



OpenSees

Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center

NEESit

PEER/NEESit OpenSees User Workshop

Presented by the OpenSees Community

August 14, 2006

Sponsored by:

National Science Foundation

Pacific Earthquake Engineering Research Center

NEESit

Context

- PEER Research Program in Performance-Based Earthquake Engineering.
- Development of enabling technology is expected of NSF research centers.
- User base of OpenSees growing as are applications.
- NEESgrid adopted OpenSees as the simulation component for the NEES system integration project.
- NEESit is supporting OpenSees to provide simulation capability and integration with NEESit services for NEES research.

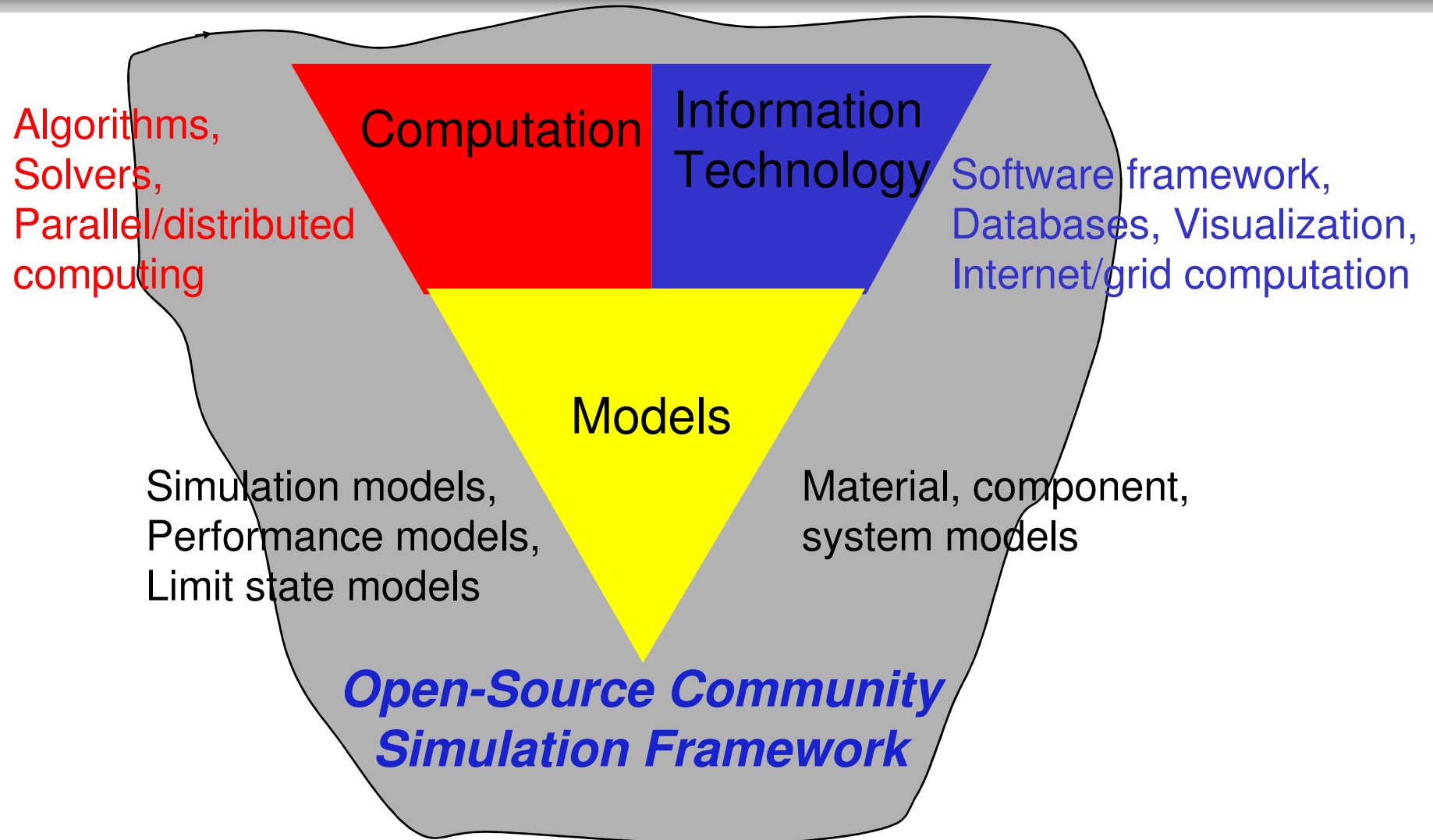
Observations on Current Situation

- 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.

What is OpenSees?

- A software *framework* for simulation applications in earthquake engineering using finite element methods. OpenSees is not a code.
- 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.

Conceptual Approach for Simulation

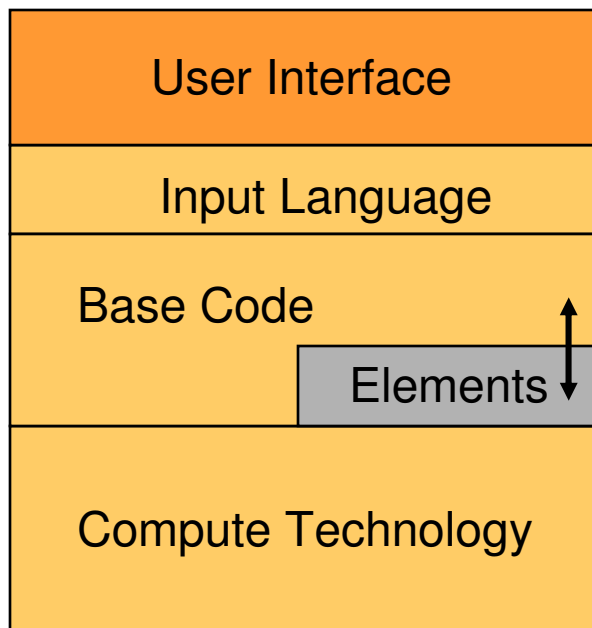


Software Framework

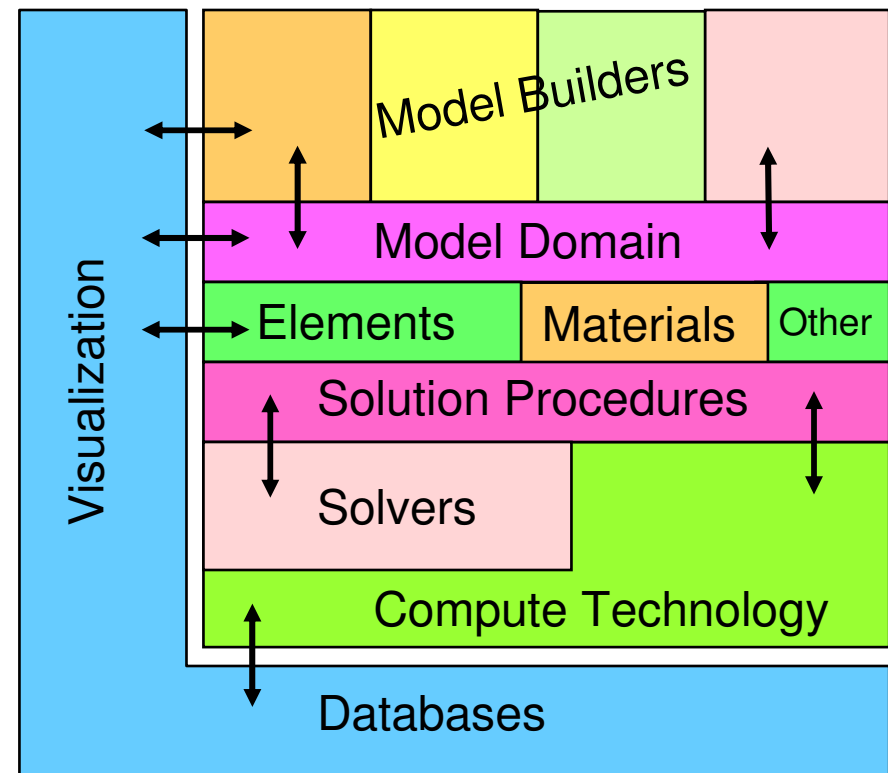
- A *framework* is a set of cooperating software components for building applications in a specific domain.
- A framework dictates the architecture of the application. It must represent the design decisions common to the application domain.
- A framework is based on the assumption that an architecture will work for most applications within the domain.
- Loose-coupling of components within the framework is essential for extensibility and re-useability for applications.
- Examples: Visualization (GLUT), MS Office, compilers ...
- *A framework is not a “code”*

Simulation Software Alternatives

Traditional Code



Framework of Components



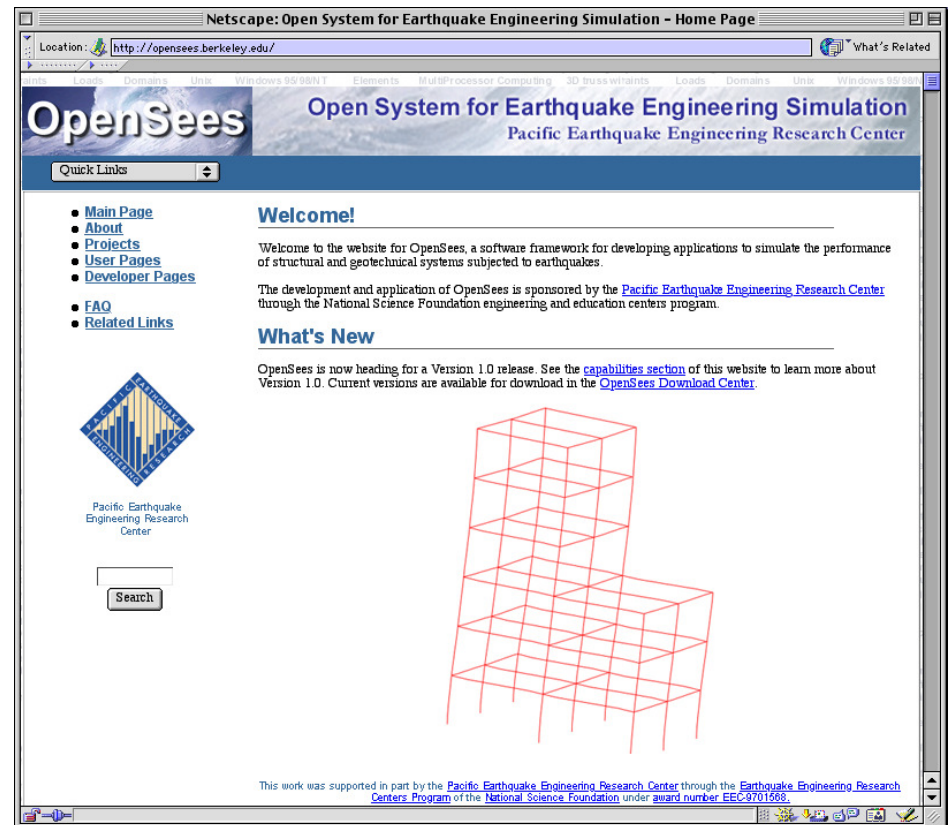
↔ Application Program Interface (API)

OpenSees

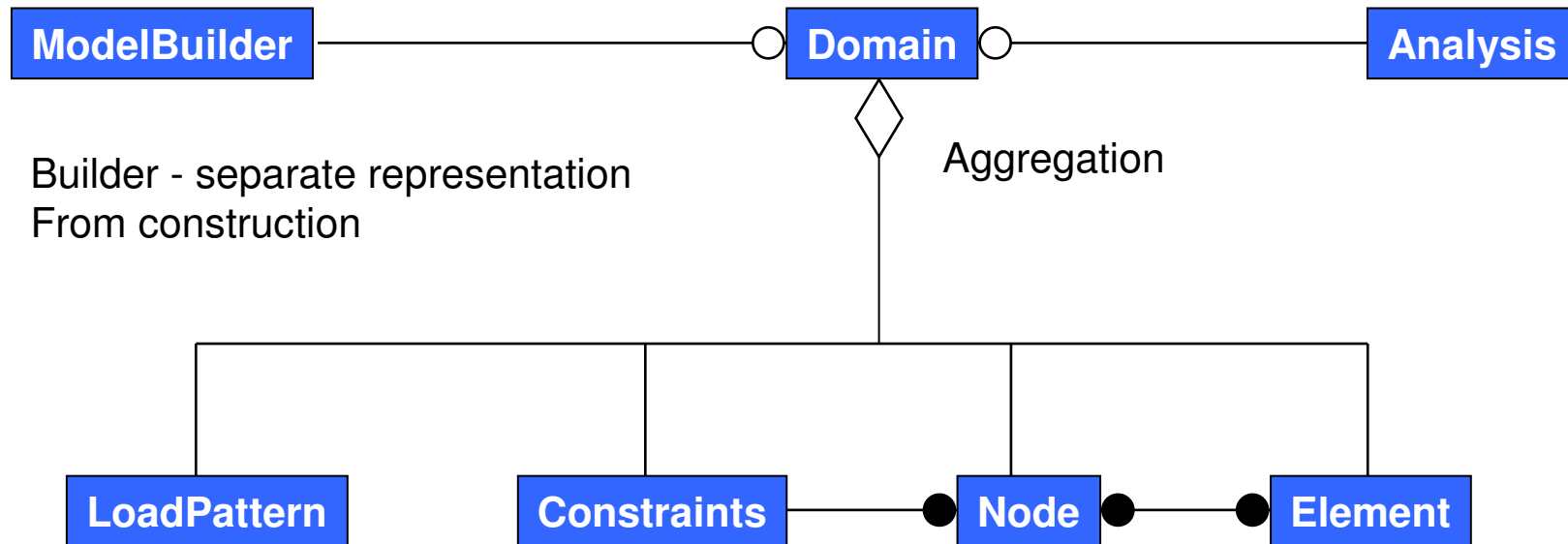
Open System for Earthquake Engineering Simulation
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<http://opensees.berkeley.edu>

- OpenSees has been under development by PEER since before 1997.
- Core group of developers and users.
- PEER will continue research and development for PBEE applications in OpenSees.
- Copyrighted by UC Regents and free for use.
- Google search hits as proxy for interest (8/8/06)?
 - OpenSees-64,200
 - ABAQUS [finite]-266,000
 - SAP2000-336,000

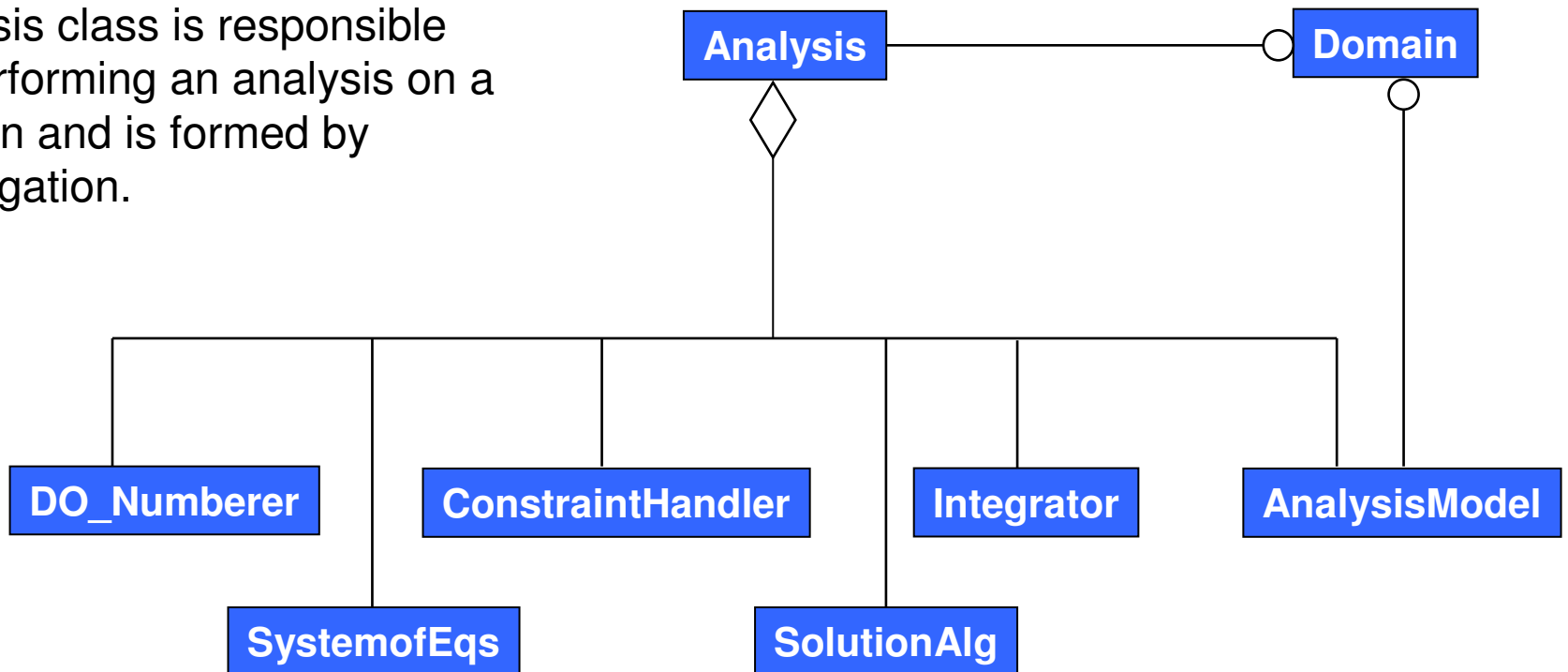


Structural Models as Aggregation Pattern

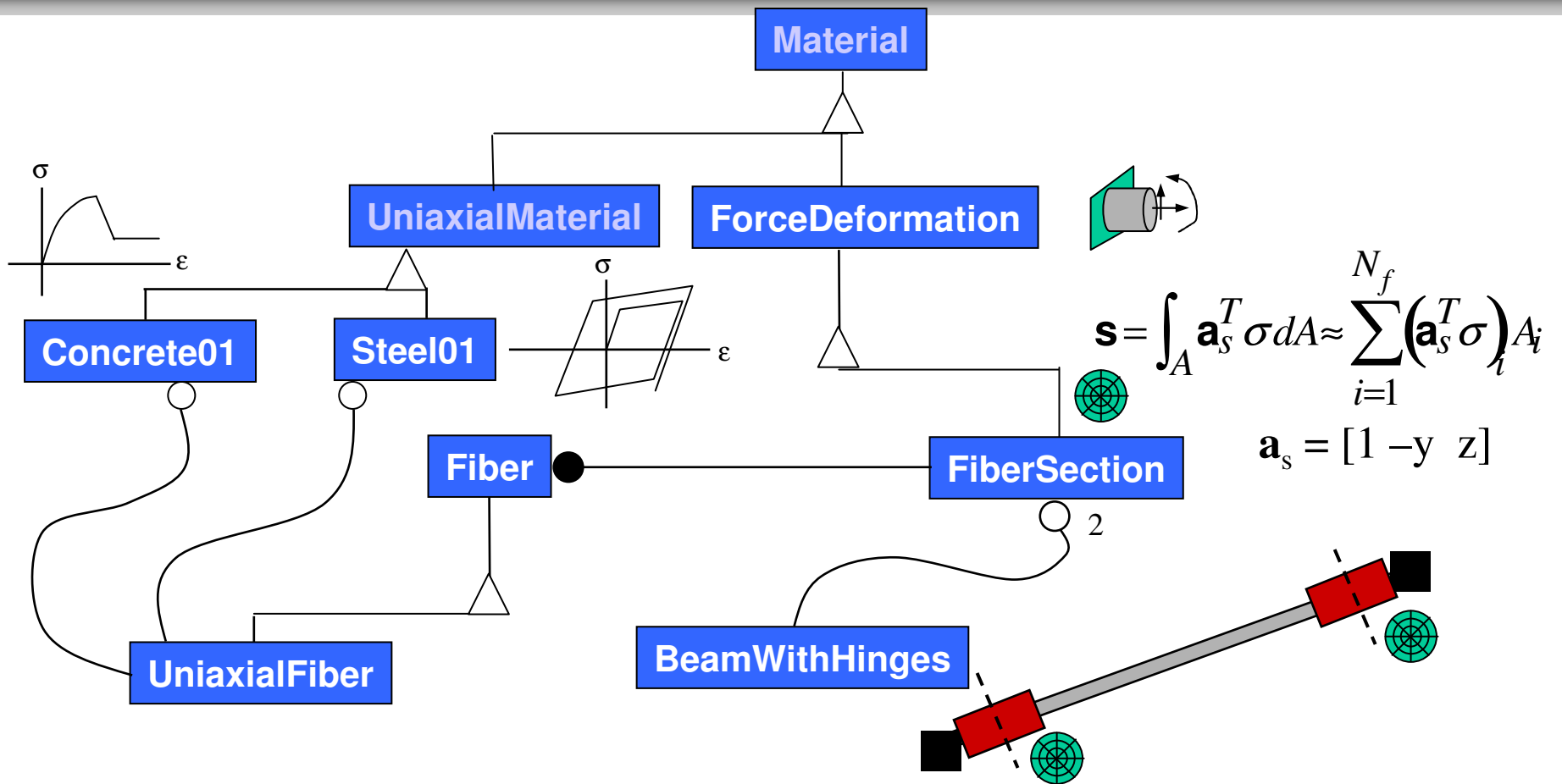


Analysis Class for Simulation

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



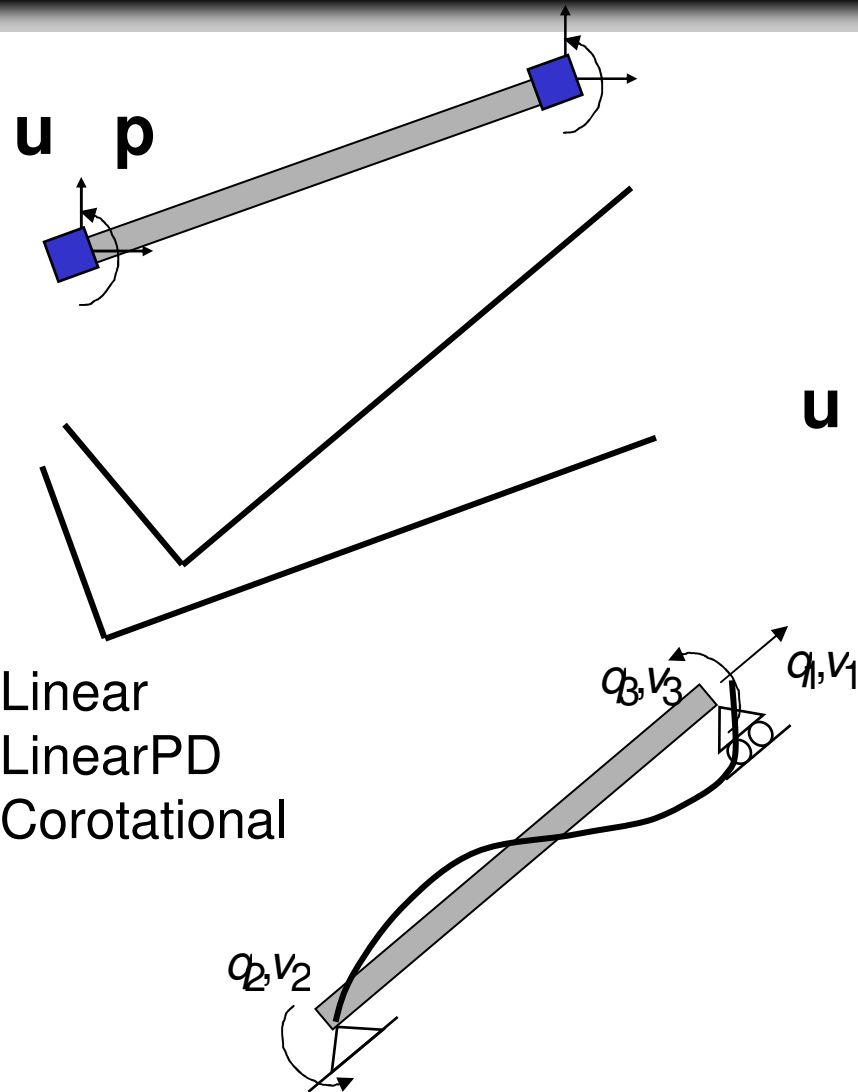
Form Follows Mechanics



$$\mathbf{s} = \int_A \mathbf{a}_s^T \sigma dA \approx \sum_{i=1}^{N_f} (\mathbf{a}_s^T \sigma)_i A_i$$

$$\mathbf{a}_s = [1 \ -y \ z]$$

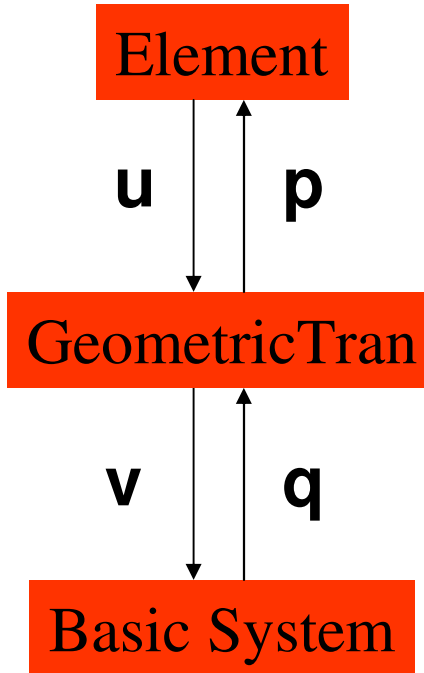
Beam-Column Models I



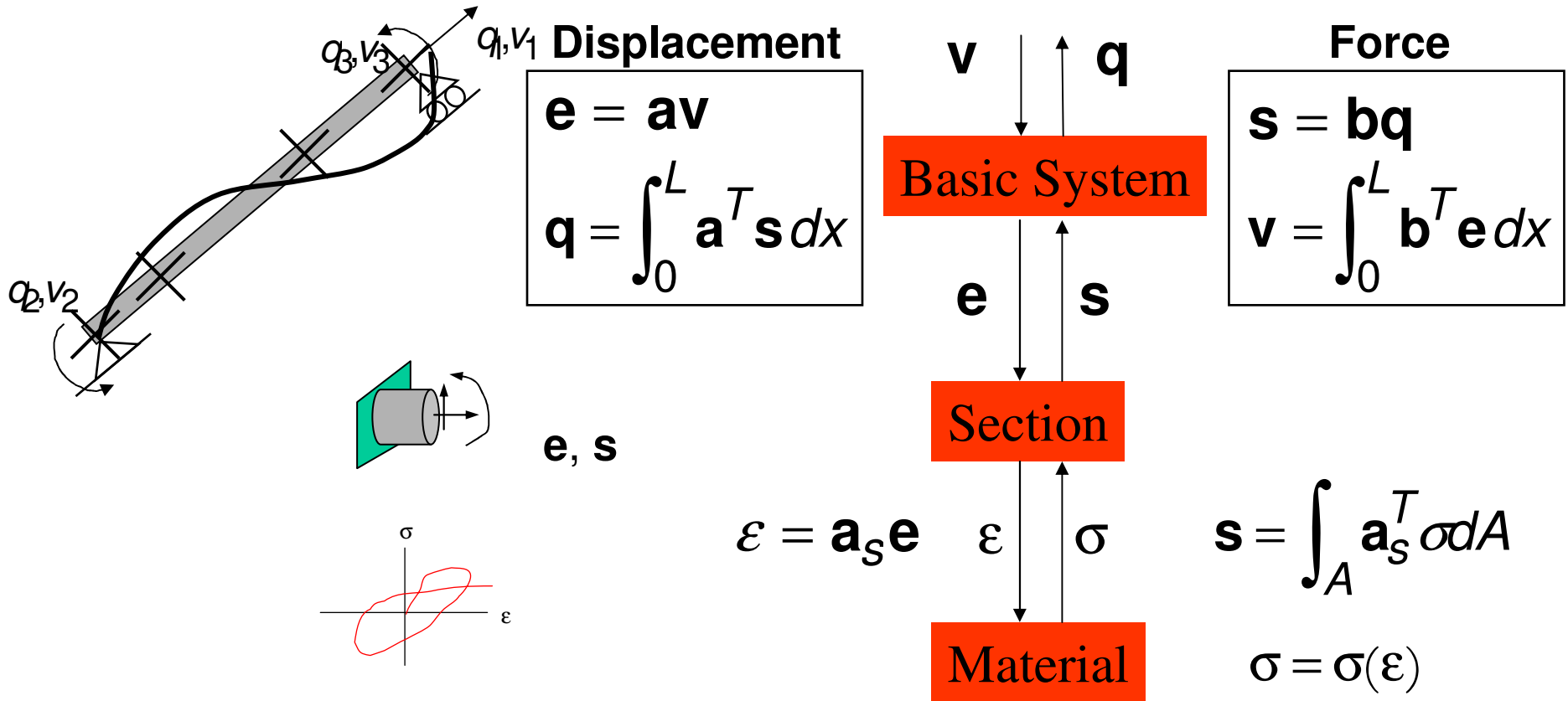
$$\mathbf{u} = \mathbf{a}_f \mathbf{u}$$

GeometricTran

$$\mathbf{p} = \mathbf{a}_f^T \mathbf{q}$$



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

Scripting Models

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 $Xframe Hcol $Hcol Lcol $Lcol Lbeam $Lbeam          FRAME
   Gblc $Gblc GrhoCol $GrhoCol GPcol $GPcol GMfact $GMfact {
6. { source Static.tcl; # load procedure for static analysis          }
7. { source Dynamic.tcl;      # load procedure for dynamic analysis    }
8. puts FRAME$Xframe.....FRAME$Xframe.....
9. puts STATIC_ANALYSIS
10. Static $Xframe $Hcol $Lcol $Lbeam $Gblc $GrhoCol $GPcol $GMfact ;
11. puts DYNAMIC_ANALYSIS
12. foreach GroundFile $GroundFile {          GROUND MOTION
13.     puts GroundMotion$GroundFile
14.     Dynamic $Xframe $Hcol $Lcol $Lbeam $Gblc $GrhoCol $GPcol $GMfact $GroundFile;
15. }
16. }
```

Online User Guide

The screenshot shows a web browser window displaying the OpenSees User Manual. The browser's address bar shows the URL <http://peer.berkeley.edu/~silvia/OpenSees/manual/html/>. The page features a header with the OpenSees logo and the text "Open System for Earthquake Engineering Simulation" and "Pacific Earthquake Engineering Research Center". Below the header, there are two main sections: a "Contents" sidebar on the left and a main content area on the right. The "Contents" sidebar lists various sections of the manual, including "title", "Introduction", "OpenSees", "Getting Started on OpenSees", "Download OpenSees", "Run OpenSees", "Problem Definition", "Model Builder", "Getting Started -- Nodes & Elements", "Elements & Element Connectivity", "Gravity Loads", "Recorders", "Lateral Loads", "Getting Going (under development)", "Model-Building Objects", "Recorder Objects", "Analysis Objects", "Miscellaneous Commands", "How To...", "References", and "Index". The main content area displays the title "Open System for Earthquake Engineering Simulation User Manual" in large, bold black text. Below the title, the authors are listed: "Software Authors: Frank McKenna, Gregory L. Fenves, et al." and "Manual Authors: Silvia Mazzoni, Frank McKenna, Michael H. Scott, Gregory L. Fenves, et al." The text also mentions the "Pacific Earthquake Engineering Research Center" and "University of California, Berkeley". At the bottom of the main content area, it says "version x." and "please send questions and comments about the manual to silvia@peer.berkeley.edu".

OpenSees User Manual version 2.0

<http://peer.berkeley.edu/~silvia/OpenSees/manual/html/>

OpenSees Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center

Contents Index

title

Open System for Earthquake Engineering Simulation User Manual

Software Authors: Frank McKenna, Gregory L. Fenves, et al.

Manual Authors: Silvia Mazzoni, Frank McKenna, Michael H. Scott, Gregory L. Fenves, et al.

Pacific Earthquake Engineering Research Center

University of California, Berkeley

version x.

please send questions and comments about the manual to silvia@peer.berkeley.edu

Framework Design/Source for Developers

Class Specification Application Program Interface

Source Code Viewing/Updating With CVS

The screenshot shows a Netscape browser window titled "Netscape: Contents". The address bar contains the URL <http://opensees.berkeley.edu/OpenSees/api/contents.html>. The page header features the "OpenSees" logo and the text "Open System for Earthquake Engineering Simulation" and "Pacific Earthquake Engineering Research Center". Below the header is a "Quick Links" dropdown menu. The main content area is titled "OpenSees API Specification" and contains a section labeled "Class Index" with a list of classes organized into a tree structure:

- Matrix Classes
 - Matrix
 - Vector
 - ID
- Domain Classes
 - DomainComponent
 - Element
 - Truss
 - ZeroLength
 - ElasticBeam2d
 - ElasticBeam3d
 - BeamWithHinges2d
 - BeamWithHinges3d
 - NI_BeamColumn2d
 - NI_BeamColumn3d
 - FourNodeQuad
 - Damper
 - Node
 - Load
 - NodalLoad
 - ElementalLoad
 - SP_Constraint
 - MP_Constraint
 - LoadPattern
 - EarthquakePattern
 - UniformExcitation
 - TimeSeries
 - ConstantSeries
 - LinearSeries
 - RectangularSeries

The screenshot shows a Netscape browser window titled "Netscape: OpenSees Source Code Browser: /SRC/material/uniaxial". The address bar contains the URL <http://millen.ce.berkeley.edu/cgi-bin/cvsweb/SRC/material/uniaxial/>. The page has a "Quick Links" dropdown menu. Below the menu is a text box with instructions: "Click on a directory to enter that directory. Click on a file to display its revision history and to get a chance to display diffs between revisions." The current directory is listed as "/SRC/material/uniaxial". A list of files and directories is shown, including:

- [UP] Previous Directory
- [TXT] Concrete01.cpp
- [TXT] Concrete01.h
- [TXT] Concrete01.tex
- [TXT] EPPGapMaterial.cpp
- [TXT] EPPGapMaterial.h
- [TXT] ElasticMaterial.cpp
- [TXT] ElasticMaterial.h
- [TXT] ElasticMaterial.tex
- [TXT] ElasticPPMaterial.cpp
- [TXT] ElasticPPMaterial.h
- [TXT] ElasticPPMaterial.tex
- [TXT] HardeningMaterial.cpp
- [TXT] HardeningMaterial.h
- [TXT] HystereticMaterial.cpp
- [TXT] HystereticMaterial.h
- [TXT] Makefile
- [TXT] ParallelMaterial.cpp
- [TXT] ParallelMaterial.h
- [TXT] ParallelMaterial.tex
- [TXT] PathIndependentMaterial.cpp
- [TXT] PathIndependentMaterial.h
- [TXT] SeriesMaterial.cpp
- [TXT] SeriesMaterial.h
- [TXT] Steel01.cpp
- [TXT] Steel01.h
- [TXT] Steel01.tex
- [TXT] TclModelBuilderUniaxialMaterialCommand.cpp
- [TXT] UniaxialMaterial.cpp
- [TXT] UniaxialMaterial.h
- [TXT] UniaxialMaterial.tex
- [TXT] ViscousMaterial.cpp
- [TXT] ViscousMaterial.h

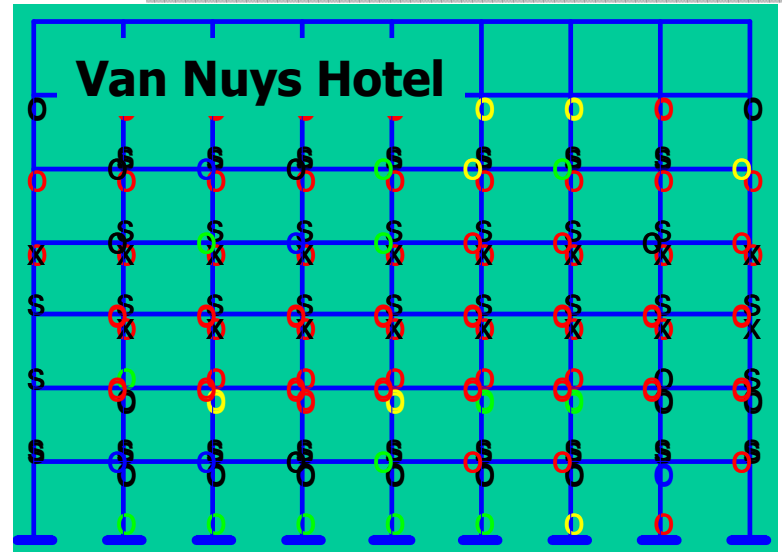
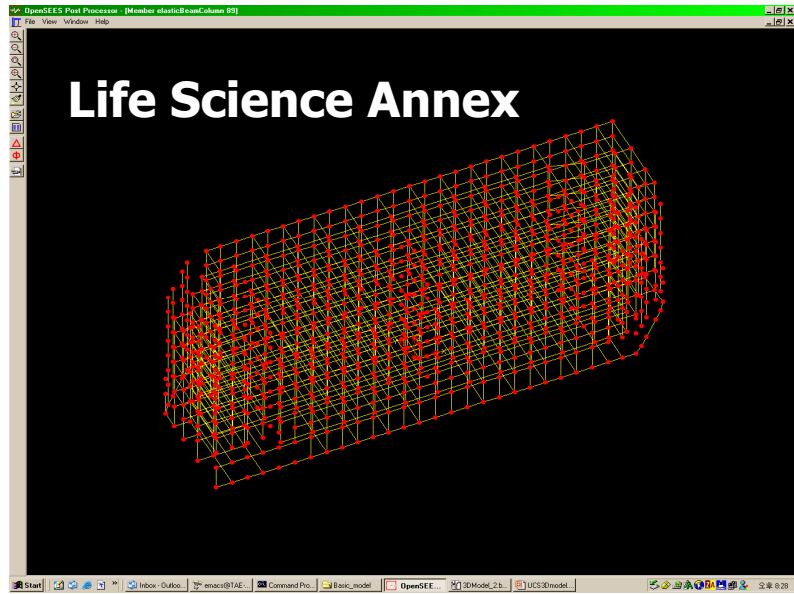
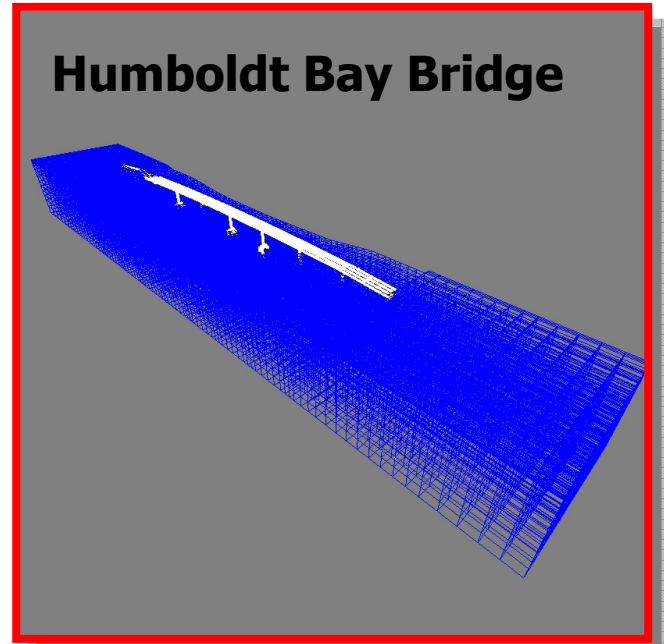
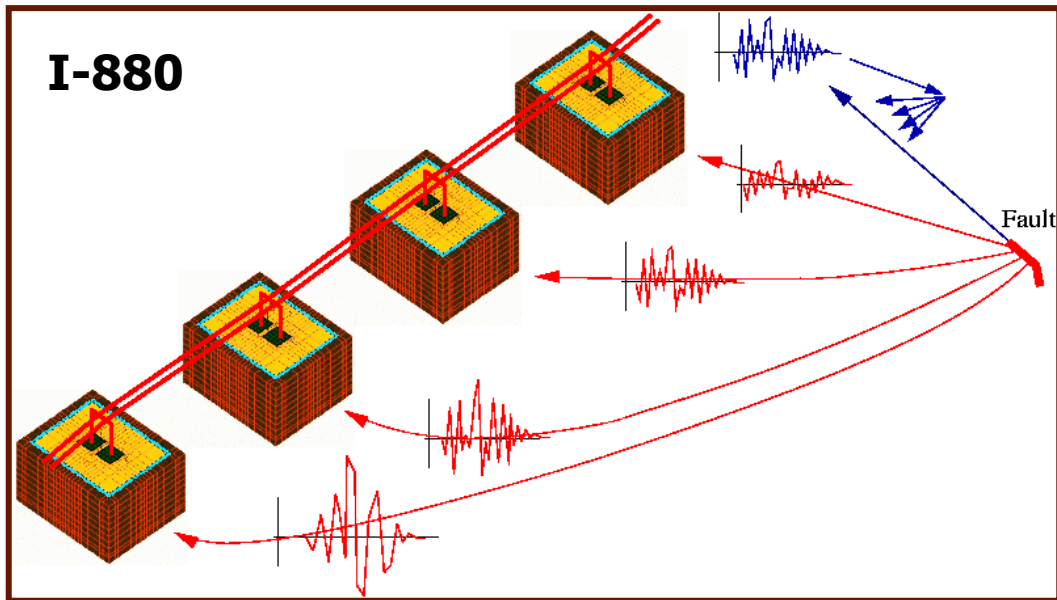
At the bottom of the page, it says "Created by cvsweb 1.0".

CVS: Concurrent
Versions System

PEER Testbed Project

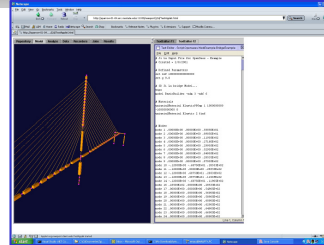
Applications of OpenSees

- All four testbeds utilized OpenSees
- The testbeds pushed the state-of-the-art in nonlinear modeling and presented challenging simulation problems
- Testbeds were used to:
 - Validate models
 - Investigate convergence and computational performance
 - Support PEER framework, including reliability computation
 - Identify improvements in models and simulation methods

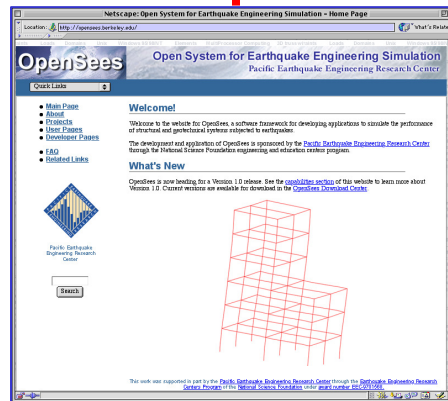


NEESit Simulation Overview

Simulation Portal



OpenSees
NCTP Plugin



Compute Resources

Data Repository

Objective of User Workshop

- 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
- Motivation to use OpenSees for your simulation problems....

Organization of Workshop

- Tcl command language; what is Tcl?
- Modeling commands
 - System, element, section, material hierarchy
- Analysis commands
 - Standard and advanced methods
- Basic examples and use of parameters
- Advanced structural and geotechnical applications

What Should be Your Expectations?

- OpenSees is a research tool at this time, but fairly stable for regular use
- 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.

Use the Community Forum!

**Bookmark the Message Board,
and use it often.**



The screenshot shows a web browser window displaying the OpenSees Community Forum. The browser's address bar shows the URL <http://opensees.berkeley.edu/phpBB2/index.php>. The page header features the OpenSees logo and the text "Open System for Earthquake Engineering Simulation" and "Pacific Earthquake Engineering Research Center". Below the header, the page title is "The OpenSees Community Forum".

The main content area displays a forum index table with the following data:

Forum	Topics	Posts	Last Post
Test category 1			
Test Forum 1 This is just a test forum.	4	14	Thu Aug 26, 2004 12:56 pm jzhong
OpenSees			
Interpreter Forum for OpenSees users to post questions, comments, etc. on the use of the OpenSees interpreter.	19	42	Thu Aug 26, 2004 4:49 PM montoya
Documentation For posts concerning the documentation, errors, omissions, general comments, etc.	1	2	Wed Jul 07, 2004 11:35 am link
Framework For developers writing C++, Fortran, Java, code who have questions or comments to make.	12	34	Sun Aug 22, 2004 1:37 pm cshk tolt
Future Directions A forum dedicated to the future direction of OpenSees, i.e. what would you like, what do you need.	6	7	Tue Aug 10, 2004 5:48 am RCBS

Below the forum index, there is a "Who is Online" section. It states: "Our users have posted a total of 99 articles. We have 48 registered users. The newest registered user is [uyazgan](#). In total there is 1 user online: 0 Registered, 0 Hidden and 1 Guest. [Administrator] [Moderator] Most users ever online was 4 on Mon Aug 09, 2004 10:42 am."

Thanks to:

- **Silvia Mazzoni**
- **Frank McKenna**
- **Lelli Van Den Einde, NEESit**
- **Yolanda West, PEER**
- *All the presenters*

NEESit, NEES Inc., PEER, and the National Science Foundation