with a 100% zoom level.

# Follow-up: <http://nees.berkeley.edu>

The screenshot shows a Windows Internet Explorer browser window displaying the homepage of nees@berkeley. The browser's address bar shows the URL <http://nees.berkeley.edu/>. The website header features the nees@berkeley logo, which includes a stylized blue circular graphic, and the text "The George E. Brown, Jr. Network for Earthquake Engineering Simulation". A navigation menu on the left side lists: Home, Facilities, Projects, Outreach, Events, Contacts, and Live Video. The main content area is titled "Welcome to nees@berkeley!" and includes a photograph of a group of people in a laboratory setting. The text below the photo describes the network's focus on modeling large-scale structural systems and experimental evaluation. A "News & Events" sidebar on the right lists upcoming events, including a "NEES Hybrid Simulation Workshop" on Dec. 11-12, 2006, and "Currently in Progress" projects like the "Hybrid Simulation of Base Isolated Structures". At the bottom of the page, there is an "Announcement" section regarding the "2006 November 08 - NEESR Proposal Assistance" and contact information for Bozidar Stojadinovic.

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The George E. Brown, Jr. Network for Earthquake Engineering Simulation

Home  
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Projects  
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Live Video

## Welcome to nees@berkeley!

... the place to find out how buildings and bridges respond to earthquakes.

We are an equipment site of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). Our specialty is modeling large-scale structural systems and experimental evaluation of their response to earthquakes. We continue the long Berkeley tradition of pioneering new experimental and numerical modeling and evaluation methods. At nees@berkeley you can certainly do conventional tests using our configurable reaction wall facility and a versatile array of actuators. However, we are very proud to have developed new hybrid simulation methods that combine physical and analytical sub-structures into a hybrid model of the entire structure using our state-of-the-art digital controllers and networks, the OpenFresco interface framework, and the latest finite element models built using the OpenSees analysis framework. We invite you to test your new ideas at nees@berkeley.

nees@berkeley is also a place of discovery. Here, you can see how earthquakes can affect structures. We have many videos of experimental testing on hand and several laboratory demonstrations ready to run for middle- and high-school students. We also run research experience sessions during the summer. [Contact us](#) to arrange your visit to nees@berkeley.

### Announcement

#### 2006 November 08 — NEESR Proposal Assistance

The NSF deadline for George E. Brown, Jr. Network for Earthquake Engineering Simulation Research (NEESR) Proposals is 2007 January 30. The RFP is available at [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=nsf07506](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf07506). If you are interested in using the nees@berkeley lab, please feel free to contact the following individuals:

Bozidar Stojadinovic [boza@ce.berkeley.edu](mailto:boza@ce.berkeley.edu) Testing Information  
Dan Glavin [dglavin@berkeley.edu](mailto:dglavin@berkeley.edu) Lab Information

## News & Events

### Upcoming!

**Dec. 11-12, 2006**  
**NEES Hybrid Simulation Workshop**  
A team led by Bozidar Stojadinovic will present the course material and participants will conduct a real hybrid simulation experiment using the nees@berkeley Equipment Site.

### Currently in Progress

**Hybrid Simulation of Base Isolated Structures**  
PI: Steve A. Mahin (UCB)  
After accomplishing shaking table tests, the test structure has been moved to the RRW experimental facility in a new test setup for hybrid simulation. The test setup consisting of reaction frames and 6 actuators has been assembled and the project crew is dealing with instrumentation. The tests are scheduled to start in December 2006.

**September - October 2006**  
**NEES TITech and UCB Joint Research on The Seismic Performance of Bridge Columns Based on NEES & E-Defense Collaboration**  
PIs: Steve A. Mahin (UCB) Kazuhiko Kawashima (TITech)  
The tests have been finished

# Thank you!

Development and operation of the nees@berkeley equipment site is sponsored by NSF.

<http://nees.berkeley.edu>

Contributions to this workshop from EVERYONE at *nees@berkeley* are gratefully acknowledged.



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