Nonlinear Simulations for Soil-Structure Interaction and Performance-Based Design

Boris Jeremić

University of California, Davis
Lawrence Berkeley National Laboratory, Berkeley

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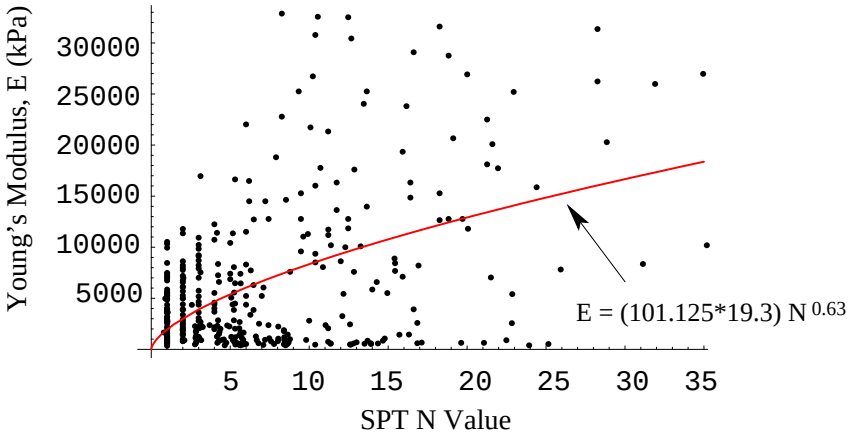
Outline

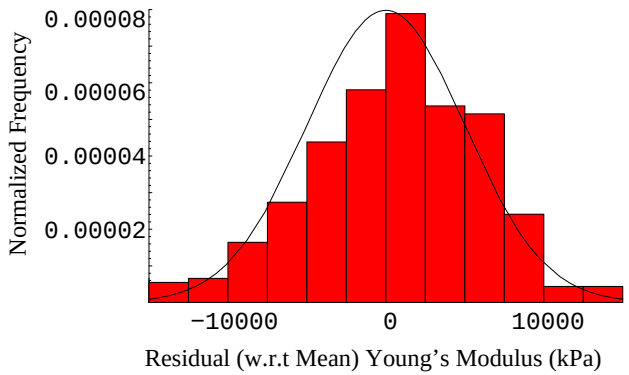
Motivation

- Improve seismic design of soil structure systems
- Earthquake Soil Structure Interaction (ESSI) in time and space, plays a decisive role in successes and failures
- Accurate following and directing (!) the flow of seismic energy in ESSI system to optimize for
  - Safety and
  - Economy
- High fidelity numerical modeling and simulation tool to analyze realistic ESSI behavior: The **Real ESSI** Simulator (aka: Врло Просто, Muy Fácil, Molto Facile, 真简单 , 本当に簡単 , Πραγματικά Εύκολο, آسان واقعی, Très Facile, Вистински Лесно, Wirklich Einfach)

Modeling and Parametric Uncertainty

- Modeling uncertainty: (unrealistic) modeling simplifications for important features
  - Inelastic material: soil, rock, concrete, steel; Contacts, foundation–soil, dry, saturated slip–gap; Nonlinear buoyant forces; Isolators, Dissipators
  - Seismic Motions: 6D, inclined, body and surface waves (translations, rotations); Incoherency
- Parametric Uncertainty:





Predictive Capabilities

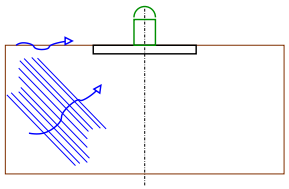
- Verification: provides evidence that the model is solved correctly. Mathematics issue. Well developed (for the Real ESSI Simulator).
- Validation: provides evidence that the correct model is solved. Physics issue. Work in progress, a new US-DOE project.
- Prediction: use of computational model to foretell the state of a physical system under consideration under conditions for which the computational model has not been validated.
- Goal is to predict and inform, not diagnose or fit.

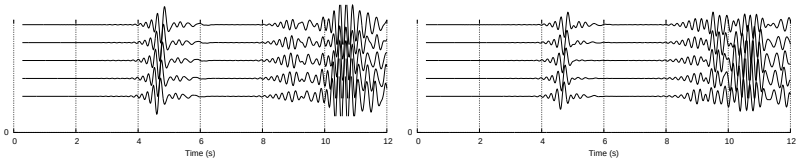
Outline

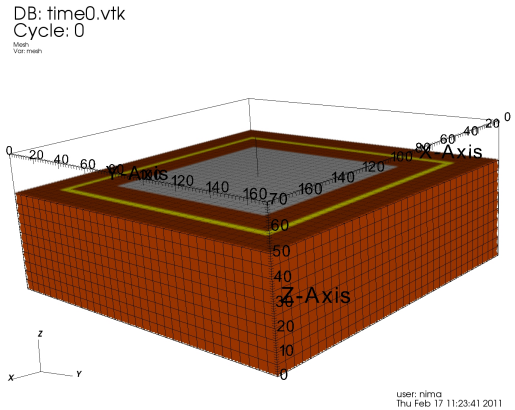
Real ESSI Models

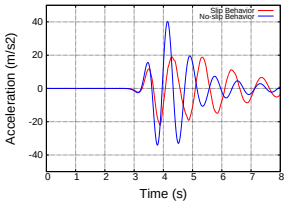
- Full (6D) seismic motion input (body and surface waves)
- Inelastic (saturated or dry) soil/rock
- Inelastic (saturated or dry) contact (foundation – soil/rock)
- Buoyant (nonlinear) forces
- Inelastic structural modeling
- Verification (extensive) and Validation (in progress)

Inelastic Contact, Base Slip and Gap









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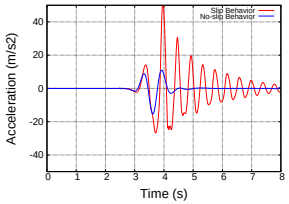

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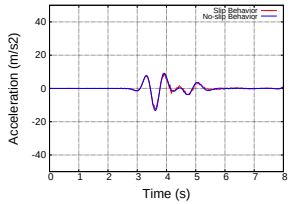

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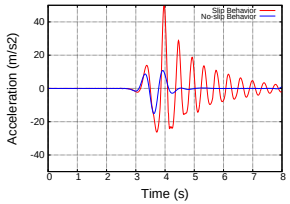

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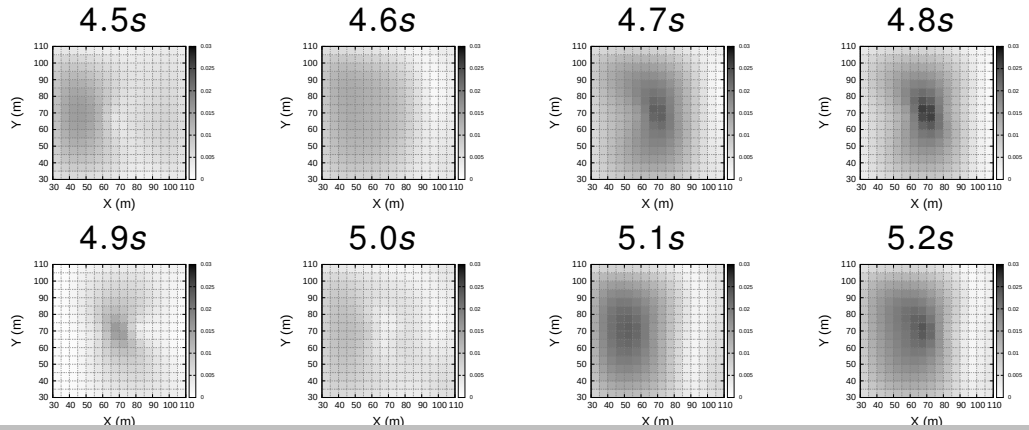
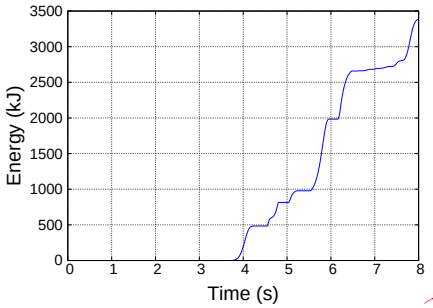
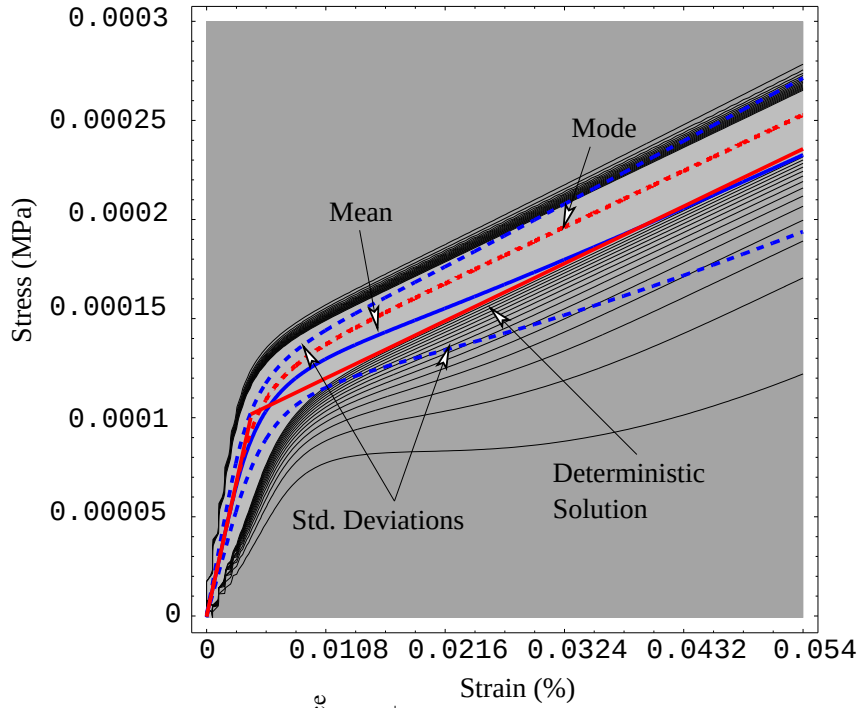
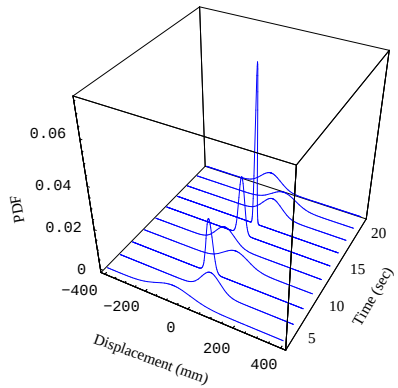


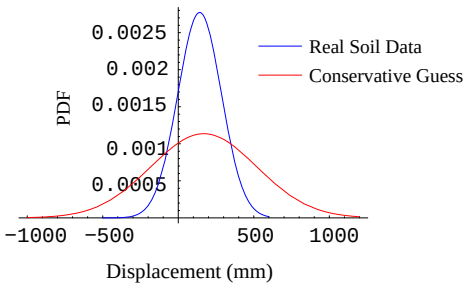


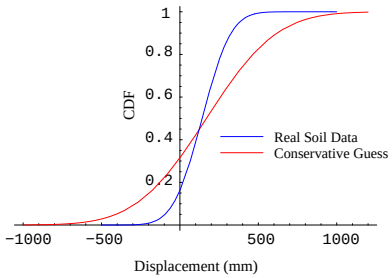
Uncertain Inelastic Wave Propagation

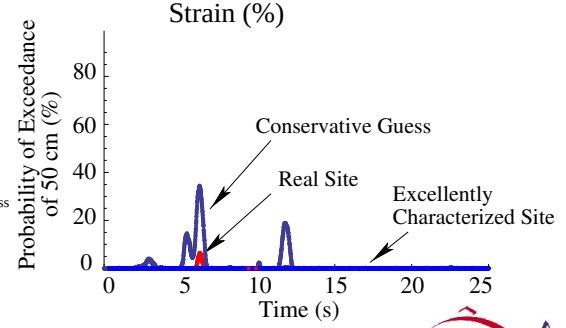
- Probabilistic Elasto-Plasticity
- Stochastic Elastic-Plastic Finite Element Method





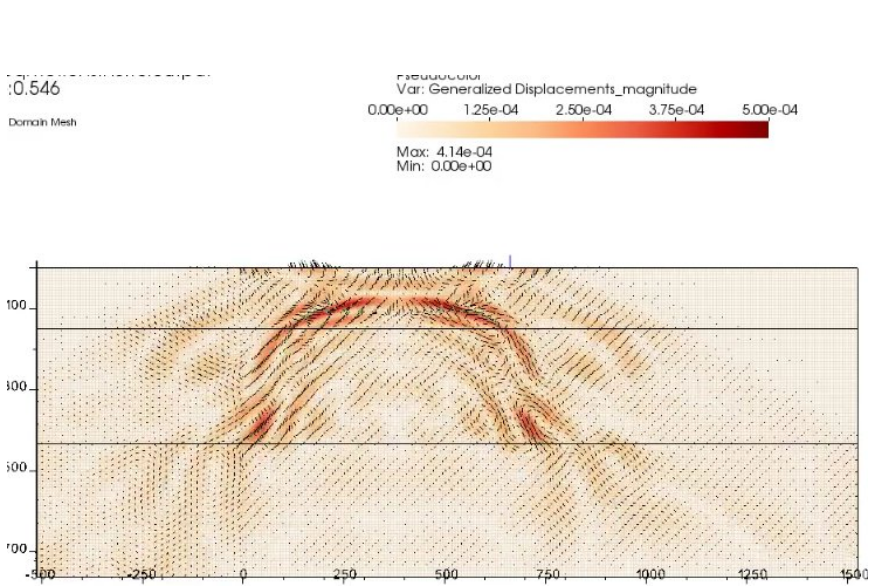


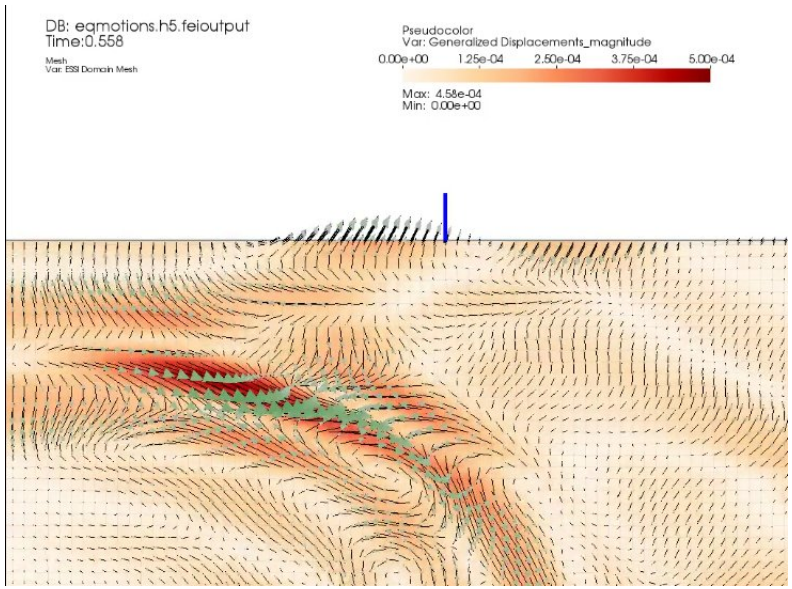




Outline

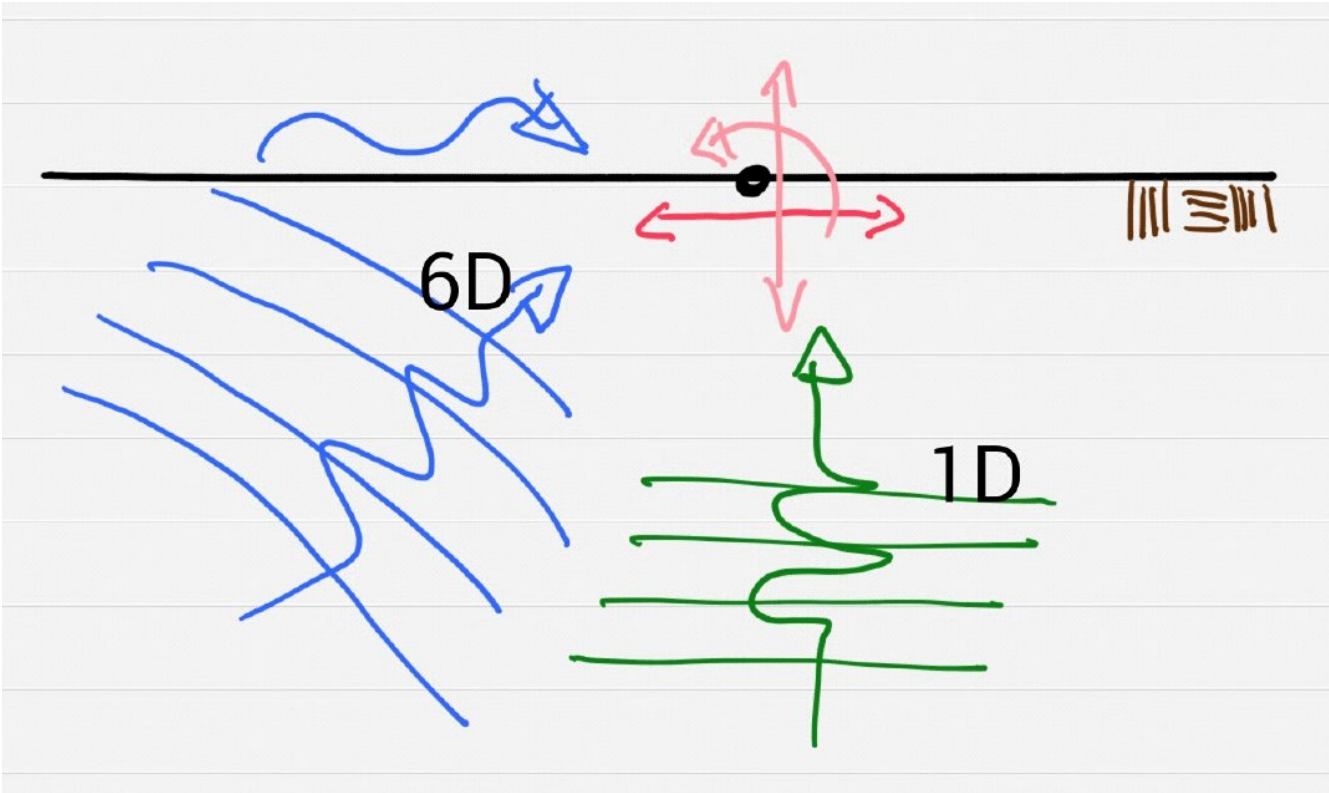
6D Motions: Free Field



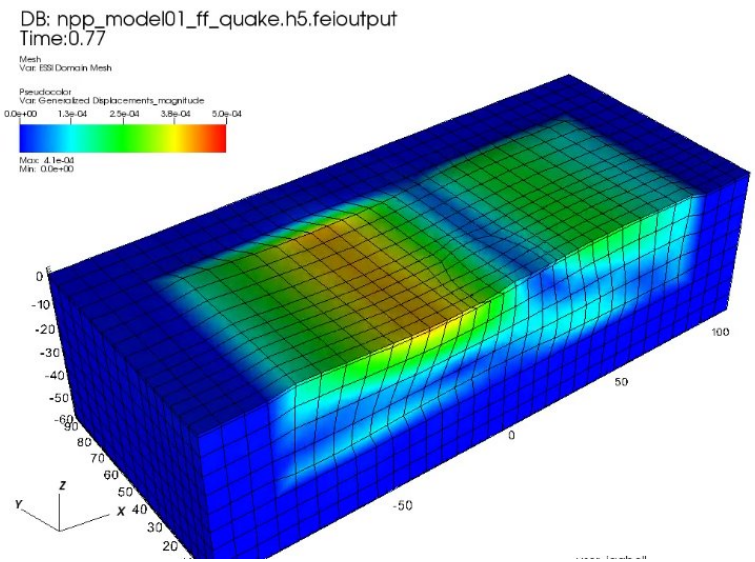


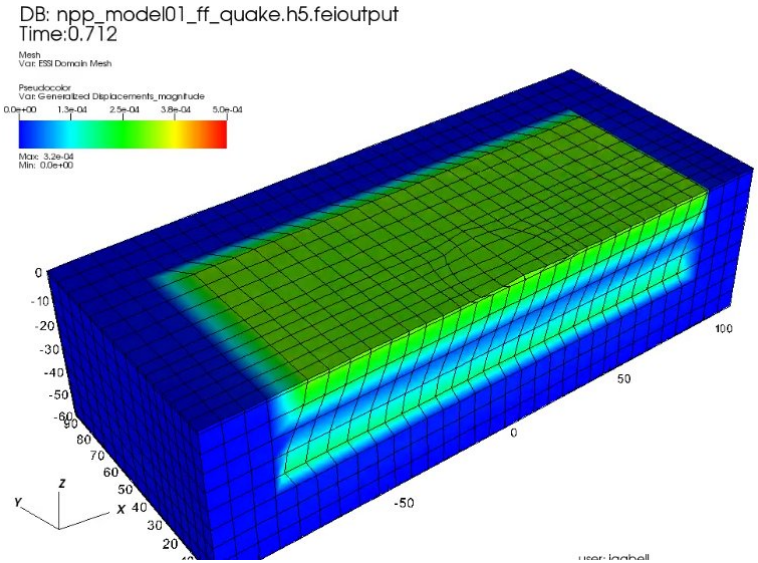
From 6D to 1D?

- Record a full 6D (3D) motions in one horizontal direction
- Develop a vertically propagating shear wave in 1D
- Apply 1D vertically propagating shear wave

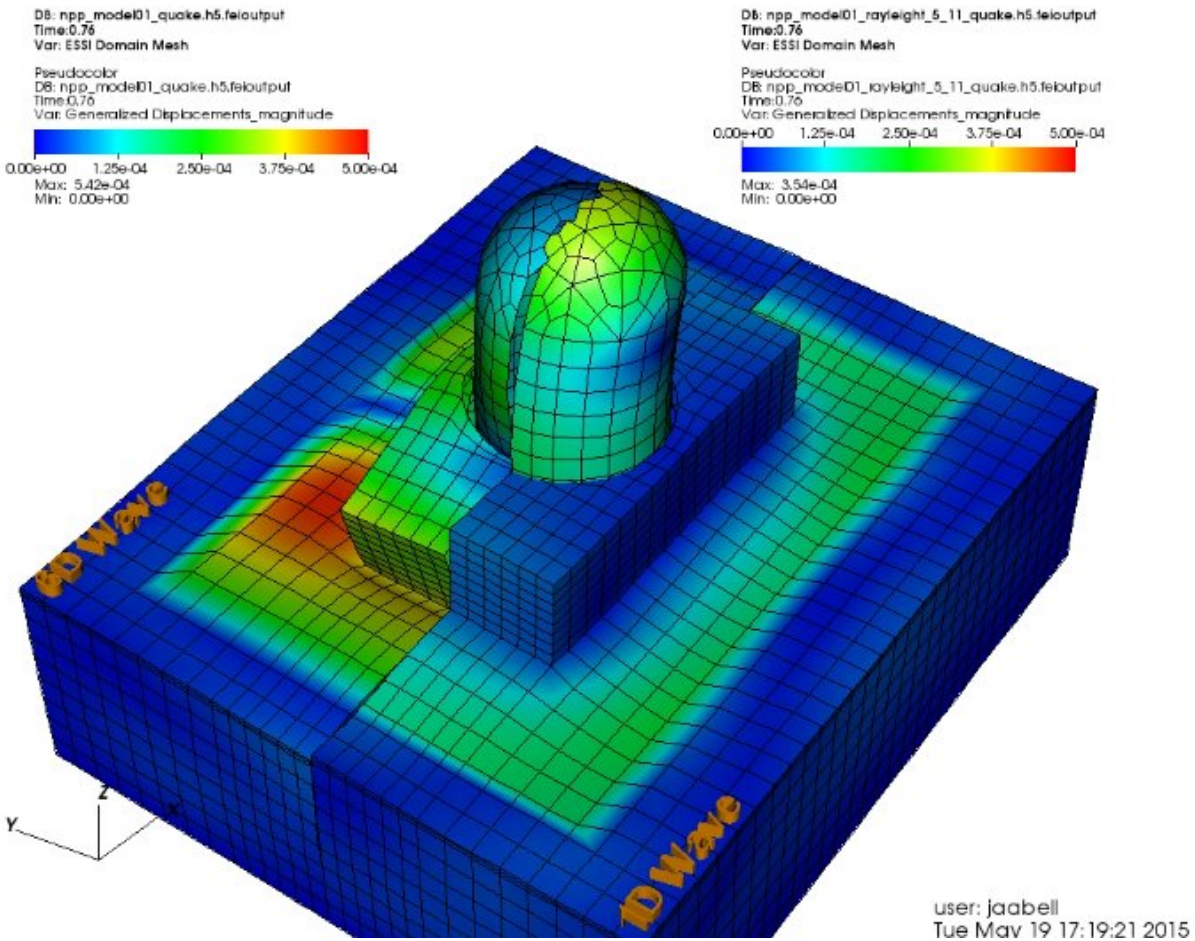


6D and 1D: Free Field





6D vs 1D: NPP ESSI Response

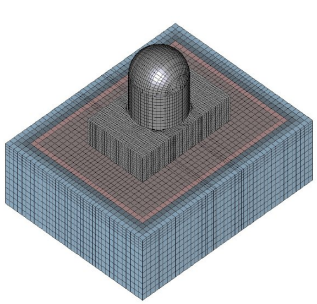
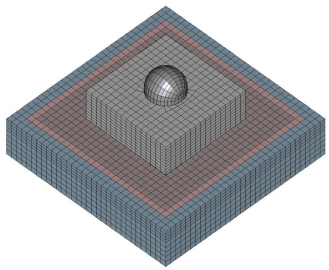
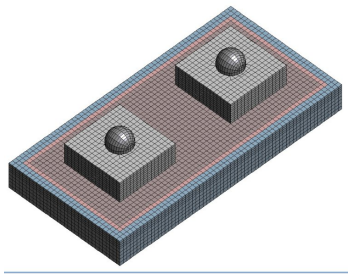
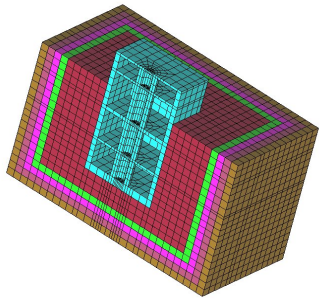
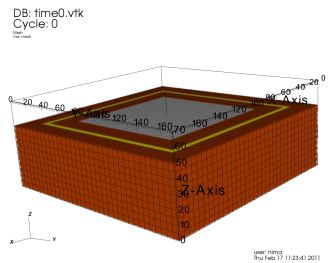


New 5 Year U.S. DOE Project

- Development of advanced computational tools for modeling and simulating the earthquake response of nuclear facilities
- Enhance understanding of the expected levels of damage, and margins against failure, for critical facilities subjected to earthquake ground motions
- Project Team:
  - Dr. David McCallen (Project Leader), UCOP and LBNL
  - Prof. Ian Buckle (Validation Experiments), UNR
  - Prof. Boris Jeremic (Code development), UCD and LBNL

Concluding Remarks

- High fidelity numerical modeling and simulation (inelastic, time domain) used to reduce modeling uncertainty
- Parametric uncertainty needs to be taken into account
- Goal is to predict and inform, not fit or diagnose
- Change state of practice (and research)
- Education (designers, regulators, owners, &c.) is essential

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