



OpenSees

Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center

NEESit

PEER/NEESit OpenSees User Workshop

Presented by the OpenSees Community

August 26, 2005

Sponsored by the National Science Foundation
through NEESit, NEES Inc. and
Pacific Earthquake Engineering Research Center

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.

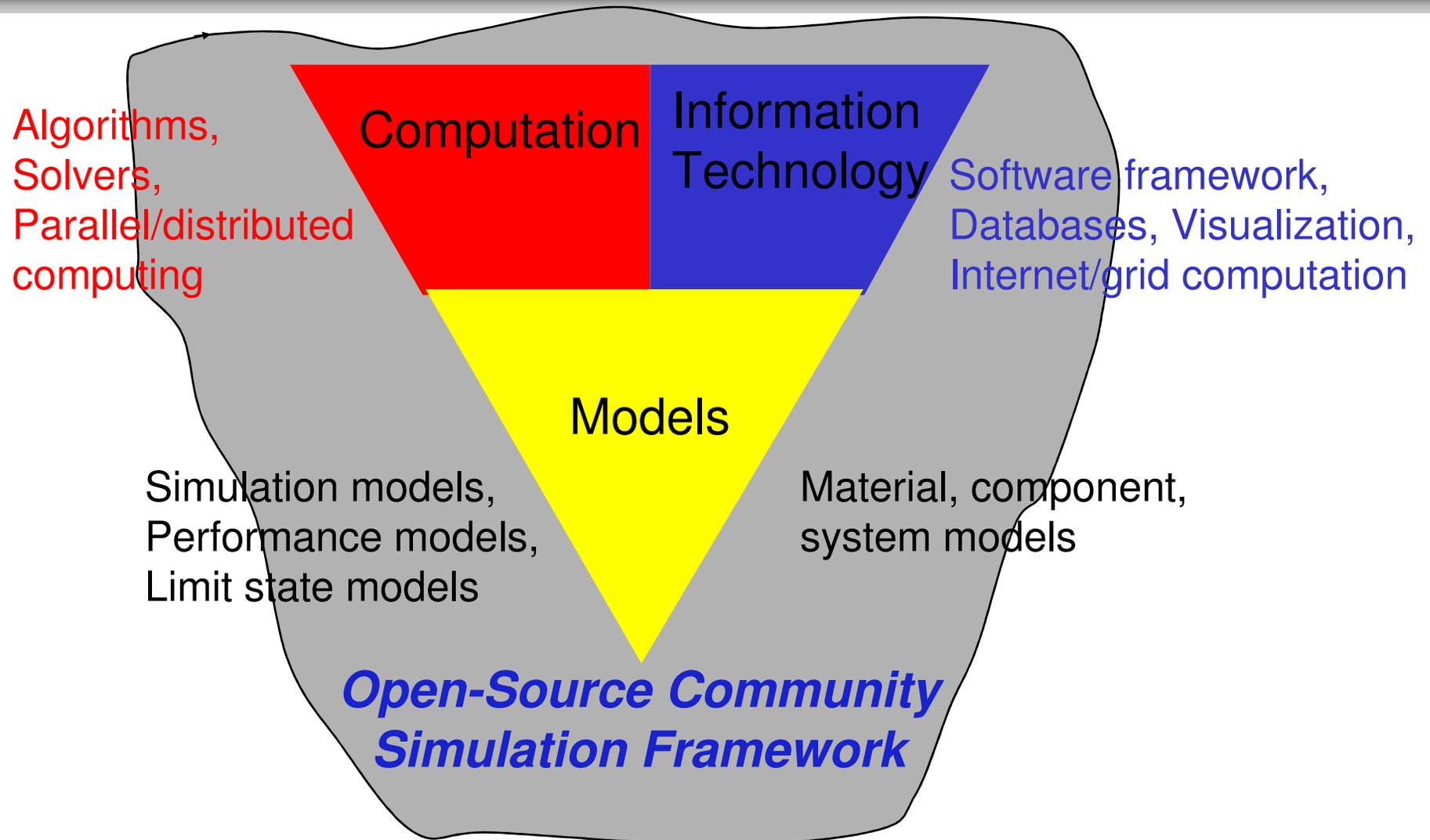
Observations on Current Situation

- 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 within PEER, and beyond, 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

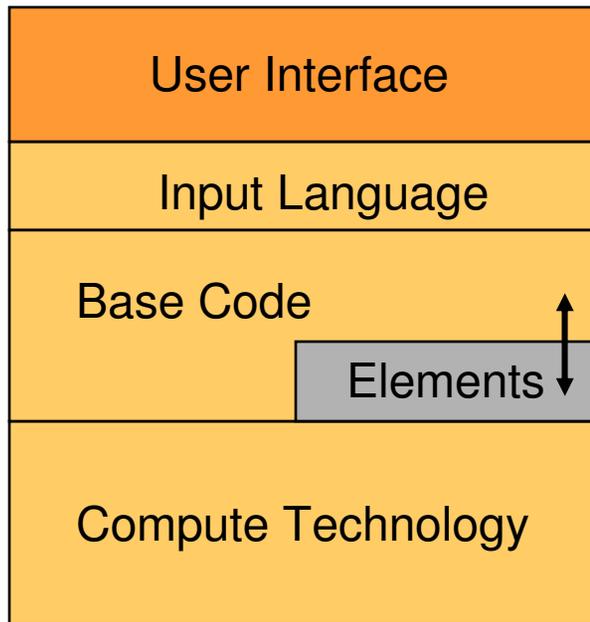


Software Framework

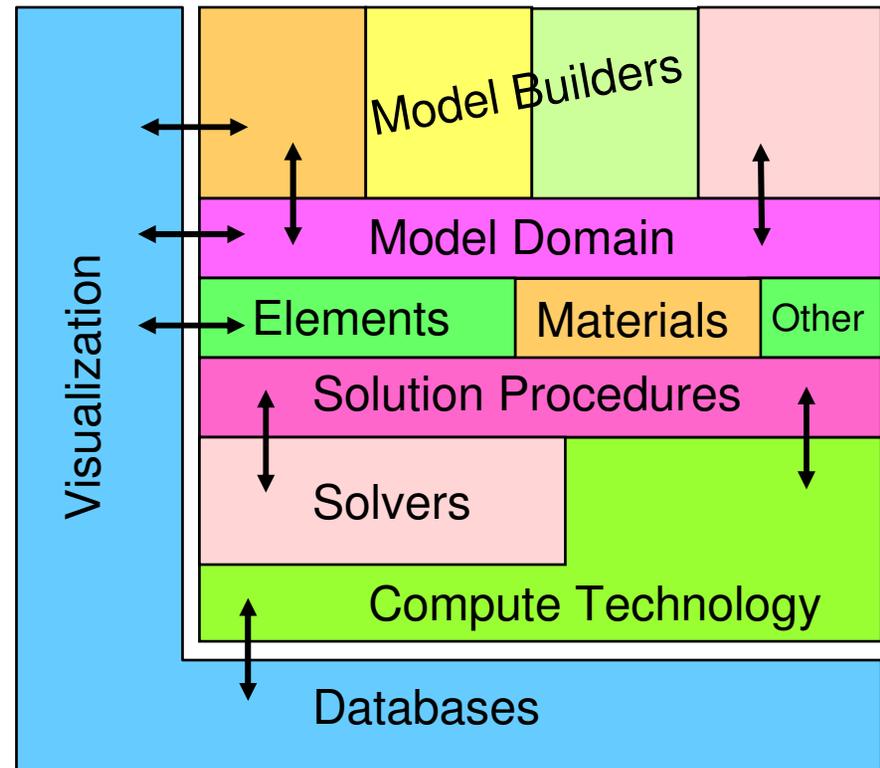
- A *framework* is a set of cooperating software components for building applications in a specific domain.
- A framework dictates the architecture of the application. It must represent the design decisions common to the application domain.
- A framework is based on the assumption that an architecture 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



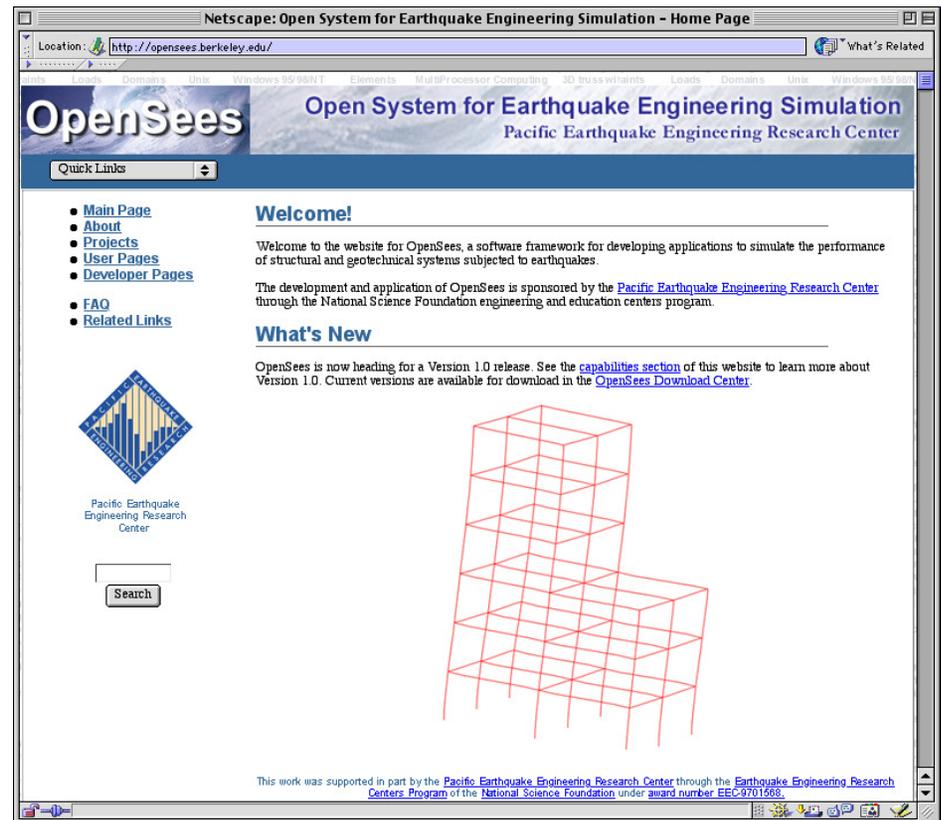
↔ Application Program Interface (API)

OpenSees

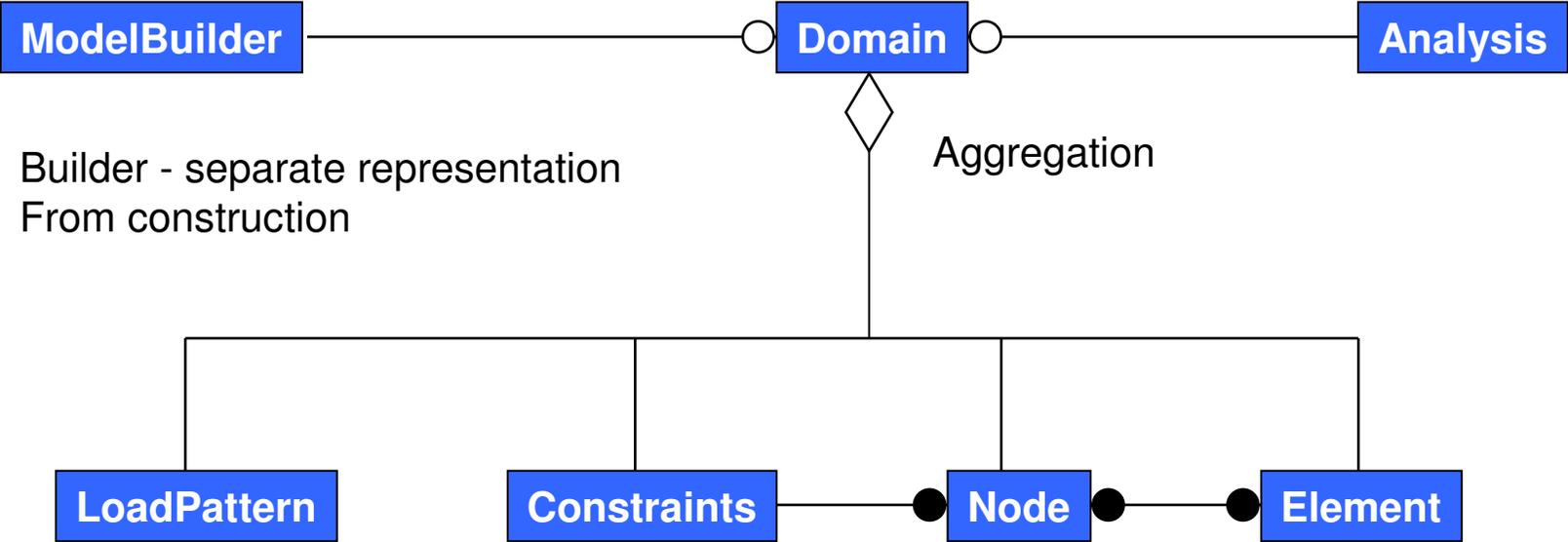
Open System for Earthquake Engineering Simulation
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<http://opensees.berkeley.edu>

- 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 (8/15/05)?
 - OpenSees-25,400
 - ABAQUS [finite]-53,200
 - SAP2000-51,700

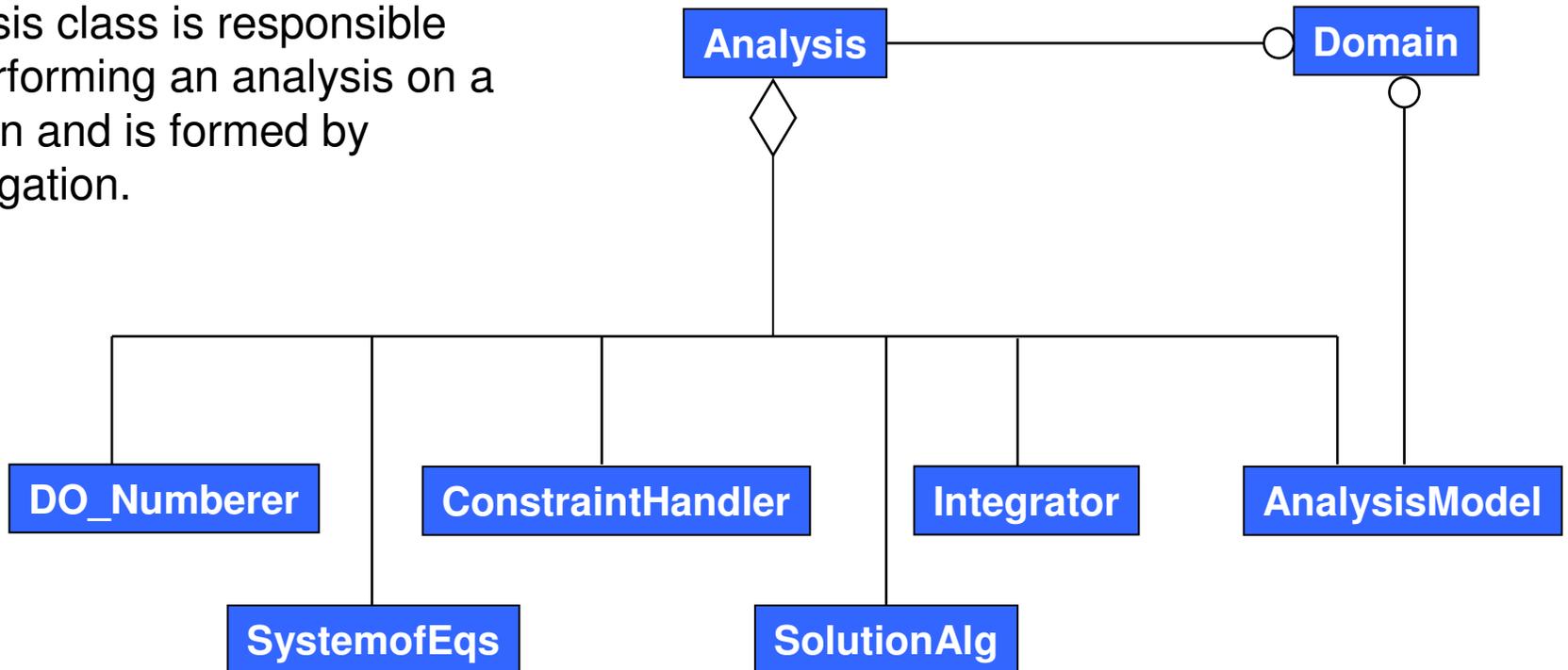


Structural Models as Aggregation Pattern

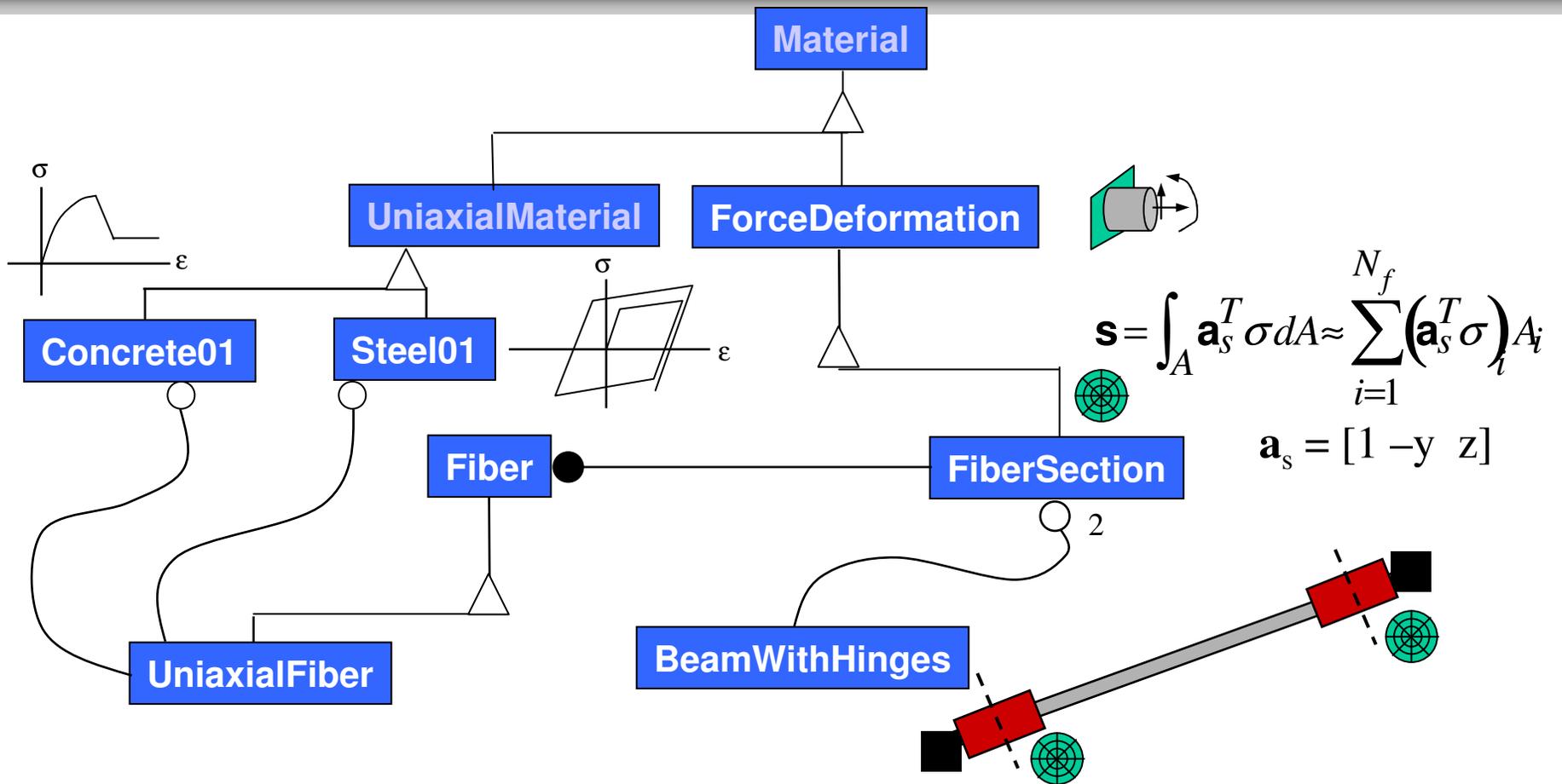


Analysis Class for Simulation

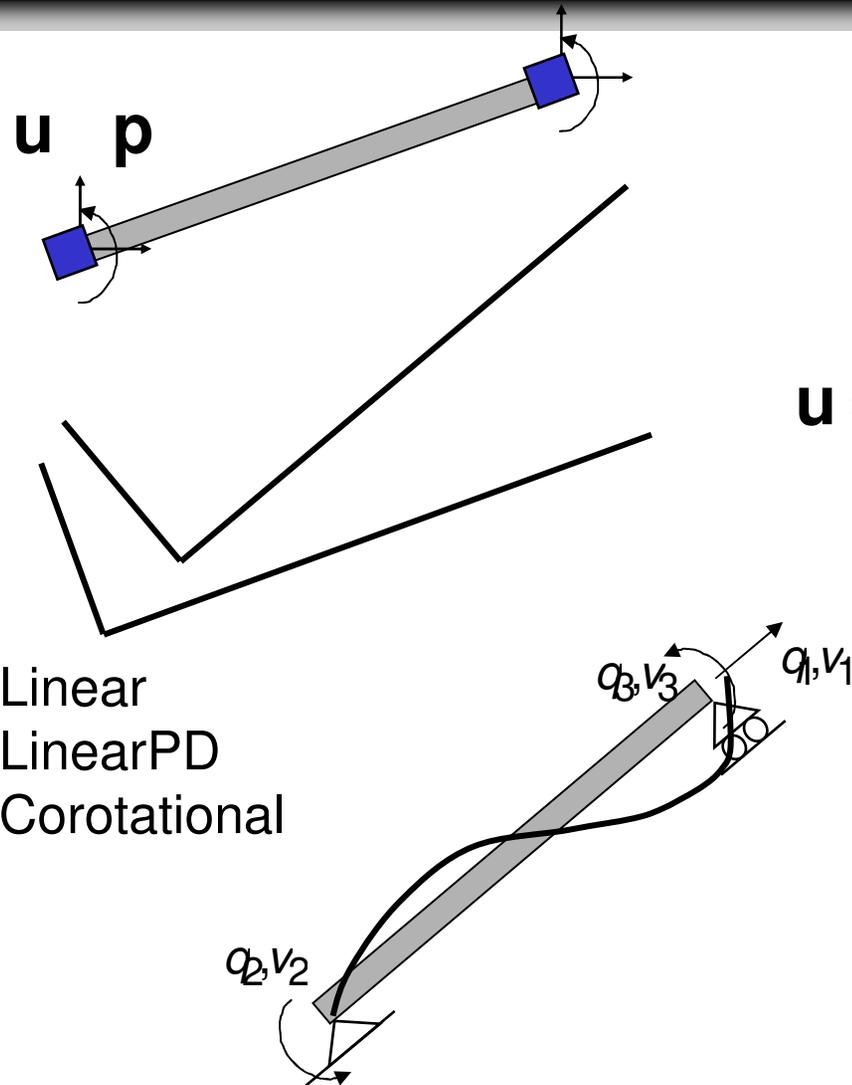
Analysis class is responsible for performing an analysis on a domain and is formed by Aggregation.



Form Follows Mechanics



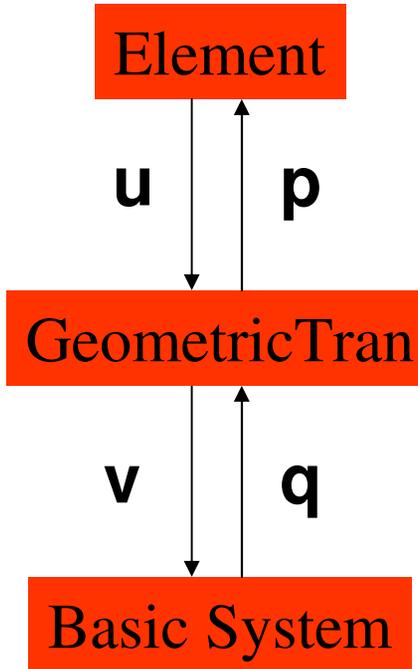
Beam-Column Models I



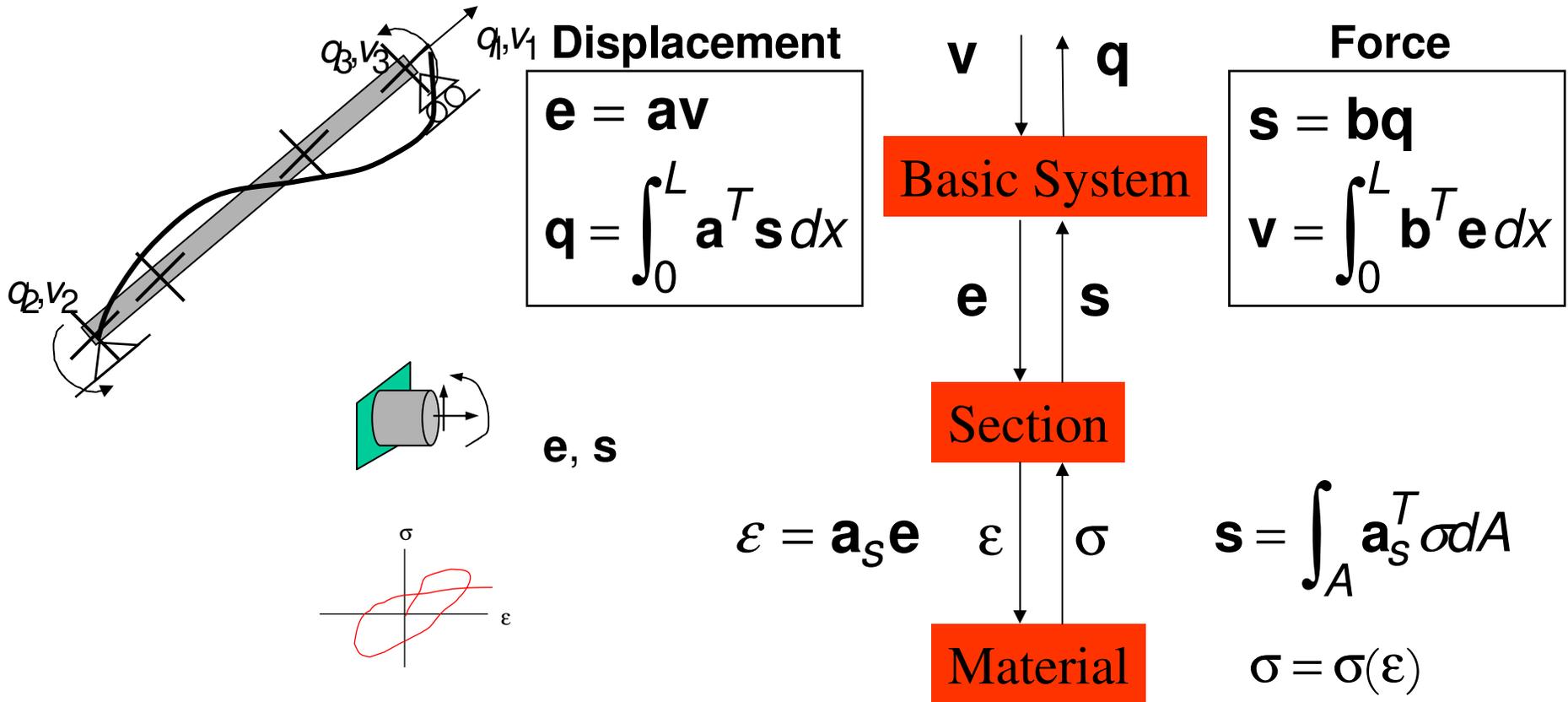
$$\mathbf{u} = \mathbf{a}_f \mathbf{u}$$

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". A navigation menu on the left lists various sections, with "title" selected. The main content area displays the title "Open System for Earthquake Engineering Simulation User Manual" and lists authors and contact information.

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

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title

Open System for Earthquake Engineering Simulation User Manual

Software Authors: Frank McKenna, Gregory L. Fences, *et al.*

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

Pacific Earthquake Engineering Research Center

University of California, Berkeley

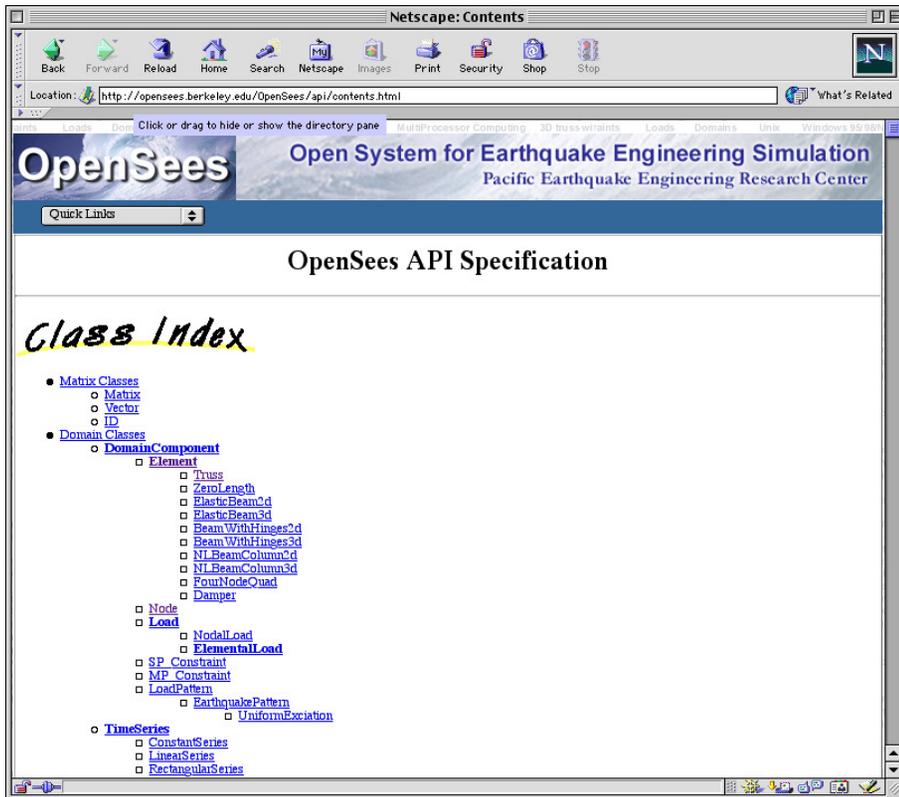
version x.

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

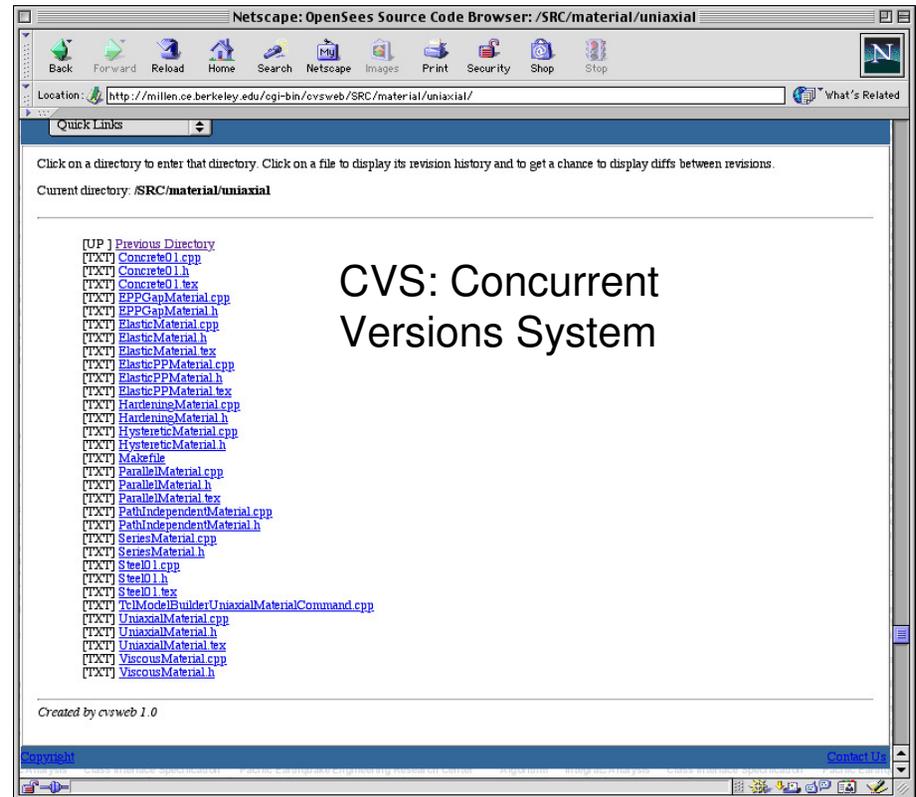
Framework Design/Source for Developers

Class Specification Application Program Interface

Source Code Viewing/Updating With CVS



The screenshot shows a Netscape browser window titled "Netscape: Contents". The address bar displays "http://opensees.berkeley.edu/OpenSees/api/contents.html". The page content includes the OpenSees logo and the text "Open System for Earthquake Engineering Simulation" and "Pacific Earthquake Engineering Research Center". Below this, there is a "Quick Links" section and a heading "OpenSees API Specification". The main content is a "Class Index" with a tree structure of classes and sub-classes, including "Matrix Classes", "Domain Classes", "Element", "Node", "Load", "SP_Constraint", "MP_Constraint", "LoadPattern", "TimeSeries", and "UniformExcitation".



The screenshot shows a Netscape browser window titled "Netscape: OpenSees Source Code Browser: /SRC/material/uniaxial". The address bar displays "http://millen.ce.berkeley.edu/cgi-bin/cvsweb/SRC/material/uniaxial/". The page content includes a "Quick Links" section and a heading "CVS: Concurrent Versions System". The main content is a list of files and directories, including "Previous Directory", "Concrete01.cpp", "Concrete01.h", "Concrete01.tex", "EPPCapMaterial.cpp", "EPPCapMaterial.h", "ElasticMaterial.cpp", "ElasticMaterial.h", "ElasticMaterial.tex", "ElasticPPMaterial.cpp", "ElasticPPMaterial.h", "ElasticPPMaterial.tex", "HardeningMaterial.cpp", "HardeningMaterial.h", "HystereticMaterial.cpp", "HystereticMaterial.h", "Makefile", "ParallelMaterial.cpp", "ParallelMaterial.h", "ParallelMaterial.tex", "PathIndependentMaterial.cpp", "PathIndependentMaterial.h", "SeriesMaterial.cpp", "SeriesMaterial.h", "Steel01.cpp", "Steel01.h", "Steel01.tex", "TclModelBuilderUniaxialMaterialCommand.cpp", "UniaxialMaterial.cpp", "UniaxialMaterial.h", "UniaxialMaterial.tex", "ViscousMaterial.cpp", and "ViscousMaterial.h". The page also includes a footer "Created by cvsweb 1.0" and a "Contact Us" link.

PEER Testbed Project

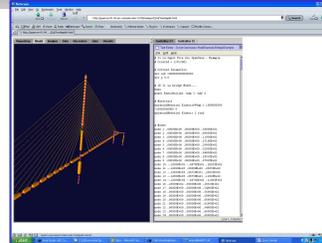
Applications of OpenSees

- 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

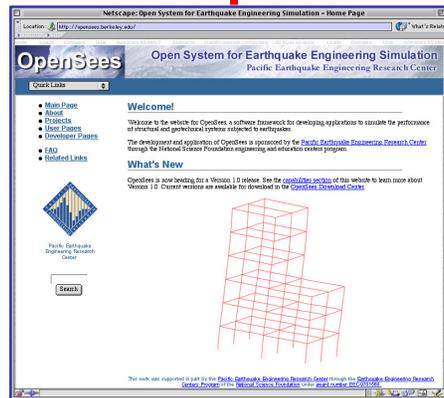


NEESgrid Simulation Overview

Simulation Portal



OpenSees
NCTP Plugin

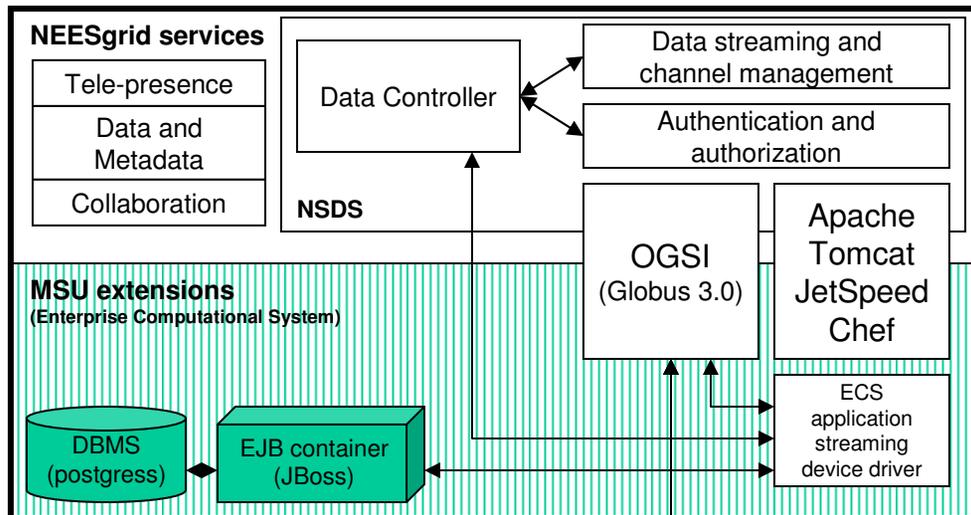


Compute Resources

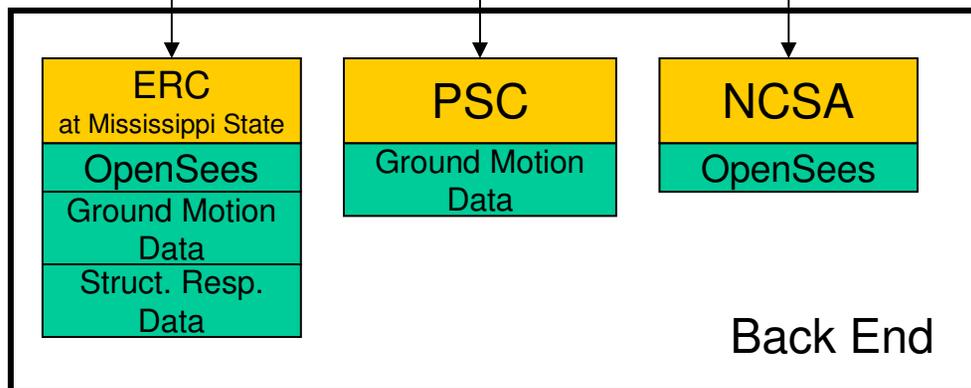
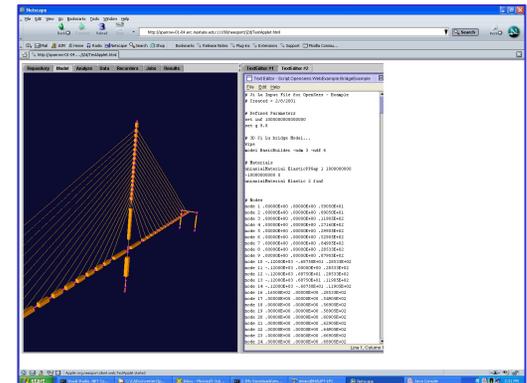
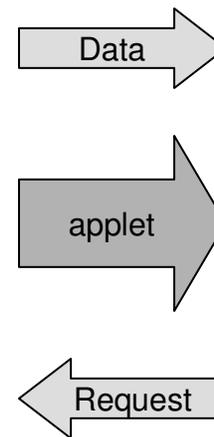
Data Repository

Portal Architecture

NEESpop (middleware)



Front End



NEESgrid OpenSees Web Portal

The screenshot displays the NEESgrid OpenSees Web Portal interface. The main window is a Netscape browser displaying a web application. The interface is divided into several sections:

- Repository:** A list of scripts from the server, including:
 - Script.OpenSees.WebExample.Solid03
 - Script.OpenSees.WebExample.Solid_PressureSensitiveE3D
 - Script.OpenSees.WebExample.Example.8.1
 - Script.OpenSees.WebExample.Zero.length.1
 - Script.OpenSees.WebExample.Example.7.1
 - Script.OpenSees.WebExample.Example.6.1
 - Script.OpenSees.WebExample.Zero.length.2
 - Script.OpenSees.WebExample.BridgeExample
 - dummydir/OpenSees.web.example.3.1
 - Script.OpenSees.WebExample.Zero.length.4
 - nodeDefn.Example.3.1.nodeDefnExample
- 3D Model:** A 3D visualization of a bridge structure with nodes and elements.
- Text Editor #1:** A text editor window showing the input file for the OpenSees job, including parameters like `set inf 1000000000000000` and `set g 9.8`.
- Job Submission:** A dialog box with the message "Job submitted job table updated." and an "OK" button.

The bottom of the screen shows the Windows taskbar with various applications open, including Visual Studio .NET, CAD converter, and Netscape.

**T. Haupt, MSU
with PEER**

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

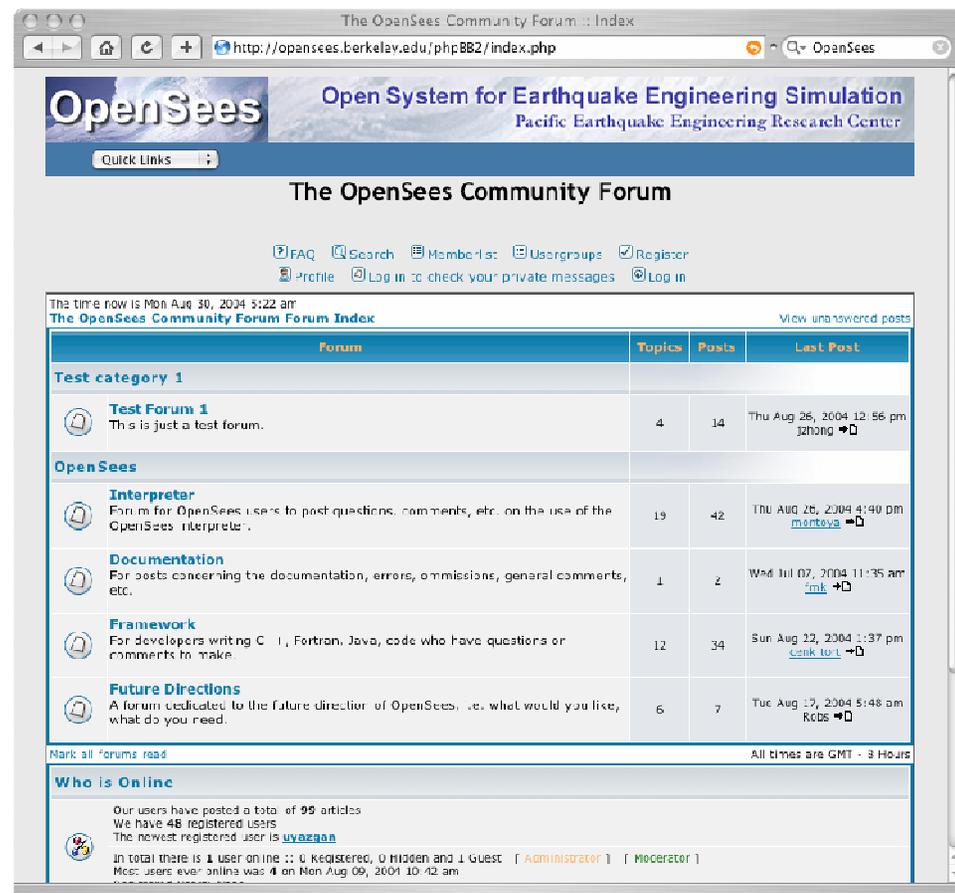
- Tcl command language; what is Tcl?
- Modeling commands
 - System, element, section, material hierarchy
- Analysis commands
 - Standard and advanced methods
- Basic examples and use of parameters
- Advanced structural and geotechnical applications

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,
<http://opensees.berkeley.edu/community/index.php>
and use it often.



The OpenSees Community Forum :: Index

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Quick Links

The OpenSees Community Forum

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Profile Log in to check your private messages Log in

The time now is Mon Aug 30, 2004 5:22 AM
The OpenSees Community Forum Forum Index [View unanswered posts](#)

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 17, 2004 5:48 am RCBS

Mark all forums read [All times are GMT - 8 Hours](#)

Who is Online

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**
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- Lelli Van Den Einde
- Anke Kamrath
- Yolanda West

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