STATEWIDE CALIFORNIA EARTHQUAKE CENTER

FROM SOURCE TO STRUCTURE

A roadmap for the future of ground motion simulation, validation, and utilization at SCEC

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GOAL:

Validation & Impact

I Validate the mean ground motion curve

Compare high-fidelity simulated IM distributions against empirical GMMs and ground motion records across frequency, distance, and site class, establishing simulation-based hazard curves.

II Quantify the spread (sigma)

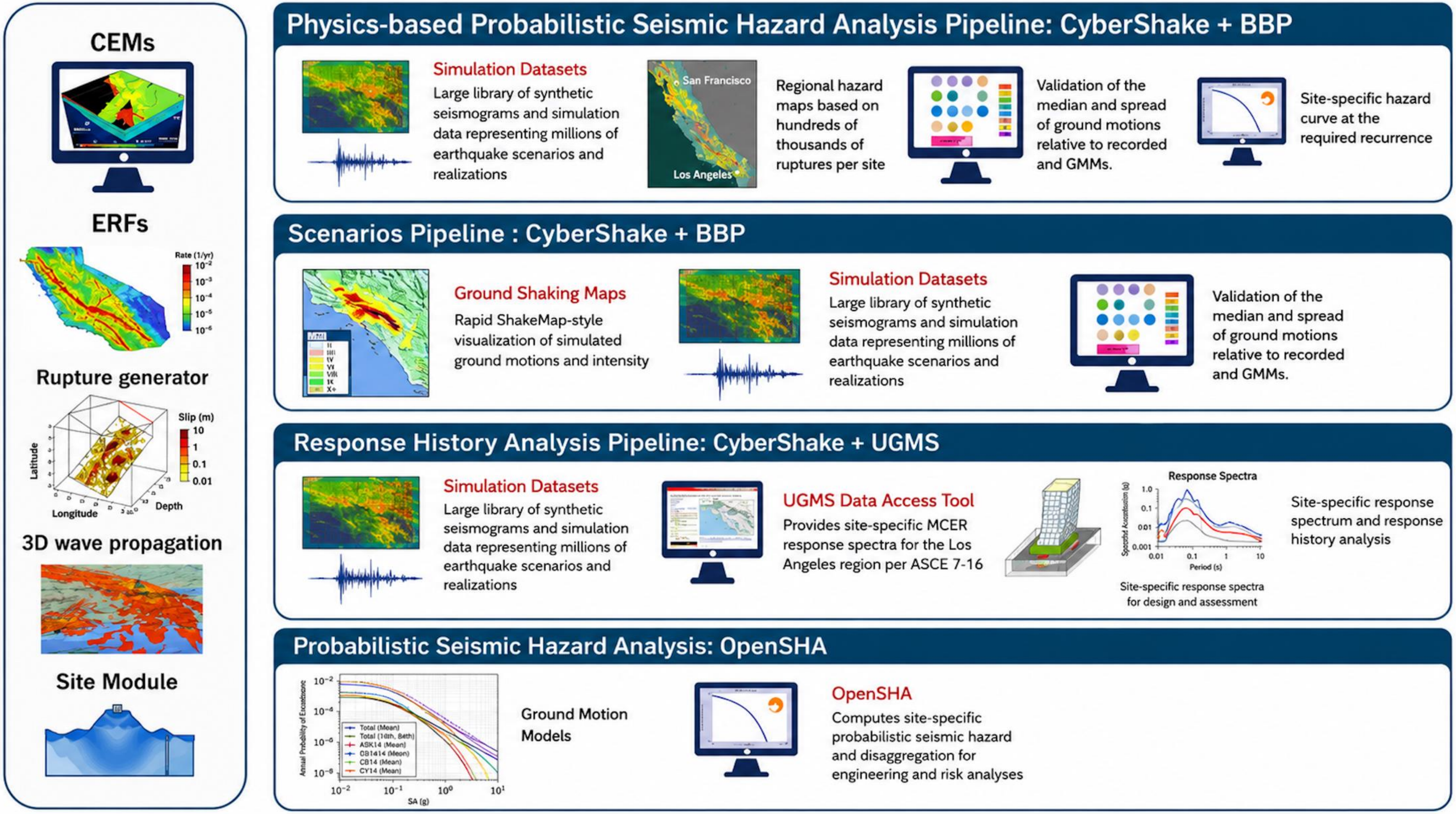
Decompose total variability into source, path, site, and model components using ensemble simulations. Identify which sigma terms are reducible with better physics.

III Fill the near-fault data gap

A rich near-fault library, directivity pulses, hanging-wall effects, and supershear signatures dramatically expands the observational record where recordings are sparse.

IV Quantify effects on structures, infrastructure & people

Apply validated waveforms in nonlinear structural models to produce loss, downtime, and casualty estimates, enabling physics-informed risk at portfolio scale.


CEMs
ERFs
Rate (1/yr)
10^-2
10^-3
10^-4
10^-5
10^-6
Rupture generator
Slip (m)
10
1
0.1
0.01
Latitude
Longitude
Depth
3D wave propagation
Site Module
Physics-based Probabilistic Seismic Hazard Analysis Pipeline: CyberShake + BBP
Simulation Datasets
Large library of synthetic seismograms and simulation data representing millions of earthquake scenarios and realizations
San Francisco
Los Angeles
Regional hazard maps based on hundreds of thousands of ruptures per site
Validation of the median and spread of ground motions relative to recorded and GMMs.
Site-specific hazard curve at the required recurrence
Scenarios Pipeline : CyberShake + BBP
Ground Shaking Maps
Rapid ShakeMap-style visualization of simulated ground motions and intensity
Simulation Datasets
Large library of synthetic seismograms and simulation data representing millions of earthquake scenarios and realizations
Validation of the median and spread of ground motions relative to recorded and GMMs.
Response History Analysis Pipeline: CyberShake + UGMS
Simulation Datasets
Large library of synthetic seismograms and simulation data representing millions of earthquake scenarios and realizations
UGMS Data Access Tool
Provides site-specific MCER response spectra for the Los Angeles region per ASCE 7-16
Response Spectra
Spectral Acceleration (g)
Period (s)
Site-specific response spectra for design and assessment
Site-specific response spectrum and response history analysis
Probabilistic Seismic Hazard Analysis: OpenSHA
Annual Probability of Exceedance
Total (Mean)
Total (16th, 84th)
ASK14 (Mean)
CB14 (Mean)
CY14 (Mean)
SA (g)
Ground Motion Models
OpenSHA
Computes site-specific probabilistic seismic hazard and disaggregation for engineering and risk analyses

THE SIMULATION ARC

NOVA: Next Generation Open Source Validated and AI-Powered

01

EARTHQUAKE SOURCE

Dynamic rupture · Supershear · AI source models

02

→ 3D VELOCITY MODEL

High-resolution CVMs · ML surrogates · UQ

03

→ SITE RESPONSE

3D site response · Beyond Vs30 · Nonlinear soils

04

→ HIGH-FIDELITY WAVEFORMS

Broadband synthetics · Near-fault pulses · CyberShake

05

→ STRUCTURAL RESPONSE

GMSVU · AI-NLRHA · Performance and life safety

Validated end to end, from fault rupture to building performance.

01

EARTHQUAKE SOURCE

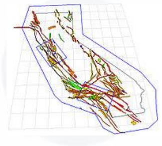
Physics-based rupture ensembles for the next generation of hazard.

KEY INNOVATIONS

From empirical rupture rules to physics-based, uncertainty-aware earthquake-source ensembles.

PHYSICS-BASED RUPTURE

Multi-fault events · Supershear · Dynamic rupture



EARTHQUAKE-CYCLE FORECASTING

Long synthetic catalogs · Sequence clustering · Time-dependent hazard

AI-ACCELERATED ENSEMBLES

FNO surrogates · ≥1,000× faster · Physics-grounded UQ

Beyond empirical scaling: rupture physics, sequence evolution, and uncertainty in one framework.

02

3D VELOCITY MODELS

Open, high-resolution, uncertainty-aware models for next-generation wave propagation.

ADVANCING WAVE PROPAGATION

From static community velocity models to swappable, learnable, uncertainty-aware 3D propagation ensembles.

OPEN CVM INFRASTRUCTURE

UCVM-Next · interchangeable CVMs · versioned ensemble comparisons

ML SURROGATE WAVEFIELDS

Fast 3D propagation · FNOs and ROMs · rapid scenario evaluation

UNCERTAINTY-QUANTIFIED ENSEMBLES

Propagate CVM uncertainty · sigma attribution · sensitivity analysis

Turning velocity-model uncertainty into a quantifiable, reducible component of ground-motion uncertainty.

03

SITE RESPONSE

Data-integrated, high-resolution models for local amplification and site effects.

- Vs30 (baseline)
- Vs profiles
- H/V spectral ratio
- Ambient noise tomography

AI-POWERED INNOVATIONS

From baseline proxies to data-integrated, high-resolution 3D site-response models.

3D SITE MODEL CONSTRUCTION

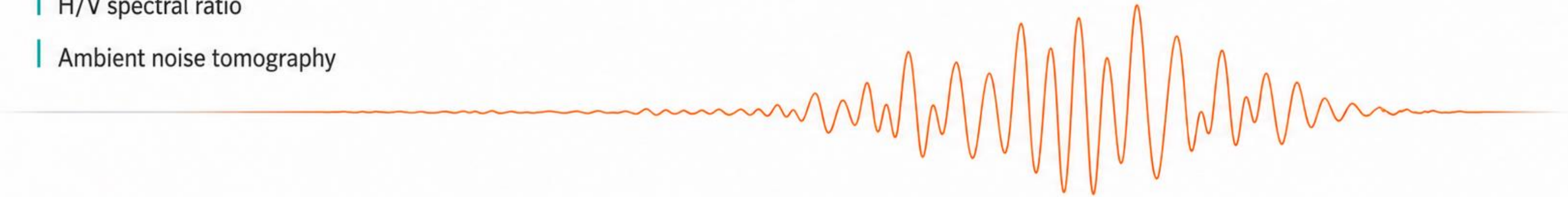
Integrate Vs30, Vs profiles, H/V ratios, and ambient-noise constraints.

3D SITE WAVE PROPAGATION

Propagate regional wavefields through high-resolution 3D site models.

SITE CHARACTERIZATION DATABASE

Boreholes · CPT · HVSR · arrays · UCVM-ready data.



Better site models, more accurate amplification, lower uncertainty.

04

PHYSICS-BASED GROUND MOTIONS

From scenario ruptures to broadband, near-fault, site-aware waveform ensembles.

HIGH-FIDELITY WAVEFORMS

Physics-based broadband ground motions for hazard, engineering, and validation.

BROADBAND SYNTHETICS

Low-to-high frequency waveforms · source-to-site simulation · validation-ready outputs

NEAR-FAULT & BASIN EFFECTS

Directivity and pulse effects · basin amplification · 3D path and site response

CYBERSHAKE LIBRARIES

Large scenario ensembles · hazard-consistent selection · engineering-ready records

Broadband waveforms that connect rupture physics to hazard, validation, and structural response.

04

PHYSICS-BASED GROUND MOTIONS

From scenario ruptures to broa near-fault, site-aware wa es.

HIGH-FIDELITY WAVEFORMS

Physics-based broadband ground motions for hazard, engineering, and validation.

A NEW CYBER INFRASTRUCTURE FOR ACCESSING AND VISUALIZATION OF CYBERSHAKE SIMULATION AND POST-PROCESSING PIPELINES. STAY TUNED!

tputs

AR-FAULT & BASIN EFFECTS

Directivity and pulse effects · basin amplification · 3D path and site response

CYBERSHAKE LIBRARIES

Large scenario ensembles · hazard-consistent selection · engineering-ready records

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05

UTILIZATION

UTILIZATION

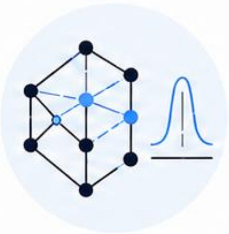
From broadband waveforms to performance, recovery, and resilience decisions.

DECISION-READY UTILIZATION

From life-safety checks to AI-enabled, portfolio-scale functional recovery assessment.

DIRECT WAVEFORM UTILIZATION

Beyond response spectra · preserve phase, duration, and nonstationarity



AI-ACCELERATED NLRHA

Fast surrogates · thousands of analyses · rapid nonlinear response

PORTFOLIO & RECOVERY ASSESSMENT

Buildings and lifelines · downtime and loss · community impacts

Turning waveform simulations into scalable structural and community resilience decisions.

GOAL:

Validation & Impact

Share with us your dreams! Together we will make them happen!

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