Seismic Analysis Capabilities Supporting DOE and NNSA Missions

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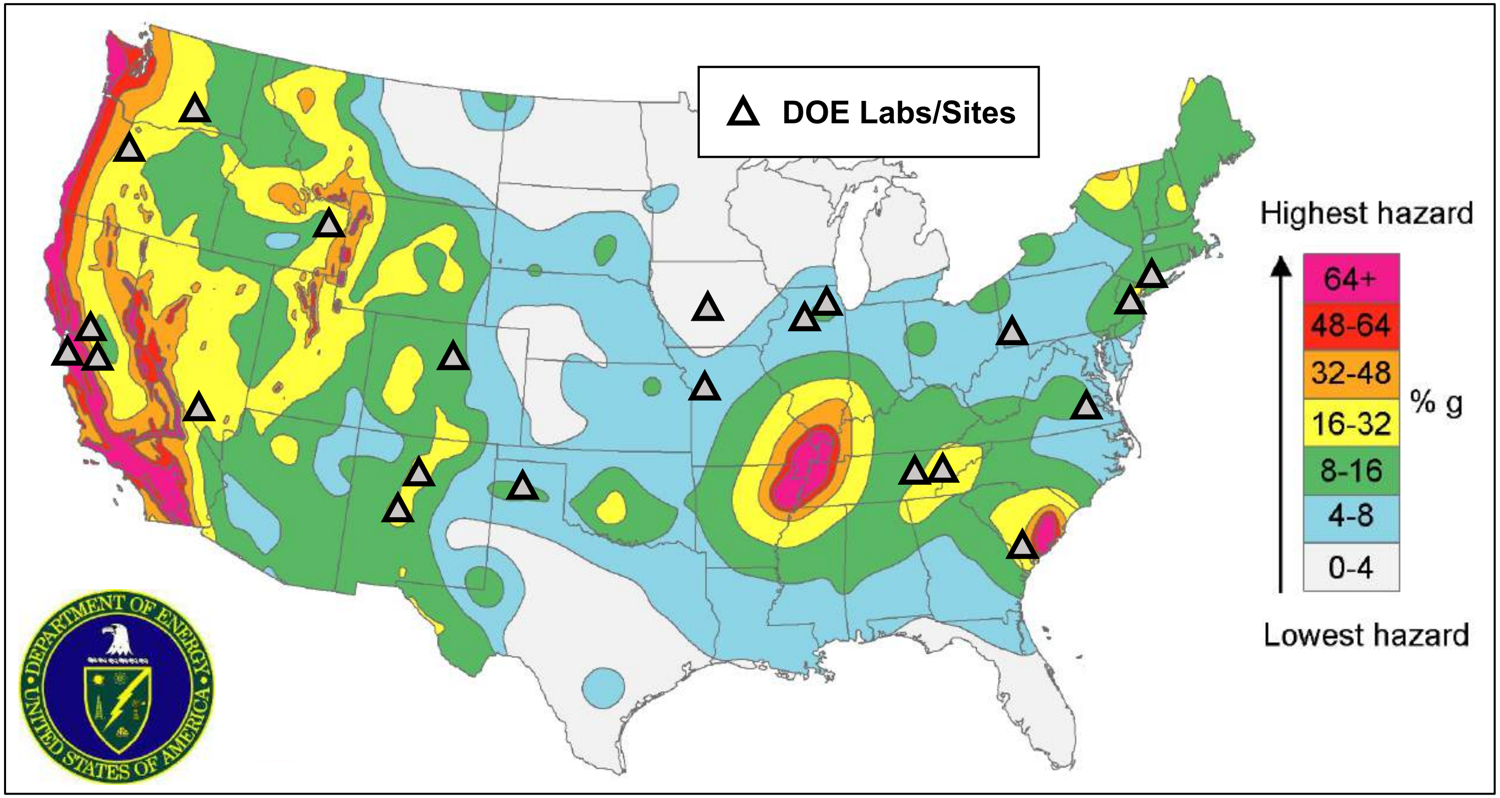
BERKELEY LAB

National Nuclear Security Administration

Office of Science
U.S. Department of Energy

EXASCALE COMPUTING PROJECT

DOE/NNSA own many mission-critical facilities in regions of high seismic hazard



Savannah River

Los Alamos

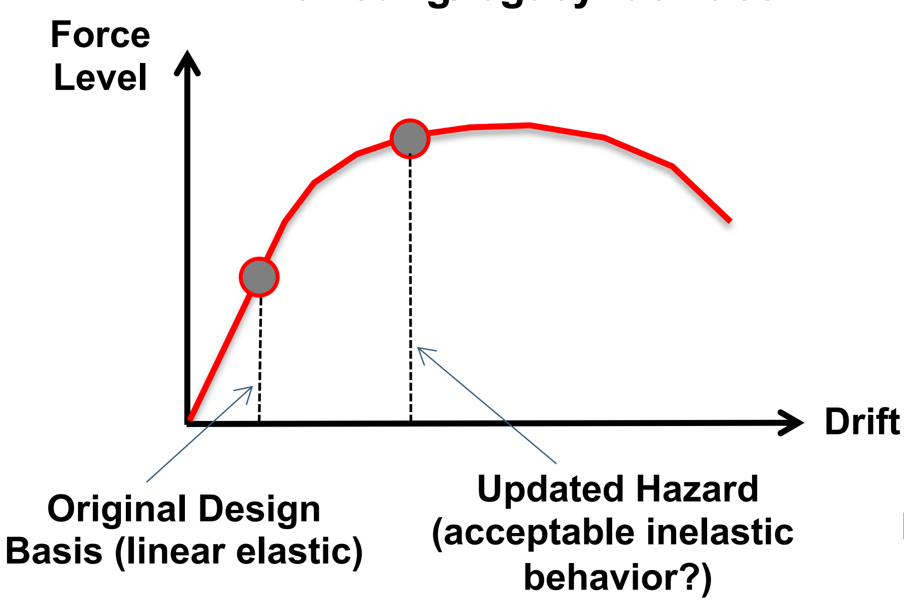
Livermore

Y-12

DOE seismic considerations span from older legacy facilities to new modern facilities

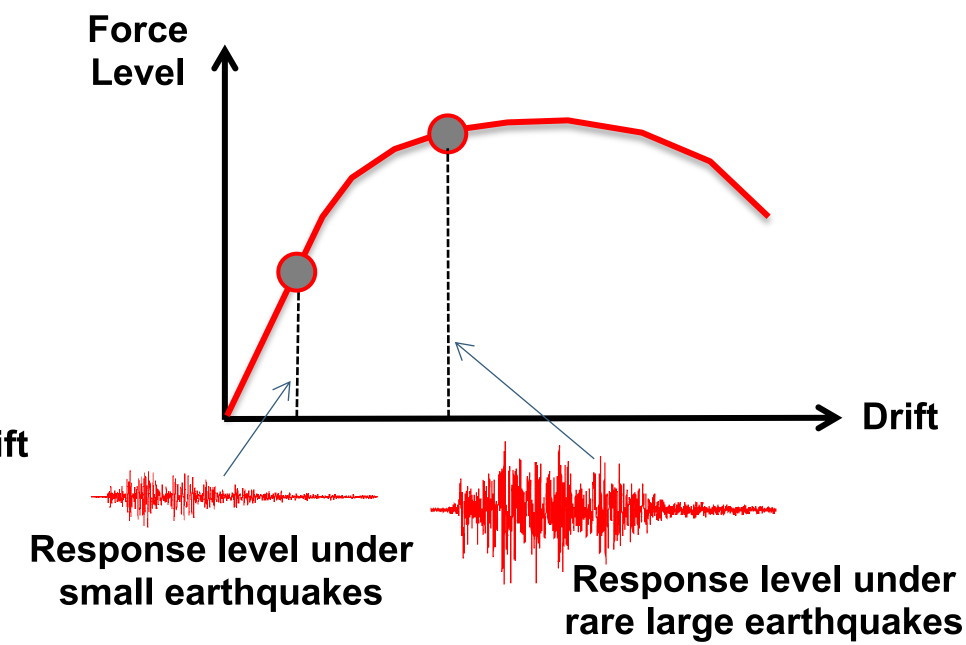
Canyon facility - Savannah River

Beyond design basis margin assessments for existing/legacy facilities



Uranium Processing Facility - Y12

Enabling performance-based design of new facilities



The 1980 Livermore earthquake was a defining event for the DOE complex

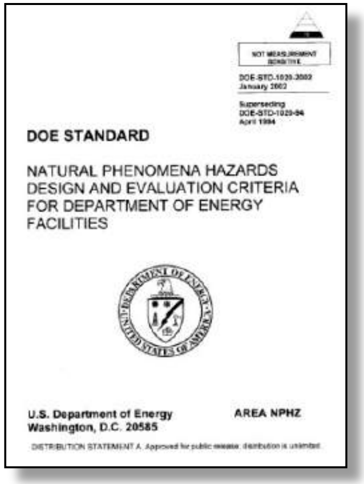
Extensive disruption

- Extensive building damaged
- Program laser system damaged
- Complete loss of site electrical power
- Extensive disruption of facilities
- No strong motion instruments on-site
- Initiated a decade+ seismic upgrade program

This event helped initiate DOE leadership in risk-informed, performance-based standards

1980's

Bob Kennedy
Bob Murray (LLNL)
Jim Hill (DOE)


NOT MEASUREMENT SENSITIVE

DOE-STD-1020-2002
January 2002

Superseding
DOE-STD-1020-94
April 1994

DOE STANDARD

NATURAL PHENOMENA HAZARDS DESIGN AND EVALUATION CRITERIA FOR DEPARTMENT OF ENERGY FACILITIES

U.S. Department of Energy
Washington, D.C. 20585

AREA NPHZ

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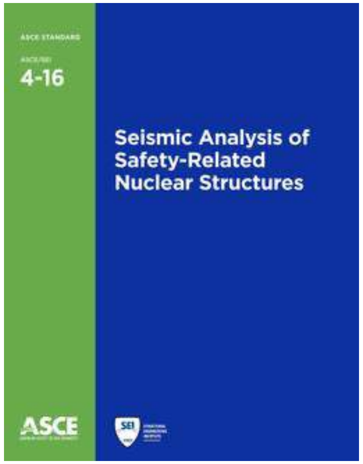


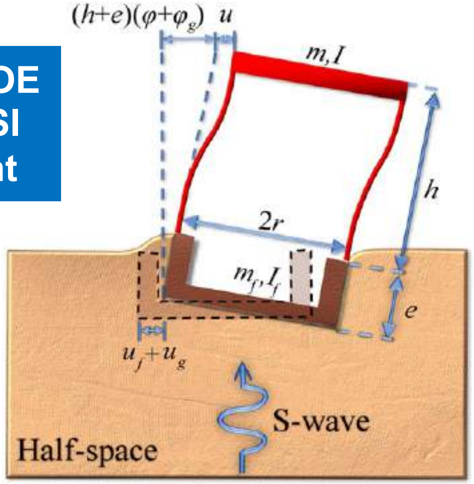
Today

Mike Salmon
ASCE 4

TABLE 1-4. Structural Deformation Limits for Limit State

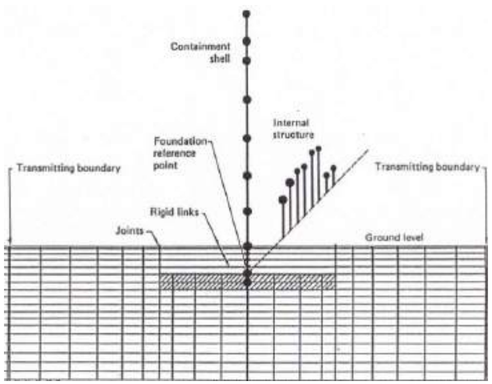
Limit State	Structural Deformation Limit
A	Large permanent distortion, short of collapse *Significant damage*
B	Moderate permanent distortion *Generally repairable damage*
C	Limited permanent distortion *Minimal damage*
D	Essentially elastic behavior *No damage*

For many DOE facilities SSI is important

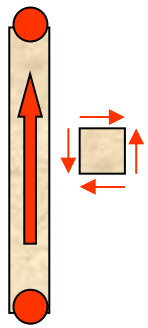


Robust simulation capabilities are essential to fully realize performance-based design

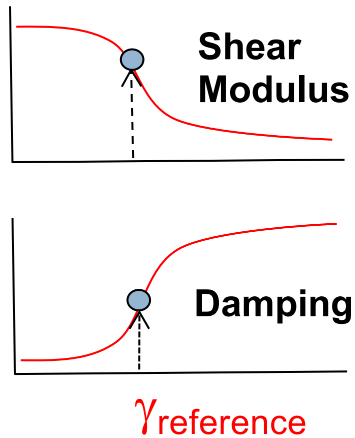
Lower order system models



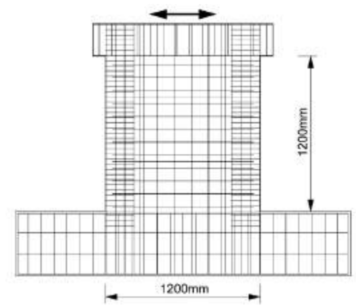
Incident motions (1D)

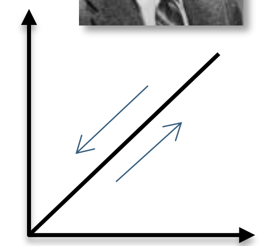


Soil



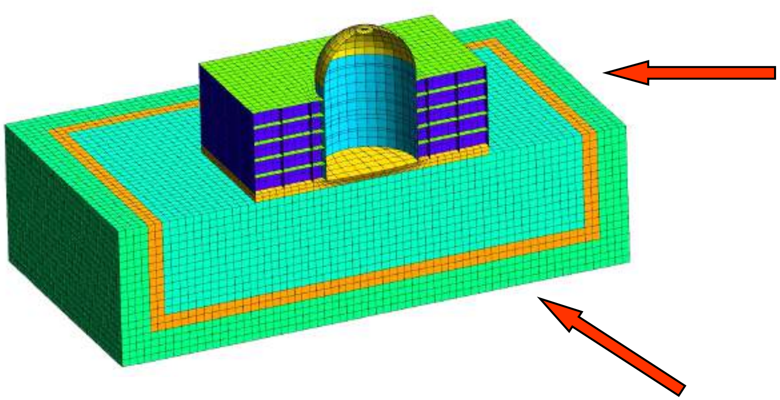
Structure





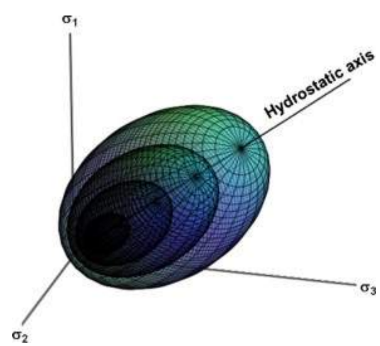
Traditional Linear

High fidelity system models

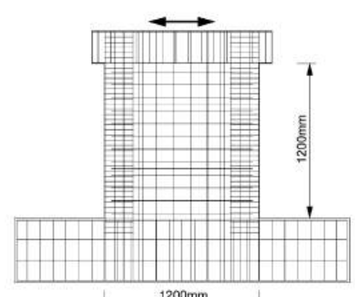


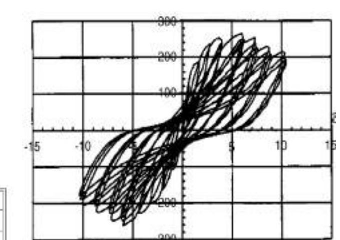
Incident motions (3D)

Soil



Structure

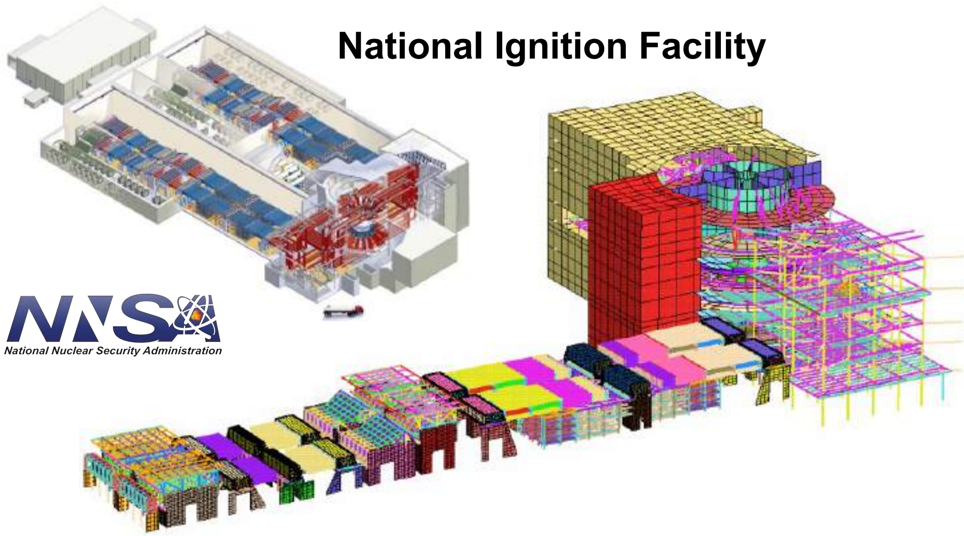




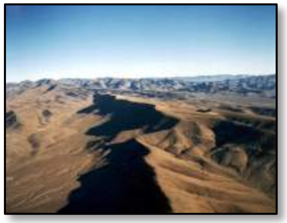
Nonlinear

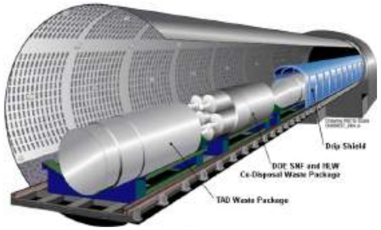
The National Labs have often brought advanced simulations to seismic issues

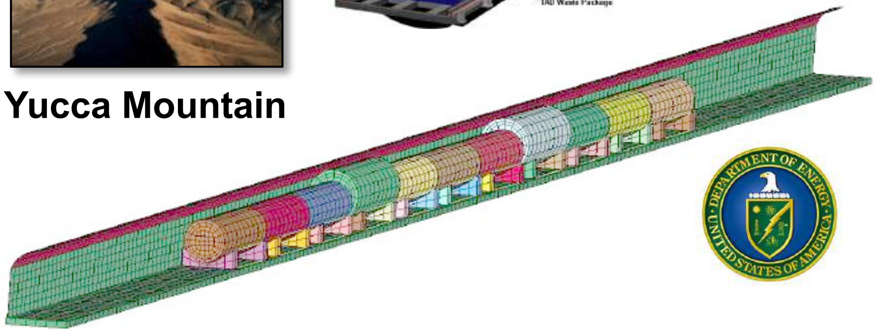
National Ignition Facility



Yucca Mountain

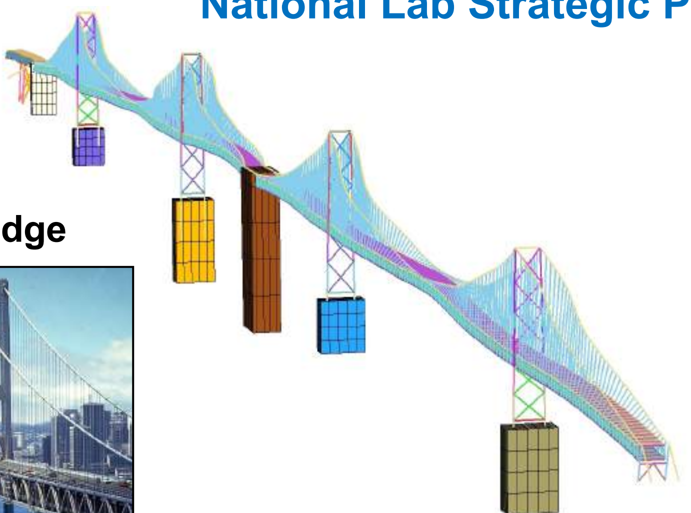


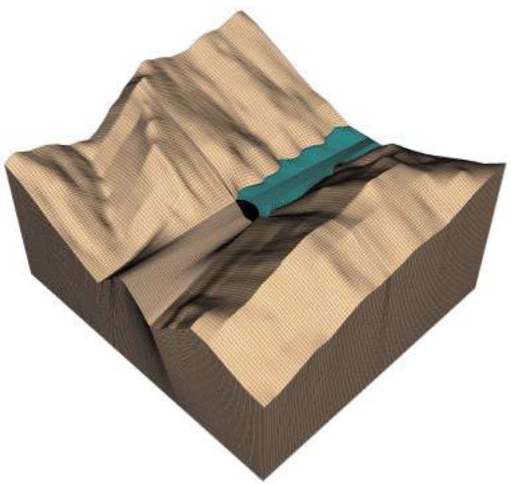




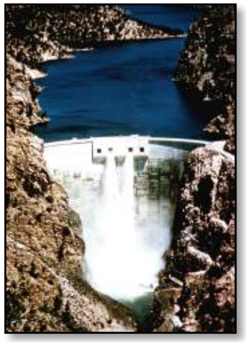
National Lab Strategic Partnership Projects

SF Bay Bridge



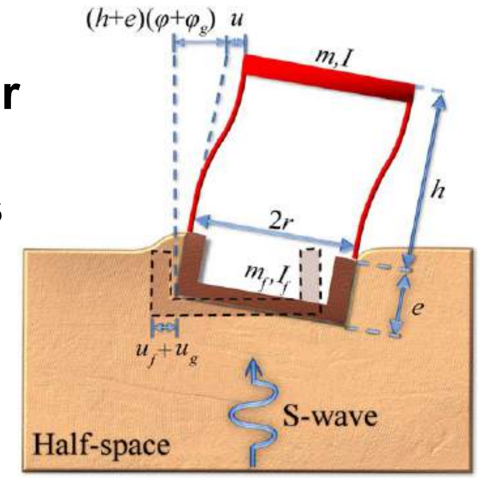


Morrow Point

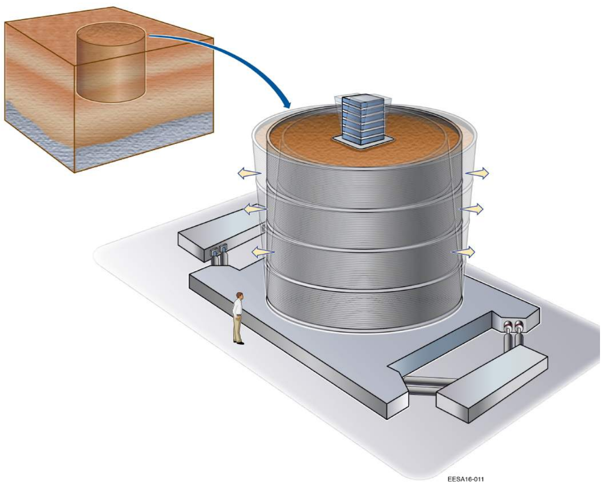


Three components of an LBNL DOE project supporting simulation code capabilities

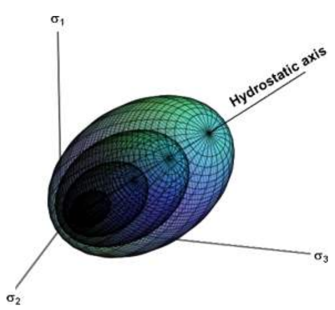
Nonlinear system analysis



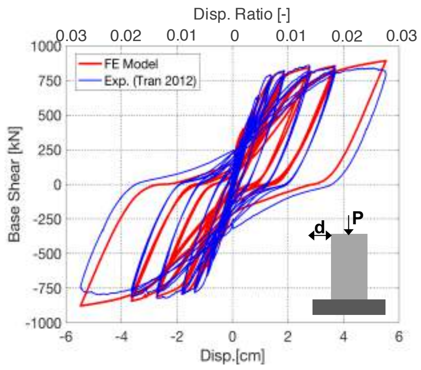
1) An experimental capability for validation



2) Implement new capabilities for nonlinear analysis of both soils and structures

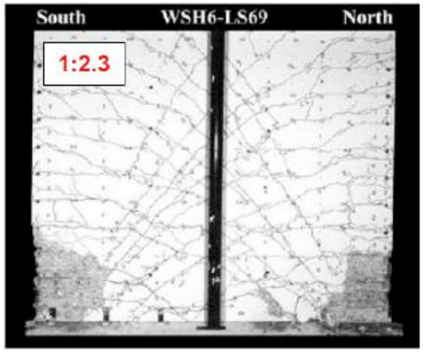


Nonlinear soils



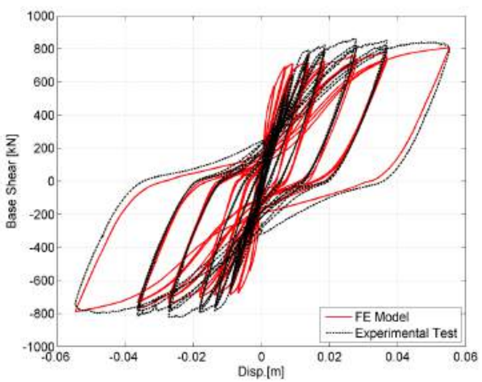
Nonlinear structures

3) Testing and utilization of computational models



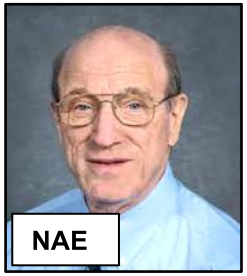
Dazio, A. , Beyer, K., Bachmann, H. 2009. "Quasi-static cyclic tests and plastic hinge analysis of RC structural walls", 31, pp. 1556-1571

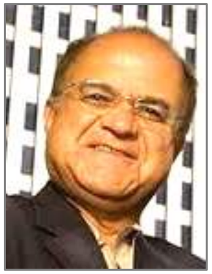
Displacement-controlled pushover



An expert panel to provide feedback along the way



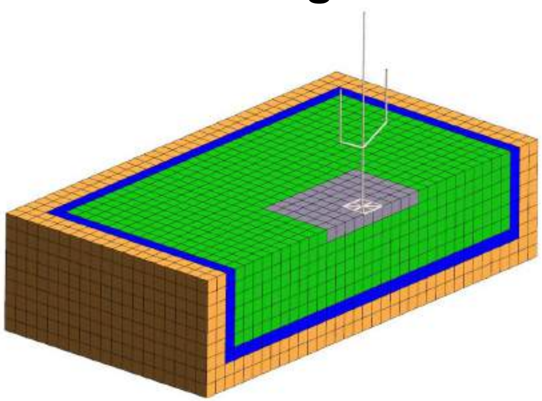


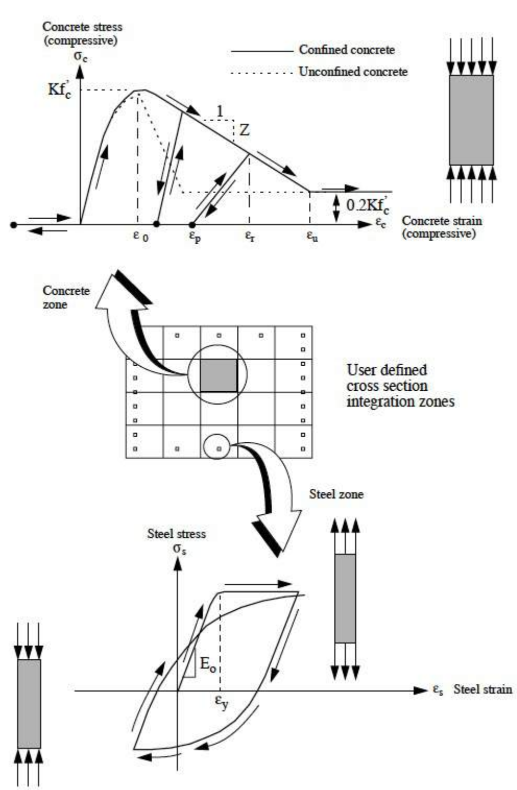


Enhancements to an HPC code for nonlinear analysis of structures and soils

Start with strong geo-mechanics and robust nonlinear algorithms

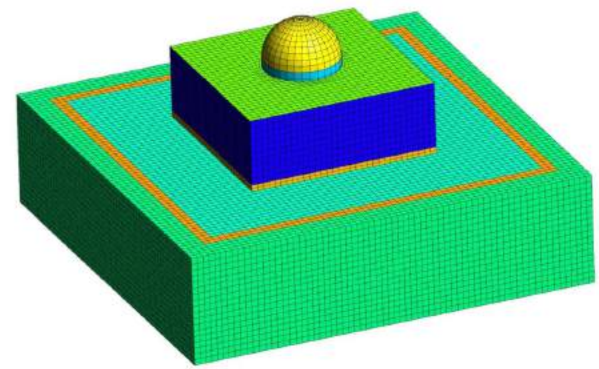


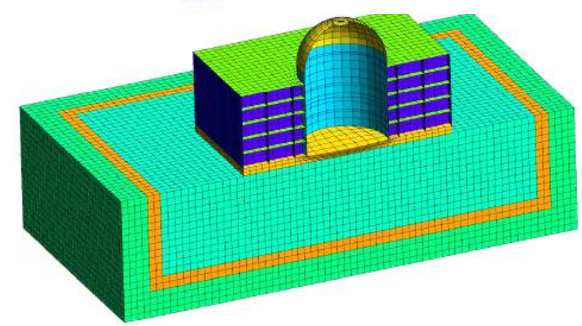
Combined with advanced nonlinear structural element technology



MSESSI

To model fully coupled soil-structure systems

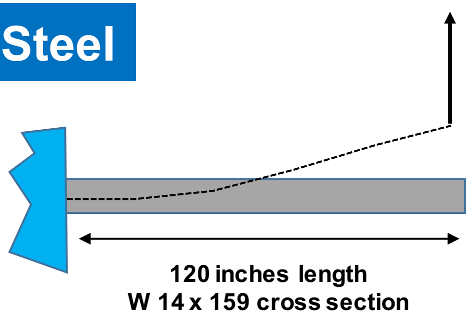


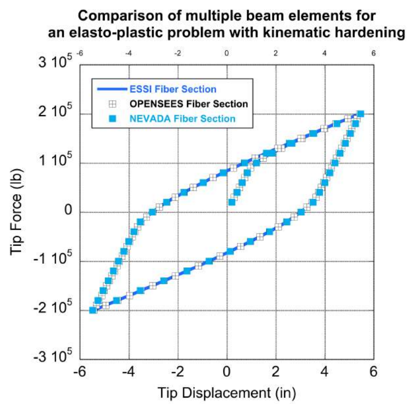


Testing, verification & validation of nonlinear capabilities

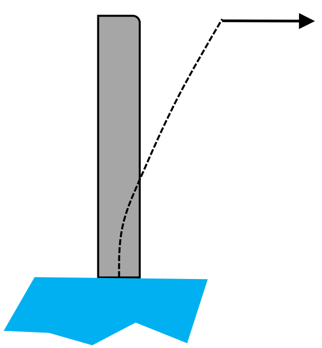
Element Level Comparisons

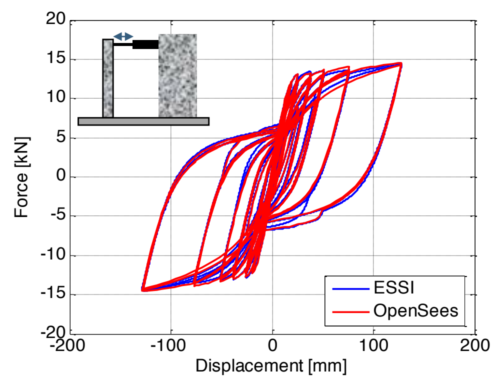
Steel





Concrete





System Level Comparisons

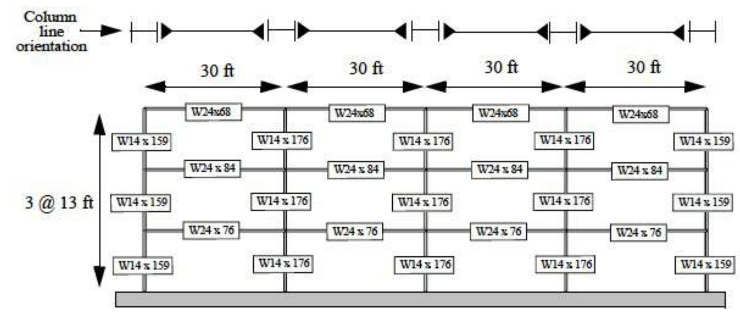
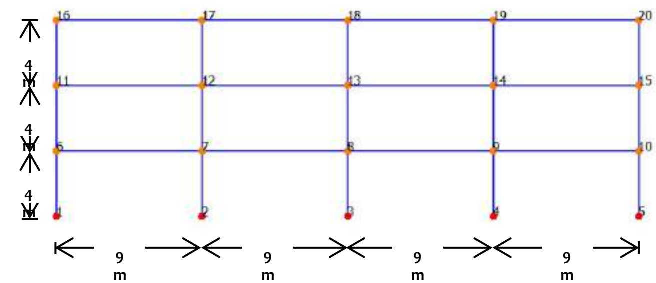
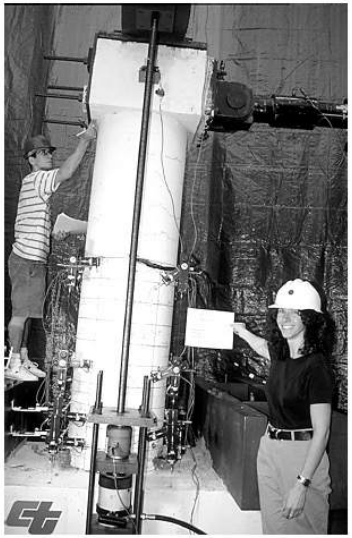


Figure 1. Three Story Steel Moment Frame Building designed for UBC Zone 3



For validation of structural elements we collected existing data from all sources

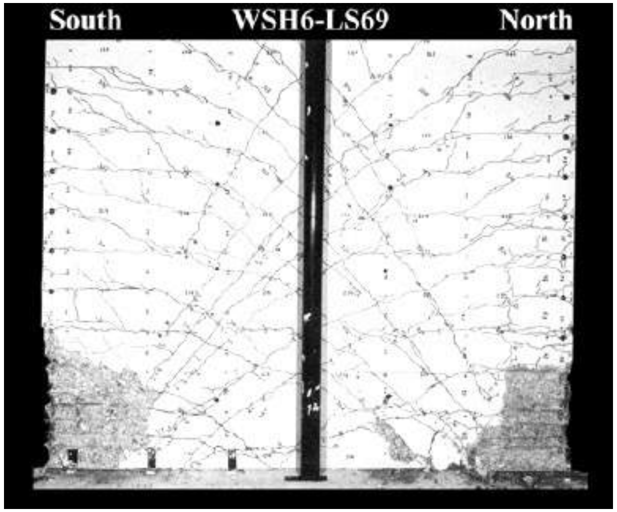
RC Columns

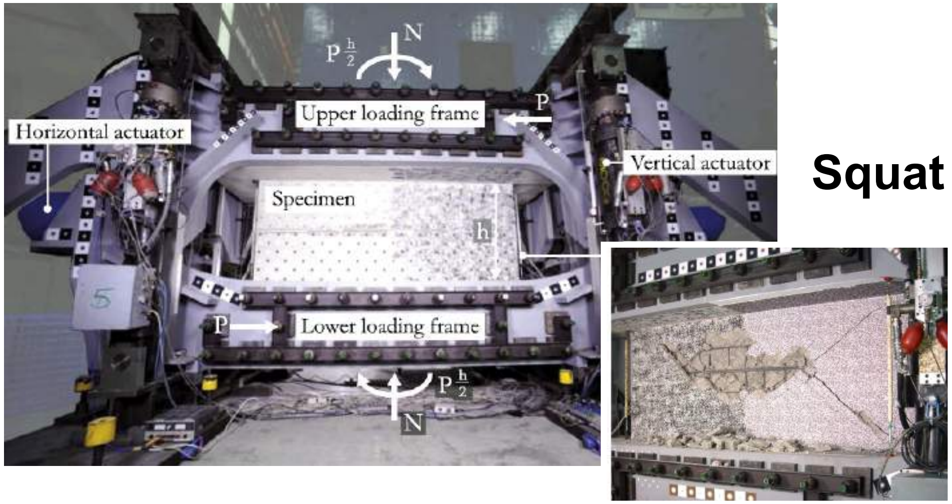


RC Shear Walls

Tall

Medium

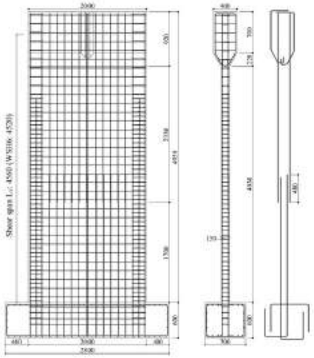




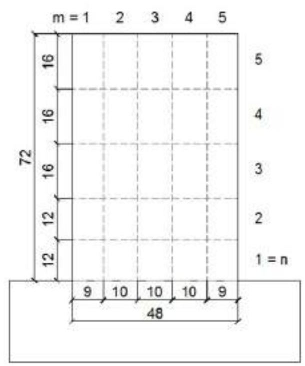
Squat

Nonlinear concrete shear walls (Fiber layer membrane element)

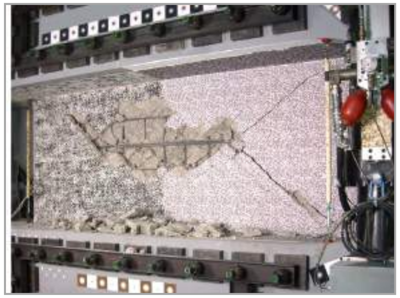
Slender



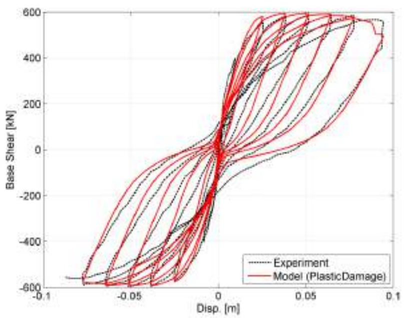
Medium



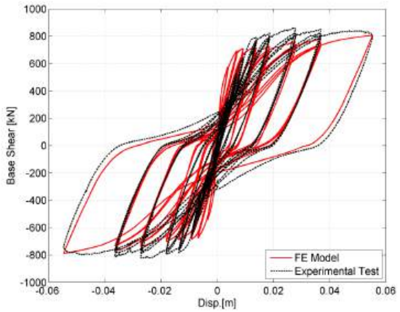
Low (Squat)



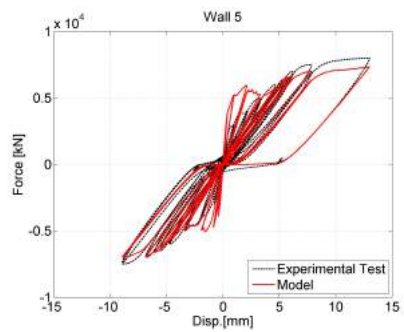
Displacement-controlled pushover



Displacement-controlled pushover



Displacement-controlled pushover



Engineering Structures

ELSEVIER

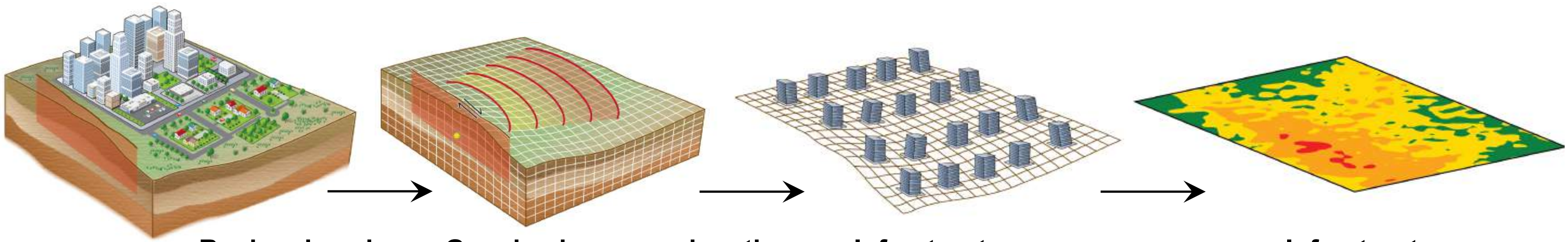
A versatile numerical model for the nonlinear analysis of squat-to-tall reinforced-concrete shear walls

Floriana Petrone, Frank McKenna, Thanh Do, David McCallen

“A versatile numerical model for the nonlinear analysis of squat-to-tall reinforced concrete shear walls”

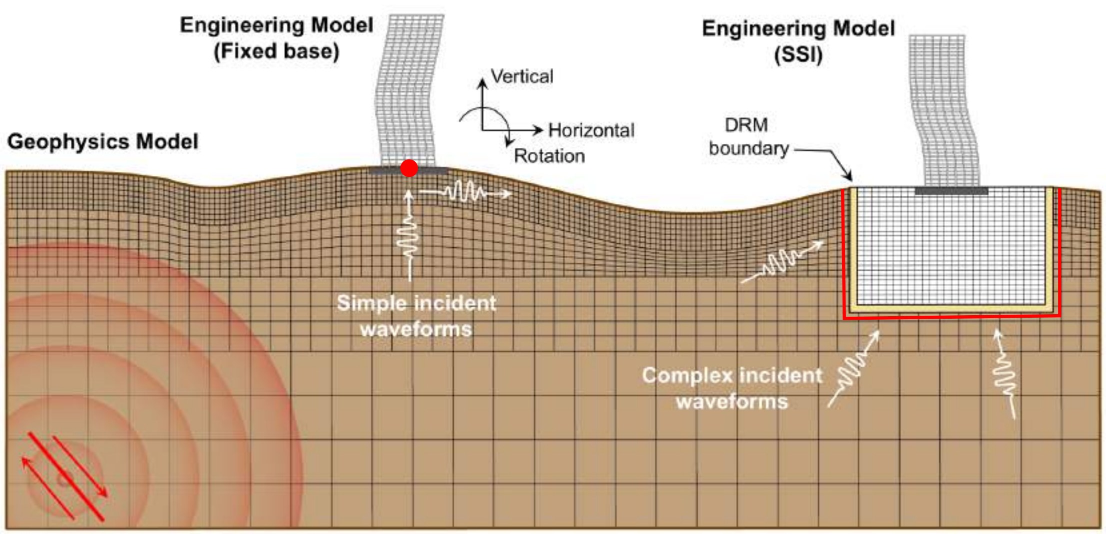
Active code development efforts are now under the DOE Exascale Computing Project

Geophysics → Engineering →



Regional-scale domain → **Geophysics ground motion simulations (billions of zones)** → **Infrastructure response simulations (thousands of stations)** → **Infrastructure demand / risk**

Weak Coupling | **Strong Coupling**

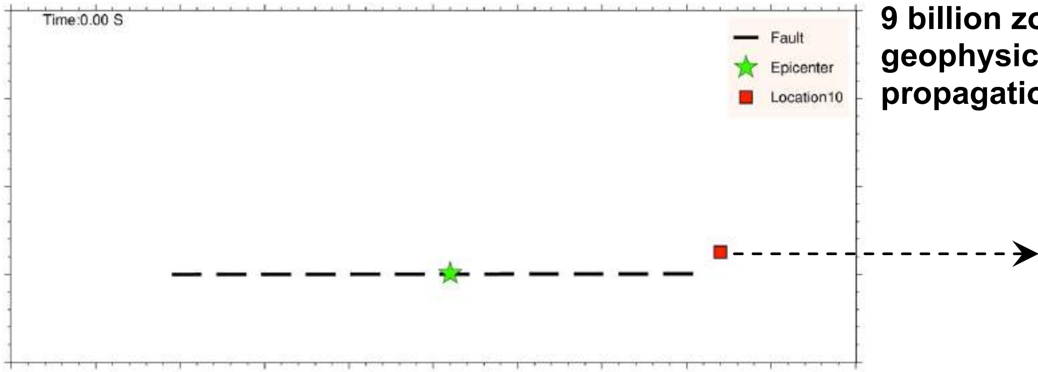


PEER Pacific Rim forum June 16-17

Office of Science
U.S. Department of Energy

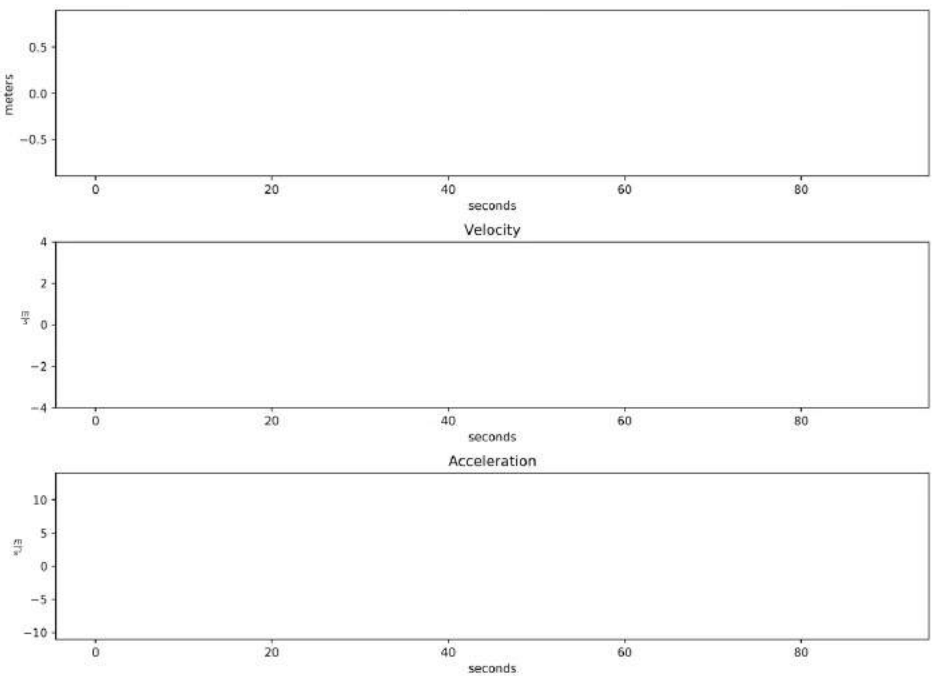
ECP
EXASCALE COMPUTING PROJECT

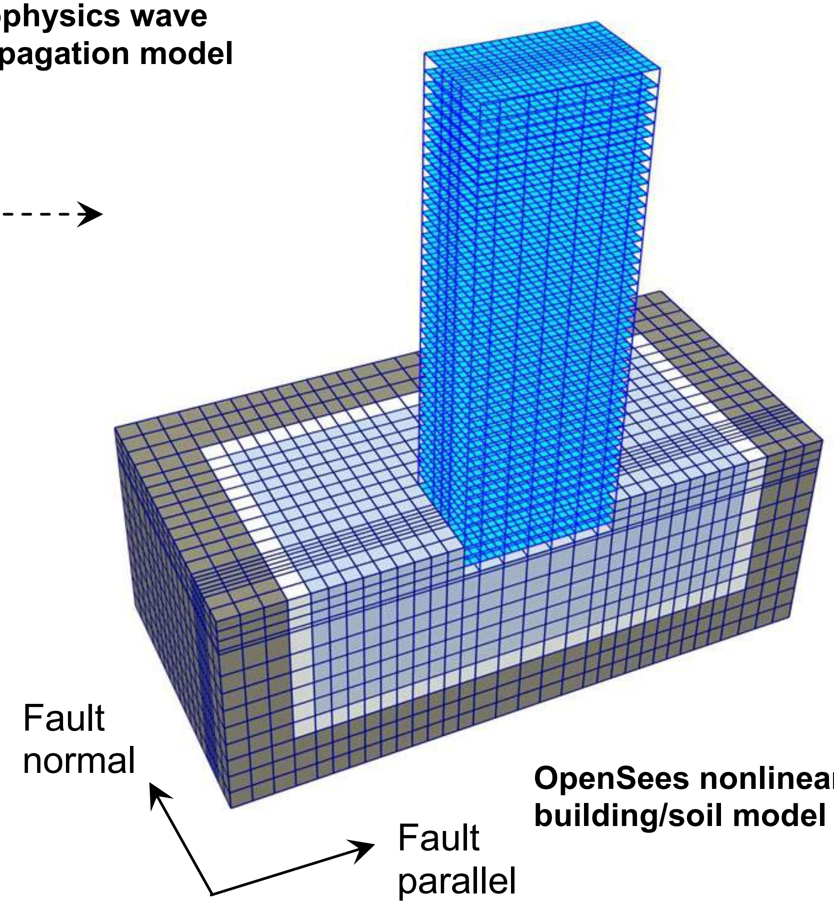
Fully coupled ground motion – structure simulations (SSI + complex incident waves)



9 billion zone SW4 geophysics wave propagation model

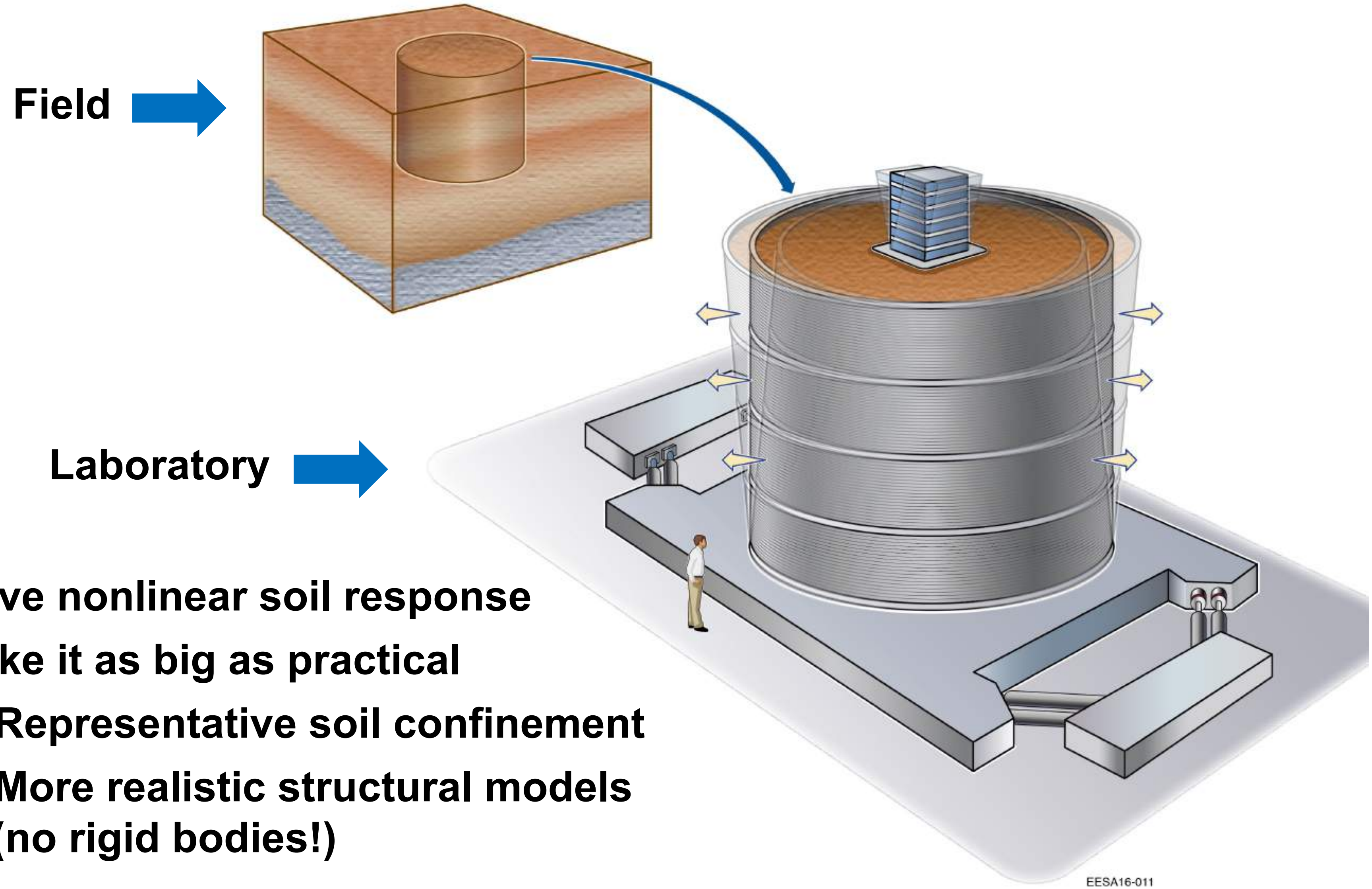
Fault normal displacement, velocity and acceleration





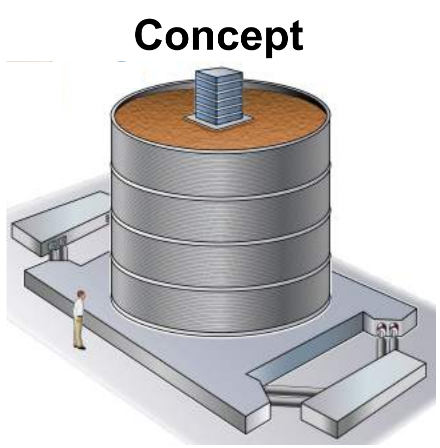
OpenSees nonlinear building/soil model

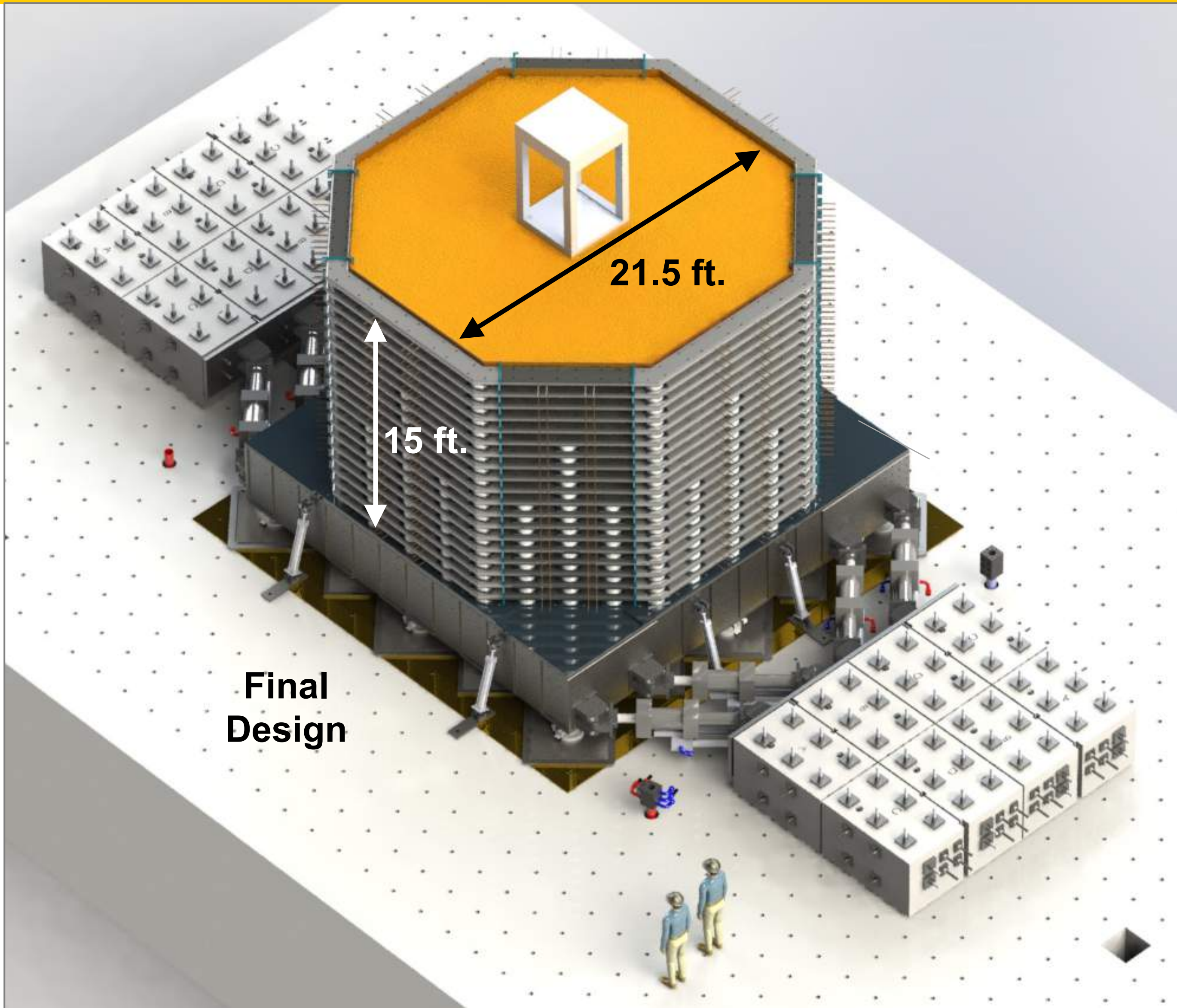
Early conceptualization of the Large Scale Laminar Soil Box (LLSB)



- Drive nonlinear soil response
- Make it as big as practical
  - Representative soil confinement
  - More realistic structural models (no rigid bodies!)

Completing a major design effort - from cartoon to detailed design



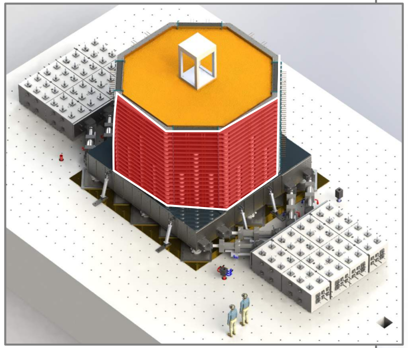


The platen is complete and assembled, fit-up was exceptional and very flat

Laminar Soil Box fabrication

Soil box construction

Soil box completed



Bearing plate precision leveling check

Laser level

Reaction blocks, actuators and bearings/bearing plates

The final phase of construction - hydraulics

“Down in the basement”

Next

- **Commissioning**
  - **- Comprehensive testing of all systems and system performance validation**
- **Ready for Experiments**
  - **- New insight into nonlinear site response**
  - **- Data for confronting site response and SSI simulations**