Developing International Standards and Guidelines for Validating, Disseminating, and Utilizing Simulated Earthquake Ground Motions

Brad Aagaard (USGS), Aysegul Askan (METU), Sanaz Rezaeian (USGS)

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USGS: U.S. Geological Survey
META: Middle East Technical University
COSMOS: Consortium of Organizations for Strong-Motion Observation Systems
SCEC: Statewide California Earthquake Center
GM-SVU: Ground-Motion Simulation, Validation, and Utilization

COSMOS Simulated Ground-Motions Working Group

strongmotion.org → Working Groups

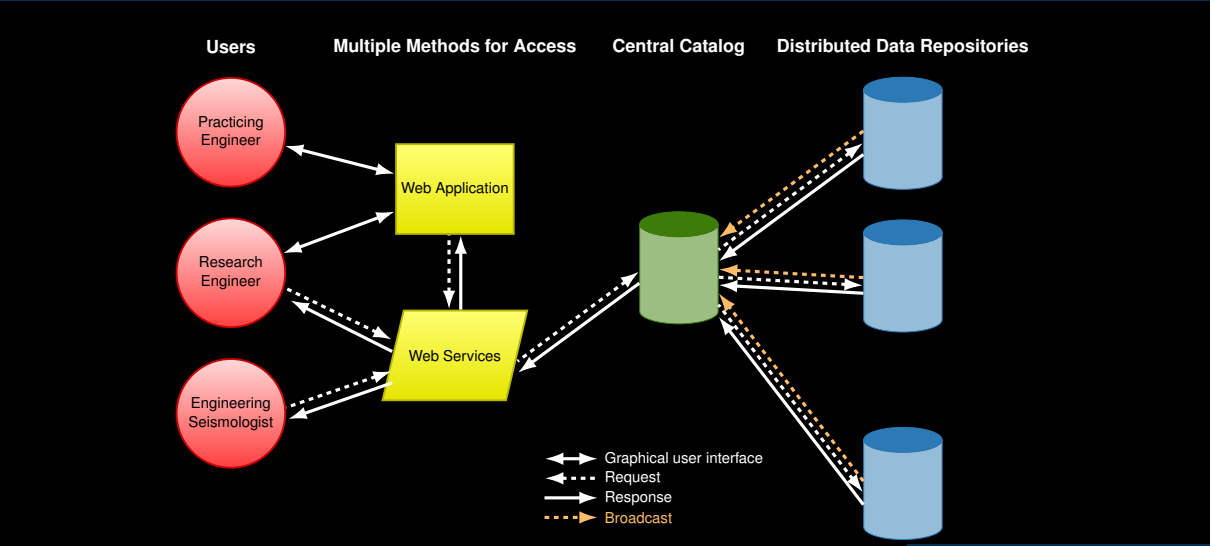
Formed in 2021 to organize COSMOS's efforts related to simulated earthquake ground motions

Purpose

- Make simulated ground motions as easy to use as recorded ground motions.
- Establish international guidelines and standards for validating, disseminating, and utilizing simulated earthquake ground motion data for engineering applications.

Vision

Want architecture for data access similar to seismology data centers (FDSN)



FDSN: International Federation of Digital Seismograph Networks

We are focusing on standardizing how data is accessed (architecture and protocols), not creating a massive central repository and implementing a graphical user interface. We envision a distributed architecture in which data is stored at data centers, high-performance computing centers, or government or educational institutions with metadata exposed to a central catalog. A variety of users access the data either through a web browser or programmatic interface through a central access point.

COSMOS Simulated Ground-Motions Working Group: Activities

- **Community Engagement**
  - COSMOS workshops
  - Participate in workshops hosted by related groups
  - Special sessions at scientific meetings
- **Inventory of projects related to simulated ground motions**
- **Development of international standards and guidelines**

Inventory of Simulated Ground-Motion Projects

We are compiling a catalog of projects related to simulated earthquake ground-motions.

Started in 2024 (COSMOS Technical Session) and added more in 2025.

A PDF file with catalog of 38 projects from 26 individuals is now available on the COSMOS website (`strongmotion.org`).

The catalog is a stepping stone towards a standard interface for accessing simulated ground-motion data.

PDF: Portable Document Format

The catalog is available at `https://www.strongmotion.org/s/COSMOS-SimWG-Project-Inventory-2026-01-27.pdf`.

Example Project

Links are shown in blue

PEER-LBNL Simulated Ground Motion Database **Contact:** David McCallen, dbmccallen@lbl.gov **Publications:** 10.1177/87552930251340960, 10.1177/87552930241270575, 10.1177/87552930241265132, 10.1177/87552930241246235, 10.1785/0120210138, 10.1002/eqe.3540, 10.1002/eqe.3366 **Status:** In progress	**Geographic region:** Western U.S. and Central U.S. **Simulation method:** 3D wave propagation (finite difference, finite element, spectral element, etc), Deterministic physics based simulation **# of simulated earthquakes:** More than 100 **# of simulated ground motions:** More than 1000 **Data:** • Ground-motion metrics • Ground-motion waveforms **Validation:** • Validation or goodness-of-fit metrics **Utilization:** • Structural response of a building • Analysis of ground-motion data

PEER: Pacific Earthquake Engineering Research Center
LBNL: Lawrence Berkeley National Laboratory
3D: three dimensional
U.S.: United States
DOI: Digital Object Identifier

Each project includes standard information. The blue text in the PDF file are links to the data, references, etc. The publications are listed using DOIs.

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Project title (blue=link)

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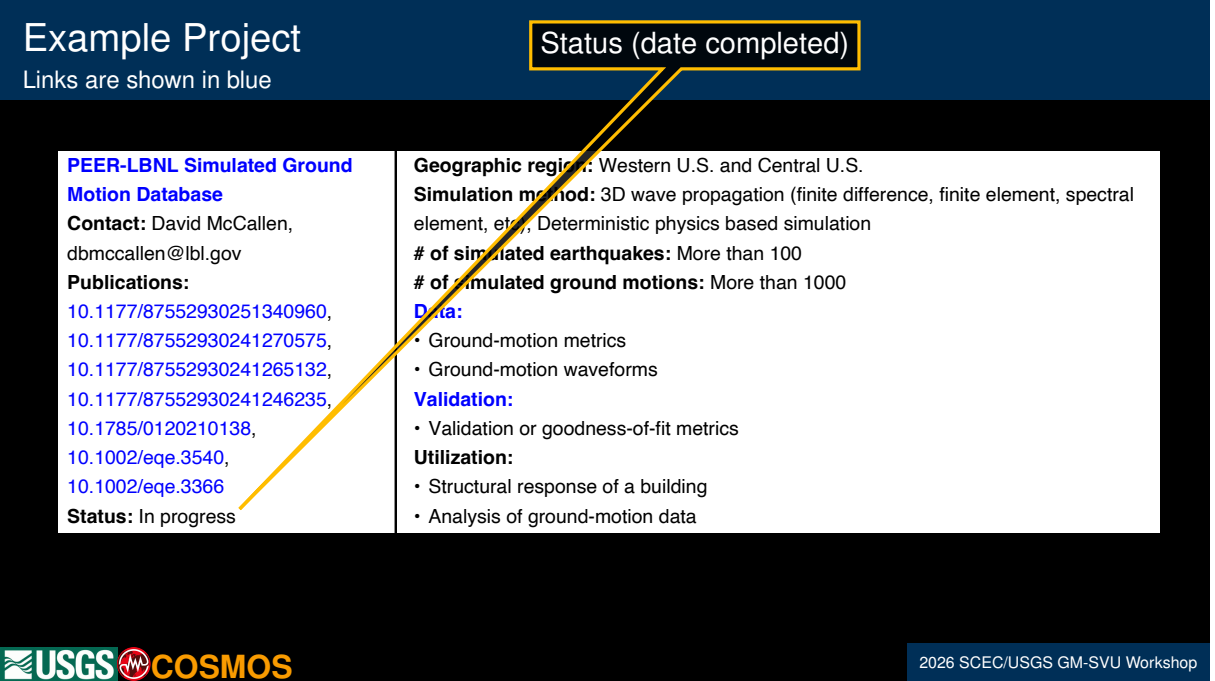

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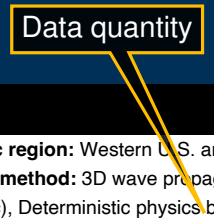

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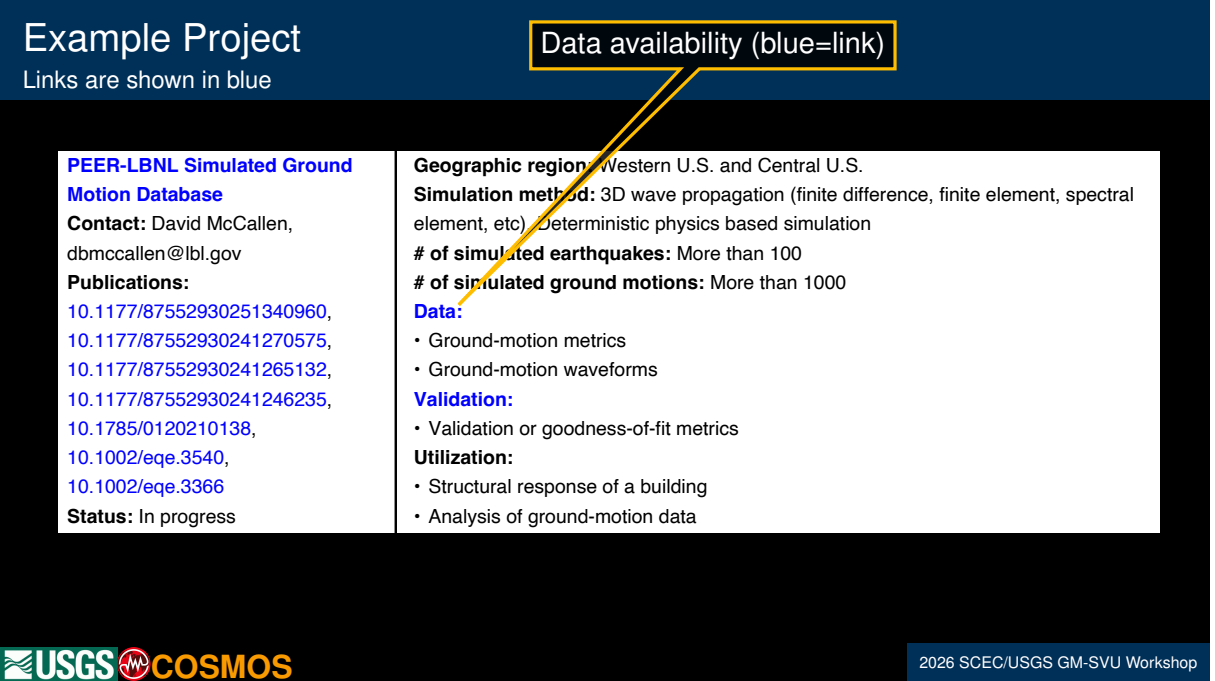

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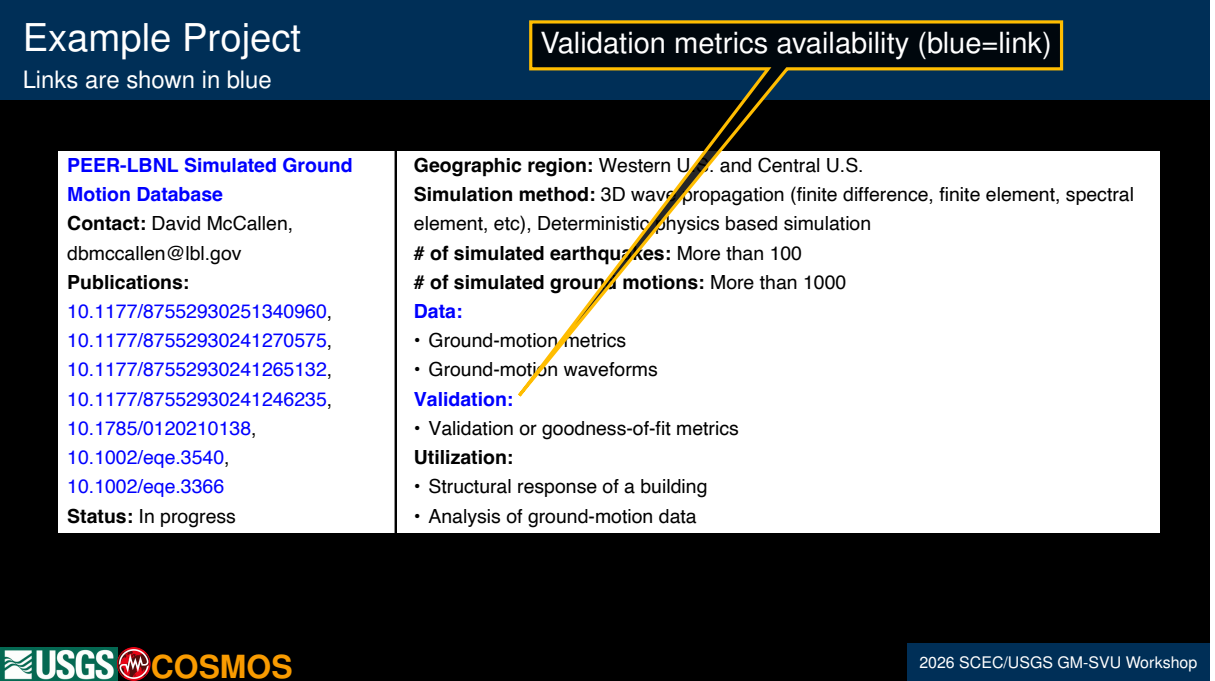

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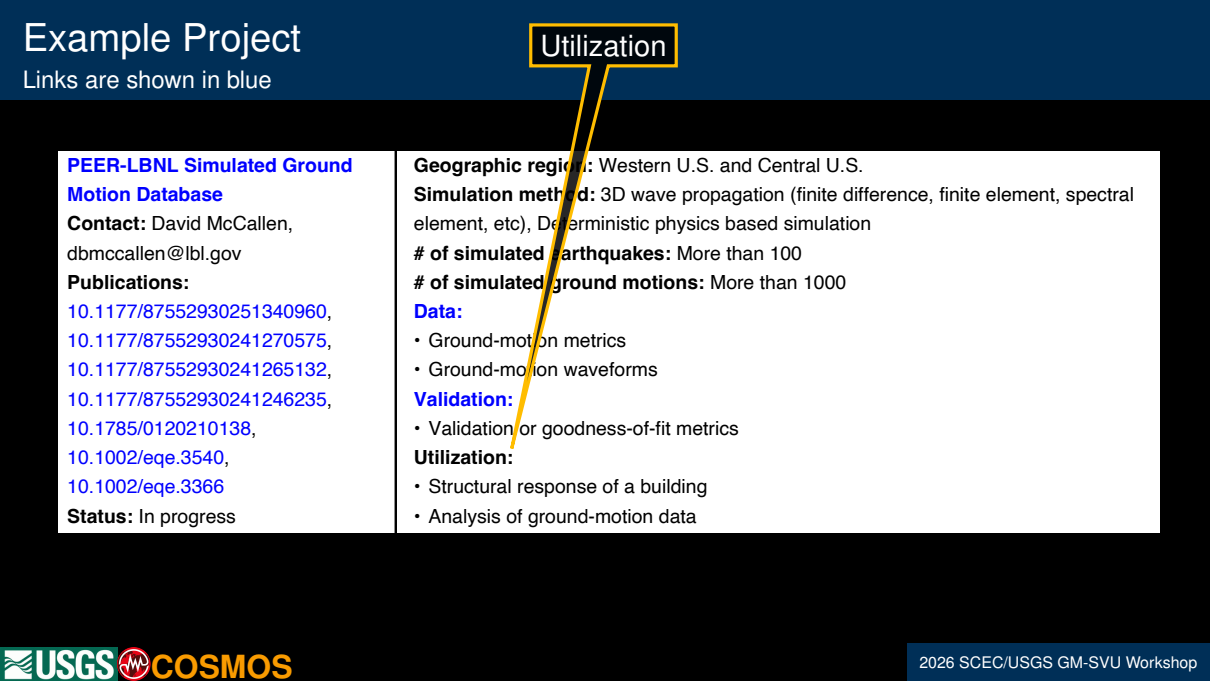

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Interface for disseminating simulated ground-motion data

Snapshot of work in progress

- **Search parameters** Address use cases of *most* users
- **Metadata**
  1. Find data based on search parameters
  2. Complete enough to capture differences among simulations
  3. Informative to users
  4. Facilitate reproducibility
- **Format of data delivery**

The standards include metadata and the format of the data delivery.

Data provided

- **Waveforms**
- **Ground-motion metrics**
- **Site metrics**
- **Rupture model**

PGA: Peak ground acceleration
PGV: Peak ground velocity
PGD: Peak ground displacement
RotDX (RotD0, RotD50, RotD100): X percentile of peak ground motion across all horizontal orientations (azimuths)
Vs30: Time-averaged shear-wave speed (m/s) in the top 30 m of the subsurface
ZX (Z1.0, Z2.5): Depth (km) to the shallowest X km/s shear wave speed isosurface

The data provided could include waveforms, ground-motion metrics, site metrics, and earthquake rupture model information. For simple cases, such as earthquake point sources, some information may be empty.

Data provided

- **Waveforms**
  - Components (georeferenced and/or relative to fault)
    - East, North, Up
    - Fault perpendicular, fault parallel, Up
  - Acceleration
  - Velocity
  - Displacement
- **Ground-motion metrics**
- **Site metrics**
- **Rupture model**

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Data provided

- **Waveforms**
- **Ground-motion metrics**
  - List of sites or on a regular grid
  - Type
    - PGA, PGV, PGD
    - Pseudospectral acceleration (PSA)
    - Fourier amplitude spectra (FAS)
    - Arias intensity
    - Cumulative absolute velocity (CAV)
    - Cumulative absolute displacement? (CAD)
  - Components
    - Individual components (East, North, Up; Fault perpendicular, Fault parallel, Up)
    - Geometric mean
    - Quadratic mean
    - RotD0, RotD50, RotD100
- **Site metrics**
- **Rupture model**

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Data provided

- **Waveforms**
- **Ground-motion metrics**
- **Site metrics**
  - Epicentral distance (km)
  - Rupture distance (km)
  - Vs30 (m/s)
  - Z1.0, Z2.5 (basin depth in km)
- **Rupture model**

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Data provided

- **Waveforms**
- **Ground-motion metrics**
- **Site metrics**
- **Rupture model**
  - Slip time histories (Components: left lateral, reverse)
  - Slip distribution (Components: left lateral, reverse)
  - Rise time (5–95%)
  - Rupture speed (Components: along strike, up dip)

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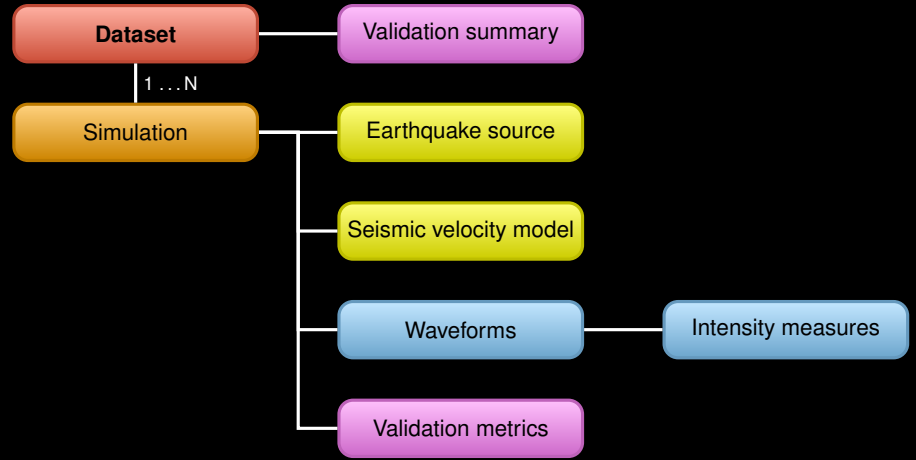

The metadata captures information about the entire dataset and each simulation, including input parameters (yellow boxes), waveforms (blue box), and validation information (purple boxes).

Next steps

1. Circulate outline of API for feedback
2. Form a small group (6–8 people) to develop a complete draft
   - Fill in details
   - Engage users and iterate

   ⋮
3. Work with 1–3 projects to develop prototype implementations of the API, including GUIs

API: Application Programming Interface
GUI: Graphical user interface