Coupled Earthquake Engineering Simulations

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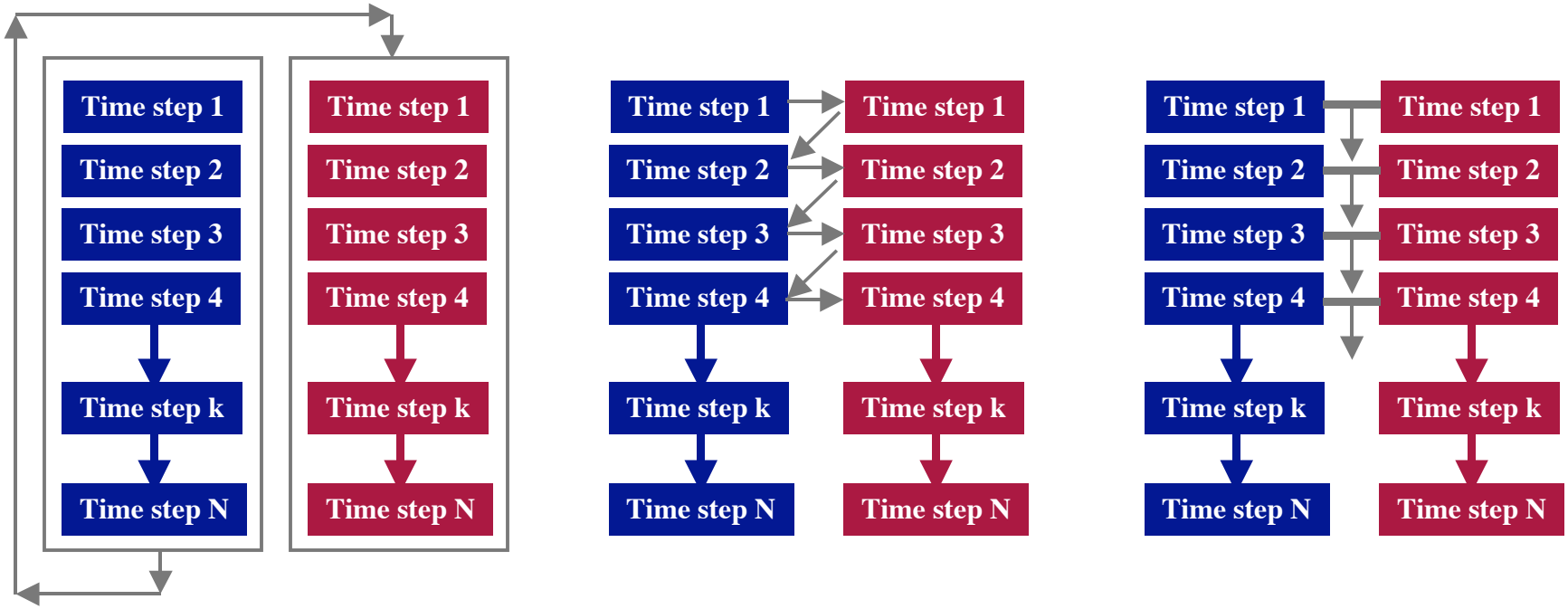
Overview

- Three ongoing threads of coupled-physics interactions
- SPUR Integration Effort
  - NSF-funded basin/building inventory model
  - Soil-structure coupling using grid technology
  - Principals: Bielak (CMU), Fenves (Berkeley)
- LLNL Morrow Point Dam Analysis
  - Excellent solid-fluid interaction example
  - Foundation-dam-reservoir coupling via interoperability
  - Principals: Noble, McCallen, Loomis (LLNL)
- Terascale Framework
  - Prototype computational subsystem for NEES
  - Soil-structure liquefaction multiphysics by design
  - Principals: Taylor (Terascale), Muraleetharan (OU)

Characteristics of Physics Interactions

- Three forms of mathematical interactions



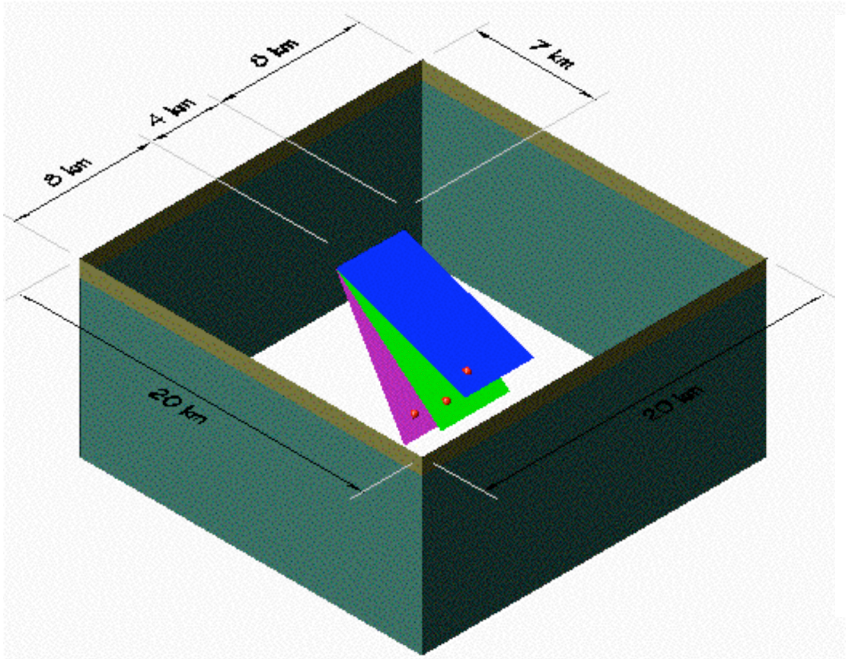
One-way coupling Loose coupling Full coupling

SPUR: Intregation by Grid

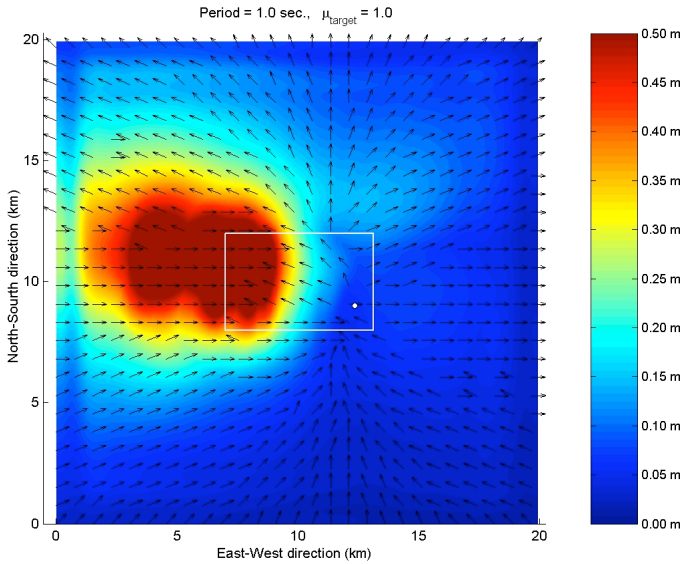
- One-way coupled basin-structure analysis
  - Precomputed basin results imposed on structural models via subgrid resolution sampling to determine foundation motions
- Ambitious attempt to use NSF-funded middleware technology
  - Harvest basin results at remote site
  - Analyze building inventory at other sites
  - Visualize by gathering all results and rendering

SPUR Results

- Schematic of Basin with ground-motions



Basin/Fault Geometry



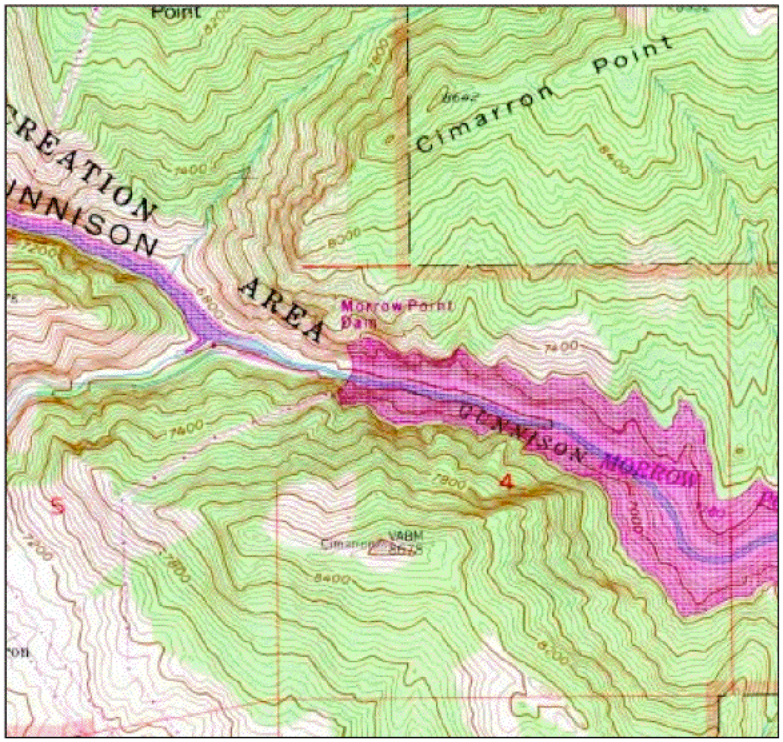
Computed Ground Motion

LLNL Morrow Point Dam Analysis

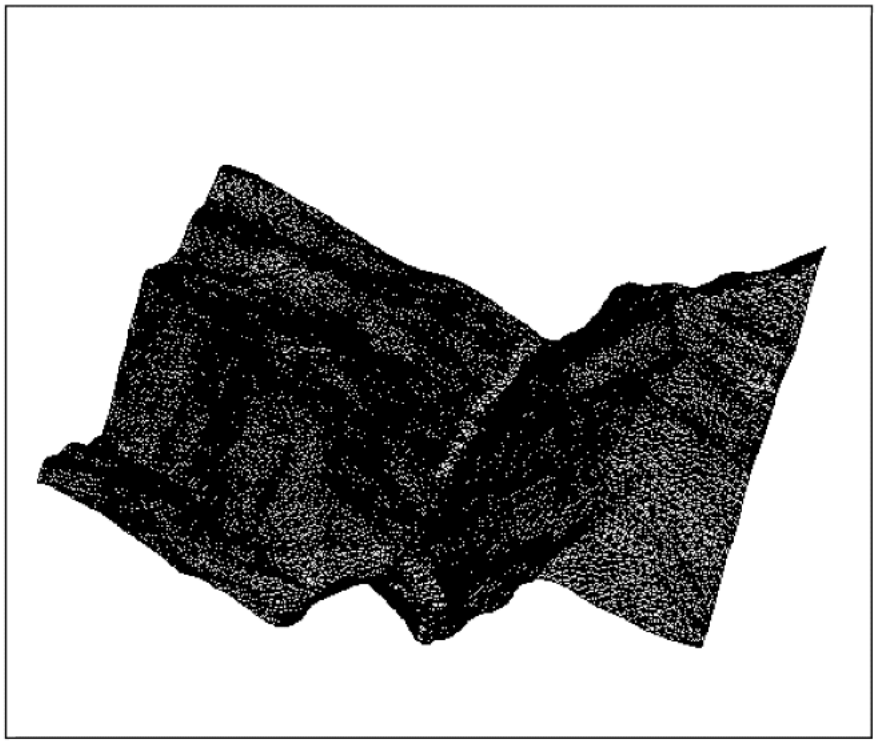
- Complex coupling problem
  - Initial states computed using NIKE3D
  - Dam-reservoir interaction computed using DYNA3D hydrodynamics code
  - Assumption of vertically propagated shear waves for application of earthquake loads
  - Analysis included complex grouted shear key details in concrete dam
- Validated using empirical reservoir results

Morrow Point Geography

- Dam is about 200 miles SW of Denver



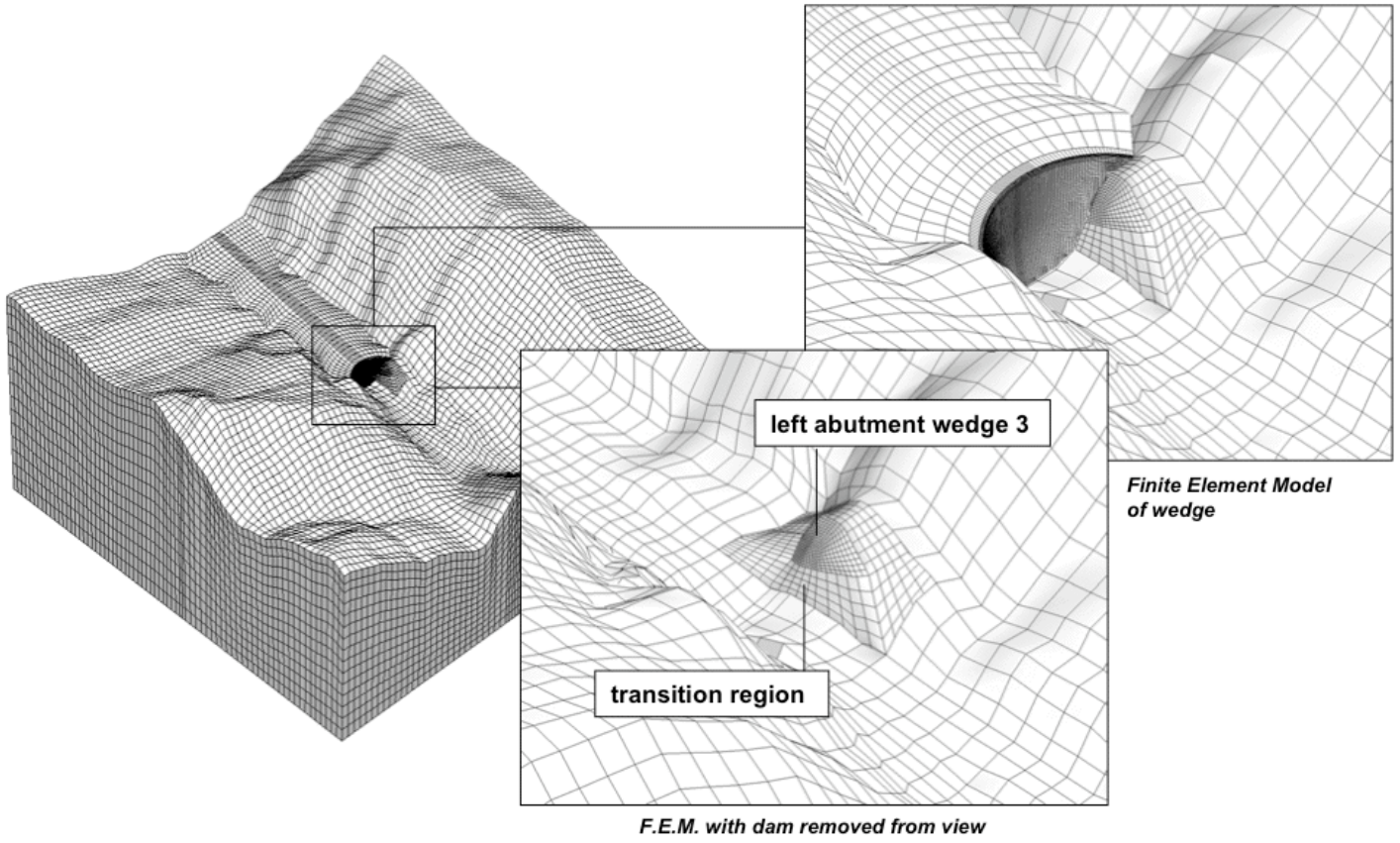
USGS 1983 Topographic Map



Generated IGES Surface for Mesh Generation

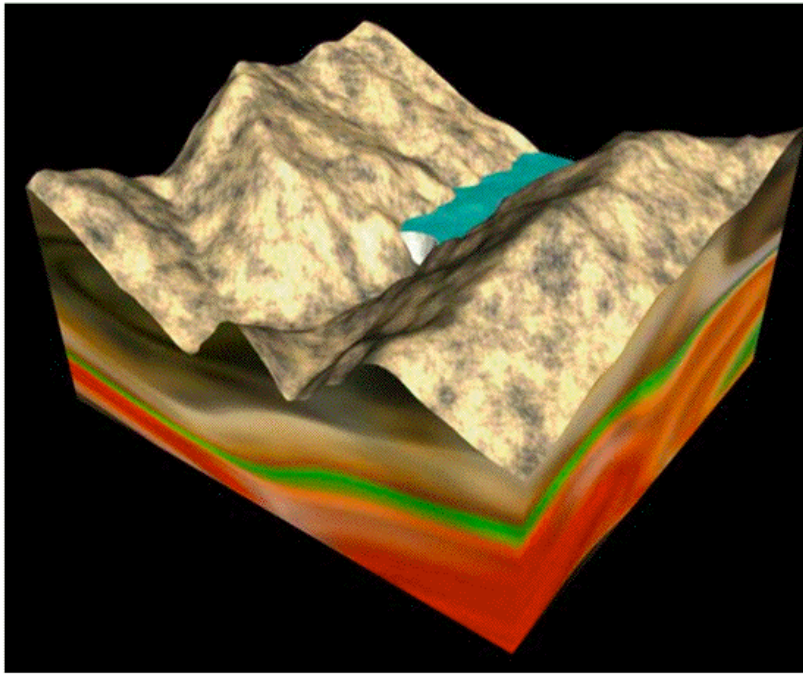
Analysis of Site, Dam, and Reservoir

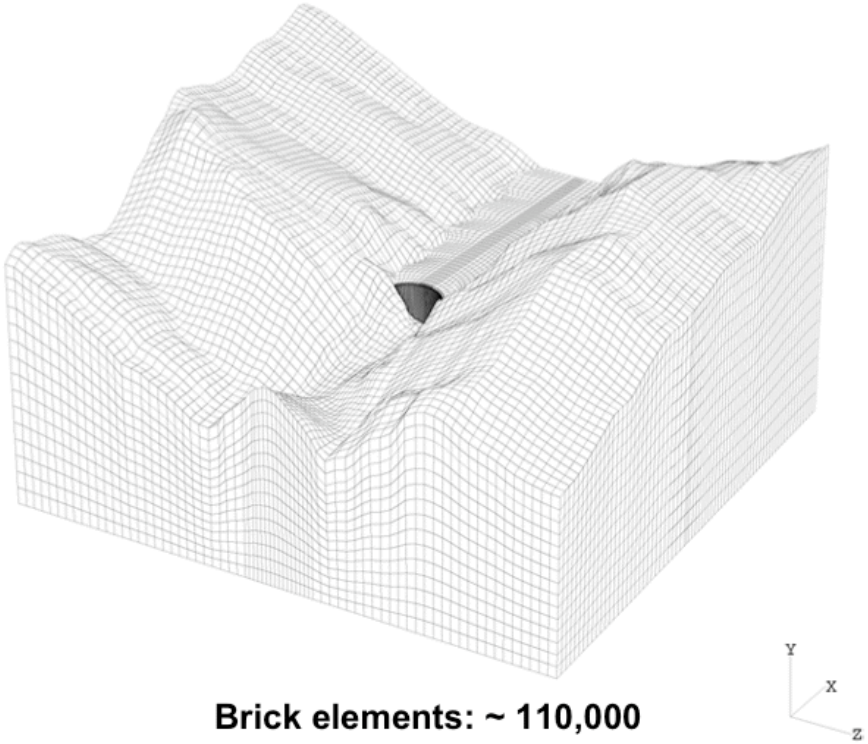
- Interoperability: NIKE3D/DYNA3D data



Morrow Point Finite-Element Mesh

- Analyze foundation, dam, and fluid in lake





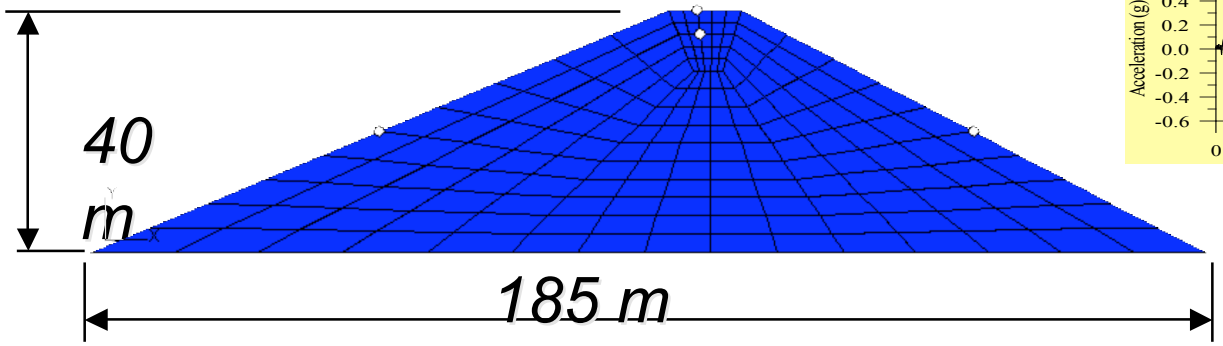
Brick elements: ~ 110,000
Discrete springs: 1640
No. of slide surfaces: 19

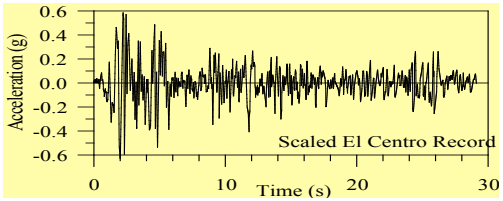
Terascale Multiphysics Simulations

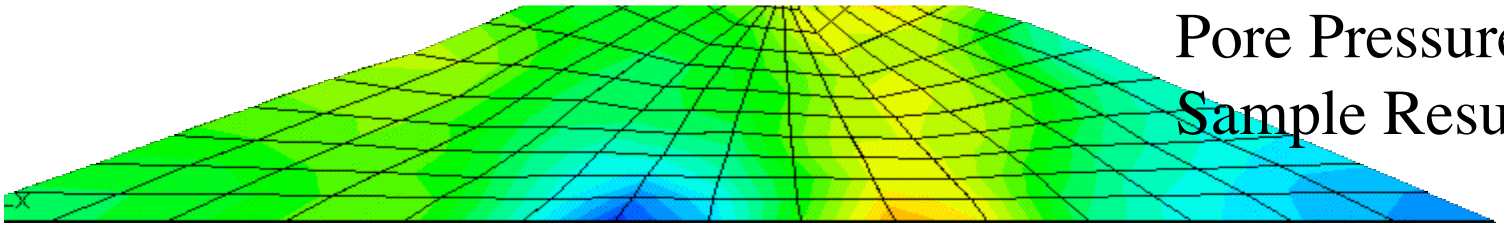
- Full or loose coupling within framework
  - Framework: general-purpose computer science infrastructure to facilitate sharing of element technology, data, transient algorithms
  - Hides computer science details (e.g., scalability) from physics methods development
- Goals on NEES MRE
  - Provide scalable platform for FE computation
  - Demonstrate interdisciplinary capabilities

Terascale Results

- Sample Saturated/Unsaturated Dynamics







Pore Pressure Sample Results

Summary

- Interdisciplinary research commonly results in physically coupled problems
- There are many ways to model the physical interactions of coupled problems
- There are many ways to design the computational infrastructure to handle the coupled physics
- Tsunami simulations may likely involve difficult physics, but simpler coupling