



OpenSees

Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center



NEES / PEER OpenSees Days 2011

Presented by the OpenSees Community
August 22-23, 2011

Sponsored by:
NEES through NEEScomm
Pacific Earthquake Engineering Research Center
National Science Foundation

<http://opensees.berkeley.edu/wiki/index.php/OpenSeesDays2011>

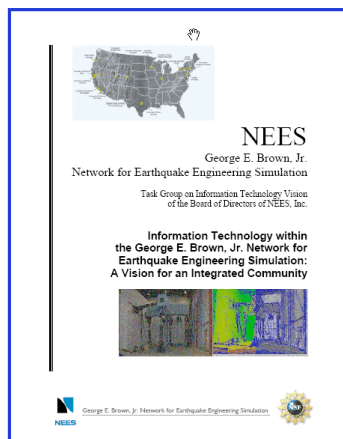
On behalf of the:
George E. Brown Network for Earthquake Engineering Simulation
(NEES)
and the
Pacific Earthquake Engineering Research Center
(PEER)

WELCOME

Simulation in Earthquake Engineering

- Research and practice is moving towards Performance-Based Seismic Engineering, which depends on high-fidelity models and simulation to assess performance.
- Simulation models capture knowledge from tests to leverage investment in limited experimentation.
- Community-based, open-source software for simulation promotes innovation in research and advanced applications for practice.
- NEES is supporting OpenSees to provide simulation capability and integration with NEEScomm services for NEES research.

Vision for Simulation



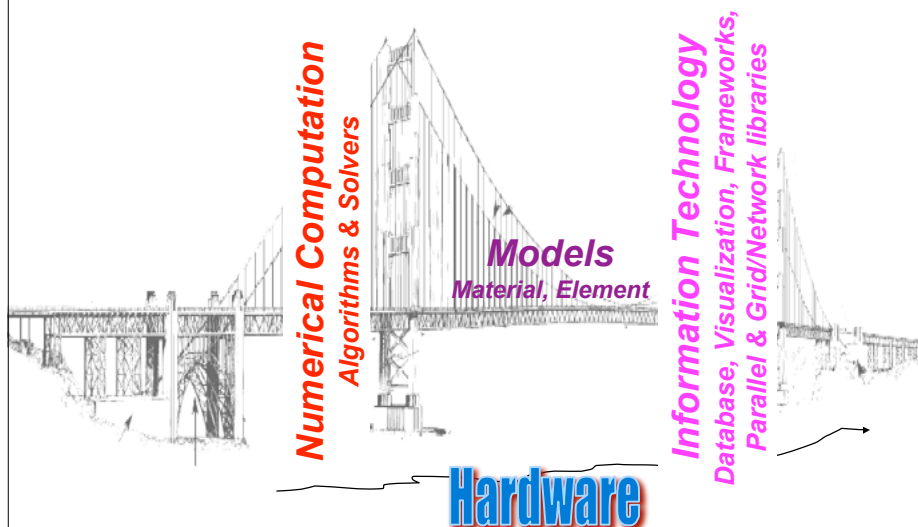
Computational modeling and simulation is central to the vision of NEES to transform the development of new earthquake engineering solutions from being primarily based on experiments to a balanced use of simulation and experimentation using computational models validated by experimental data.

A close integration of modern computational models and simulation software with other NEES applications and services will provide the earthquake engineering community, and broad engineering users, new capabilities for developing innovative and cost-effective solutions.

Observations on Current Situation

- Tight binding of models in research and commercial codes is an impediment to new research and implementation of models for professional practice.
- Embedding of computational procedures in codes makes it difficult to experiment and take advantage of computing technology:
 - Parallel and distributed computers
 - Computational grids
- “Closed-source” is the norm, whereas other fields have adopted “open-source” software for communities users.

Building Blocks for Modern Simulation Code



Open-Source - Leave it out there for community

What is OpenSees?

- A software *framework* for simulation applications in earthquake engineering using finite element methods. OpenSees is not an application.
- A communication mechanism for exchanging and building upon research accomplishments.
- As open-source software, it has the potential for a community code for earthquake engineering.



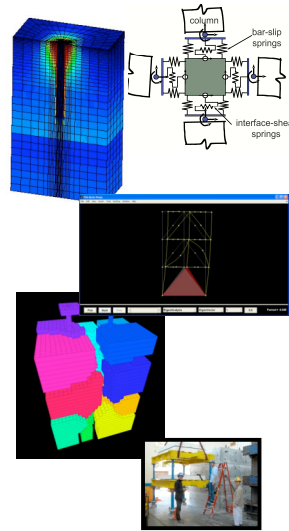
<http://opensees.berkeley.edu>

- OpenSees has been under development by PEER since before 1997.
- Large group of developers and user.
- NEES has supported integration and extension since 2003.
- Open-source and royalty free license for non-commercial use and internal commercial use.
- License must be obtained for software developers including OpenSees code in their applications.
- Written in C++ language & currently over 1000 classes (modules)

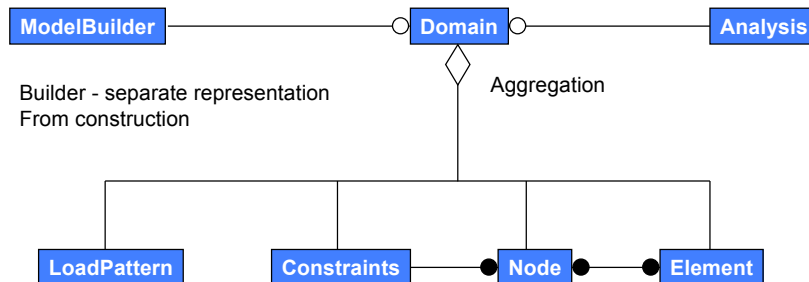
The image is a screenshot of the OpenSees website homepage. At the top, there is a navigation menu with links for HOME, USER, DEVELOPER, PROJECTS, SUPPORT, and SITE MAP. Below the menu, there is a "Welcome" section with a message from the developers. To the right, there is a "News" section with a list of recent updates, including "New Examples Manual released" and "Version 1.7.2 Released". At the bottom, there is a "Calendar" section with a list of upcoming events, including "OpenSees Summer 2006" and "OpenSees Developer". The website has a clean, professional layout with a blue and white color scheme.

OpenSees Approach to Simulation

- Basic approach:
 - Modular software design for implementing and integrating modeling, numerical methods, and IT for scalable, robust simulation
 - Focus on capabilities needed for performance-based engineering
 - Programmable interfaces
- Most users: a “application” for nonlinear analysis. Fully scriptable.
- Generally: a software framework for developing simulation applications.

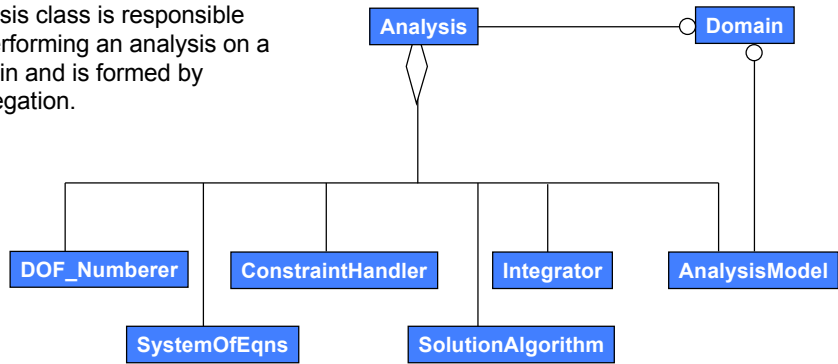


Structural Models as Aggregation Pattern

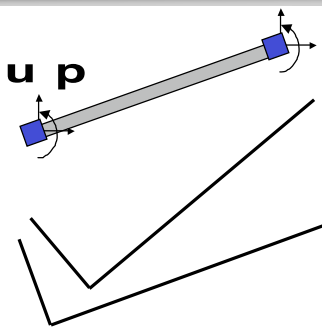


Analysis Class for Simulation

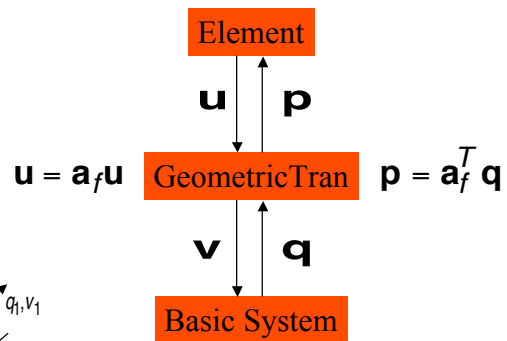
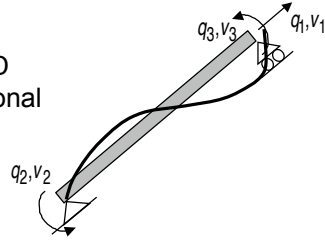
Analysis class is responsible for performing an analysis on a domain and is formed by Aggregation.



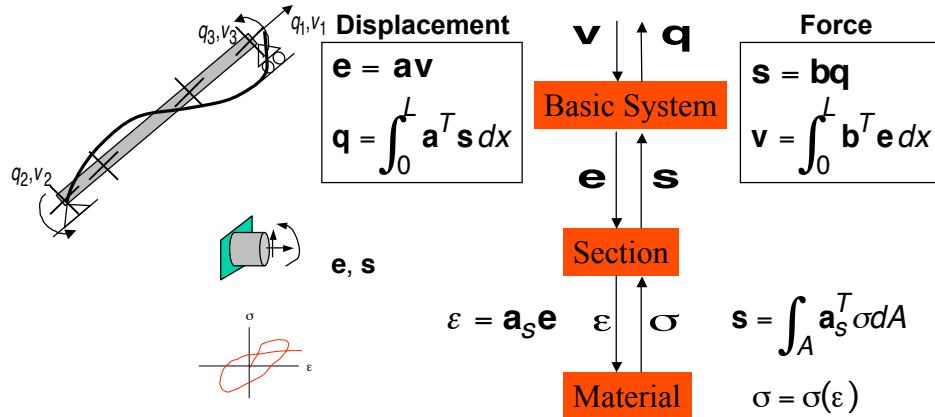
Beam-Column Models I



Linear
LinearPD
Corotational

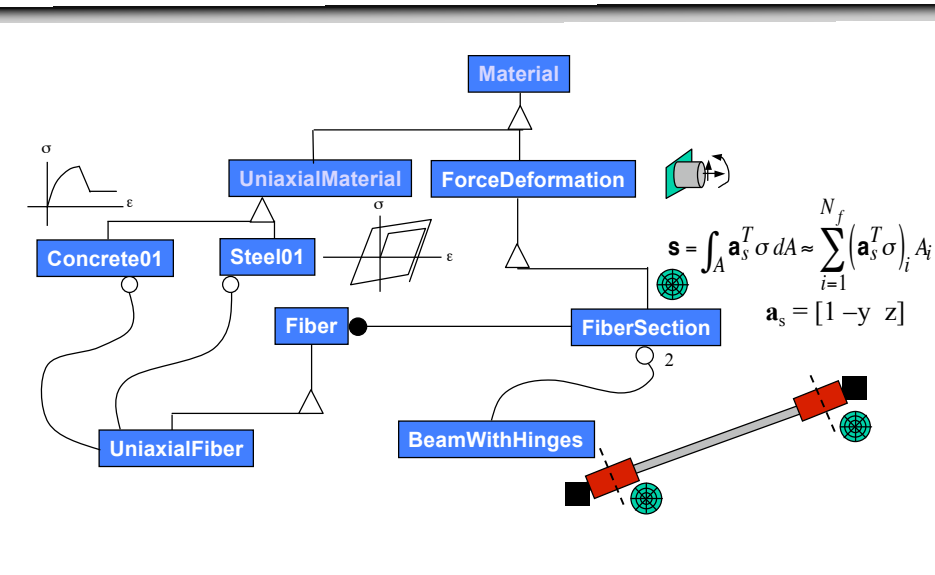


Beam-Column Models II



No assumptions are made on section or material behavior; each level in the hierarchy can be defined independently of other levels

Form Follows Mechanics



OpenSees Scripting

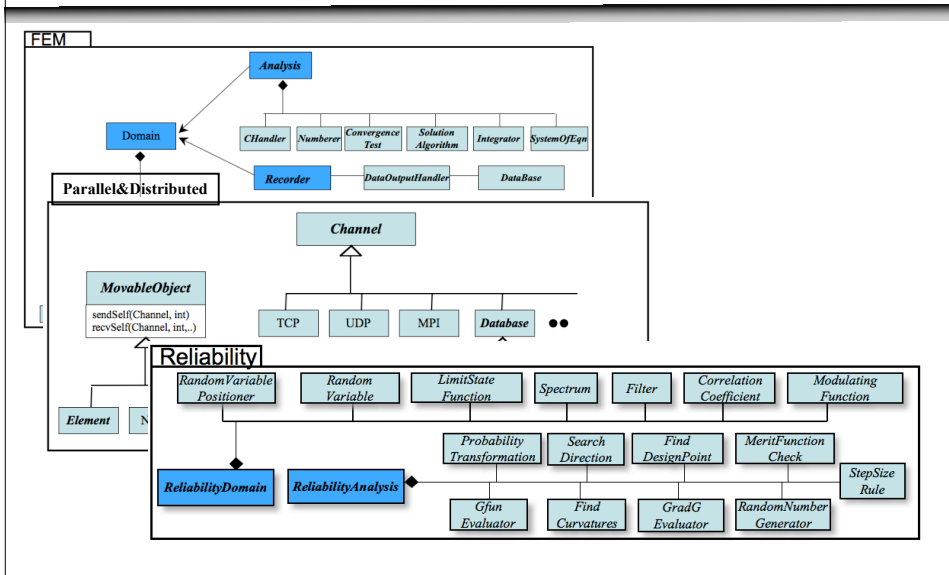
```

1. wipe
2. source Units.tcl;           # define units
3. source ParamList.tcl;      # load up parameter values
4. source GMFiles.tcl;        # load up ground-motion filenames

5. foreach Xframe $IXframe Hco $IHcol Lcol $ILcol Lbeam $ILbeam
   Gblc $IGblc GrhoCol $IGrhoCol GPco $IGPcol GMfact $IGMfact {
6.   { source Static.tcl; # load procedure for static analysis
7.     source Dynamic.tcl; # load procedure for dynamic analysis
8.     puts FRAME$Xframe.....FRAME$Xframe.....
9.     puts STATIC_ANALYSIS
10.    Static $Xframe $Hcol $Lcol $Lbeam $Gblc $GrhoCol $GPcol $GMfact ;
11.    puts DYNAMIC_ANALYSIS
12.    foreach GroundFile $GroundFile {
13.      puts GroundMotion$GroundFile
14.      Dynamic $Xframe $Hcol $Lcol $Lbeam $Gblc $GrhoCol $GPcol $GMfact $GroundFile;
15.    }
16.  }

```

OpenSees has more capabilities than the typical FE Application



NEES

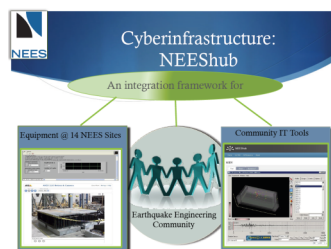
The Network for Earthquake Engineering Simulation (NEES) is a shared national network of 14 experimental facilities, collaborative tools, a centralized data repository, and earthquake simulation software.



NEEShub




- The power behind NEES at <http://nees.org>
- Maintained and developed at Purdue by NEEScomm
- A science gateway for education and research in earthquake engineering



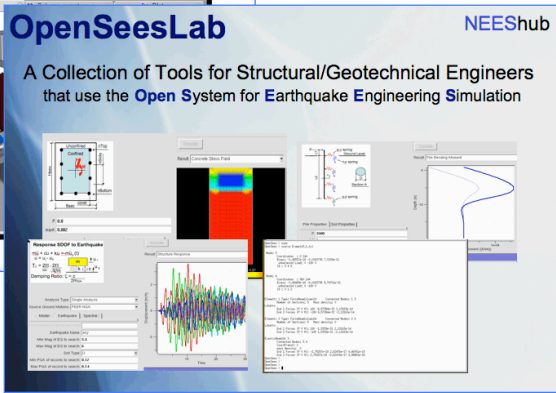
Through a browser engineers can:

- Upload and view experimental data
- Browse online seminars and courses
- Launch sophisticated tools using remote computational resources (OpenSeesLab)

NEEShub Tools and Resources



Simulation



Data Management

OpenSeesLab NEEShub

A Collection of Tools for Structural/Geotechnical Engineers that use the **Open System** for **Earthquake Engineering Simulation**

Objective of OpenSees Days

- Describe modeling and analysis capability, including hierarchy of system, element, section, material
- Overview of applications, structural and geotechnical
- Show specific examples of nonlinear analysis
- Provide hands-on starting-point for simulation tools
- Introduce NEEShub capabilities using OpenSees
- Motivation to use OpenSees for your simulation problems....

What Should be Your Expectations?

- OpenSees is primarily a research tool at this time, but fairly stable and is used in professional practice
- As with any nonlinear analysis, it requires careful consideration of model and interpretation of results
- It is under continual development by students, faculty and other researchers
- User interface development lags behind computational technology
- It is not bullet-proof
- An investment of time and learning is required
- The OpenSees *open-source community* requires contributions for the community to succeed.

Thanks to:

- PEER staff (Heidi, Veronica, & Yolanda)
- Silvia Mazzoni & Degenkolb Engineers
- Andreas Schellenberg &
- Rudi Eigenmann and Greg Rodgers
- *All the presenters*

NEEScomm, PEER, and the National Science Foundation