NEES / PEER
OpenSees Days 2012

Presented by the OpenSees Community

August 15-16, 2012

Sponsored by:

NEES through NEEScomm

Pacific Earthquake Engineering Research Center

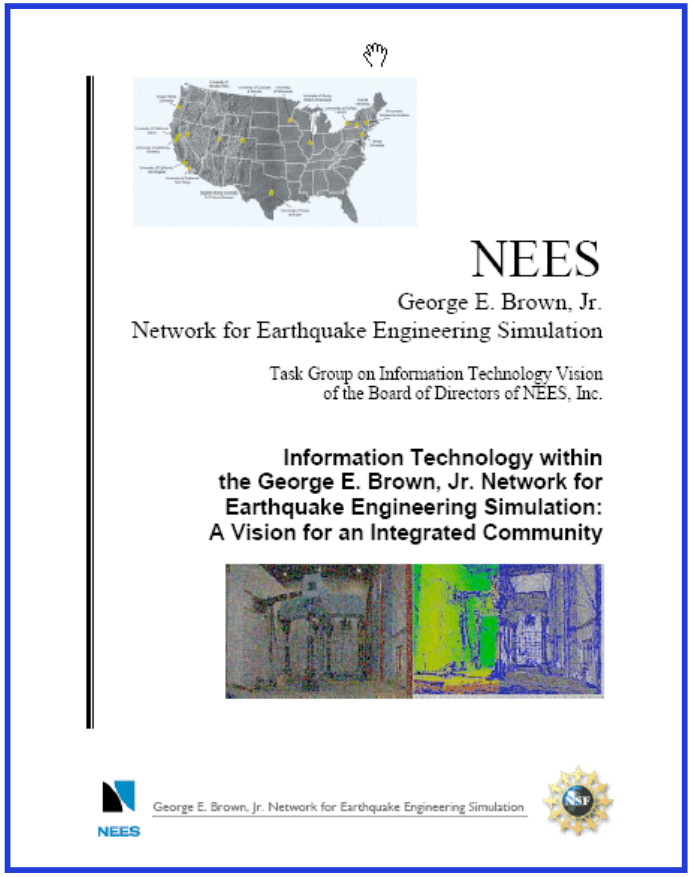
National Science Foundation

http://opensees.berkeley.edu/wiki/index.php/OpenSeesDays2012

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

WELCOME

Vision for Simulation



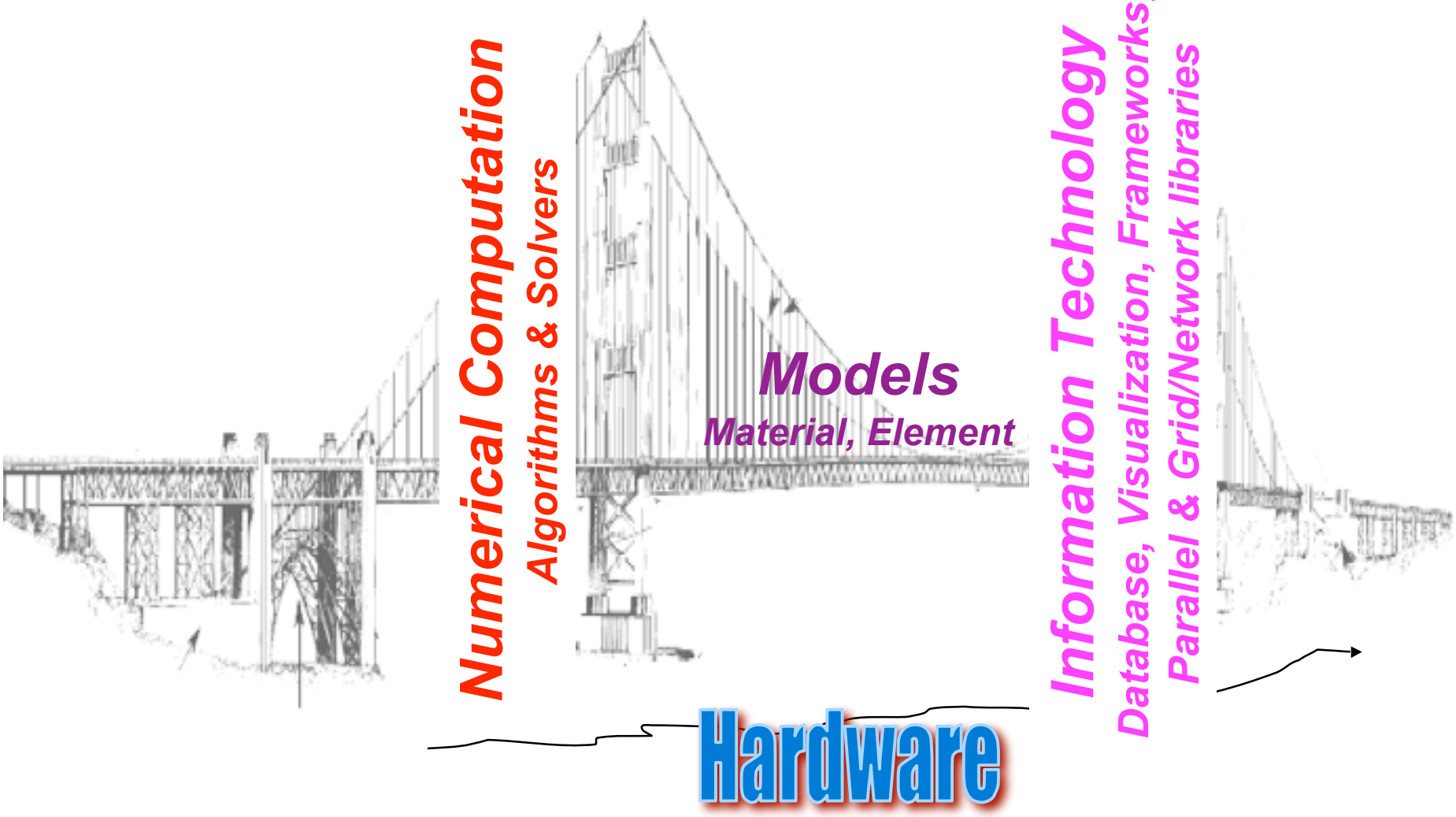
Computational modeling and simulation is central to the vision of NEES to transform the development of new earthquake engineering solutions from being primarily based on experiments to a balanced use of simulation and experimentation using computational models validated by experimental data.

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.

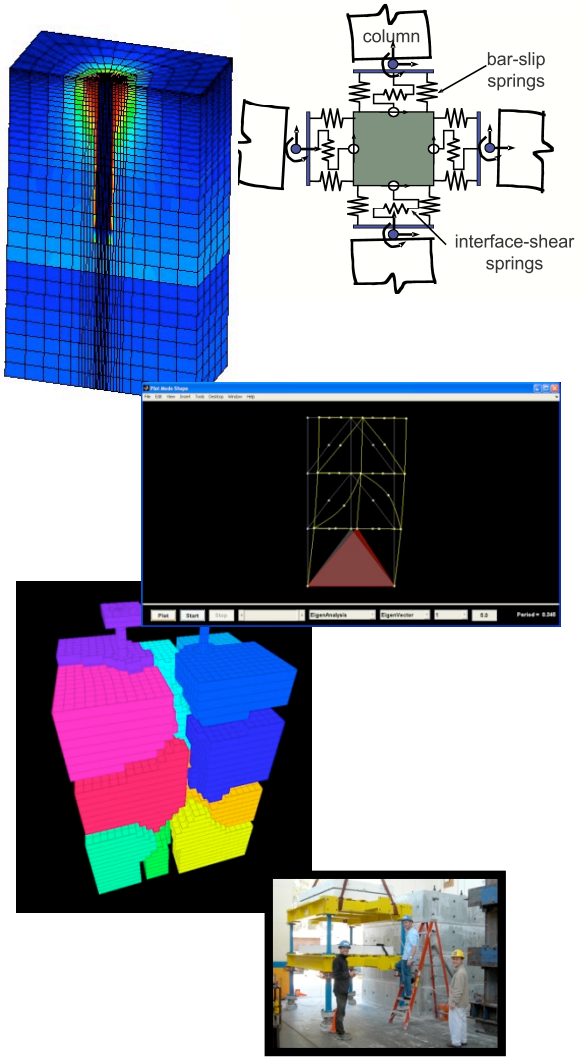
OpenSees — Open System for Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center

- OpenSees has been under development by PEER since before 1997.
- Large group of developers and user.
- NEES has supported integration and maintenance since 2003.
- Open-source and royalty free license for non-commercial use and 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).

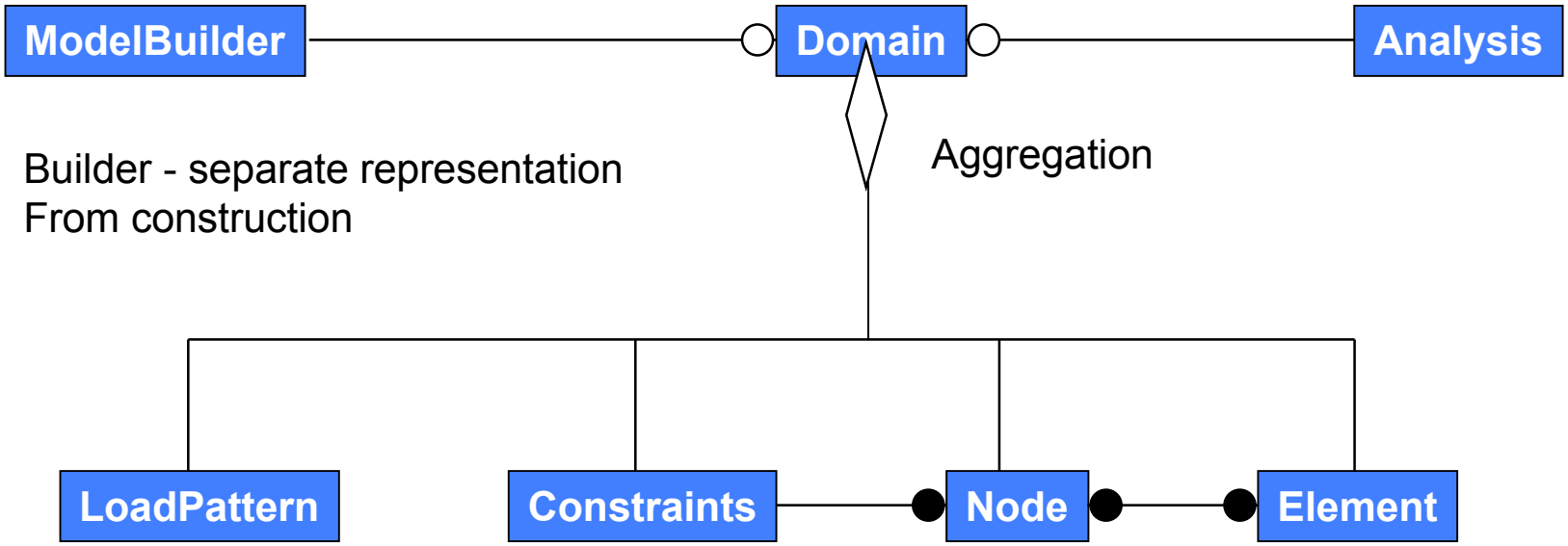
http://opensees.berkeley.edu

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.

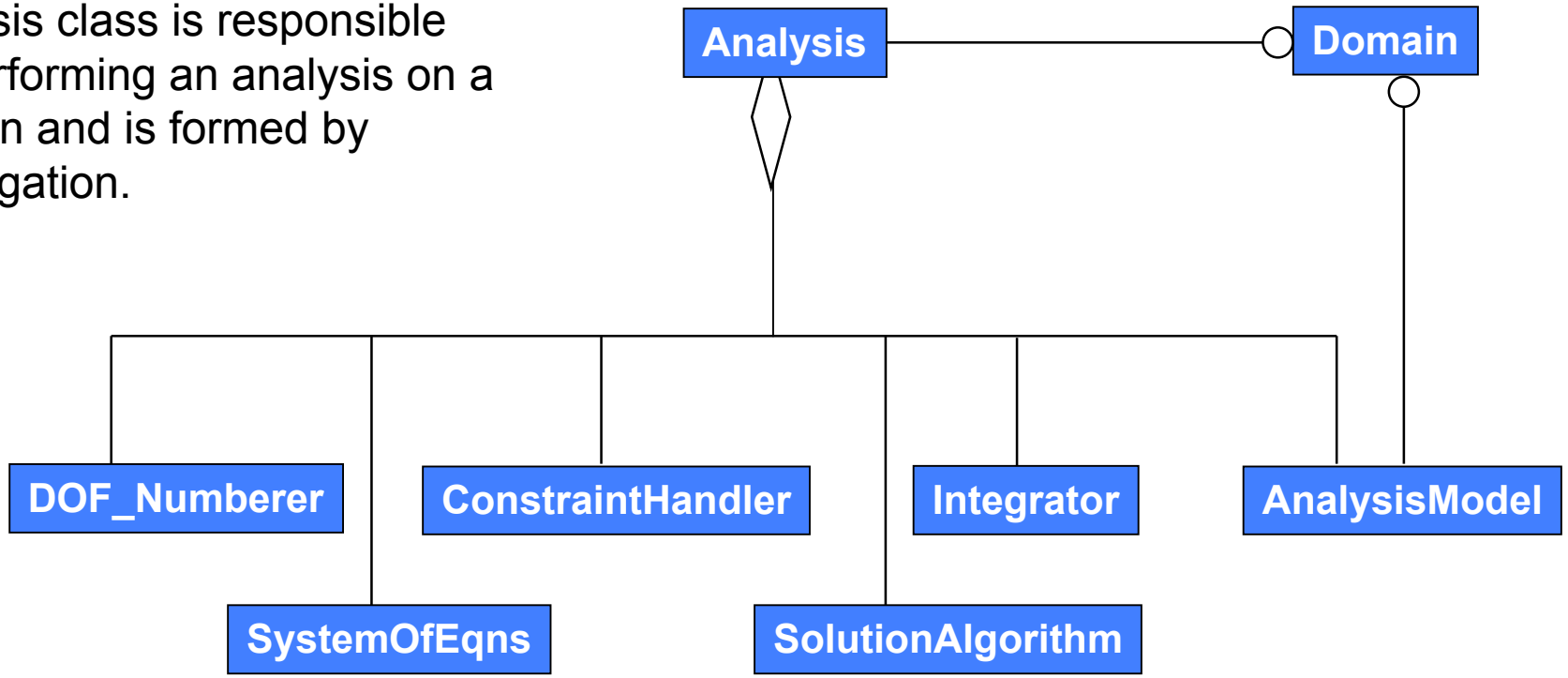


Structural Models as Aggregation Pattern

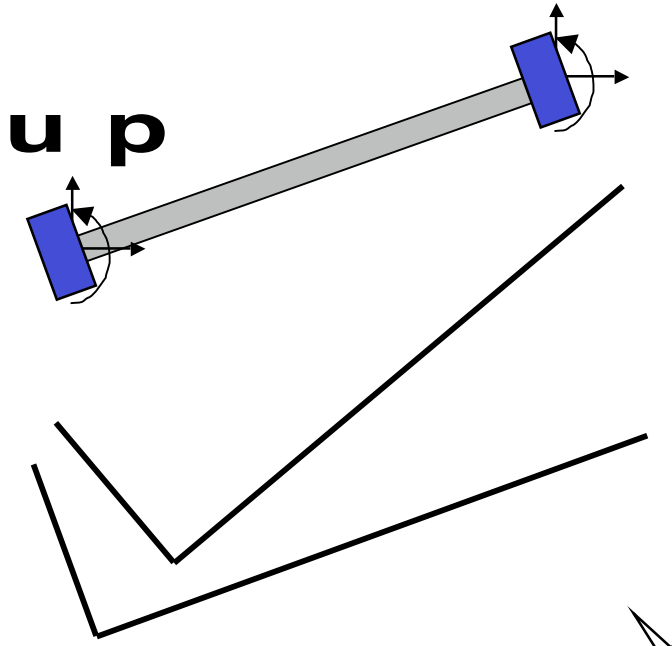


Analysis Class for Simulation

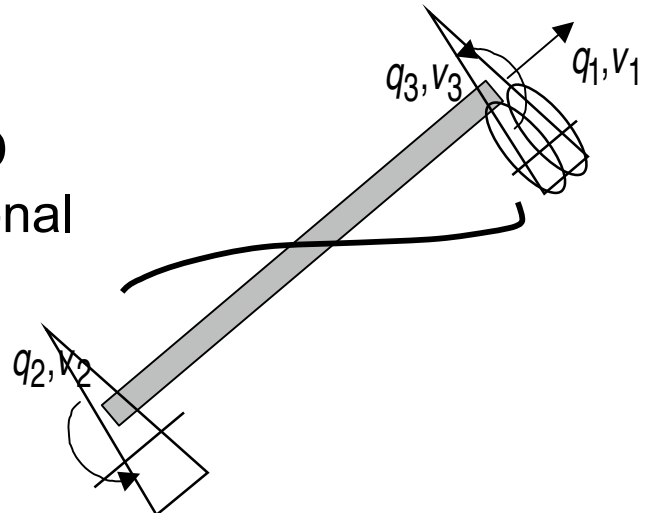
Analysis class is responsible for performing an analysis on a domain and is formed by Aggregation.

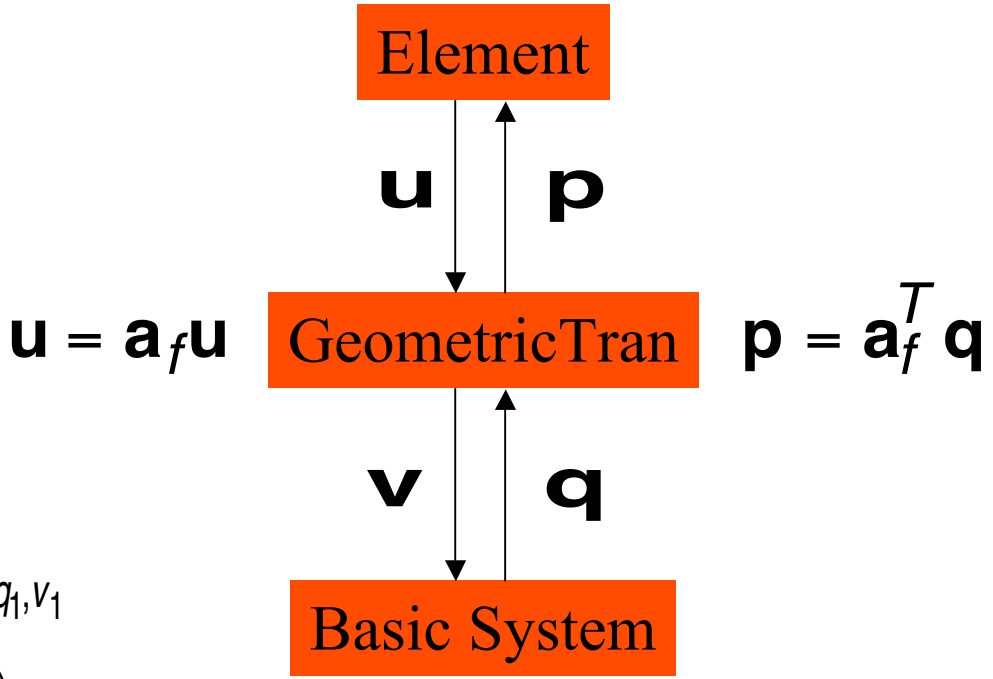


Beam-Column Models I

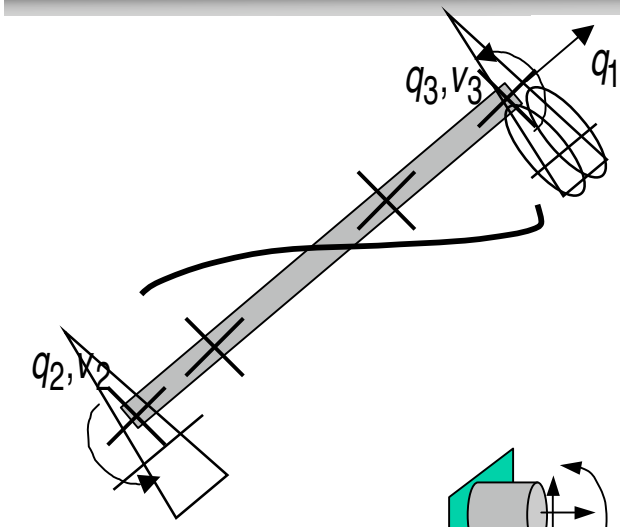


Linear
LinearPD
Corotational





Beam-Column Models II



Displacement

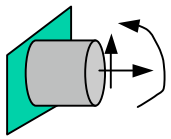
$$\mathbf{e} = \mathbf{a}\mathbf{v}$$

$$\mathbf{q} = \int_0^L \mathbf{a}^T \mathbf{s}\, dx$$

Force

$$\mathbf{s} = \mathbf{b}\mathbf{q}$$

$$\mathbf{v} = \int_0^L \mathbf{b}^T \mathbf{e}\, dx$$



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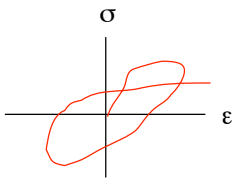
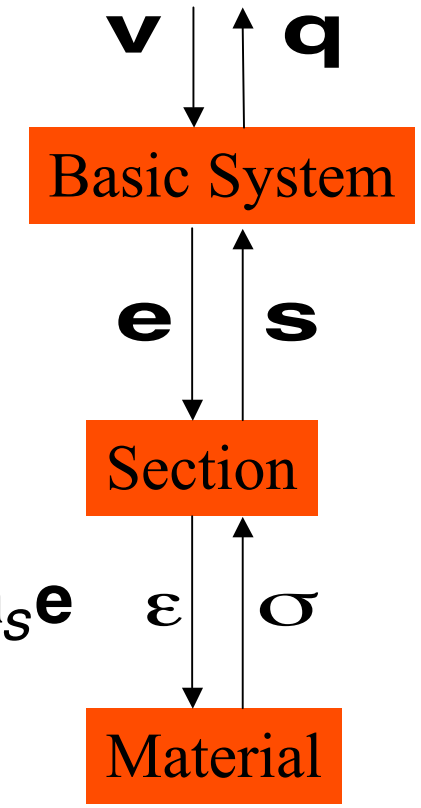




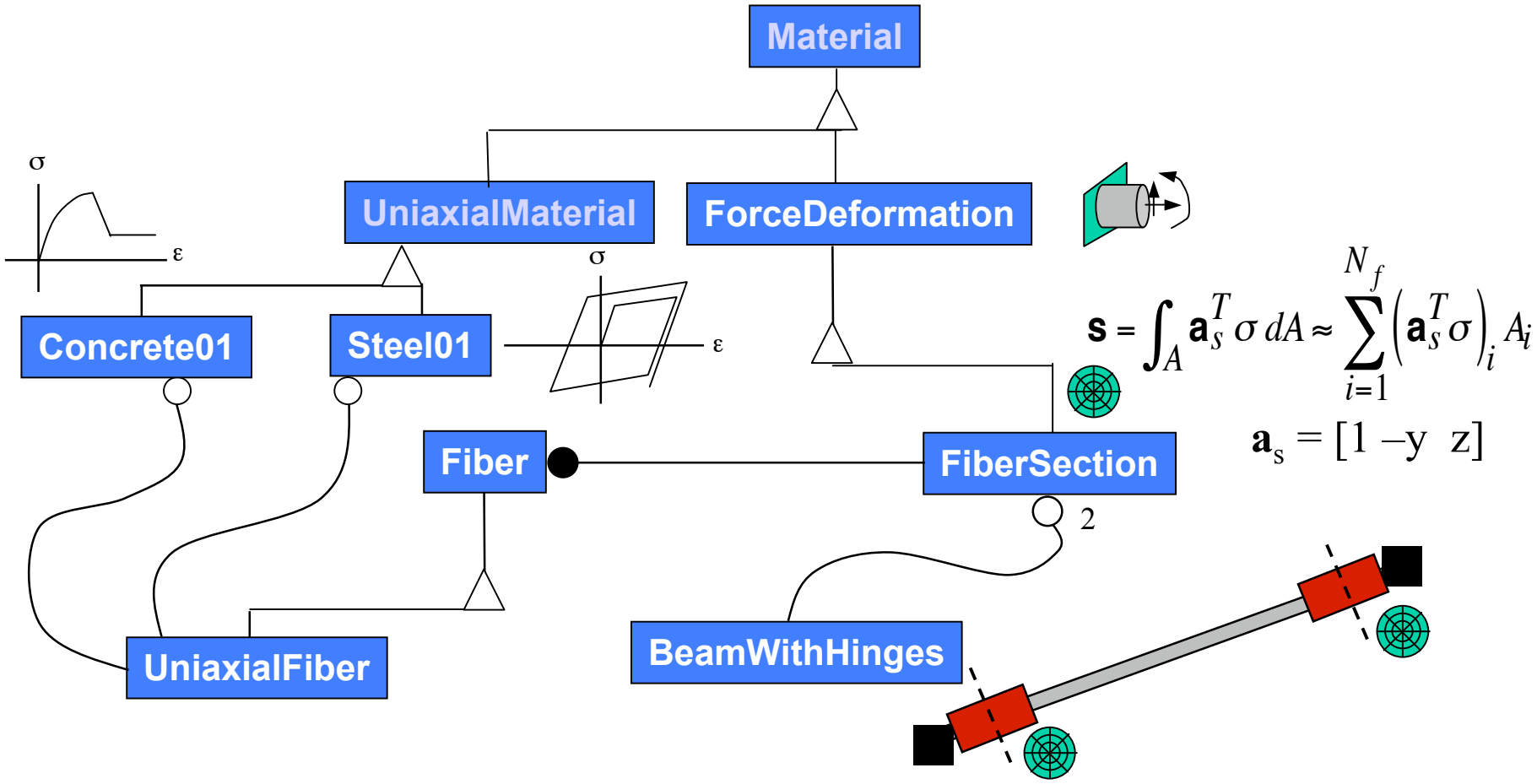
$$\varepsilon = \mathbf{a}_s \mathbf{e}$$

$$\mathbf{s} = \int_A \mathbf{a}_s^T \sigma\, dA$$

$$\sigma = \sigma(\varepsilon)$$

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

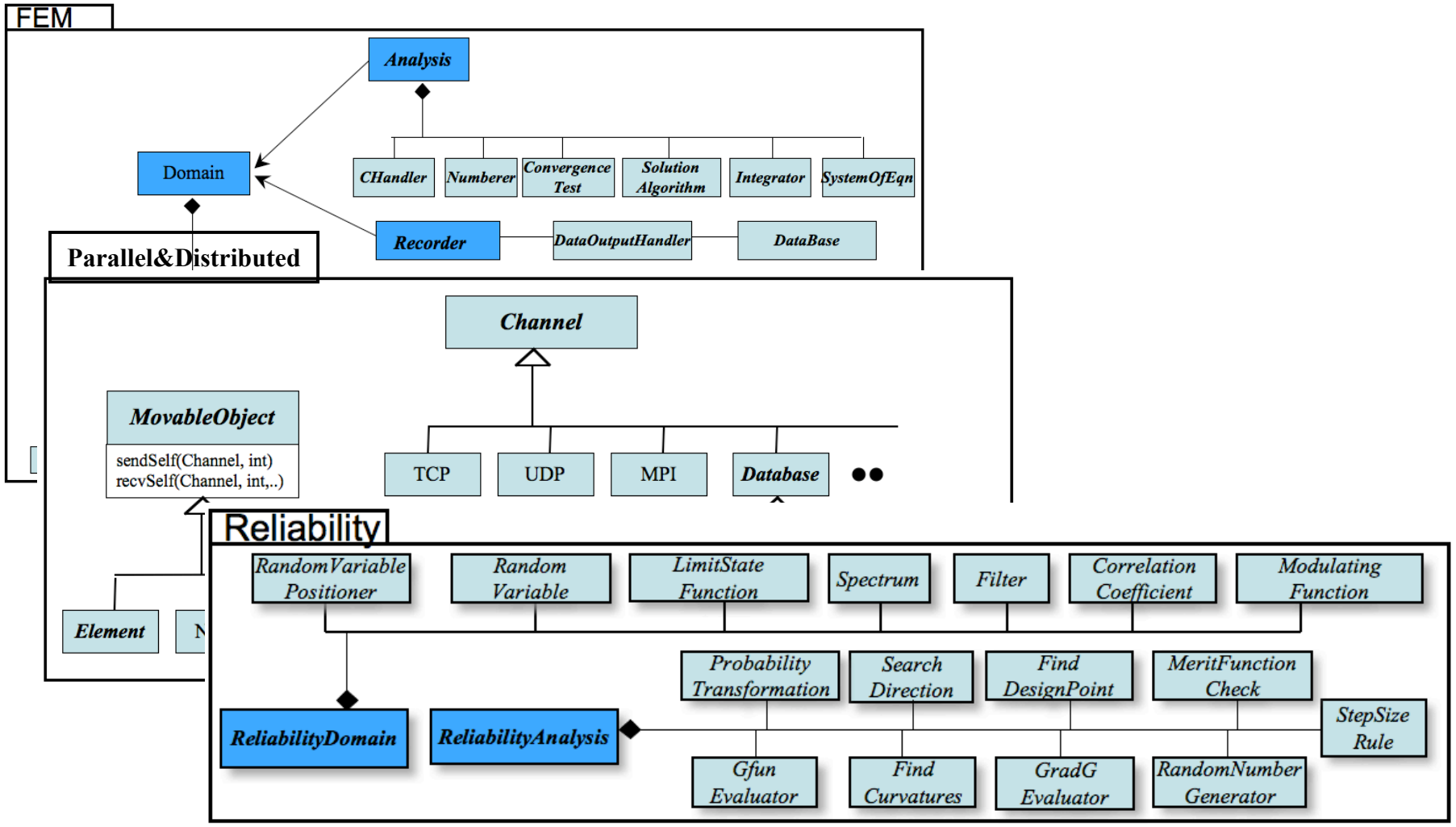
```
1.  wipe
2.  source Units.tcl;                          # define units
3.  source ParamList.tcl;                      # load up parameter values
4.  source GMFiles.tcl;                        # load up ground-motion filenames

5.  foreach Xframe $iXframe Hcol $iHcol Lcol $iLcol Lbeam $iLbeam
                Glblc $iGlblc GrhoCol $iGrhoCol GPcol $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 $Glblc $GrhoCol $GPcol $GMfact ;
11.     puts DYNAMIC_ANALYSIS
12.     foreach GroundFile $iGroundFile {
13.         puts GroundMotion$GroundFile
14.         Dynamic $Xframe $Hcol $Lcol $Lbeam $Glblc $GrhoCol $GPcol $GMfact $GroundFile;
15.     }
16. }
```

FRAME

GROUND MOTION

OpenSees has more capabilities than the typical FE Application

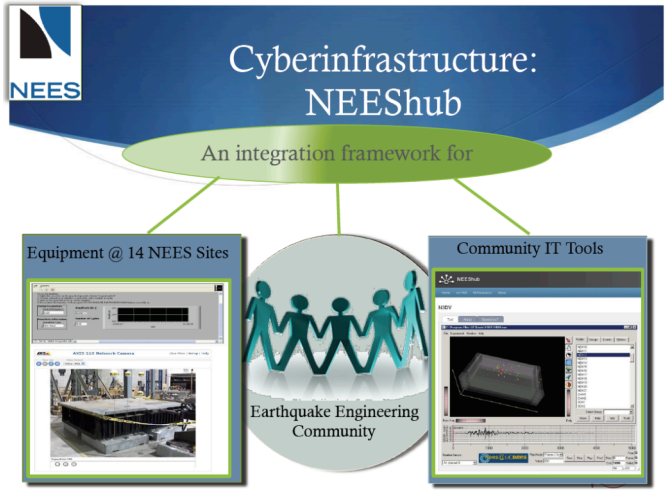


NEES

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



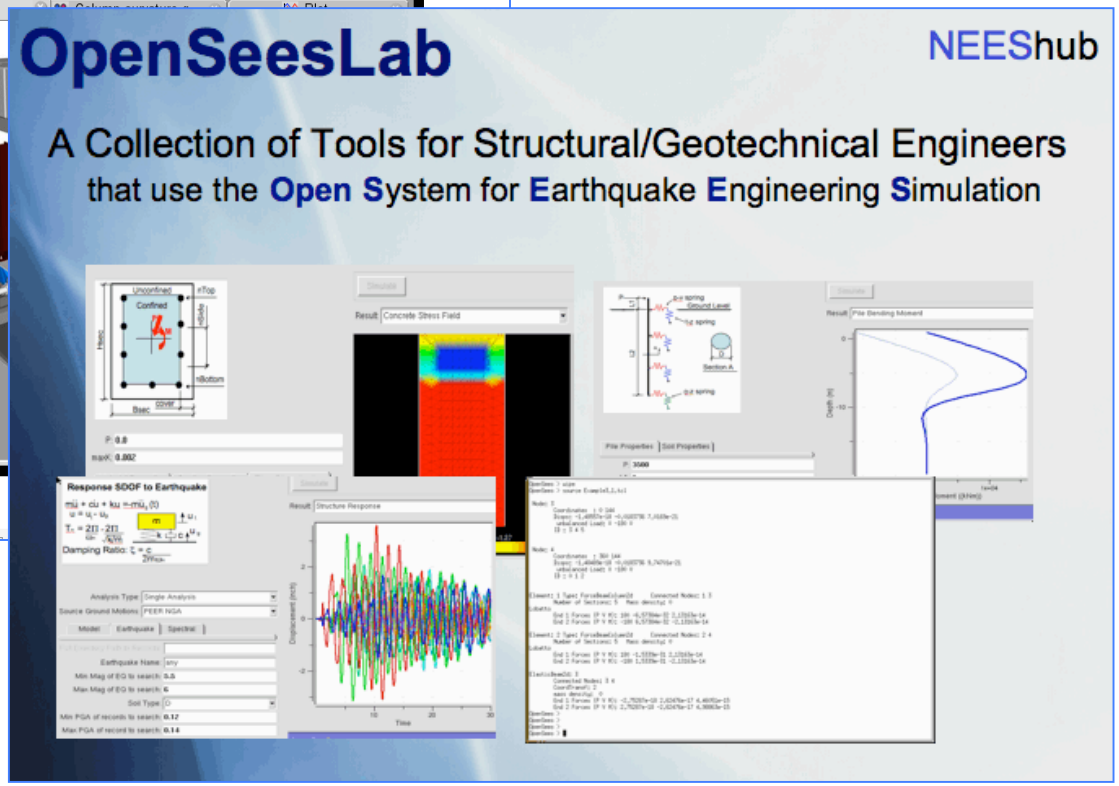
Through a browser engineers can:

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

NEEShub Tools and Resources

Data Management

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)
- *All the presenters*

  Prof. Pedro Arduino, Prof. Ahmed Elgamal, Prof. Filip Filippou, Panos Galanis, Prof. Quan Gu, Dr. Mahmoud Hachem, Rod Holland, Dr. Arash Khosravifar, Gemez Marshall, Dr. Andreas Schellenberg, Dr. Vesna Terzic

NEEScomm, PEER, and the National Science Foundation