Panel Discussion:
What is the Path Forward for GM-SVU?

Norm Abrahamson (UC Berkeley)
C.B. Crouse (AECOM)
Felipe Kuncar (U Canterbury)

Reminder:
Community Survey
Open

Let's explore priorities, partnerships, and future opportunities for expanding the use of earthquake ground motion simulations in **hazard** and **engineering applications**, and discuss potential paths forward for the GM-SVU community.

13th National Conference on
EARTHQUAKE ENGINEERING
PORTLAND, OREGON | JULY 13-17, 2026
Resilience Through Community Engagement and Technology

SCEC

USGS
science for a changing world

Rooms E141&E142
July 13, 2026 (9:00 AM – 12:00 PM)

EERI

Application Readiness & Validation Evidence:

1. What minimum validation evidence should define "application-ready" simulations for PSHA or RHA?

- Norm Abrahamson (UC Berkeley)
- C.B. Crouse (AECOM)
- Felipe Kuncar (U Canterbury)

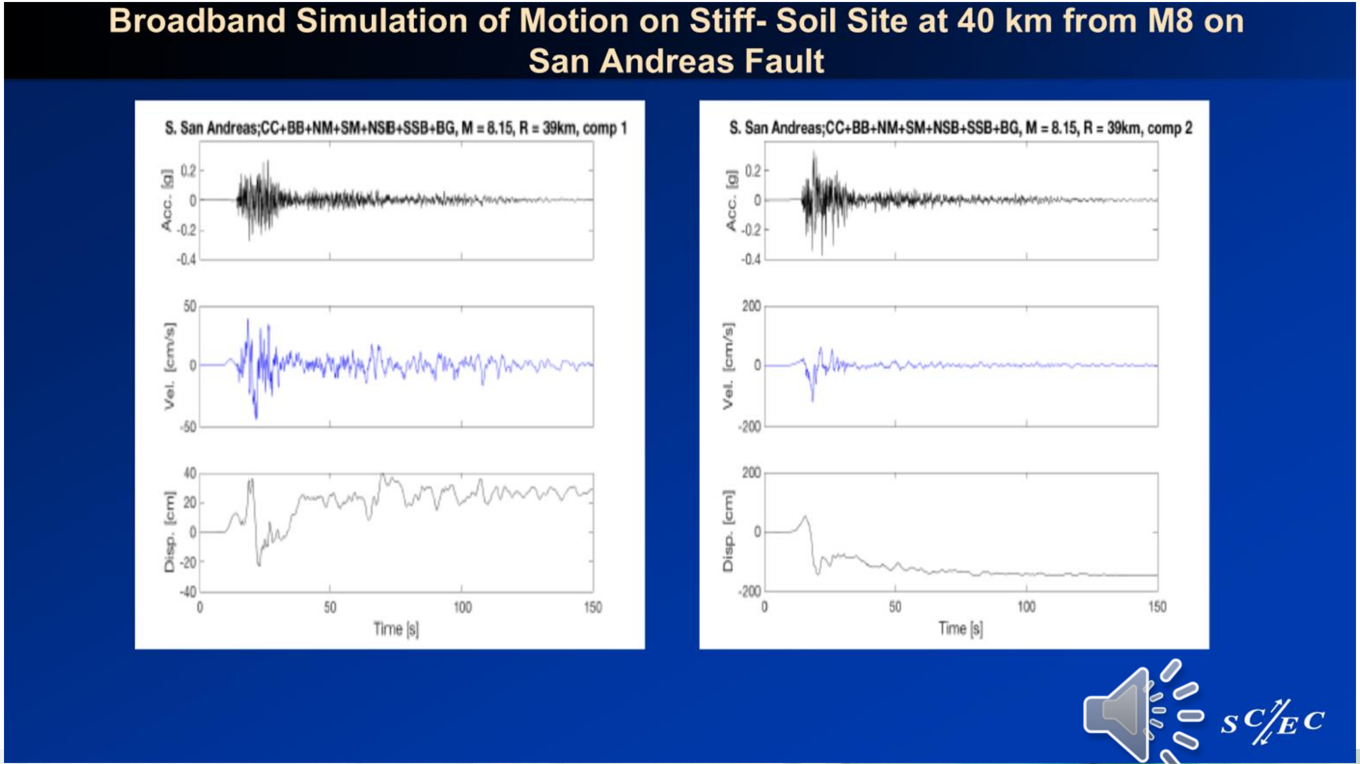
What minimum validation evidence should define "application-ready" simulations for PSHA?

	Method	Inputs (Parametric)
Apparent Aleatory Variability	- Due to unmodeled effects (includes simplifications) - Estimated from validation. (std dev of residuals using the best inputs)	Multiple realizations of the rupture for a given scenario
Epistemic Uncertainty in the Median	- Due to different simulation methods - Due to limited number of events/sites used in validation	- Different methods for rupture generators - Different distributions of parameters for a given rupture generator - Uncertainty in the velocity structure
Epistemic Uncertainty in the Size of the Apparent Aleatory Variability	Same as for the median	Same as for the median

For replacing GMMs with simulations in PSHA applications

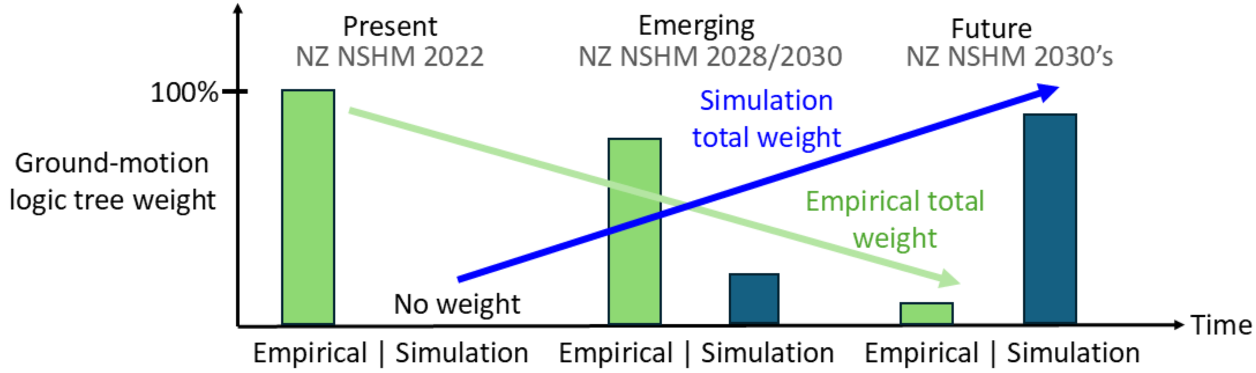
- Distribution of GM for a scenario
  - P(GM>z|scenario)
    - median and std dev
    - or non-parametric distribution
- Epistemic uncertainty in the distribution of GM
  - uncertainty in the value of P(GM>z|scenario)
    - uncertainty in median
    - uncertainty in std dev
    - or uncertainty in non-parametric distribution
- Need quantitative values in each of the six boxes

What minimum validation evidence should define “application-ready” simulations for RHA?



What minimum validation evidence should define "application-ready" simulations for NSHMs?

Application: Use of simulations in the NZ National Seismic Hazard Model (NZ NSHM)



Objective: Provide analysts with evidence to enable simulations to be assigned non-zero weights

Requirement: Comparable (or better) performance of simulations (vs. empirical GMM alternatives)

- Against observations that span the **predictor variable space and geographic domain of interest**
- Ranging from M~4-8, Rrup~0-300 km, Vs30~200-1000+ m/s
- Nationwide application: requires **large (>1000s of events) validation datasets**, that enable understanding of regional variations in simulation prediction performance
- PSHA: Proper validation and treatment of **simulation uncertainties**

Access, Metadata, and Curation Needs:

2. What must a curated, plug-and-play simulation dataset include to be trusted by the community?

- C.B. Crouse (AECOM)
- Felipe Kuncar (U Canterbury)

Needs to aid use of Broad-Band Simulations in NLRHA

- Easy-to-use search tool ~ PEER & Subduction GM tools
  - Similar metadata & drop-down menus for faults
- Inform geotech/structural engineers & building officials
  - Proper venues (e.g.,SEAOC dinner mtgs., LATBSDC mtg.)
  - Present case-history example
  - Discuss advantages
- Future code revisions to encourage use simulated motions?

Provide comprehensive validation information

- This will determine to what extent simulations can be used in different engineering applications:

Type of validation	Focus	Engineering application
Generic validation efforts	Have the rupture generator and overall simulation method been validated? This can include validation studies from other regions	May be sufficient for RHA
Region-specific validation efforts	Have the velocity model, the near-surface site representation, and other region-specific input parameters been validated?	Required for PSHA

Based on Bradley et al. "Guidance on the utilization of earthquake-induced gm sims in eng. practice" Eq Spectra 2017

Provide the input parameters/models used in the simulations, together with the raw waveforms (without site adjustments)

- Transparency, so validation consistency can be checked
- Enable users to adjust simulations. e.g., update the shallow site-response treatment by incorporating site-specific information collected after simulations have been performed

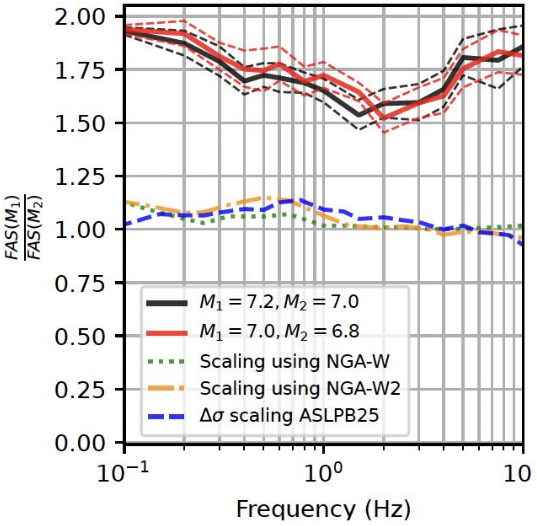
Modeling Approaches, Input Parameters & Epistemic Uncertainty Across Simulation Models:

3. How do modeling assumptions influence their applicability to hazard vs. engineering decisions?

- Norm Abrahamson (UC Berkeley)

How do modeling assumptions influence their applicability to hazard vs. engineering decisions?

- For hazard applications
  - The modeling assumptions for the forward application of the simulations need to be consistent with modeling assumptions made in the validation
- Example issue: static stress drop
  - Validation is for average static stress drop: M(rup Area) relation
  - Application for PSHA includes variability in magnitude for a given rupture area
    - The scaling of the ground motion with static stress drop from the simulations has not been validated.
      - Much stronger scaling in simulations than seen in residuals from GMMs
    - Large increase in the apparent aleatory variability from the realizations of the rupture generator
      - Example for T=3 sec: increases std dev from 0.44 to 0.70 LN units
- Example Issue: velocity model assumption and validation of rupture generator
  - Rupture generator validated based on simulations with 1-D velocity structure
  - Rupture generator is applied to a 3-D velocity model
  - If the 3-D velocity model leads to larger ground motions than for a 1-D velocity model, is the rupture generator valid for 3-D simulations?
    - For engineering decisions: Are the results from 3-D simulations unbiased?



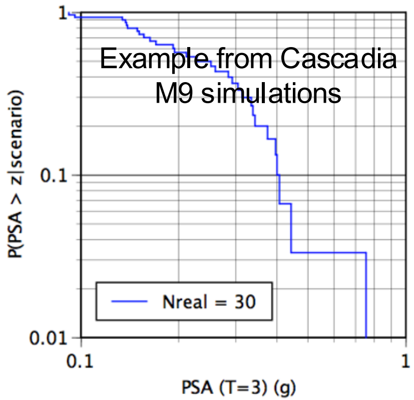
Simulation Use in PSHA:

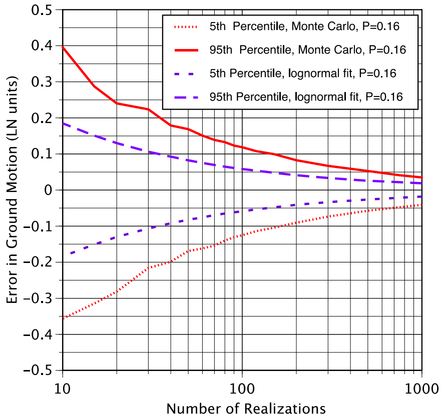
4. How many simulations are needed for PSHA?

- Norm Abrahamson (UC Berkeley)

How many simulations are needed for PSHA?

- For design ground motions, hazard is typically controlled by epsilons of 1-2.
- Apparent aleatory variability from multiple realizations of rupture generator
  - Monte Carlo sampling
    - flexible, but inefficient
- How to compute P(GM>z|scenario)?
  - Discrete values from simulations
    - Requires a large number of realizations to constrain the upper tail of the distribution
      - Need 150 realizations for 10% accuracy in P=0.16 (epsilon=1)
      - Need 350 realizations for 10% accuracy in P=0.025 (epsilon=2)
  - Parametric distribution (e.g., log normal) based on small number of realizations
    - Requires a smaller number of realizations to constrain the upper tail of the distribution, but looses the non-parametric distribution from the sampling of the rupture generator
      - Need 35 realizations for 10% accuracy in P=0.16 (epsilon=1)
      - Need 150 realizations for 10% accuracy in P=0.025 (epsilon=2)





Simulation Use in RHA:

5. What examples illustrate reliable use of simulations for building response?

What standards are needed to support adoption in practice, beyond research?

- C.B. Crouse (AECOM)

Broad-Band Simulations for NLRHA of Buildings

- M9 Simulations for CSZ used in NLRHA for tall bldgs in Seattle
- Provisions for NLRHA in ASCE 7-22. Sect. 16.2.2 on Ground Motion Selection says:
  - "Where the required number of recorded ground motions is not available, it shall be permitted to supplement the available records with simulated ground motions."
  - "Ground motion simulations shall be consistent with the magnitudes, source characteristics, fault distances, and site conditions controlling the target spectrum."
  - "A suite of not less than 11 ground motions shall be selected for each target spectrum."

Validation Challenges:

6. What are the major challenges when validating simulations against recorded data?

- Felipe Kuncar (U Canterbury)

What are the major challenges when validating simulations against recorded data?

Performing realistic ground-motion simulations and systematic validation is hard:

- Robust versioned computational workflow and high-performance computing resources
- Multiple sub-models and input parameters (e.g., 3D VMs, Vs30 models)
- High-quality observational ground-motion database with 1000s of events

In several geographic regions these required inputs are established; in most of the world they are not
→ **major challenge to fully utilizing the available global observational data for validation**

Once these ingredients are in place, some of the remaining challenges are:

- **Improving simulation performance:** Improving input parameters/models, finer spatial resolution and higher transition frequency, using validation results to refine/adjust simulations
- **Treatment and validation of simulation uncertainty:** Multiple uncertain parameters, substantial increase in computational demand
- **Validating for larger-Mw scenarios:** Likely requires ‘unified’ validation considering multiple regions (non-ergodic → ergodic)