

High Performance Computing in Earthquake Engineering

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What do I mean by a High Performance Computing?

Running our **computations** on a High Performance Computer

- A Parallel Computer- Basically Something With Multiple Processors, e.g. your desktop/laptop
- High Performance Computer – Parallel Computer with lots and lots and lots of processors.

RANK	SITE	SYSTEM	CORES	(TFLOP/S)	(TFLOP/S)	(KW)
1	National Super Computer Center in Guangzhou China	Tianhe-2 (MilkyWay-2) - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P NUDT	3,120,000	33,862.7	54,902.4	17,808
2	DOE/SC/Oak Ridge National Laboratory United States	Titan - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x Cray Inc.	560,640	17,590.0	27,112.5	8,209
3	DOE/NNSA/LLNL United States	Sequoia - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom IBM	1,572,864	17,173.2	20,132.7	7,890
4	RIKEN Advanced Institute for Computational Science (AICS) Japan	K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect Fujitsu	705,024	10,510.0	11,280.4	12,660
5	DOE/SC/Argonne National Laboratory United States	Mira - BlueGene/Q, Power BQC 16C 1.60GHz, Custom IBM	786,432	8,586.6	10,066.3	3,945

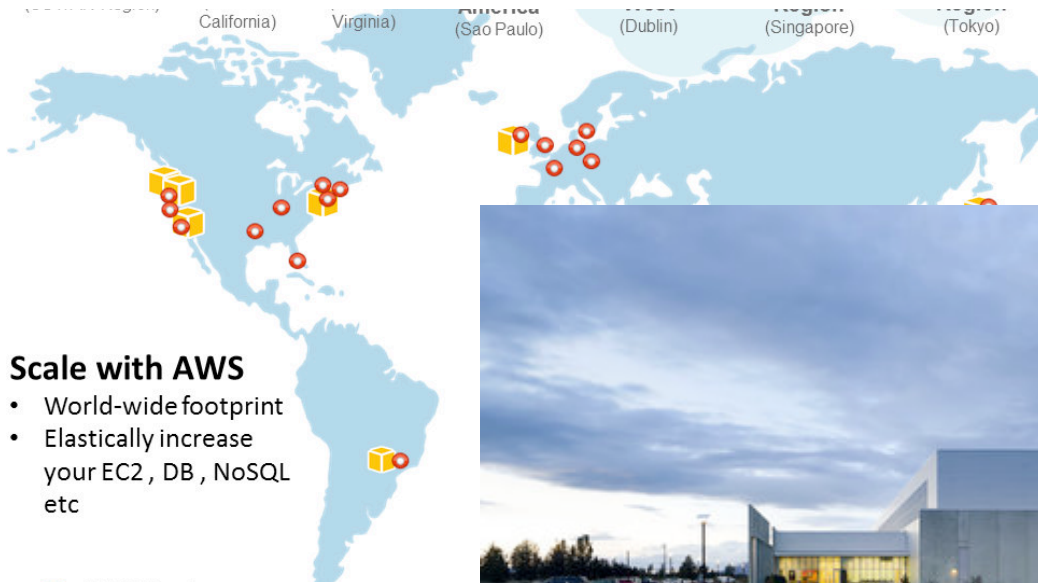
Research Community

- XSEDE Resources
 - Darter, Greenfield, Gordon, JetStream, Mason, Stampede, SuperMIC, and Wrangler
 - Coming Soon Comet and Bridges
- NHERI-ci: Stampede



500,000 cores

Industry



Scale with AWS

- World-wide footprint
- Elastically increase your EC2, DB, NoSQL etc



Amazon:
estimated 2 million processors,
2 -16 processors a core
~ 10million cores

+ IBM, Google, Apple, Salesforce

It's Cheap

General Purpose - Current Generation

t2.nano	1	Variable	0.5	EBS Only	\$0.0065 per Hour
t2.micro	1	Variable	1	EBS Only	\$0.013 per Hour
t2.small	1	Variable	2	EBS Only	\$0.026 per Hour
t2.medium	2	Variable	4	EBS Only	\$0.052 per Hour
t2.large	2	Variable	8	EBS Only	\$0.104 per Hour
m4.large	2	6.5	8	EBS Only	\$0.12 per Hour
m4.xlarge	4	13	16	EBS Only	\$0.239 per Hour

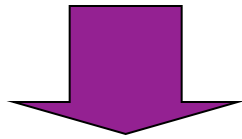
m4.2xlarge Product: **Linux/UNIX (Amazon VPC)** Instance type: **m4.xlarge** Date range: **1 month** Availability zone: **All z**



BUT

Speedup & Amdahl's Law

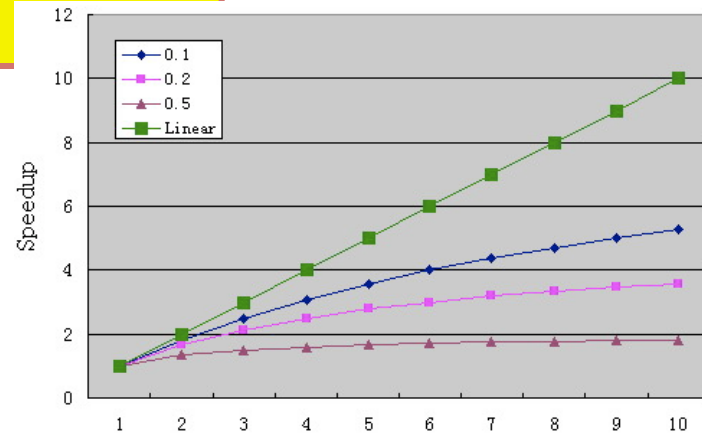
$$speedup_{PC}(p) = \frac{Time(1)}{Time(p)}$$



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

Portion of sequential

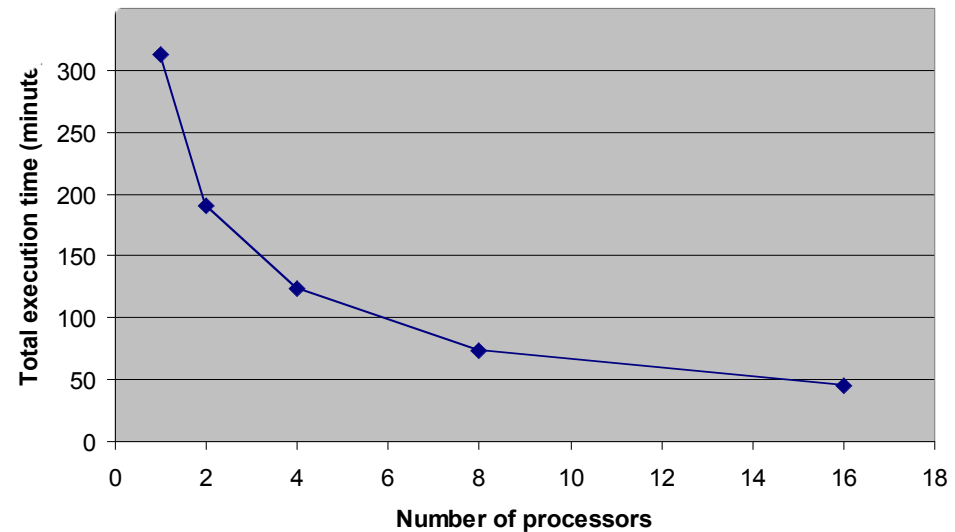
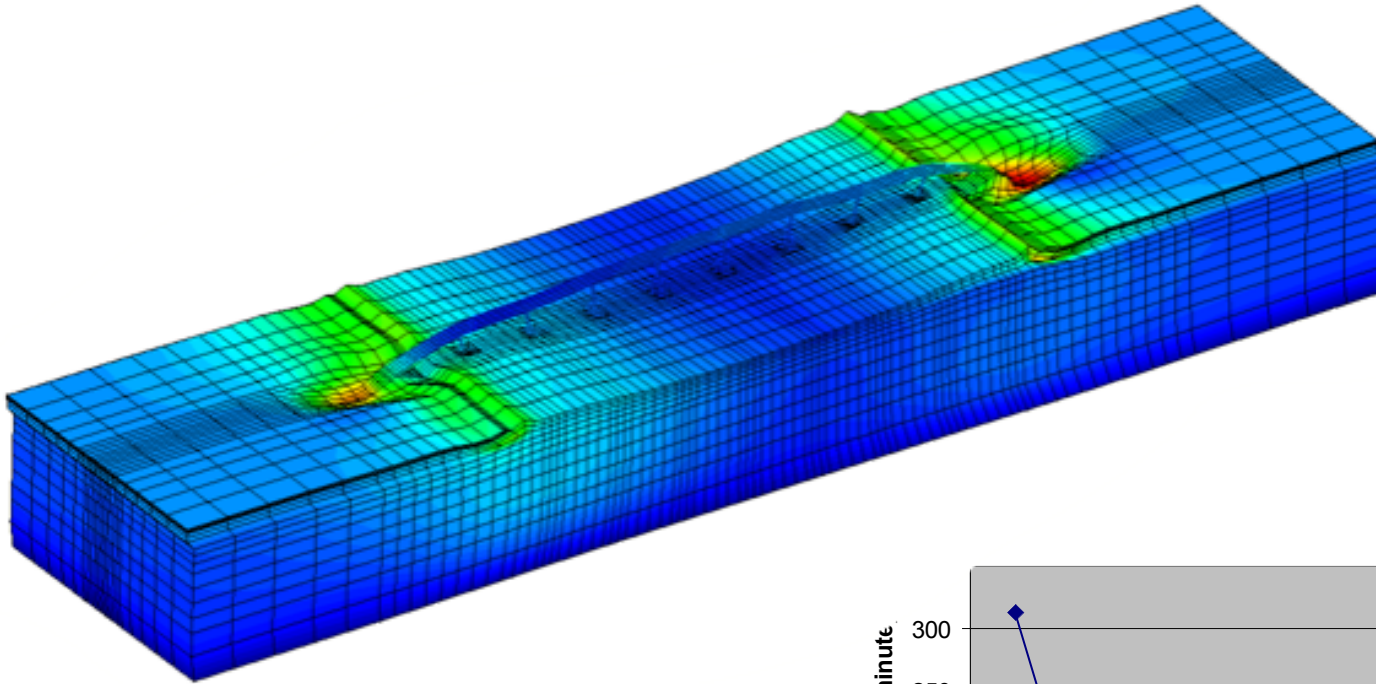
of processors



So Why Do We Need LOTS of
PROCESSORS (HPC)?

Large Model

- OpenSeesSP: An application for large models.





PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

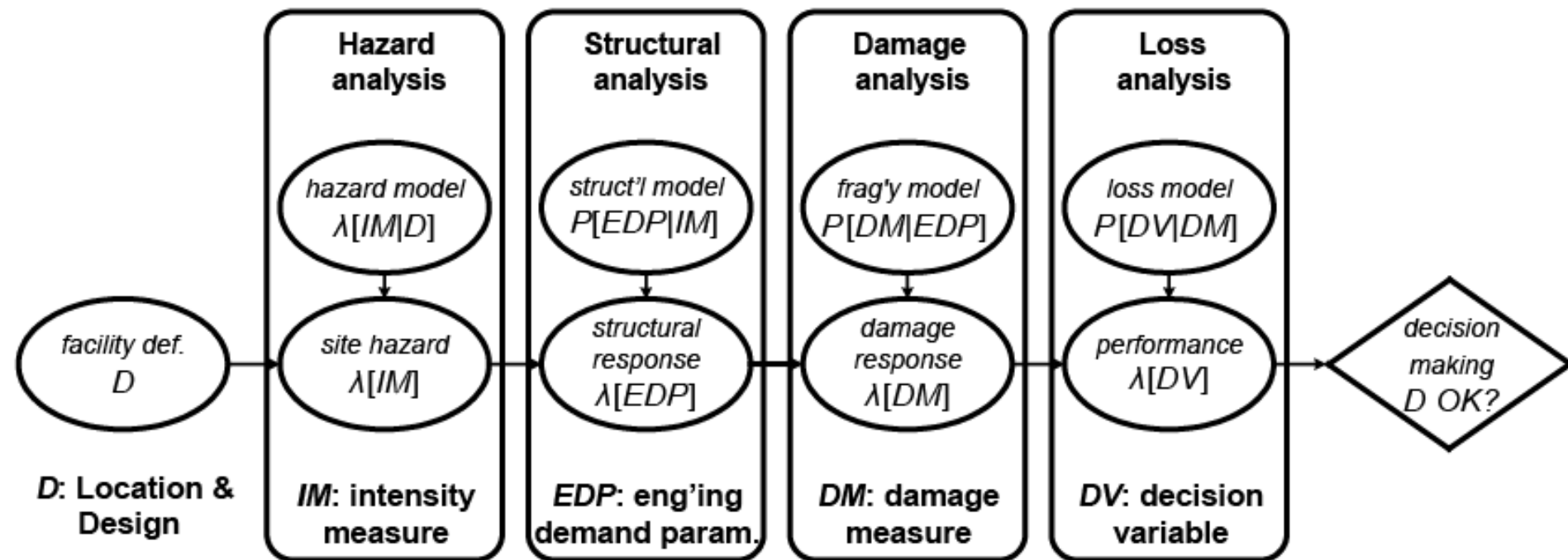
2016 PEER Annual Meeting

JANUARY 28-29, BERKELEY, CA

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DECISION-MAKING IN THE FACE OF UNCERTAINTY

PEER PBEE ANALYSIS METHODOLOGY



What We Do

Simulation of Earthquake Events



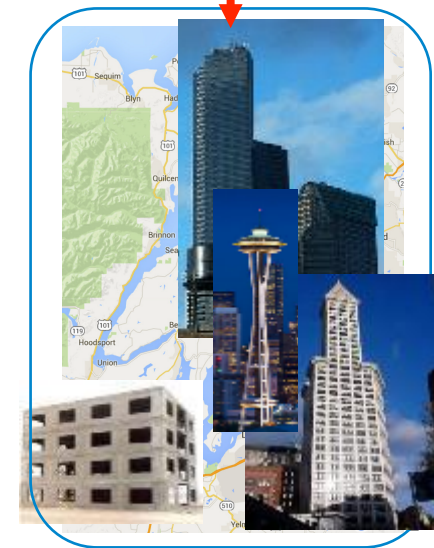
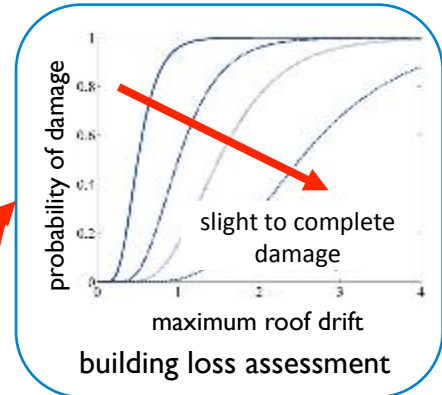
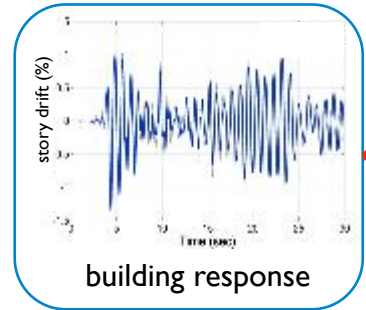
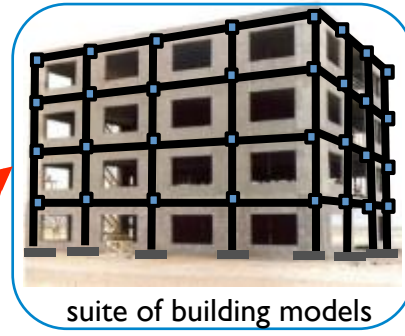
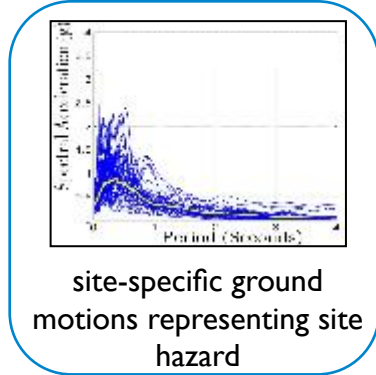
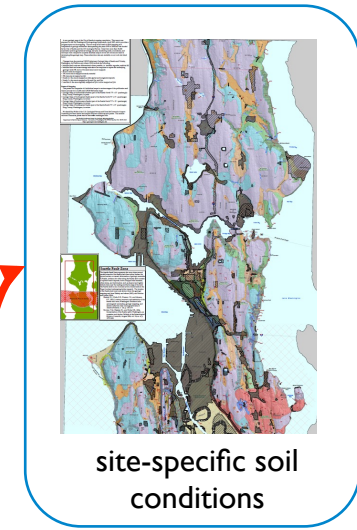
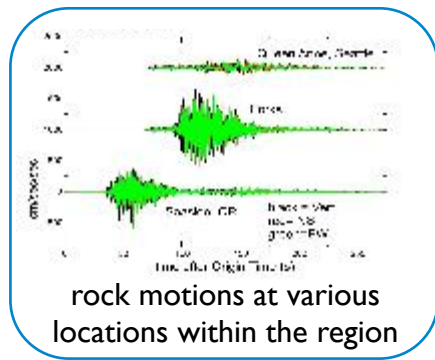
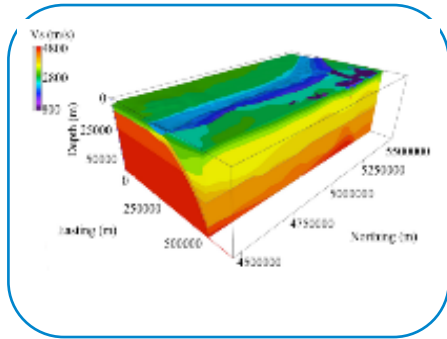
Generate Site-Specific Ground Motions



Simulate Structural Response



Estimate Loss and Assess Regional Risk



You Can Perform the WORKFLOW in OpenSeesMP

- OpenSeesMP: An application for **BOTH** large models and parameter studies.

```
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
    }
  }
}
```

3 buildings, 2 config a building, 44 records, 12 intensities, 5 hour a record, would have, taken 15840 hours or 660 days or 1.8 years. Ran on XSEDE Ranger using 88 processors in less than 7 days by adding 6 lines to script! (ATC-63/2 project using NEEShub)

EC2 OpenSees AMI & StarCluster

- Amazon is largest Cloud Services Provider
 - AWS also has more than 5 times capacity of its 14 next IaaS competitors (a Gartner report)
- MIT Provides Open Source Software for creating an Amazon Parallel Cluster and Running Jobs on this cluster (StarCluster)
- We Provide an Amazon Image for Running Sequential and Parallel OpenSees jobs: **ami-e9ff1182**
- <http://opensees.berkeley.edu/wiki/index.php/AmazonEC2>

That Moment Frame Example using OpenSeesMP on a 1000 node Amazon Cluster From your Laptop:

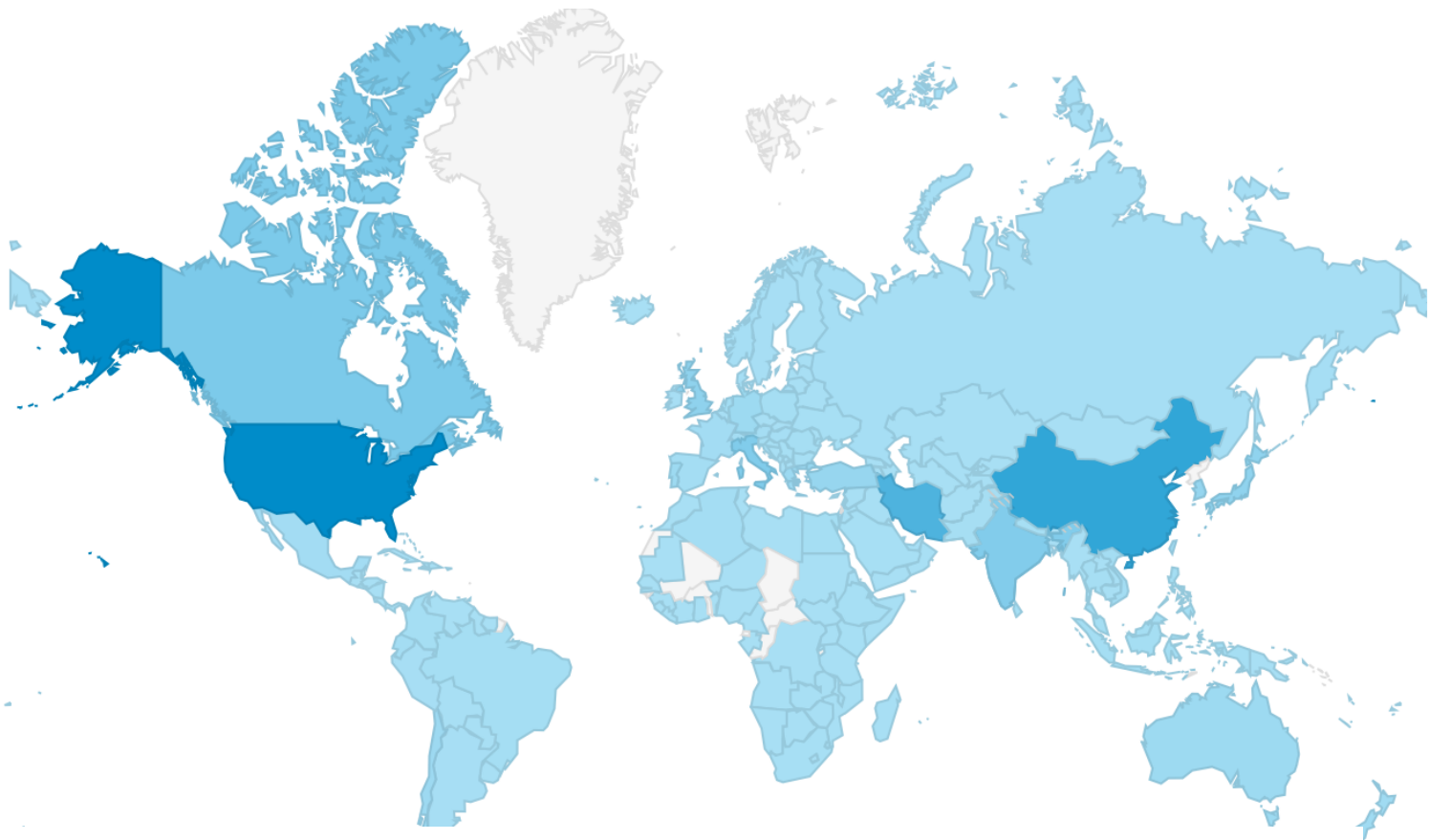
```
starcluster start smallcluster  
starcluster put smallcluster ./ /root  
starcluster sshmaster myLargecluster  
mpiexec -n 1000 OpenSeesMP Example.tcl;  
exit  
starcluster get smallcluster /root/results ./  
starcluster terminate myLargecluster
```

Amazon Makes \$

- Estimated that by 2020 most of the companies profits from these Amazon Web Services
- Data upload free, computation cheap, downloading data can be expensive
- Do your processing there

The logo for OpenSees, featuring the text "OpenSees" in a white, bold, sans-serif font with a slight drop shadow. The text is centered over a rectangular background image of a blue ocean wave with white foam, set against a dark blue sky.

OpenSees



Sessions

283,724



Users

95,939



Page Views

1,579,409





- OpenSees 3.0
- A Python Version (thanks to help from Minjie Zhu & Prof. Scott, **OSU**)
- OpenSeesIDE alpha version will be released (An application for editing scripts, running scripts, viewing model, and via the view select and print node and element responses)

The screenshot displays the OpenSees IDE interface. On the left is the 'Interpreter' window, and on the right is the 'Editor' window.

Interpreter Window:

```
OpenSees -- Open System For Earthquake Engineering Simulation
Pacific Earthquake Engineering Research Center -- 3.0.0

(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> puts "Hello World"
Hello World
OpenSees>
```

Editor Window (Example8.1.tcl):

```
1 # -----
2 # Start of model generation
3 # -----
4
5 # Create ModelBuilder with 3 dimensions and 6 DOF/node
6 model basic -ndm 3 -ndf 3
7
8
9 # create the material
10 nDMaterial ElasticIsotropic 1 100 0.25 1.27
11
12 # Define geometry
13 # -----
14
15 # define some parameters
16 set eleArgs "1"
17
18 set element stdBrick
19 #set element bbarBrick
20
21 set nz 6
22 set nx 2
23 set ny 2
24
25 set nn [expr ($nz+1)*($nx+1)*($ny+1)]
26
```

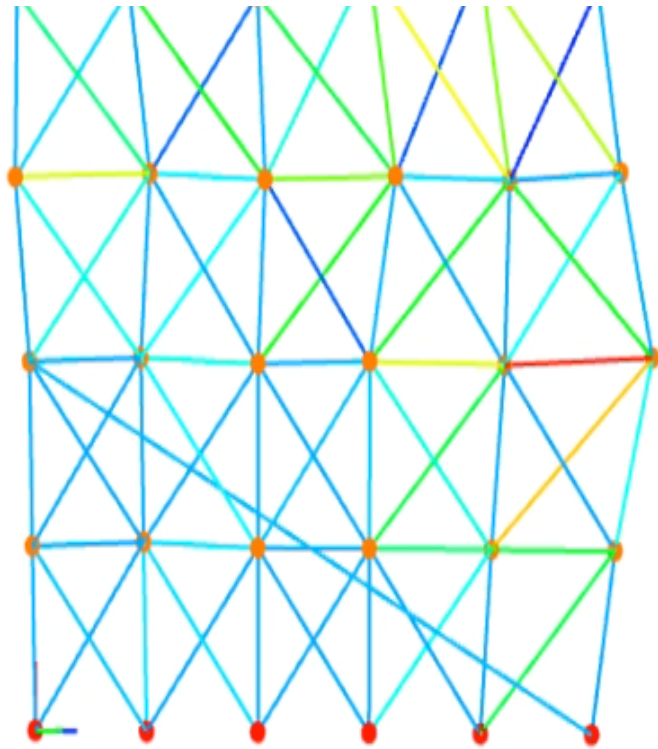
```

staticanalysis::analyze
OpenSees > analyze fail
Trying NewtonWithLineSe
WARNING: CTestNormUnbal
WARNING: CTestNormUnbal
Element: 24 type: Truss
  strain: -3.71609e-
  unbalanced load: 2
  Section:
FiberSection2d, tag: 1
  Section code: 2 1
  Number of Fibers: 2
  Centroid: 0
ConcretewBeta, tag: 1

after: 10000 iterations
NewtonLineSearch::solve
StaticAnalysis::analyze
OpenSees > analyze fail
Trying Newton with Init
SUCCESSFULL
OpenSees>
Element: 60 type: Truss
  strain: 0.00459401 axial load: -0.000126388
  unbalanced load: -0.000117348 4.69392e-05 0 0.000117348 -4.69392e-05 0
  Material: ConcretewBeta, tag: 3

Node: 11
Coordinates : 960 240
Disps: 11.8611 0.106166 0
Velocities : 0 0 0
unbalanced Load: 0 0 0

```

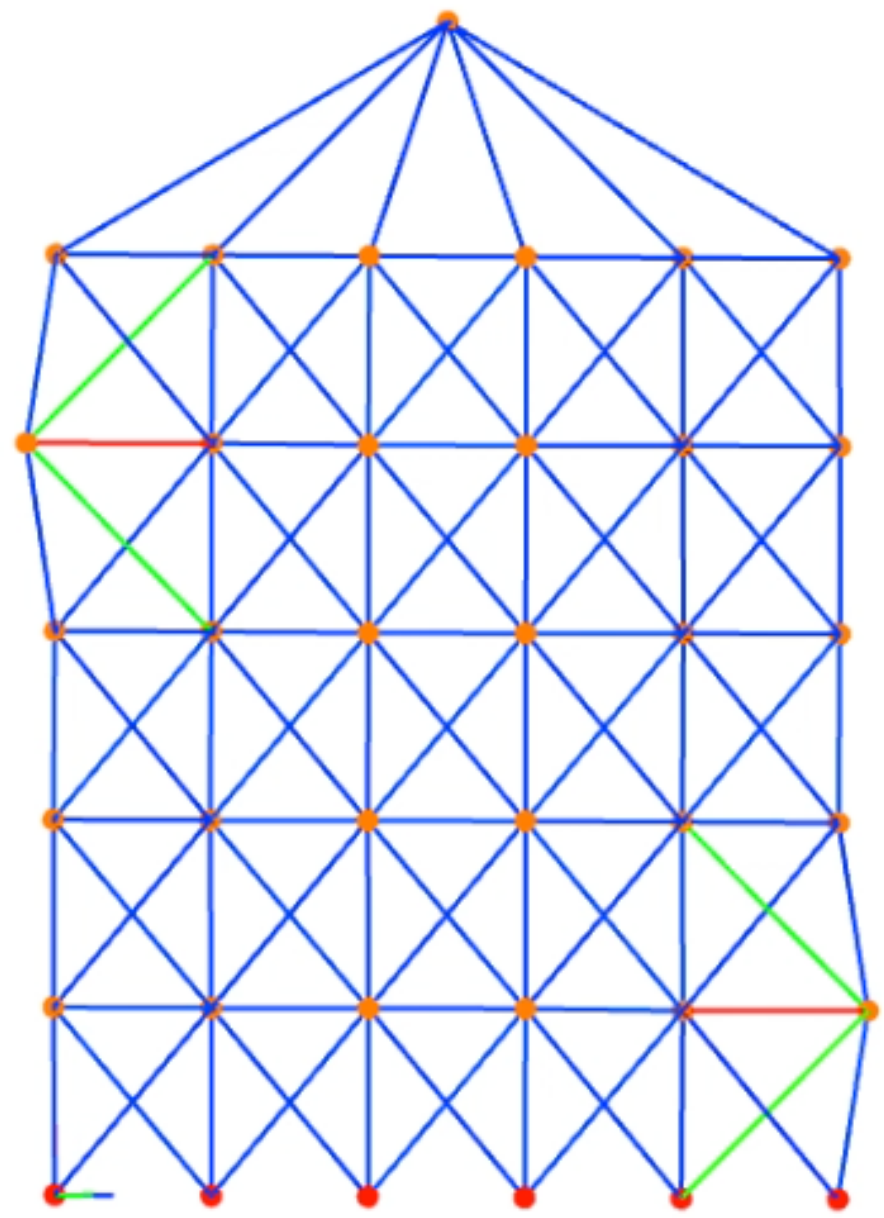


```

276 element Truss2 53 3 10 4 9 $Adiag $D
277 element Truss2 54 4 11 5 10 $Adiag $D
278 element Truss2 55 5 12 6 11 $Adiag $D
279
280 element Truss2 56 2 7 1 8 $Adiag $D
281 element Truss2 57 3 8 2 9 $Adiag $D
282 element Truss2 58 4 9 3 10 $Adiag $D
283 element Truss2 59 5 10 4 11 $Adiag $D
284 element Truss2 60 6 13 5 12 $Adiag $D
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286 element Truss2 61 7 14 8 13 $Adiag $D
287 element Truss2 62 8 15 9 14 $Adiag $D
288 element Truss2 63 9 16 10 15 $Adiag $D
289 element Truss2 64 10 17 11 16 $Adiag $D
290 element Truss2 65 11 18 12 17 $Adiag $D
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292 element Truss2 66 8 13 7 14 $Adiag $D
293 element Truss2 67 9 14 8 15 $Adiag $D
294 element Truss2 68 10 15 9 16 $Adiag $D
295 element Truss2 69 11 16 10 17 $Adiag $D
296 element Truss2 70 12 17 11 18 $Adiag $D
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298 element Truss2 71 13 20 14 19 $Adiag $D
299 element Truss2 72 14 21 15 20 $Adiag $D
300 element Truss2 73 15 22 16 21 $Adiag $D
    74 16 23 17 22 $Adiag $D
    75 17 24 18 23 $Adiag $D
    76 14 19 13 20 $Adiag $D
305 element Truss2 77 15 20 14 21 $Adiag $D
306 element Truss2 78 16 21 15 22 $Adiag $D
307 element Truss2 79 17 22 16 23 $Adiag $D
308 element Truss2 80 18 23 17 24 $Adiag $D

```


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9.129e-02



THANKS

- Any QUESTIONS?