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.
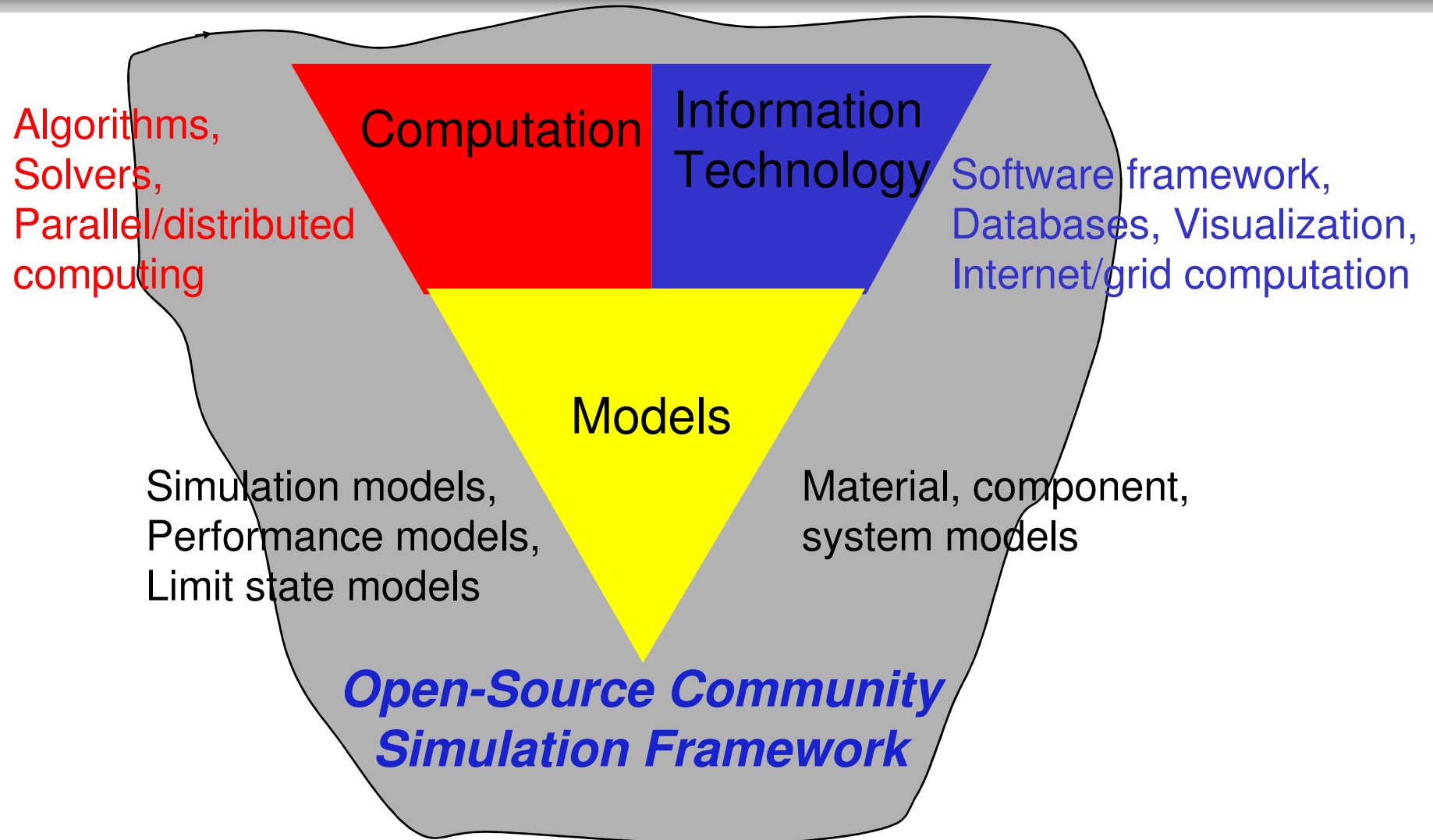
Observations on Current Situation

- 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.

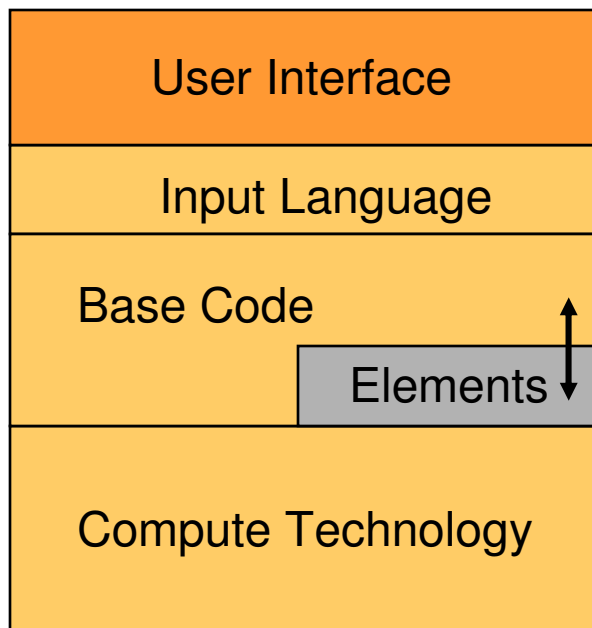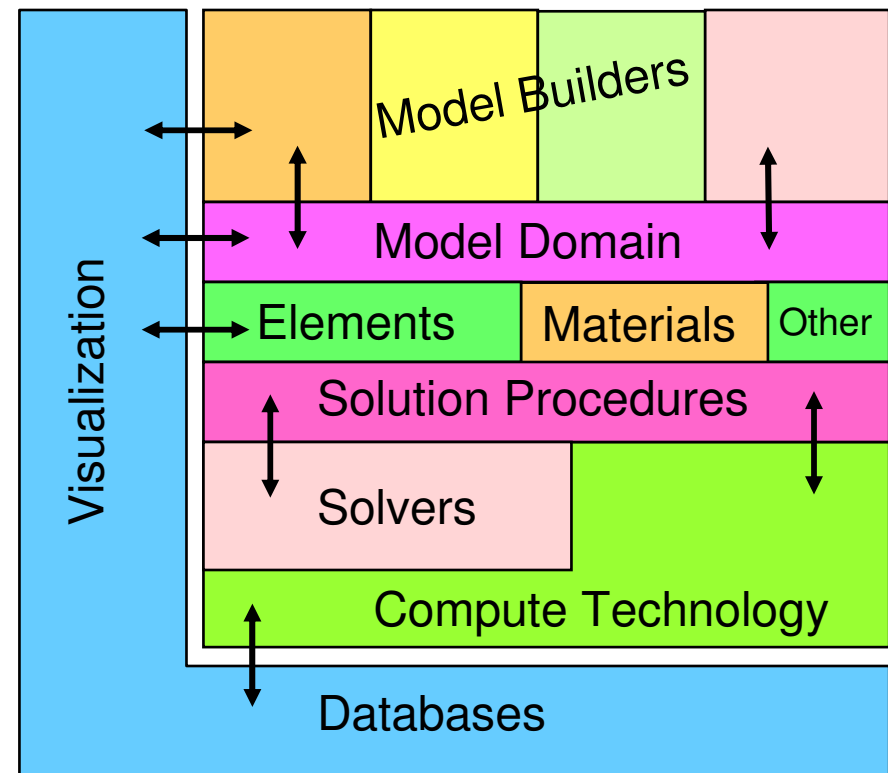# Conceptual Approach for Simulation

Algorithms,
Solvers,
Parallel/distributed
computing

Computation

Information Technology

Software framework,
Databases, Visualization,
Internet/grid computation

Models

Simulation models,
Performance models,
Limit state models

Material, component,
system models

Open-Source Community Simulation Framework

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 frameworks 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

User Interface
Input Language
Base Code / Elements
Compute Technology

Framework of Components

Visualization

Model Builders

Model Domain

Elements | Materials | Other

Solution Procedures

Solvers

Compute Technology

Databases

Application Program Interface (API)

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
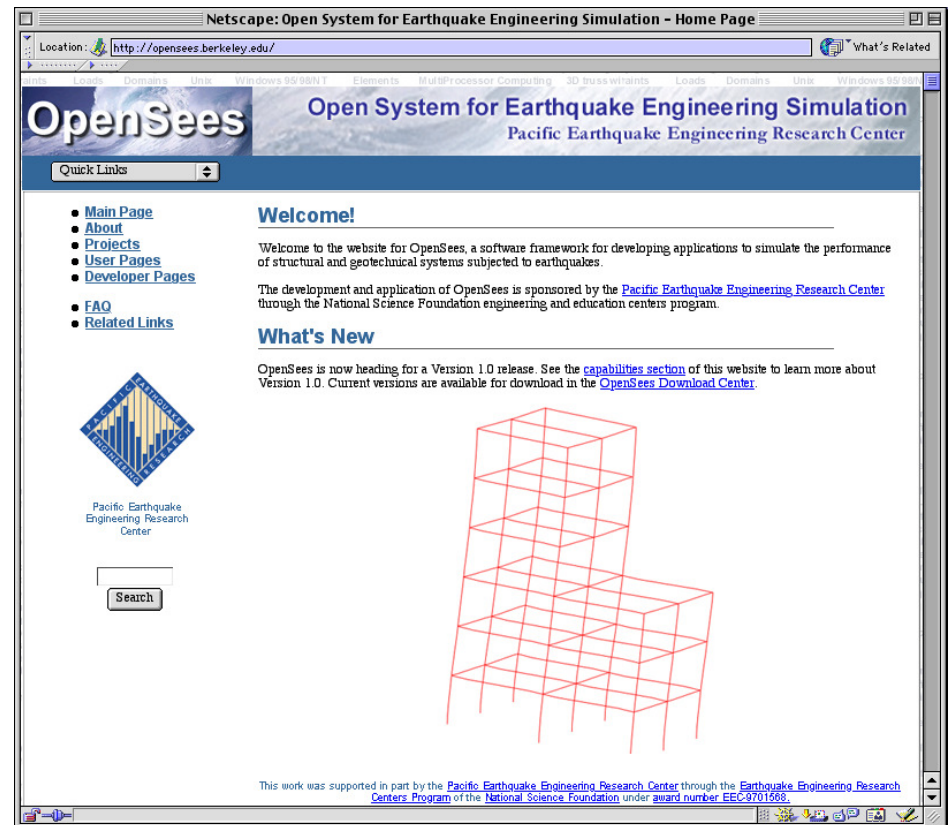
Structural Models as Aggregation Pattern

ModelBuilder —————○ Domain ○————— Analysis

Builder - separate representation
From construction

Aggregation

LoadPattern   Constraints ●— Node —●———●— Element
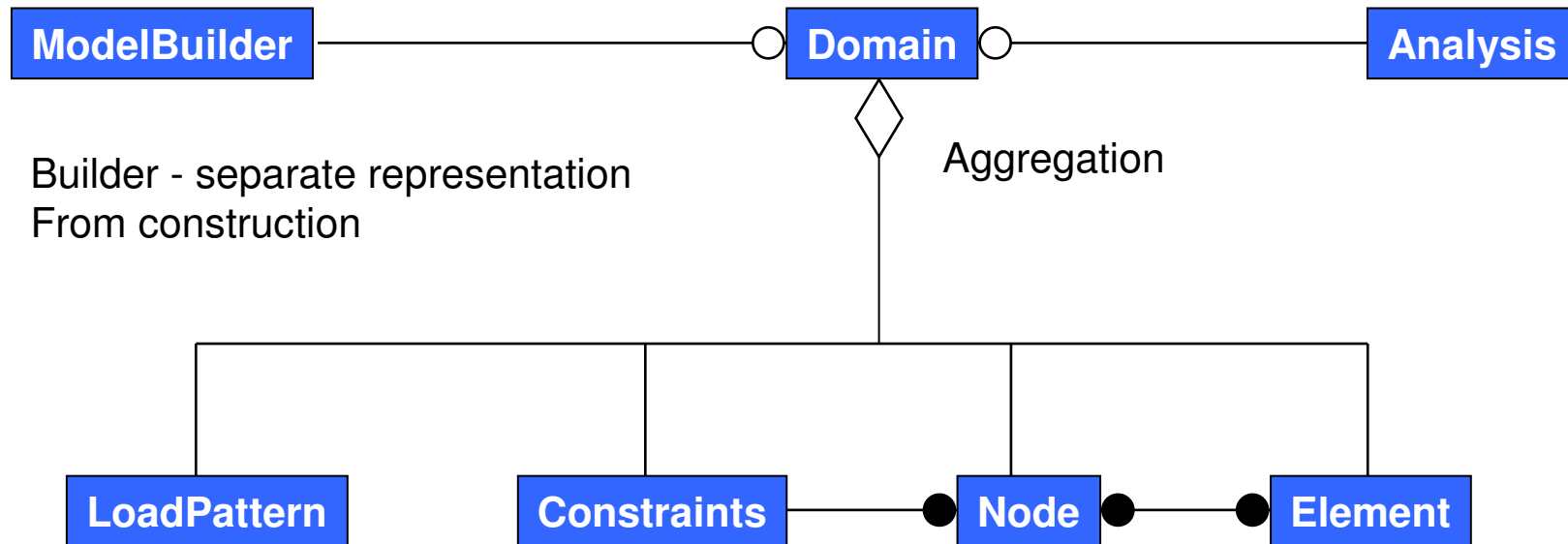
Analysis Class for Simulation

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

Form Follows Mechanics

Material

UniaxialMaterial   ForceDeformation

Concrete01   Steel01

Fiber   FiberSection

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

$$\mathbf{a}_s = \begin{bmatrix} 1 & -y & z \end{bmatrix}$$

2

UniaxialFiber   BeamWithHinges

Beam-Column Models I

u **p**

Linear
LinearPD
Corotational

q_3, v_3 q_1, v_1

q_2, v_2

Element

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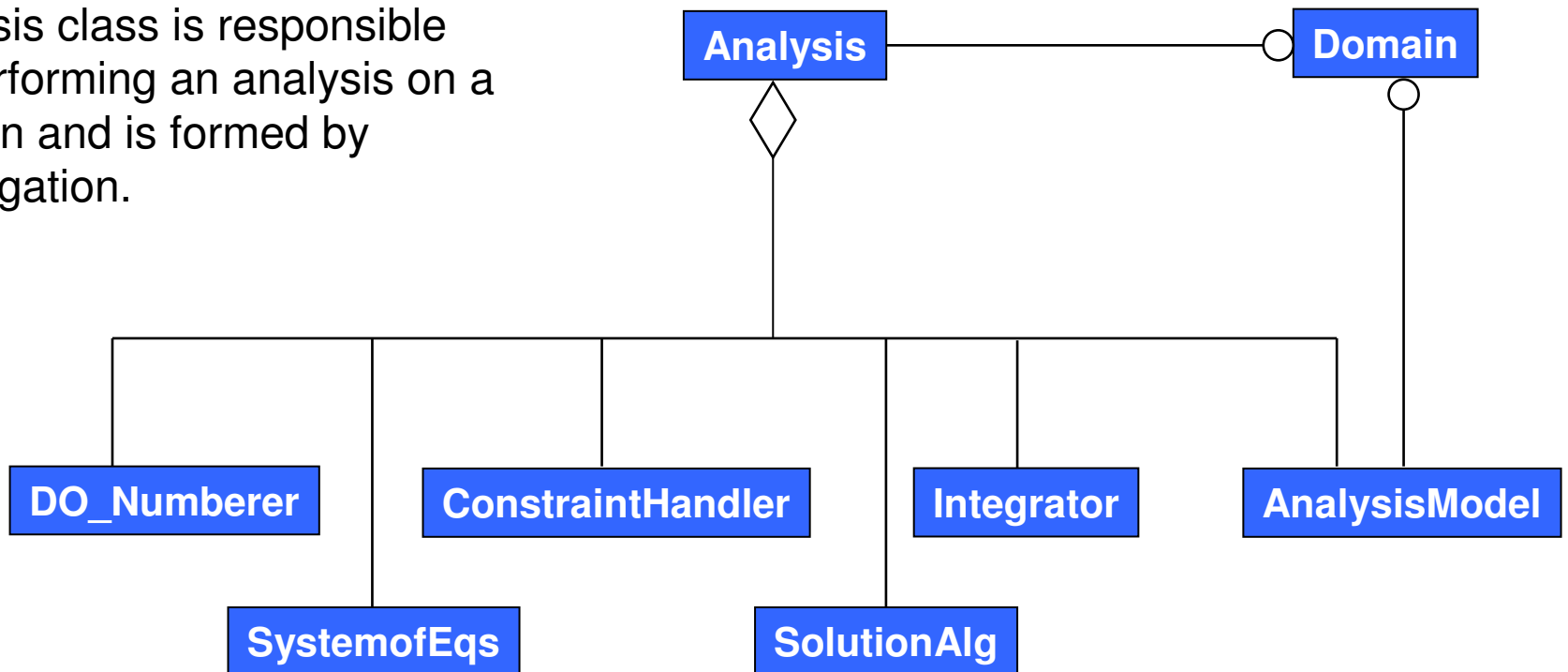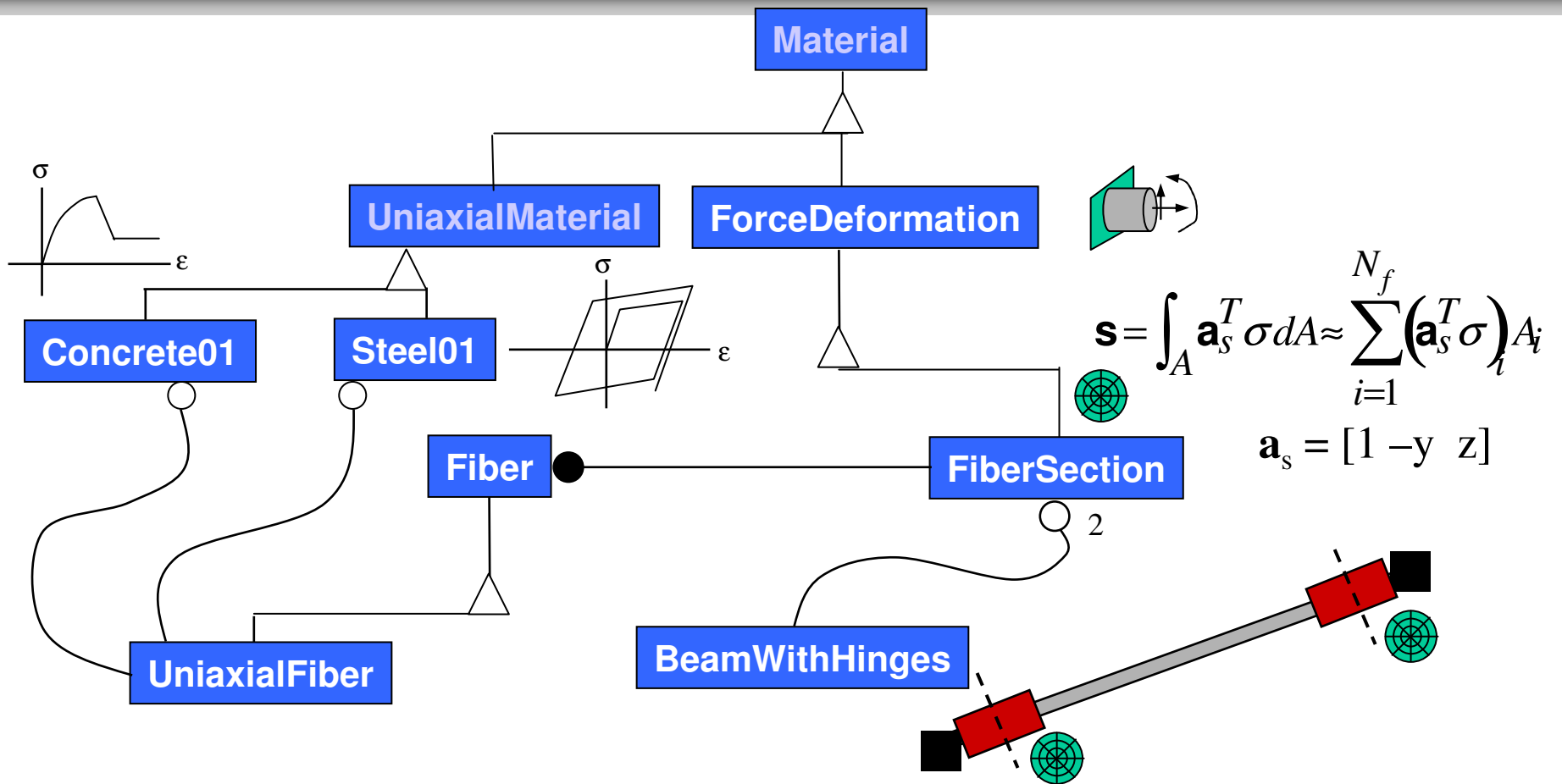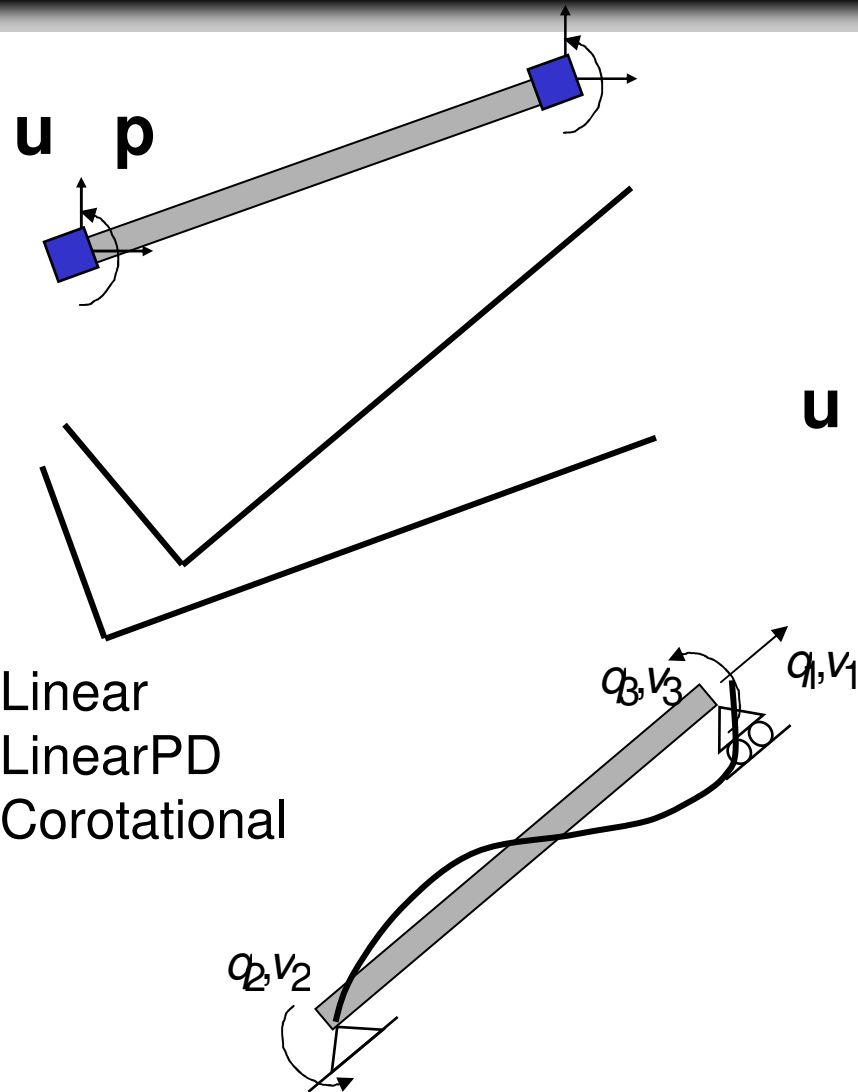
$\mathbf{u} = \mathbf{a}_f \mathbf{u}$ GeometricTran $\mathbf{p} = \mathbf{a}_f^T \mathbf{q}$

v **q**

Basic System

Beam-Column Models II

Displacement

q_3,v_3 q_1,v_1

$$e = av$$

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

q_2,v_2

e, s

$$\varepsilon = a_S e$$

$v \quad q$

| Basic System |

$e \quad s$

| Section |

$\varepsilon \quad \sigma$

| Material |

Force

$$s = bq$$

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

$$s = \int_A a_S^T \sigma\, dA$$

$$\sigma = \sigma(\varepsilon)$$
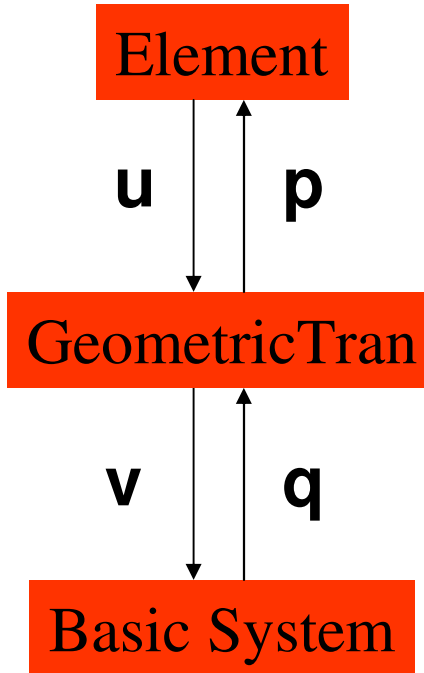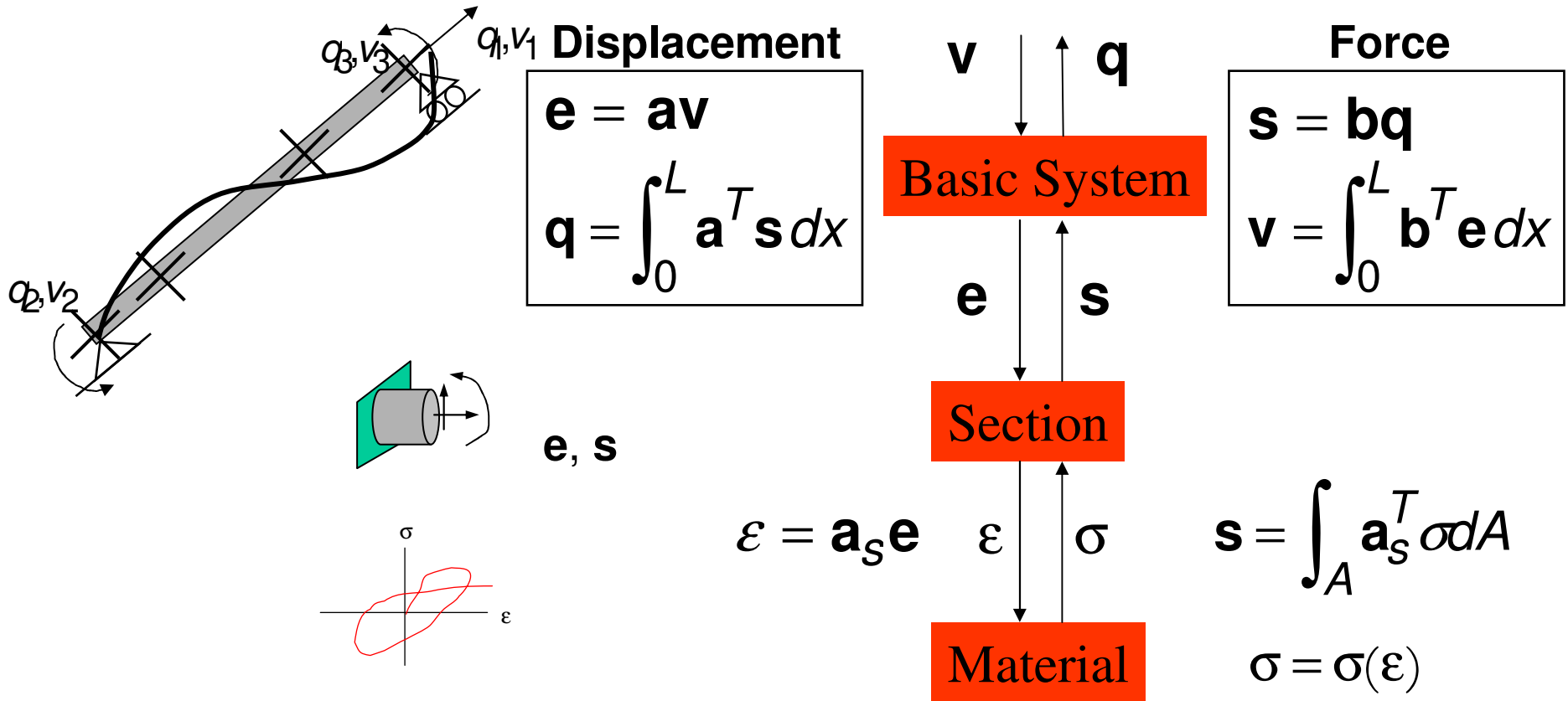
No assumptions are made on section or material behavior; each level in the hierarchy can be defined independently of other levels

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

Online User Guide

Framework Design/Source
for Developers

Class Specification
Application Program Interface

Source Code Viewing/Updating
With CVS

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
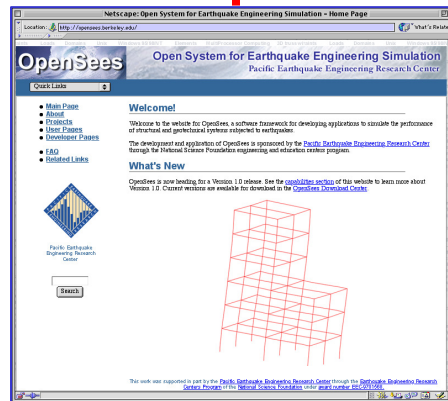 - Identify improvements in models and simulation methods

I-880

Fault

Humboldt Bay Bridge

Life Science Annex

Van Nuys Hotel
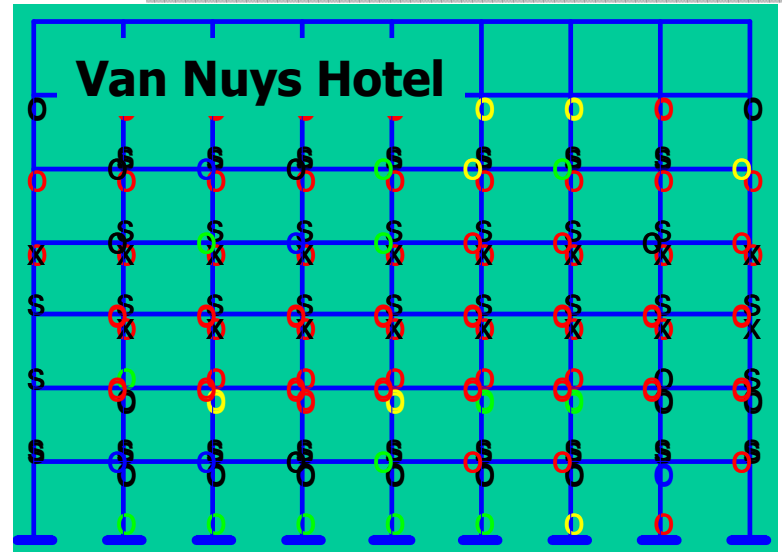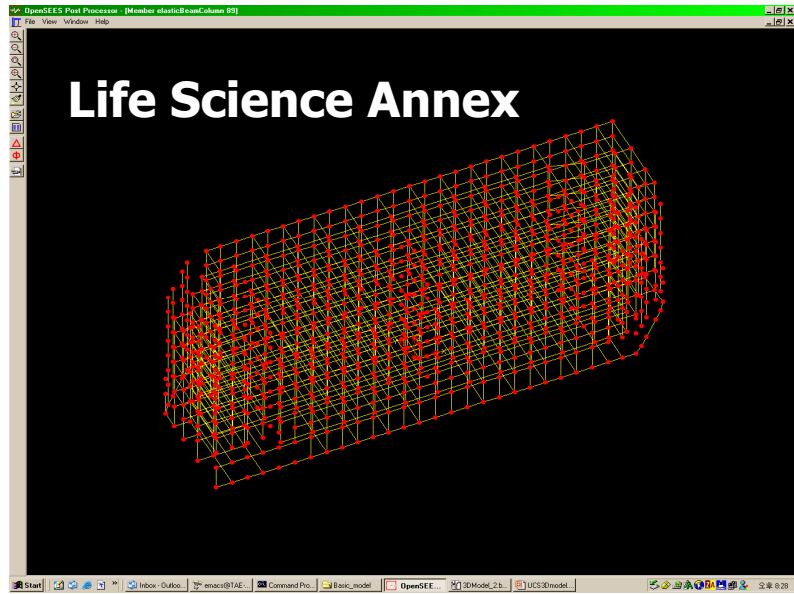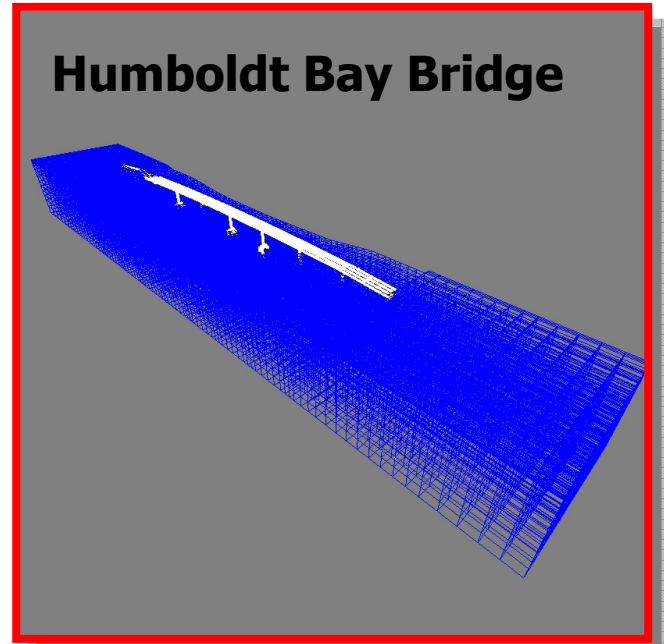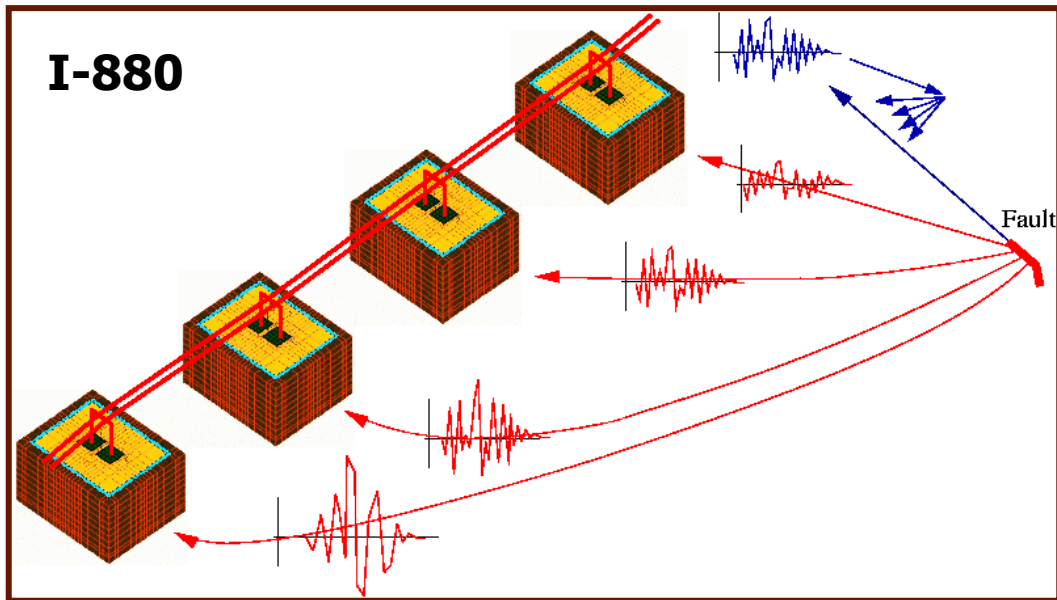
NEESit Simulation Overview

Simulation Portal
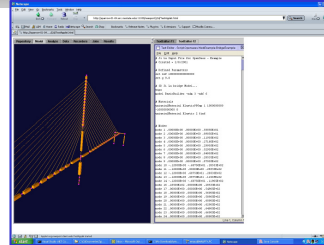
OpenSees NCTP Plugin

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.

Thanks to:

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

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