OpenSees

Computational Simulation

Frank McKenna
UC Berkeley

QuickTime™ and a
decompressor
are needed to see this picture.

NEES NEEScomm NSF

Coming Soon
Version 2.3.1

- Version 2.3.1 (almost ready)
  - New Materials
  - Mumps Sequential Solver
  - 64bit Version for Windows

Changes in the Works

Version 2.4.0 - (early 2012)

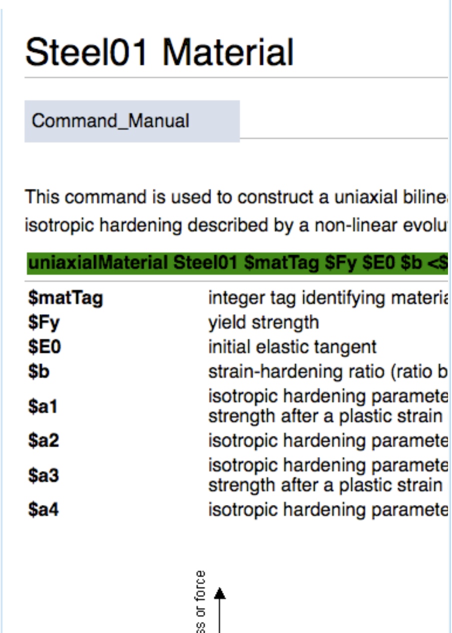
1. Code will be classified as Green, Yellow, Red

    Green (Verified & Validated)

    Yellow (It Works & Output Matches Input Provided)

    Red (Compiles but Not As Described)

It Will be Reflected in the Model



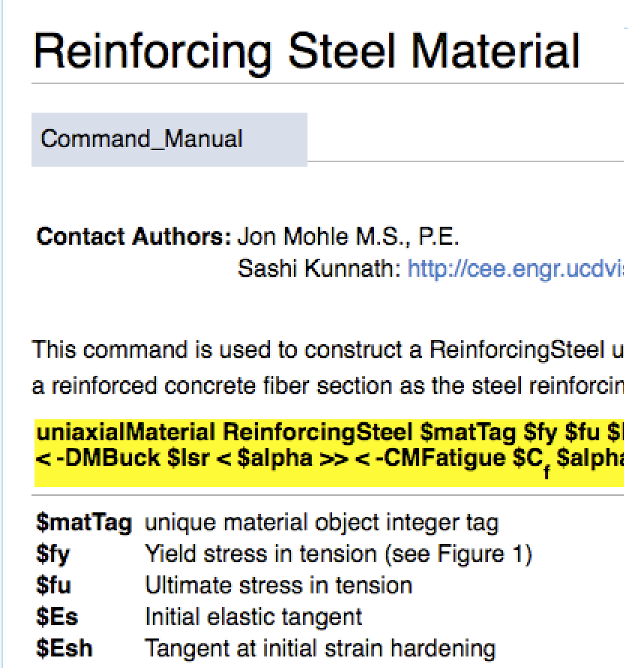
Steel01 Material

Command_Manual

This command is used to construct a uniaxial biline
isotropic hardening described by a non-linear evolu

uniaxialMaterial Steel01 $matTag $Fy $E0 $b <$

$matTag	integer tag identifying materi
$Fy	yield strength
$E0	initial elastic tangent
$b	strain-hardening ratio (ratio b
$a1	isotropic hardening paramete strength after a plastic strain
$a2	isotropic hardening paramete
$a3	isotropic hardening paramete strength after a plastic strain
$a4	isotropic hardening paramete



Reinforcing Steel Material

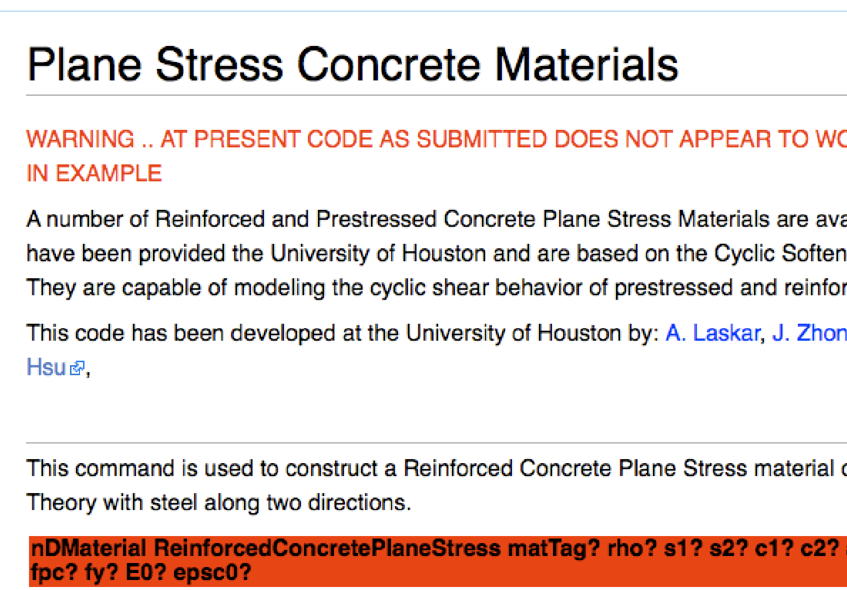
Command_Manual

Contact Authors: Jon Mohle M.S., P.E.
Sashi Kunnath: http://cee.engr.ucdvi

This command is used to construct a ReinforcingSteel u
a reinforced concrete fiber section as the steel reinforcin

uniaxialMaterial ReinforcingSteel $matTag $fy $fu $I
< -DMBuck $lsr < $alpha >> < -CMFatigue C_f$ $alpha

$matTag	unique material object integer tag
$fy	Yield stress in tension (see Figure 1)
$fu	Ultimate stress in tension
$Es	Initial elastic tangent
$Esh	Tangent at initial strain hardening



Plane Stress Concrete Materials

WARNING .. AT PRESENT CODE AS SUBMITTED DOES NOT APPEAR TO WO
IN EXAMPLE

A number of Reinforced and Prestressed Concrete Plane Stress Materials are ava
have been provided the University of Houston and are based on the Cyclic Soften
They are capable of modeling the cyclic shear behavior of prestressed and reinfor

This code has been developed at the University of Houston by: A. Laskar, J. Zhon
Hsu,

This command is used to construct a Reinforced Concrete Plane Stress material c
Theory with steel along two directions.

nDMaterial ReinforcedConcretePlaneStress matTag? rho? s1? s2? c1? c2?
fpc? fy? E0? epsc0?

Longer Out

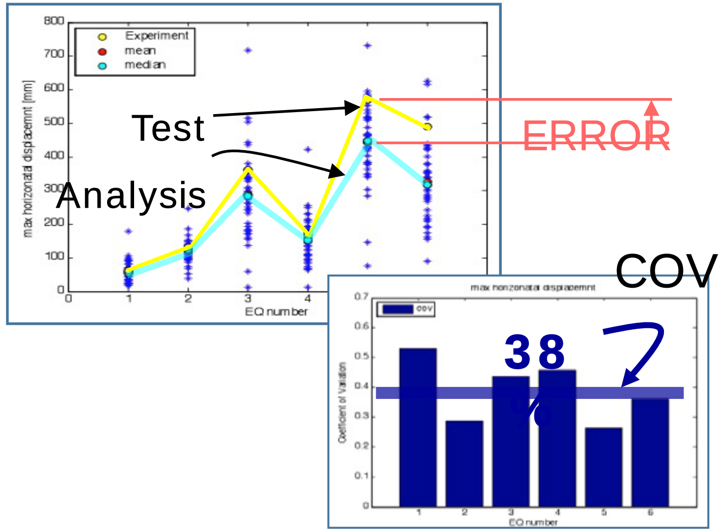
- Multiple Interpreters
  - Tcl, Python, Ruby, Matlab

Terminal — emacs-i386 — 82×26

```
void *
OPS_Dodd_Restre
{
  int    iData[
  double dData[
  if (numDoddRestrepo == 0) {
    numDoddRestrepo++;
    opserr << "Dodd_Restrepo unaxial material - Written by L.L. Dodd & J. Restepo\
\n";
  }

  int numArgs = OPS_GetNumRemainingInputArgs();
  if (numArgs < 8 || numArgs > 10) {
    opserr << "WARNING wrong # args: uniaxialMaterial $tag $Fy $Fsu $ESH $ESU $Yo\
ungs $ESHI $FSHI <$OmegaFac $Conv>" << endln;
    return 0;
  }

  numData = 1;
  if (OPS_GetIntInput(&numData, iData) != 0) {
    opserr << "WARNING invalid uniaxialMaterial ElasticPP tag" << endln;
    return 0;
```

Developer Acknowledged if Used in Script
(could put in please reference blah blah blah if used)

USES API



PEER-NEES RC Column Blind Analysis Contest - 2010

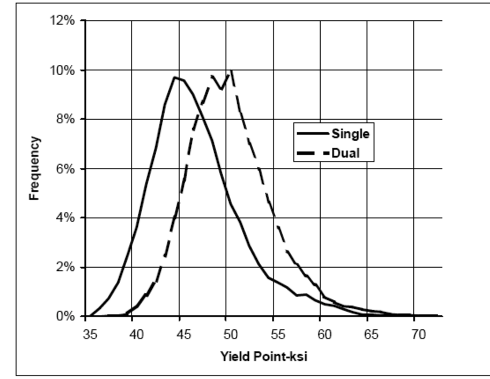
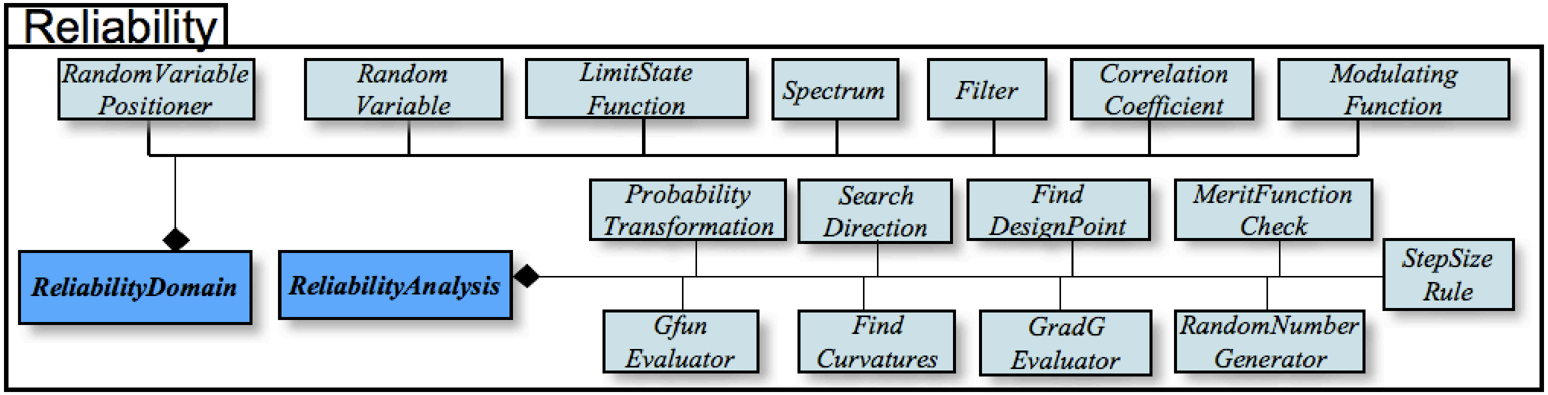


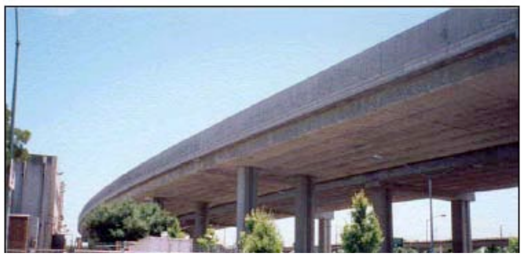
Figure 4-7 Yield Point Histogram of A36 Grade Material

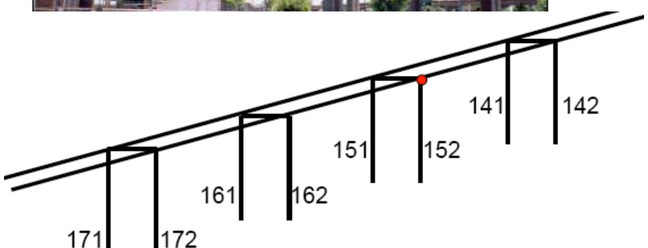
"The uncertainty is as important a part of the result as the estimate itself… An Estimate without a standard error is practically meaningless" [Jeffreys (1967)]

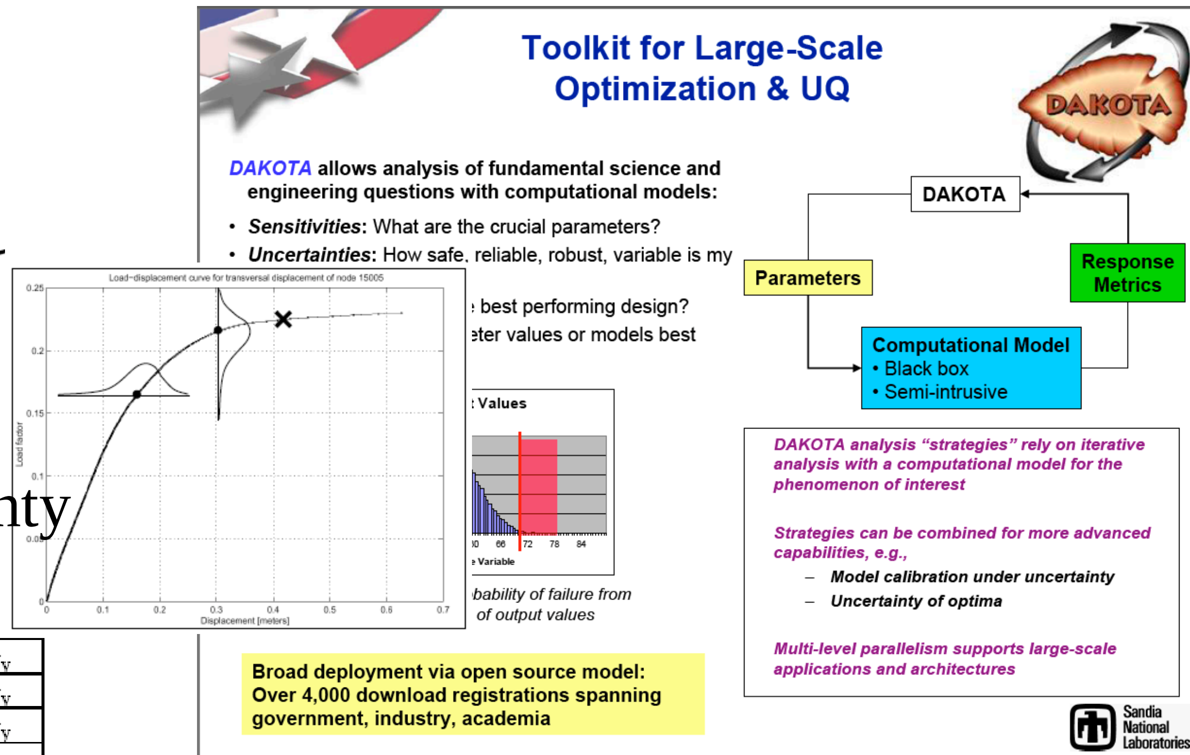
- OpenSees Will Generate Uncertainty Quantification for Any Input Model
  - Probability Distributions built into code
  - Expert users will be able to control these
  - Only for GREEN Code



I-880 PEER Testbed project







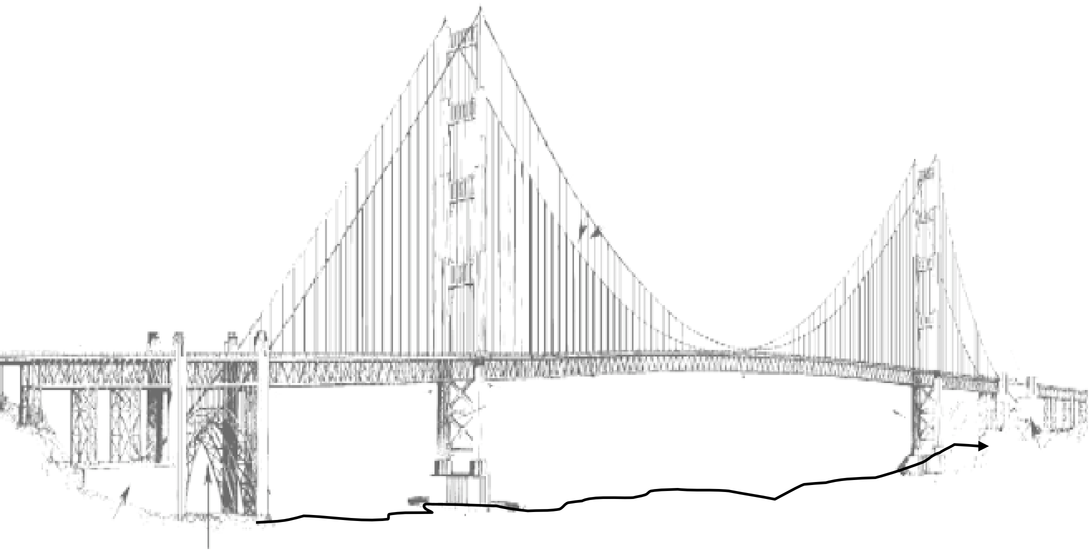
Uncertainty

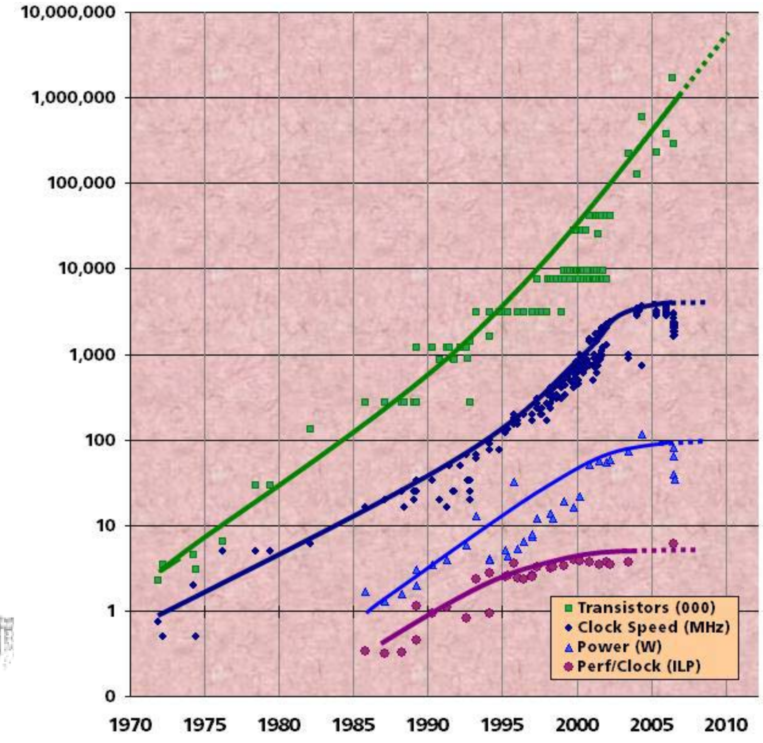
Sensitivity

1	-0.603	Element	141	σ_y
2	-0.538	Element	142	σ_y
3	-0.280	Element	151	σ_y
4	0.240	Element	142	f'_c
5	0.232	Element	142	ε_{cu}
6	-0.188	Element	152	σ_y

http://dakota.sandia.gov/index.html

Technology is Changing





Intel Processor Speed

Hardware

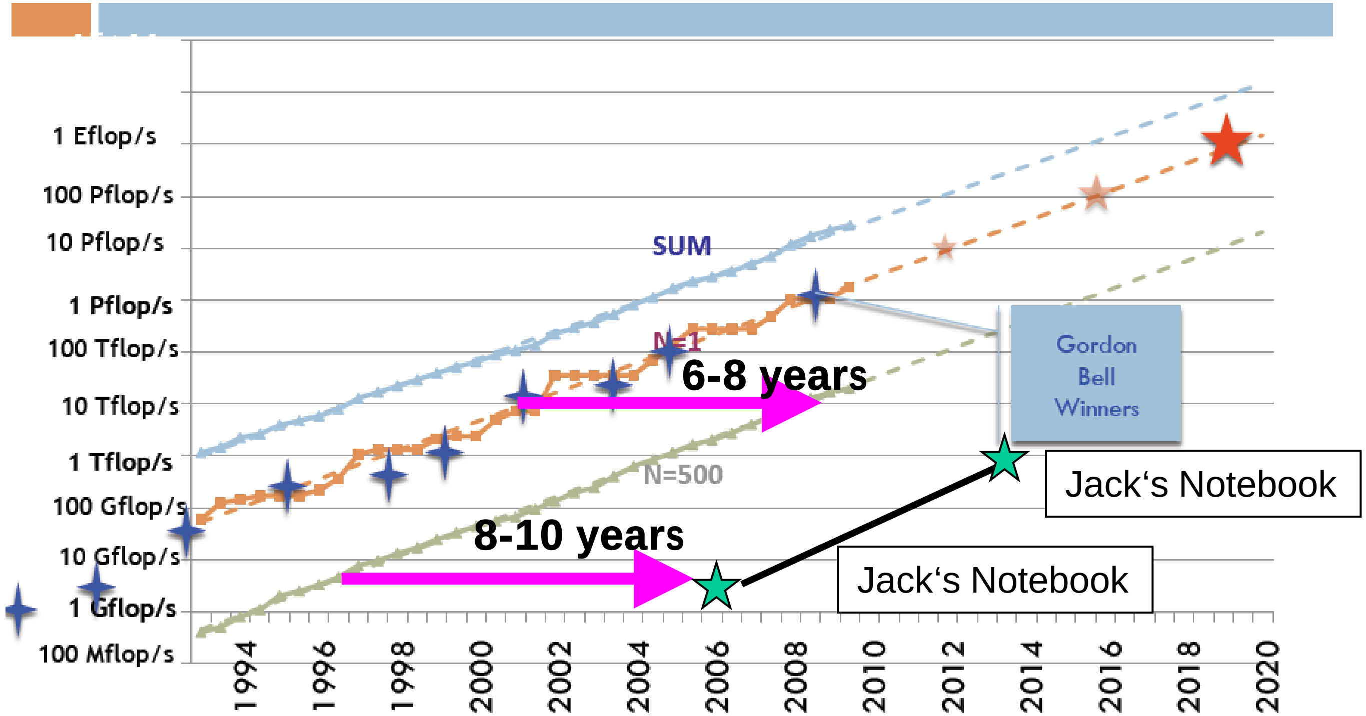
Your childs game (Wii, Xbox Playstation) has more raw numerical processing power than your desktop!

Nintendo Wii	61GFlops
Xbox360	355Glops
Sony PS3	2018Gflops

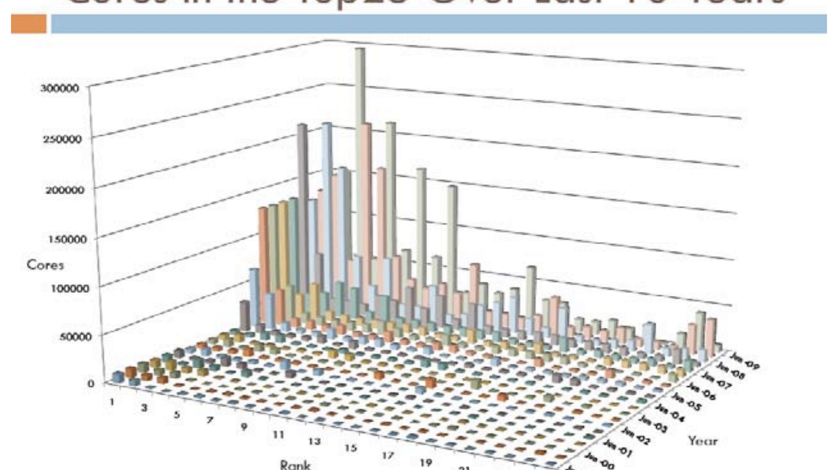
XeonE7Server	72Gflop
i7Desktop	55GFlop
i7Mobile	30GFlop
i5Desktop	40GFlop
i5Mobile	22GFlop
Core2 Extreme	52GFlop
Core2 Quad	48GFlop

Trends in Parallel Computing

(according to Jack)



Cores in the Top25 Over Last 10 Years

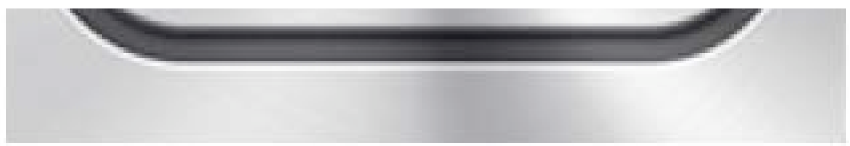


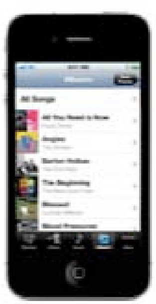
•Hardware has changed drastically while software ecosystem has remained stagnant

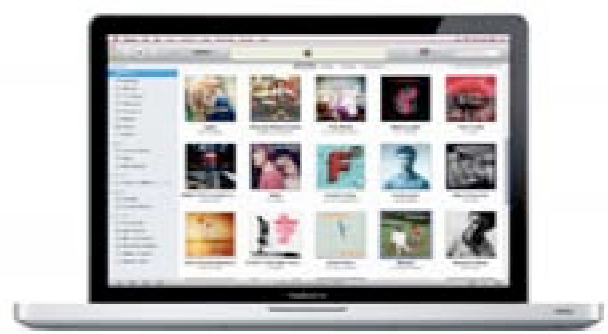
•Community codes unprepared for sea change in architecture

Cloud Computing (according to Steve)

Cloud computing is internet-based computing , whereby shared resources, software, and information are provided by computers and other devices on demand, like the electricity grid. source: wikipedia







PC and Mac Demoted to a Device”

BEFORE YOU GET ALL EXCITED

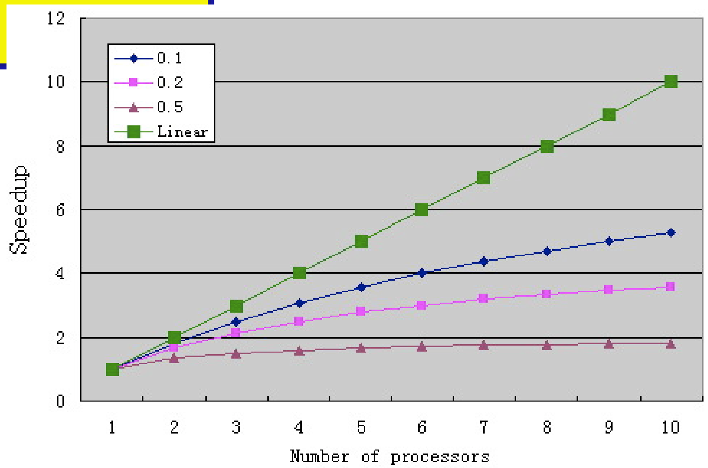
Speedup & Amdahl's Law

$$speedup_{PC}(p) = \frac{Time(1)}{Time(p)}$$

$$Speedup_{PC} = \frac{T_1}{\alpha T_1 + \frac{(1-\alpha)T_1}{n}} \rightarrow \frac{1}{\alpha} \text{ as } n \rightarrow \infty$$

Portion of sequential (α)

# of processors (n)



Improving Real Performance

Peak Performance grows exponentially, a la Moore's Law

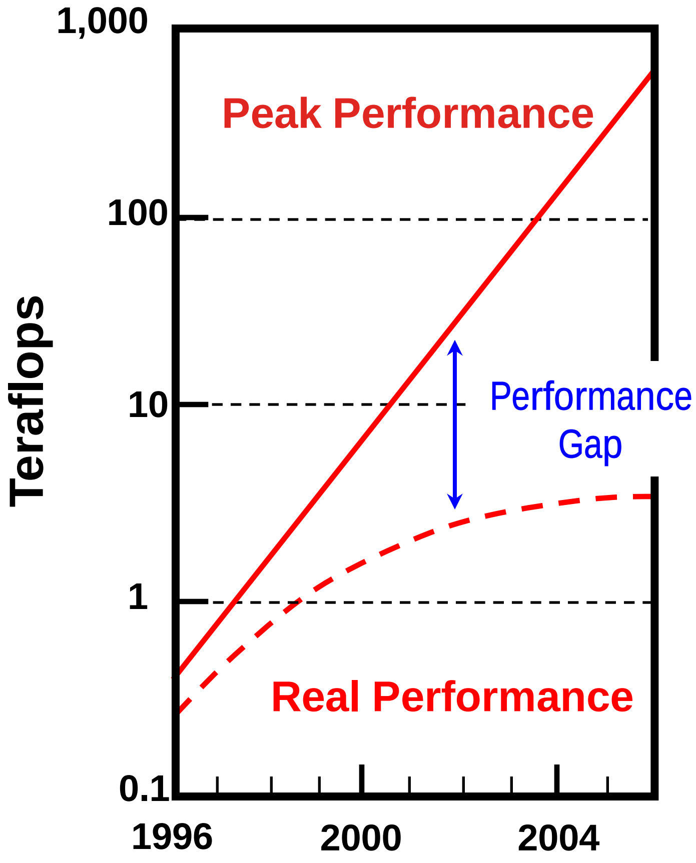
- In 1990's, peak performance increased 100x; in 2000's, it will increase 1000x

But efficiency (the performance relative to the hardware peak) has declined

- was 40-50% on the vector supercomputers of 1990s
- now as little as 5-10% on parallel supercomputers of today

Close the gap through ...

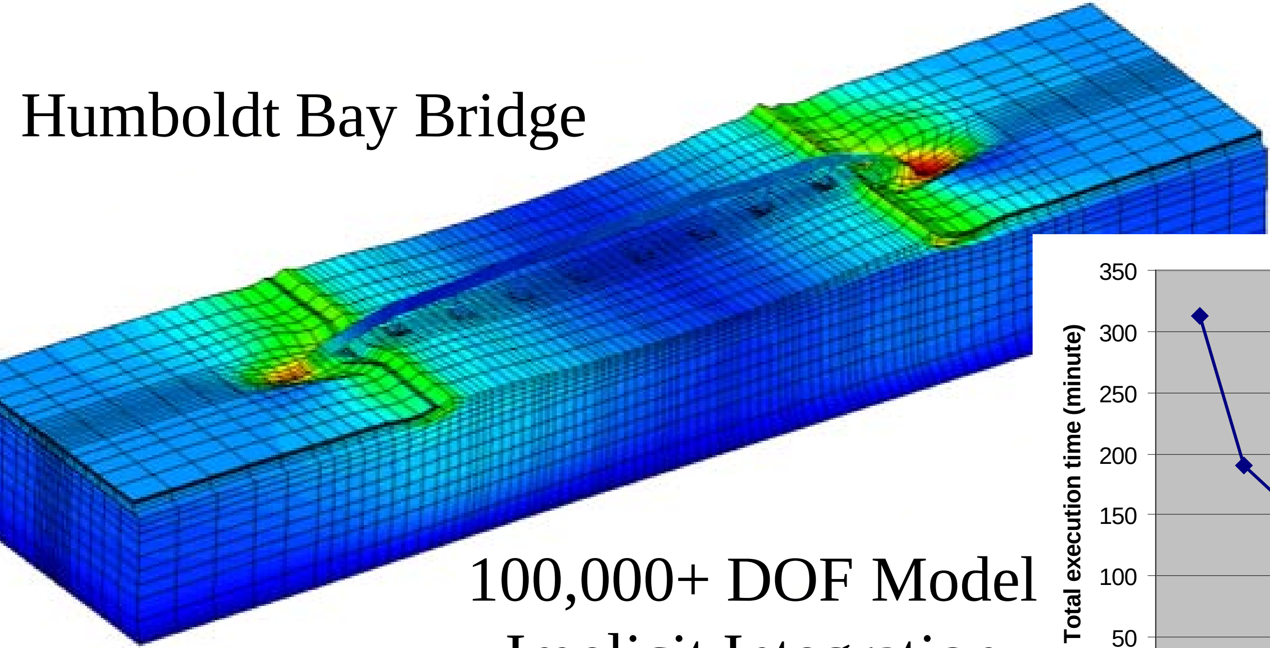
- Mathematical methods and algorithms that achieve high performance on a single processor and scale to thousands of processors
- More efficient programming models and tools for massively parallel supercomputers



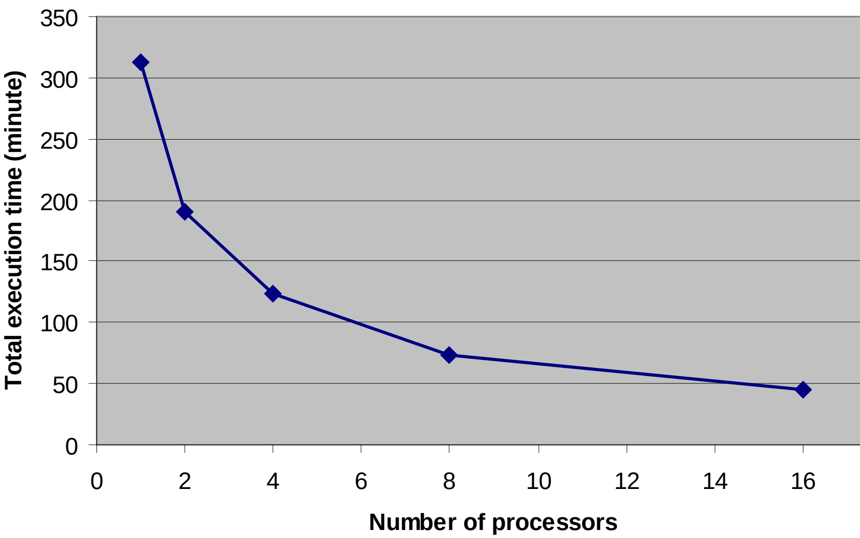
Source: Jim Demmell, CS267 Course Notes

OpenSees Parallel Examples

Humboldt Bay Bridge

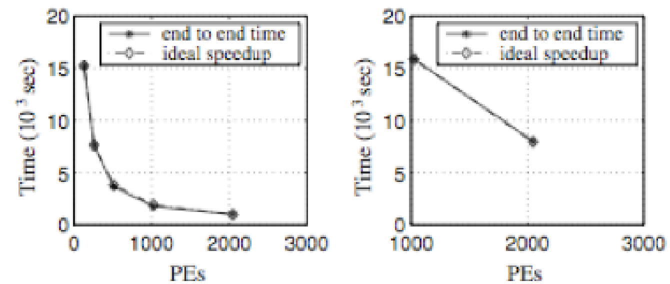


100,000+ DOF Model
Implicit Integration
Mumps Direct Solver

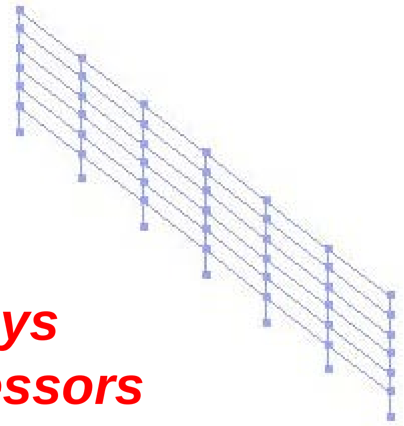


Made Up Continuum Model

Run	el. size (m)	Elements	Nodes	DOFs
A	20	54,026	59,032	156,768
B	10	404,751	424,512	1,193,283
C	5	3,130,301	3,208,822	9,307,563
D	2.5	24,615,801	24,928,842	73,515,123



Steel Building Study

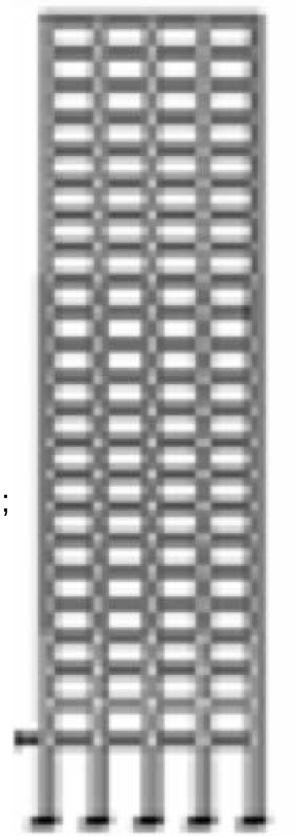


7200 records
2 min a record
240 hours or 10 days
Ran on 2000 processors
on teragrid in less than 15 min.

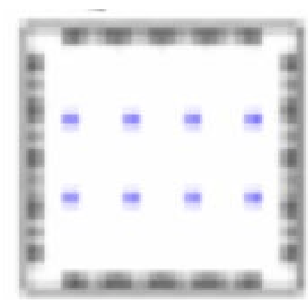
```
set pid [getPID]
set np [getNP]
set recordsFileID [open "peerRecords.txt" r]
set count 0;

foreach gMotion [split [read $recordsFileID] ¥n] {
  if {[expr $count % $np] == $pid} {

  source model.tcl
  source analysis.tcl

  set ok [doGravity]

  loadConst -time 0.0

  set gMotionList [split $gMotion "/"]
  set gMotionDir [lindex $gMotionList end-1]
  set gMotionNameInclAT2 [lindex $gMotionList end]
  set gMotionName [string range $gMotionNameInclAT2 0 end-4 ]

  set Gaccel "PeerDatabase $gMotionDir $gMotionName -accel 384.4 -dT dT -nPts nPts"
  pattern UniformExcitation 2 1 -accel $Gaccel

  recorder EnvelopeNode -file $gMotionDir$gMotionName.out -node 3 4 -dof 1 2 3 disp

  doDynamic [expr $dT*$nPts] $dT

   wipe
  }

  incr count 1;
}
```

Concrete Building Study

```
set pid [getPID]
set np [getNP]
set count 0;
source parameters.tcl
source ReadSMDFileNewFormat.tcl;
foreach GMfile $iGMFile {
   foreach Factor1248 $iFactor1248 {

      if {[expr $count % $np] == $pid} {

          set inFile $GMdir/$GMfile.AT2
          set outFile $GMdir/$GMfile.g3;
          ReadSMDFileNewFormat $inFile $outFile dt npts;

          wipe
          source GravityAnalysisScript.tcl

          loadConst -time 0.0;
          wipeAnalysis

          source  EQ_Recorder.tcl
          source EQAnalysisScript.tcl

         if {$ok == 0} {
             puts "Process $pid $GMfile x $Factor1248 FINISHED OK modelTime [getTime]]"
          } else {
             puts "Process $pid $GMfile x $Factor1248 FINISHED FAIL modeTime [getTime] desiredTime $TmaxAnalysis]"
          }
          incr count 1
      }
   }
}
```



113 records, 4 intensities
3 hour a record, would have taken 1356 hours or 56.5 days
Ran on 452 processors of a Teragrid in less than 5 hours.



OpenSees in the clouds using Open Science Grid

André R. Barbosa, Joel P. Conte, and José I. Restrepo, ***UCSD***

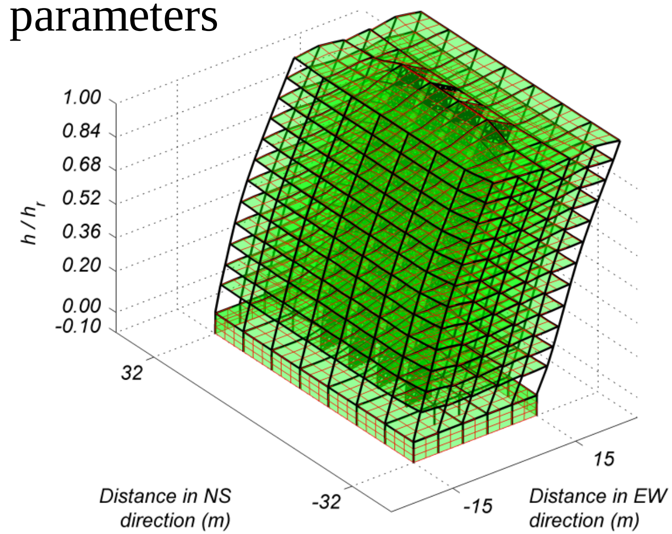
❑ Motivation

- Perform parametric studies that involve large-scale nonlinear models of structure or soil-structure systems with large number of parameters and OpenSees runs.

OpenSees

❑ Application example

- Nonlinear time-history (NLTH) analyses of advanced nonlinear FE model of a building
- Probabilistic seismic demand hazard analysis making use of the "cloud method"
  - 90 bi-directional historical earthquake records (unscaled and scaled by a factor of two)
- Sensitivity of probabilistic seismic demand to FE model parameters



❑ Some numbers

Number of NLTH analyses per parameter set realization	180
Average duration of NLTH analysis	12 hours
Average size of output data	1.5 GB
Parameters considered	6
Perturbations considered	4
Estimated clock time (180x12x[(6x4x2)+1])	**106,800 hours (12.2 years)**
Estimated output data (180x1.5x[(6x4x2)+1])	**12 TB**

Open Science Grid

30 days on OSG versus 12 years on Desktop!

NEESHub

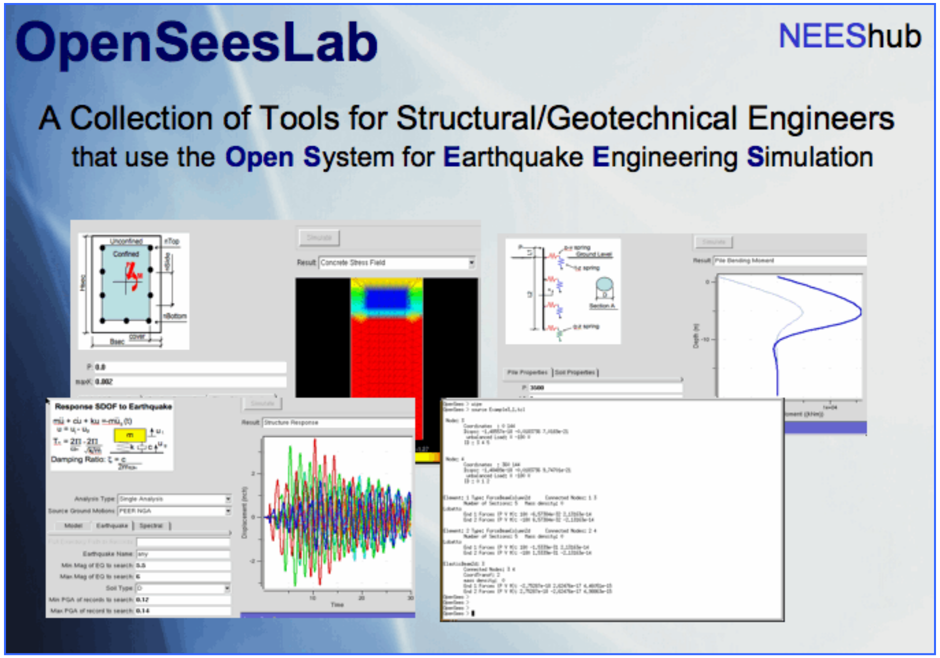
- The power behind NEES at http://nees.org
- Maintained and developed at Purdue by NEEScomm
- Built using proven HUBzero technology (nanoHUb > 100,000 users)
- A science gateway for education and research in earthquake engineering

Through a browser engineers can:

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

The OpenSeesLab tool:

http://nees.org/resources/tools/openseeslab



Is a suite of Simulation Tools powered by OpnSees for:

1. Submitting OpenSees scripts (input files) to HUB resources
2. Educating students and practicing engineers
3. Performing useful tasks

OpenSees Interpreter Tool

hub

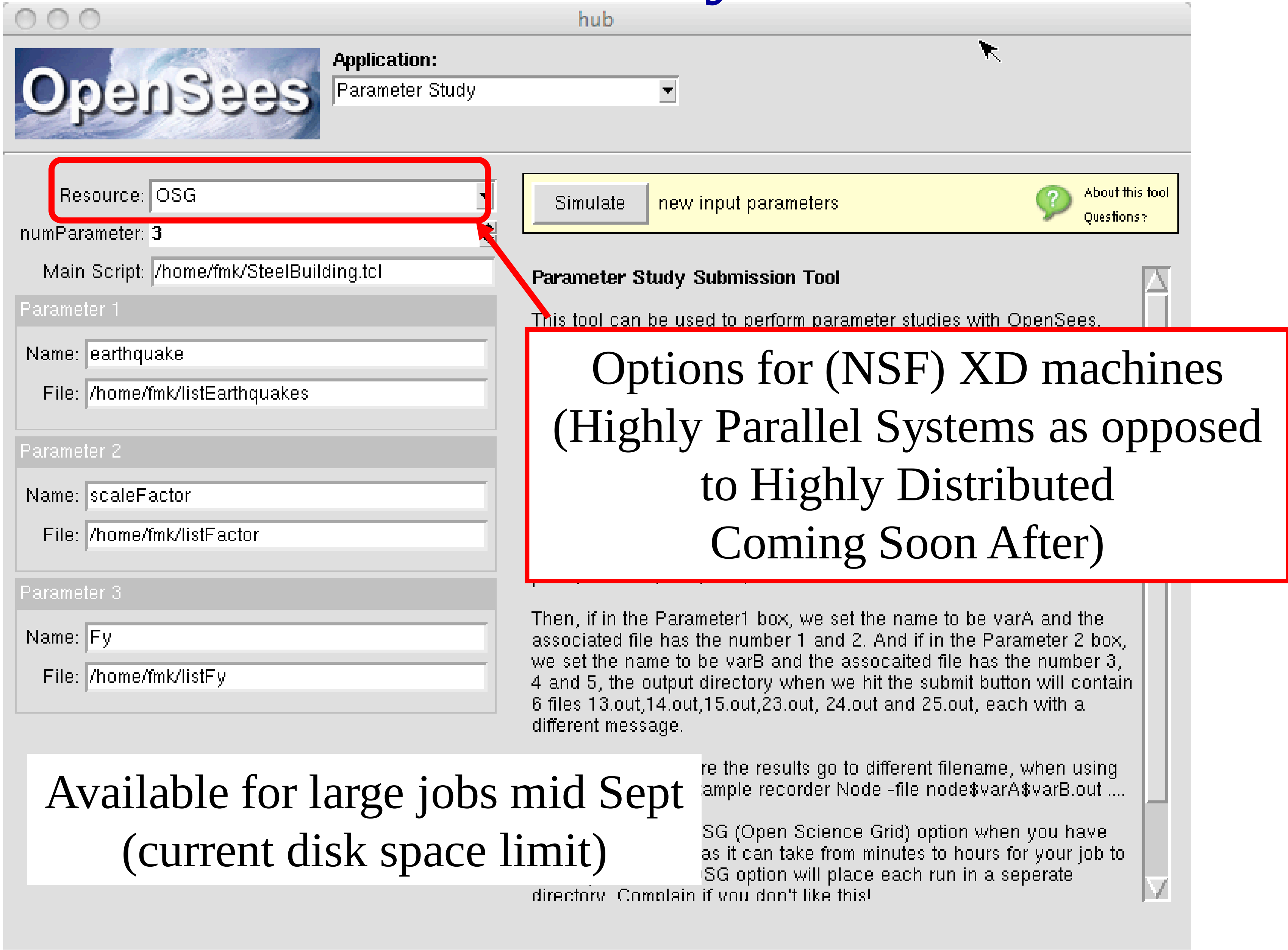
Java Applet Window

OpenSees

Application: OpenSees Interpreter

```
        OpenSees -- Open System For Earthquake Engineering Simulation
       Pacific Earthquake Engineering Research Center -- 2.2.1

           (c) Copyright 1999,2000 The Regents of the University of California
                                 All Rights Reserved
    (Copyright and Disclaimer @ http://www.berkeley.edu/OpenSees/copyright.html)


OpenSees > tar xBf A_Example.tar
OpenSees > cd A_Example
OpenSees > source Ex8.tcl
couldn't read file "Ex8.tcl": no such file or directory
OpenSees > ls
A8.tcl
ExampleSP1.tcl
Node.out
analysis.tcl
model.tcl
peerRecords.txt
OpenSees > source A8.tcl
WARNING analysis Transient dt tFinal - no LinearSOE specified,
 ProfileSPDLinSOE default will be used

 Node: 525
        Coordinates  : 1 1 10
        Disps: 0.00977277 0.00977277 -0.00409793
        Velocities   : 0.0141832 0.0141832 -0.00878414
        commitAccels: 0.128284 0.128284 0.228457
         unbalanced Load: 0 0 0
        ID : 0 1 2

Simulation Time 192
OpenSees > cd ..
OpenSees > tar cBf A_Example.tar A_Example
OpenSees >
```

Parameter Study Tool



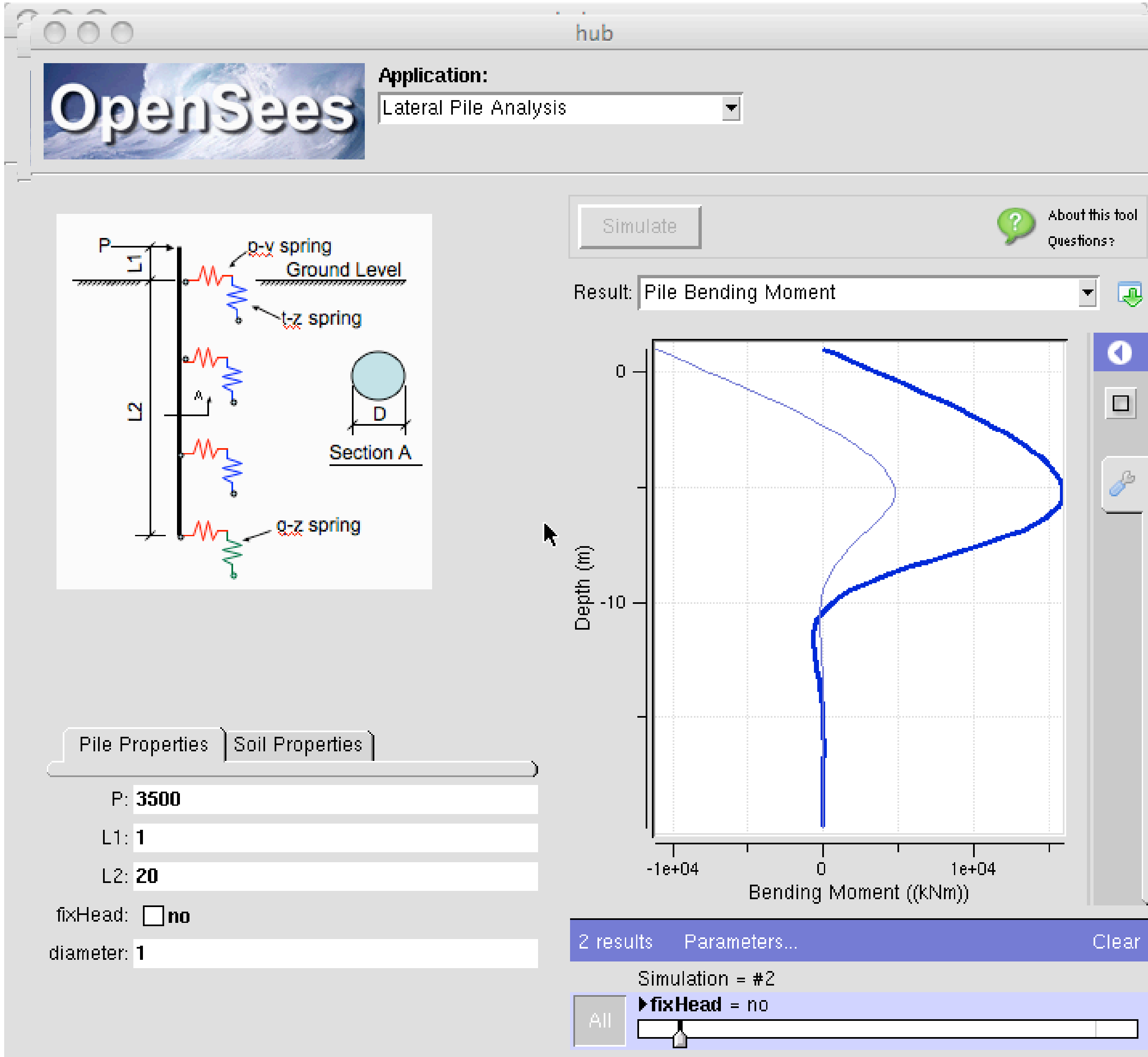
Options for (NSF) XD machines (Highly Parallel Systems as opposed to Highly Distributed Coming Soon After)

Available for large jobs mid Sept (current disk space limit)

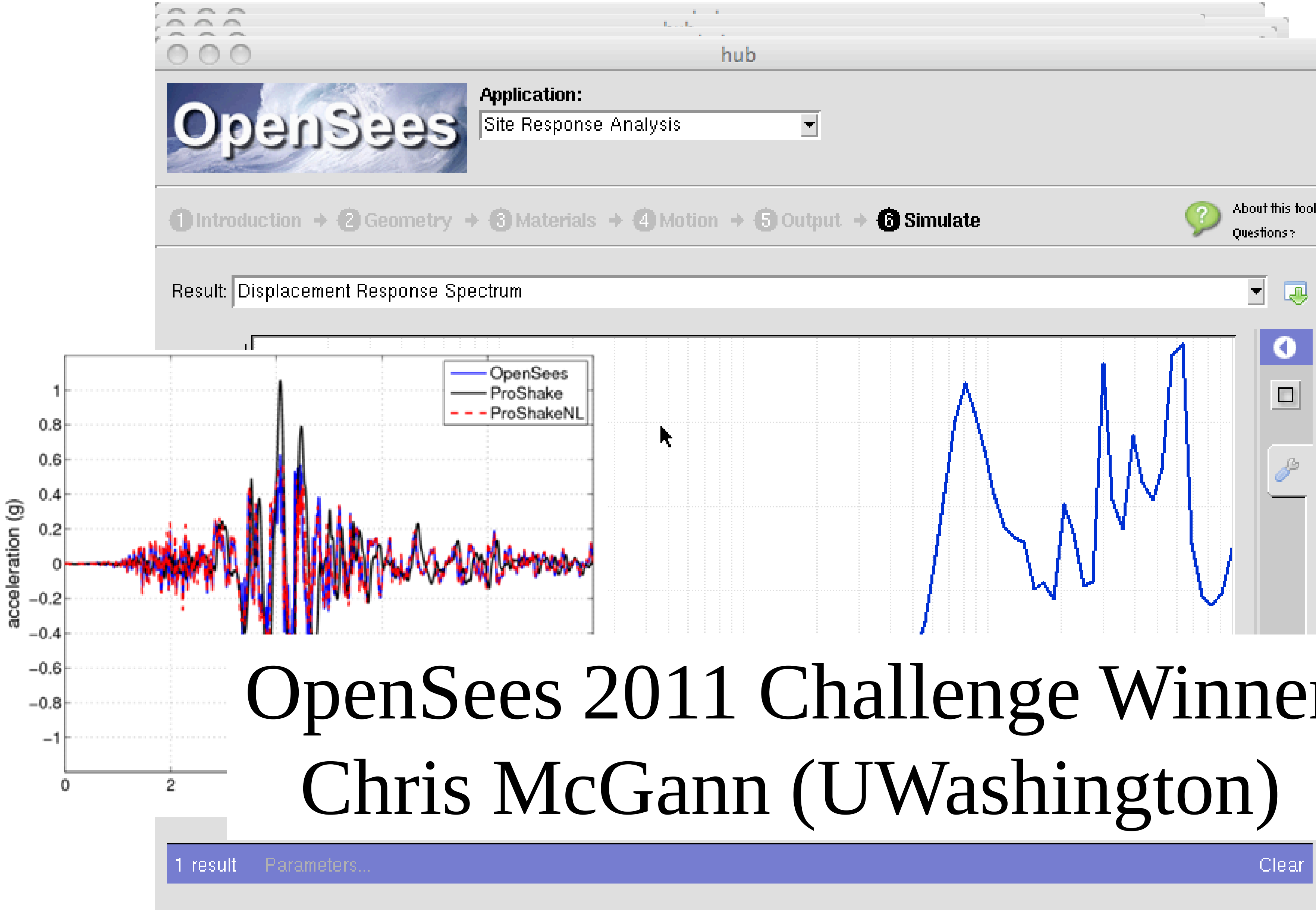
Lateral Pile Analysis

http://opensees.berkeley.edu/wiki/index.php/Laterally-Loaded_Pile_Foundation

Chris McGann U. Washington



Site Response Analysis



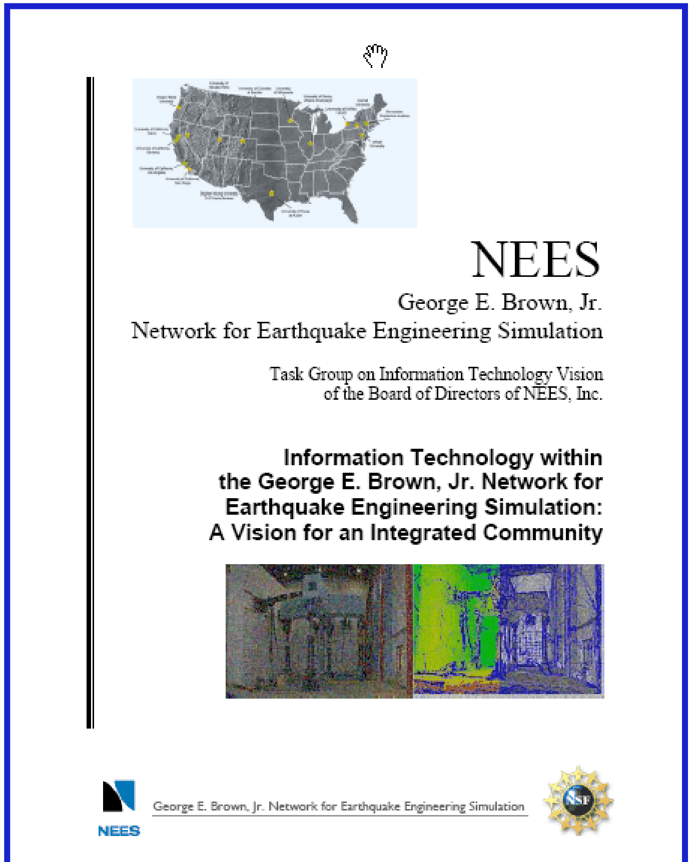
OpenSees 2011 Challenge Winner

Chris McGann (UWashington)

OpenSees Challenge 2012

At next years OpenSees Days Workshop (late August or early Sept), **I** will award an iPod to the person (anyone other than myself) who submits the best **OpenSees powered app** to NEEShub. Winner will be judged by Workshop participants.

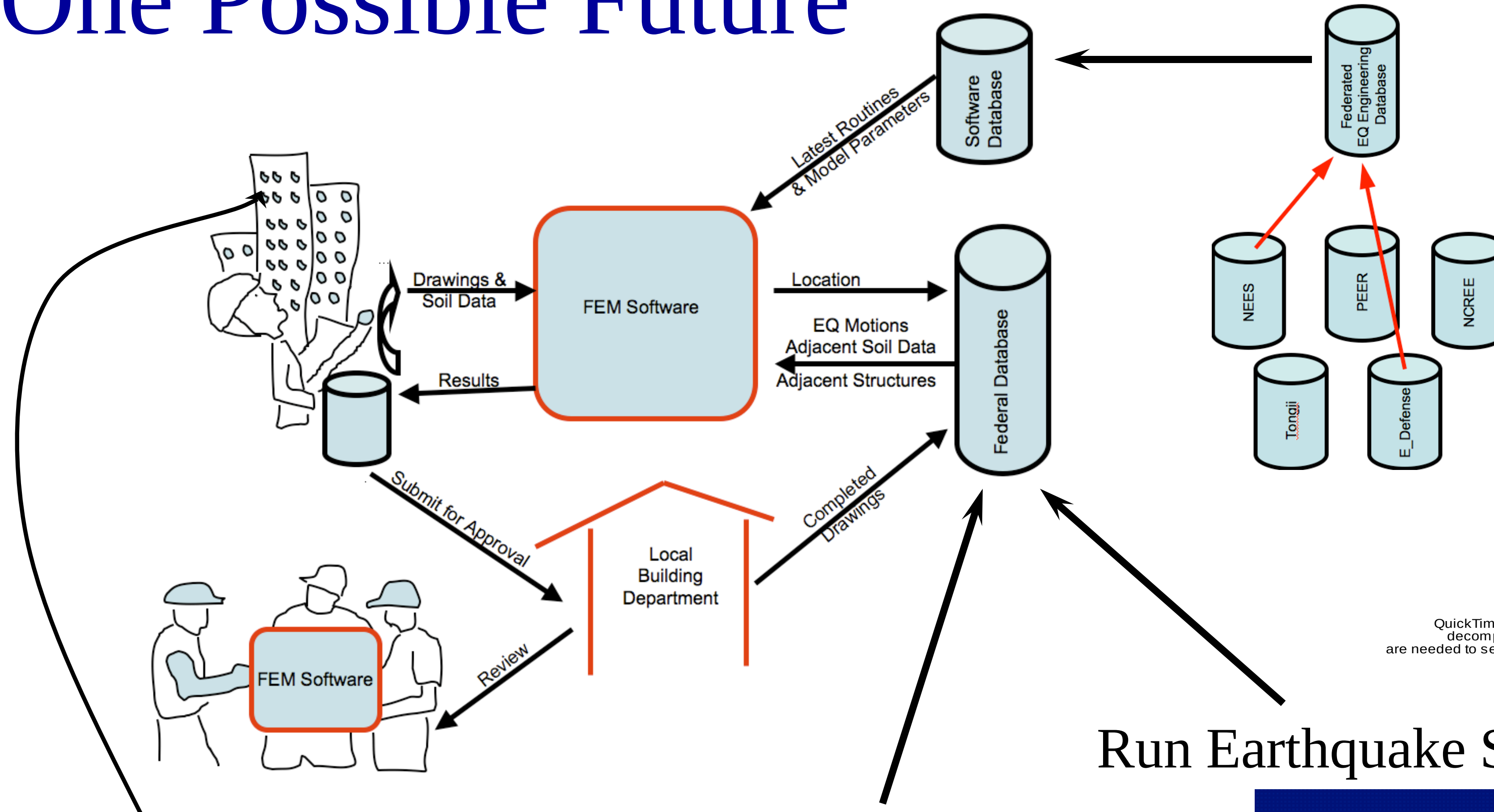
Vision for Computational Simulation



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.

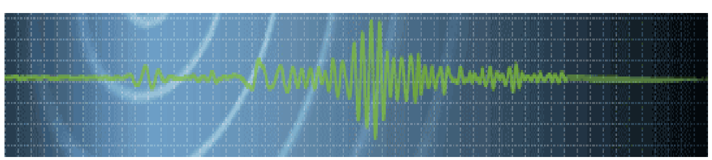
One Possible Future



QuickTime™ and a decompressor are needed to see this picture.

Run Earthquake Scenario

QuickTime™ and a decompressor are needed to see this picture.



Detects EQ - back calculates fault scenario, rupture to rafters analysis & causes EQ alarm in vulnerable buildings to sound!

Any Questions?