An Overview of the NHERI SimCenter

Matthew Schoettler

Associate Director for Operations

UC Berkeley

December 13-14, 2018

Mission

"Transforming the nation's ability to understand and mitigate adverse effects of natural hazards on the built environment through computational simulation"

Grounded in the present

Five year focus

Ten year vision

Goals

- Develop a **computational framework** that supports decision-making to enhance community resilience to natural hazards in the face of uncertainty;
- **Design the framework** to be sufficiently **flexible, extensible, and scalable** so that any component can be enhanced to improve the analysis and thereby meet the needs of a user group;
- **Seed the framework** with **connectivity to existing simulation tools** and **data** so it can be readily employed and improve as users identify new needs;
- **Release tools/applications built using this framework** that meet the computational needs of researchers in natural hazards engineering;
- **Provide an ecosystem** that fosters collaboration between scientists, engineers, urban planners, public officials, and others who seek to improve community resilience to natural hazards.

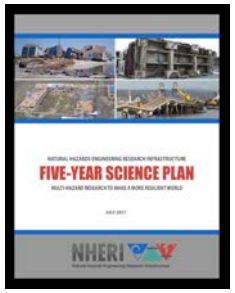
https://simcenter.designsafe-ci.org

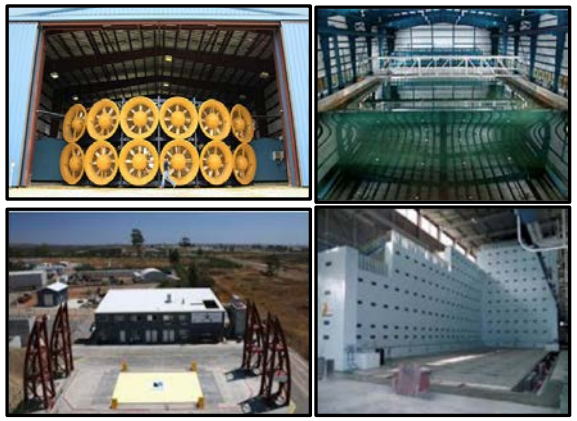
SimCenter Research Tools
https://simcenter.designsafe-ci.org/research-tools

Software Source Codes and Contributions
https://github.com/NHERI-SimCenter

Role in NHERI

Network Coordination Office





Experimental and RAPID facilities

DesignSafe-ci.org is a comprehensive cyberinfrastructure environment for research in natural hazards engineering.

- **Data Storage and Sharing**
- **Access to HPC at TACC**

Data Depot Stampede2

- **Cloud platform for running deployed applications**

OpenSees OpenFOAM ADCIRC LS Dyna

- **Collaboration Tools**

slack

Back-end

SimCenter Application Framework

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NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

Agave Platform TACC web API

SimCenter NHERI
Center for Computational Modeling and Simulation

Cloud-enabled research applications
Scalable to run on HPC with emphasis on UQ

Front-end

SimCenter Research Applications

UQ FEM PBE EE-UQ CWE UQ

Leadership Group

Sanjay Govindjee
UC Berkeley

Ahsan Kareem
Notre Dame

Laura Lowes
Washington

Greg Deierlein
Stanford

Camille Crittenden
UC Berkeley

Frank McKenna
UC Berkeley

Matt Schoettler
UC Berkeley

Software Development Team

Peter (UW), Michael, Adam (Stanford), Frank, Chaofeng, Wael, Pedro (UW)

Caigui

Nikhil

Jaiwai (ND)

Domain Experts

Additional experts in engineering, urban planning, social science, and computer and information science


Iris Tien


George Deodatis


Patrick Lynette


Alex Taflanidis


Jack Baker


Ann-Margret Esnard


Joel Conte


Vesna Terzic


Jonathan Bray


Tracy Kijewski-Correa


Michael Motley


Paul Waddell


Filip Filippou


Ewa Deelman


Kincho Law


Ertugrul Taciroglu


Stella Yu


Eduardo Miranda

Strategy

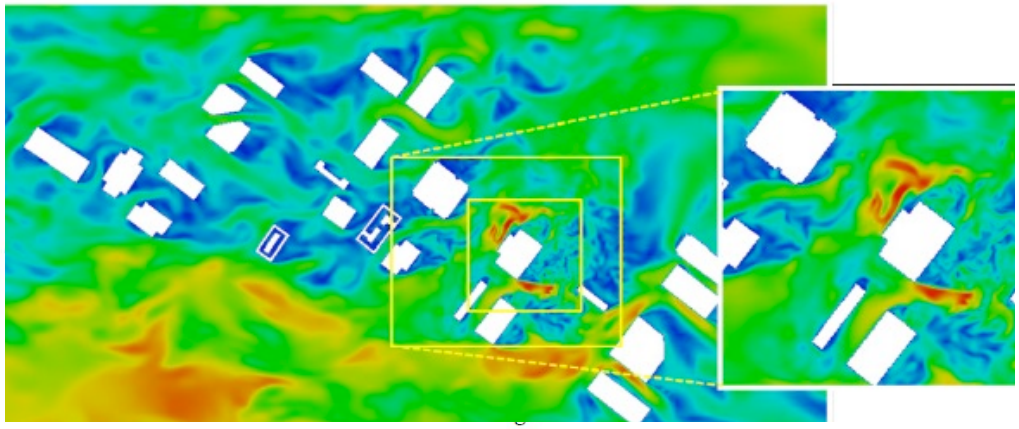
Current software is often good, but:

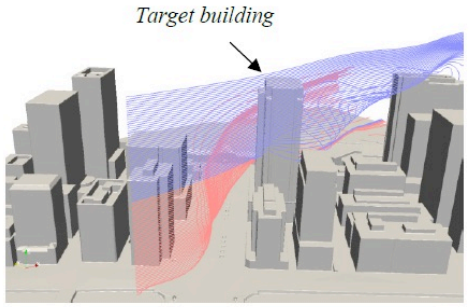
- Regular software updating needed,
- Unable to scale to HPC,
- Difficult to interact with and move data from one app to another.

- Move to cloud-based HPC environment,
- Provide integrated “plug and play” capability to link multiple software apps together into workflows

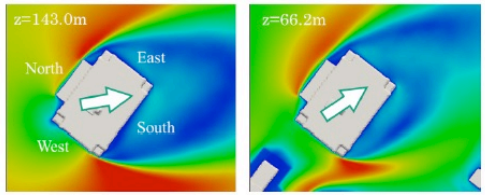
API Facilitated Application of Applications

Desired Outcome





T. Tamura Group TIT



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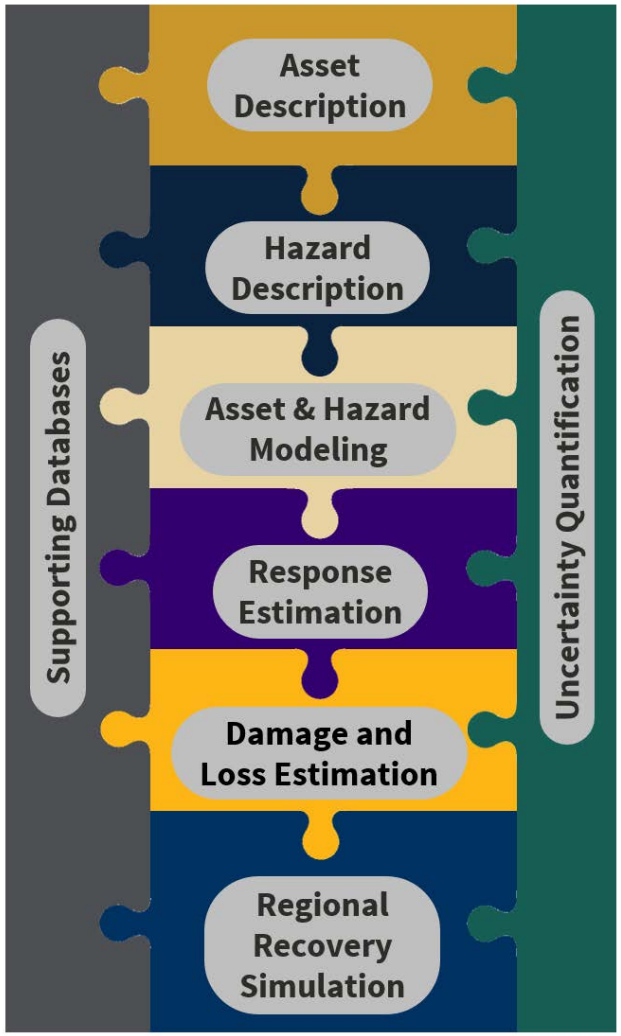
Application Framework & Research Apps



describe the region
specify characteristics of buildings and infrastructure in t

describe the hazard
specify the regional distribut

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NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

for each random regi
propagate uncertain characteristics

for each asset in the region:

describe the asset
create stochastic models for response, damage, and loss estimation

CWE
EE

describe the event at the site
specify hazard-consistent loads for response estimation

for each random asset-event sample:
propagate uncertainties in asset models and event description

FEM

estimate asset response to the event
describe the response with engineering demand parameters

estimate asset damage and its consequences
prepare a stochastic description of damage and loss for the asset

PBE

describe regional damage and direct losses
aggregate damages and losses in the region considering dependencies

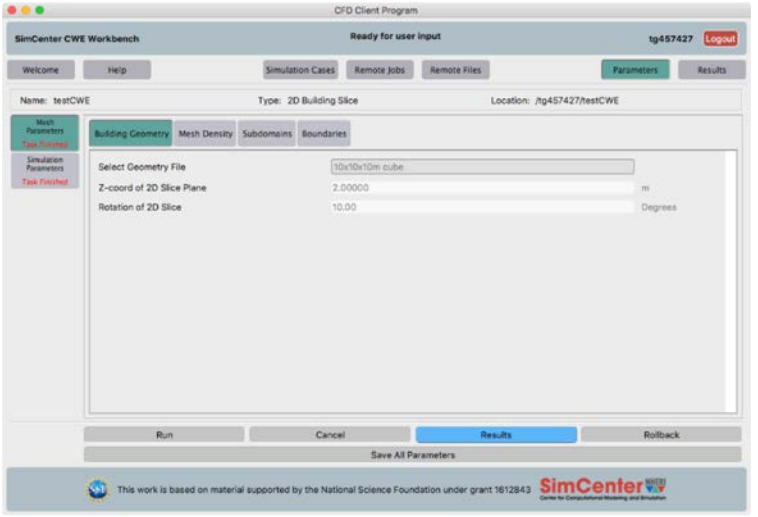
estimate indirect regional consequences
describe regional consequences of infrastructure- and social disruption

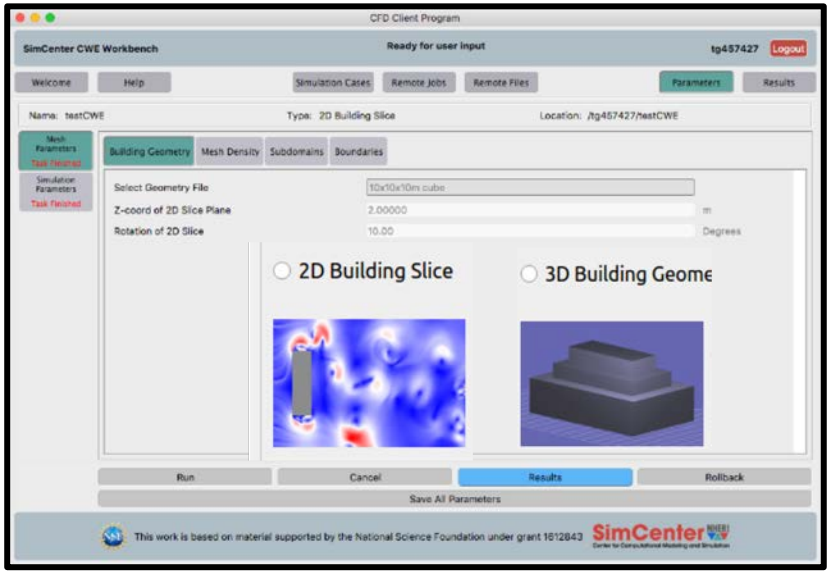
simulate regional recovery
estimate the temporal and spatial variation in the recovery of communities

Computational Wind Engineering

Application:

- Interface to OpenFOAM (CFD)
- User Inputs Building Information
- User Selects from different loading options & Inputs Parameters
- User Specifies RV distributions
- The tool when run will auto generate the analysis model, obtain wind forces in building, run a set of deterministic simulations on DesignSafe.
- User selects run & views different output results.





Release Dates:

- Version 1.0 (June 2018): Wind Flow around Bluff Bodies
- Version 2.0 (2019): Wind Forces on Building
- Version 3.0 (2020): Multi-fidelity Modeling & UQ

EE-UQ Application

- Quantifies uncertainty in building response subjected to an earthquake

Application:

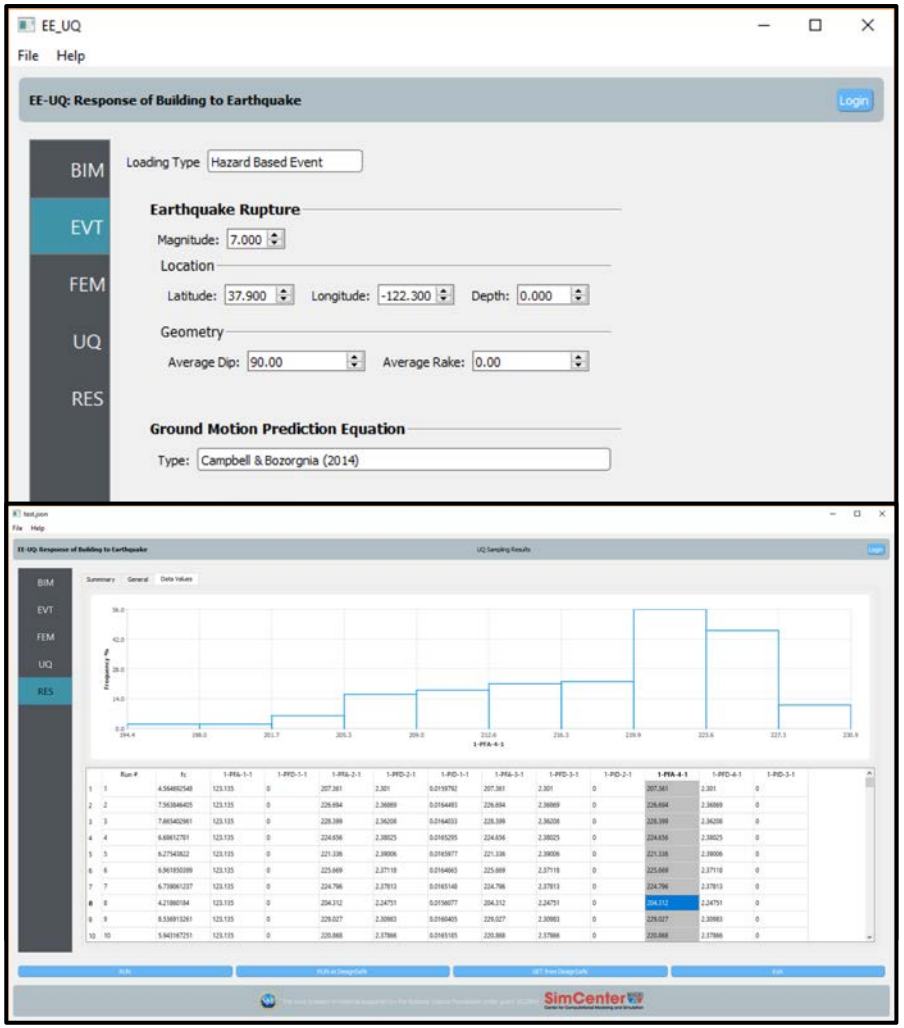
- **Inputs:** Building information, earthquake event & uncertainty specification
- **Outputs:** Uncertainty measures of building response

Release Dates:

- **V1.0 (2018)** Uniform Excitation
- **V2.0 (2019)** Rock Outcrop motions + Expert System
- **V3.0 (2020)** Soil Box around Building + Machine Learning

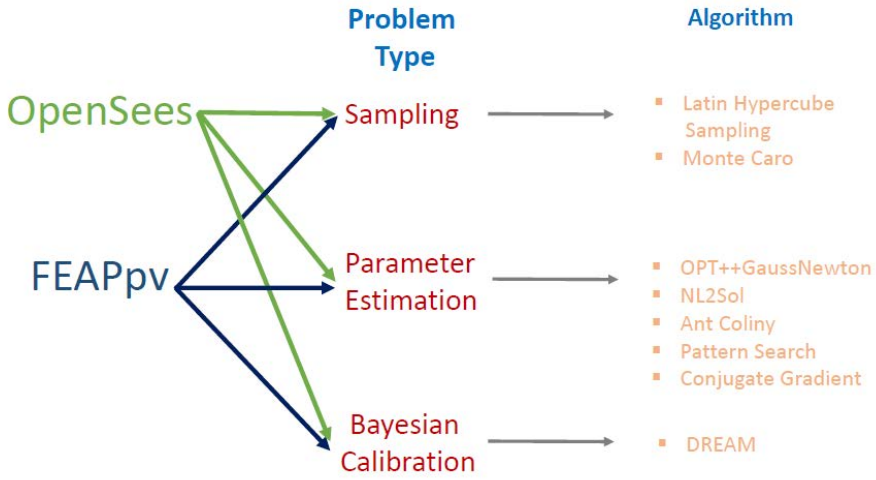
Research Opportunities:

- Finite element modeling
- Hazard characterization
- UQ including surrogate model generation
- Datasets for model calibration



uqFEM Application

- Integrates Simulation Applications with UQ Engine(s)



Application:

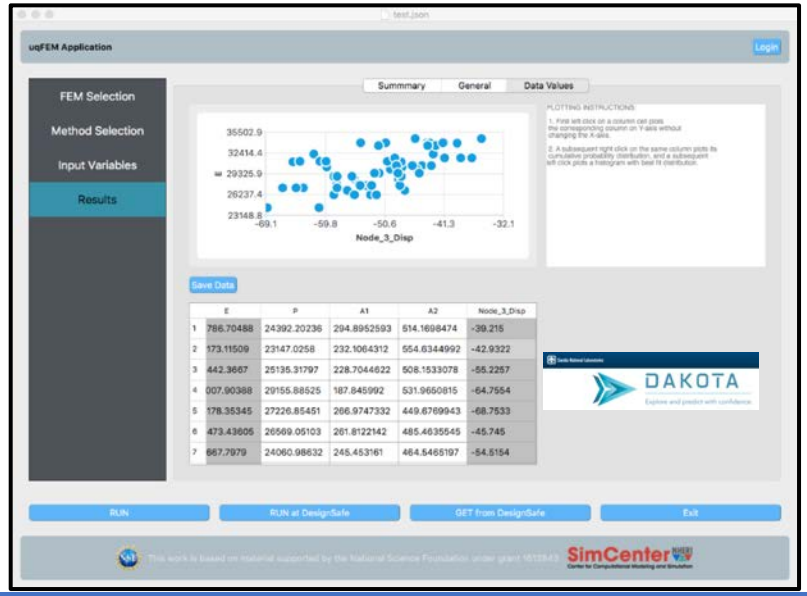
- **Inputs:** FEM model, input uncertainty specification, UQ method & post-processing script
- **Outputs:** Depends on problem type and post-processing (e.g. Uncertainty measures of outputs)

Release Dates:

- **V1.0 (June 2018)** Support for OpenSees, FEAP and Dakota
- **V2.0 (2019)** – UQ Engines other than DAKOTA (e.g. UQpy)

Research Opportunities:

- Surrogate Modeling
- Model Calibration



PBE Application

- Probabilistic damage & loss calculations of a building subjected to a natural hazard

Application:

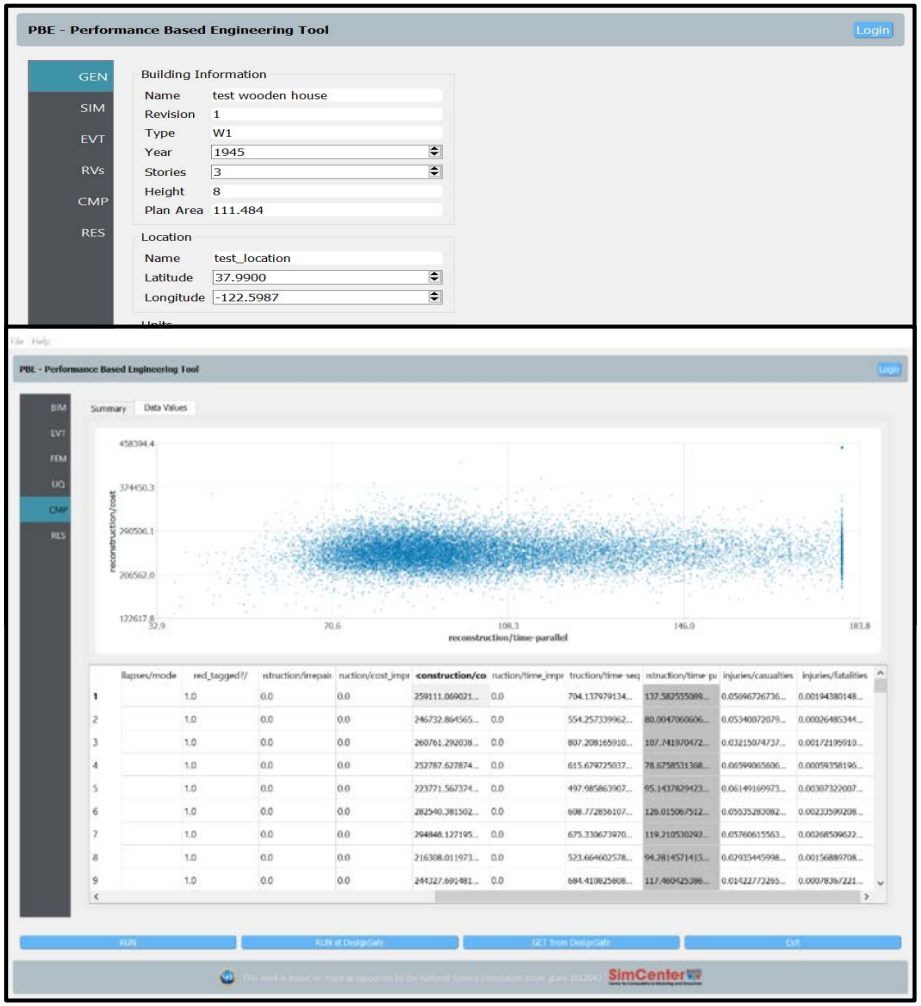
- **Inputs:**
  Building & structural information,
  Hazard characterization,
  Contents,
  Damage & loss functions, e.g. P58, Hazus or user-defined.
- **Outputs:** Damage, loss, and consequences

Release Dates:

- **V1.0 (Oct 2018)** Earthquake
- **V2.0 (2020)** Other Hazards

Research Opportunities:

- Damage & loss calculations
- Validation of fragility and consequence functions



PELICUN

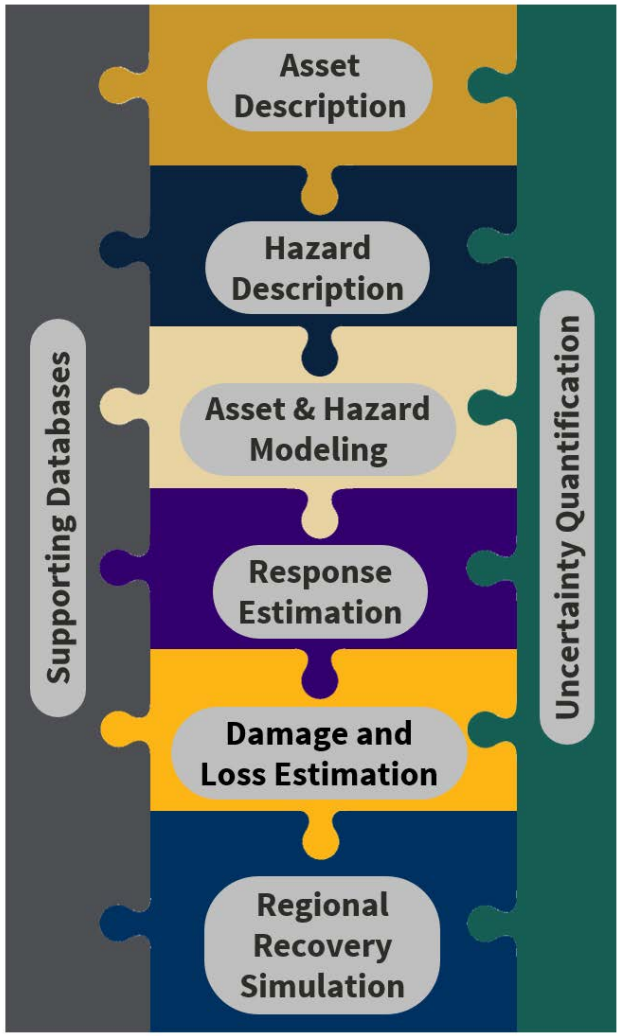
- Probabilistic estimation of losses, injuries and community resilience under natural disasters
- Hazard-agnostic loss-assessment library in python™
- Object-oriented and conceptually similar to what OpenSees is for FEM
- Open-source, transparent, cross-platform, easy to install and use

GitHub

python™ Package Index

Read the Docs

Application Framework & Research Apps



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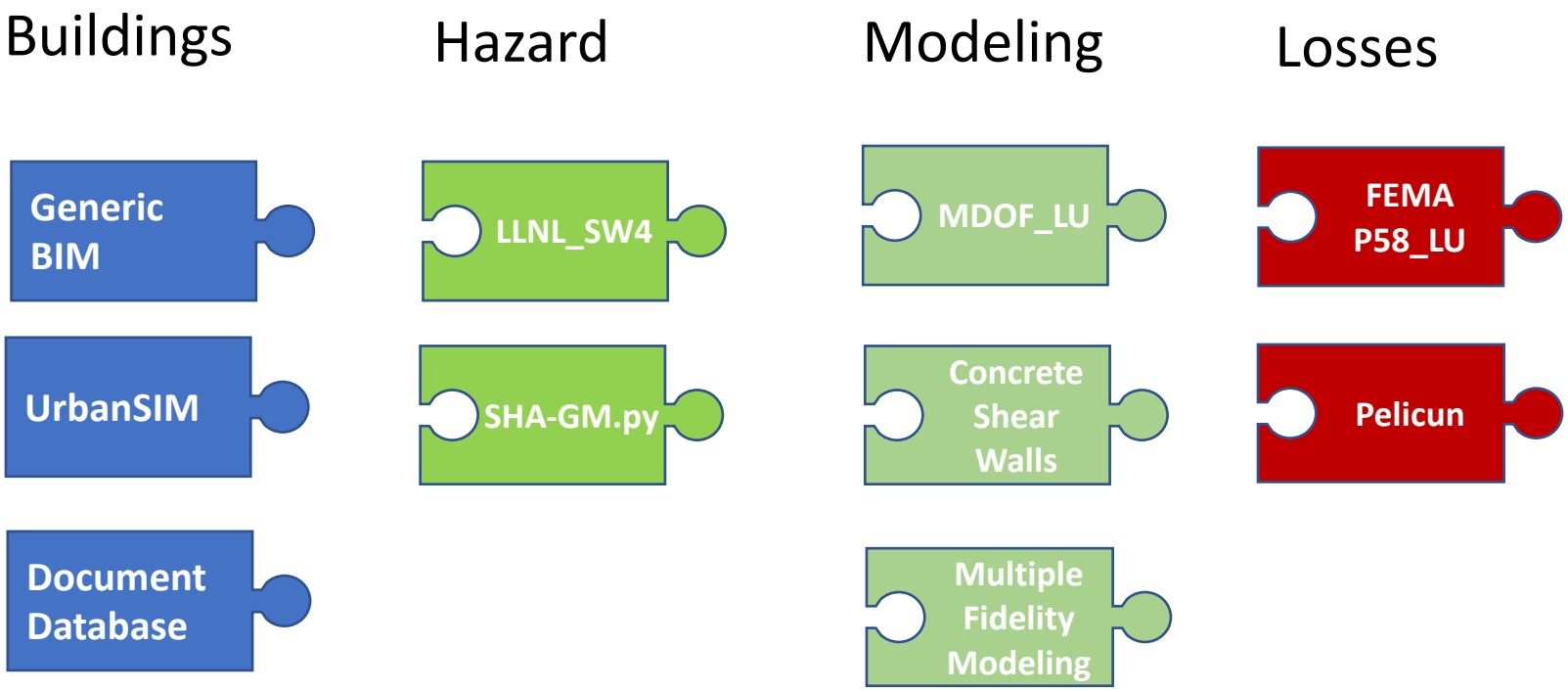
Regional Simulation

Applications

The Application Framework provides applications with standard interfaces

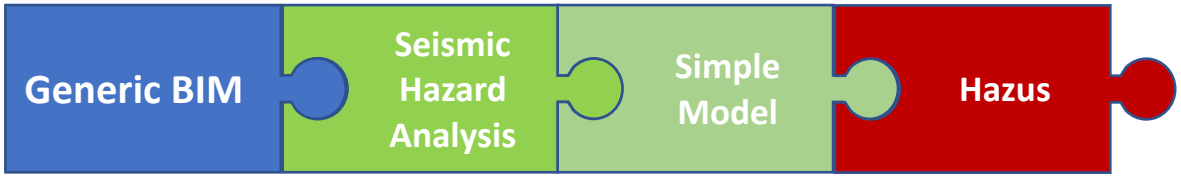


Regional Simulation

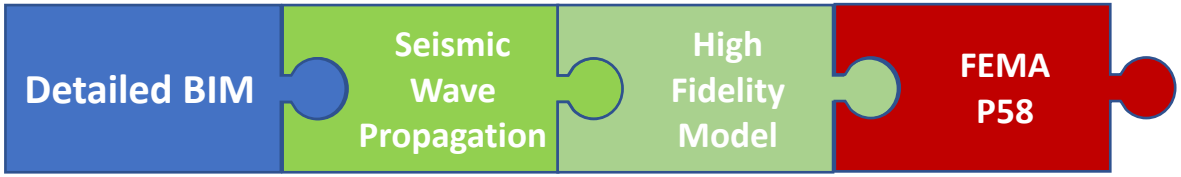
Configuration

Chain a set of applications into a building workflow

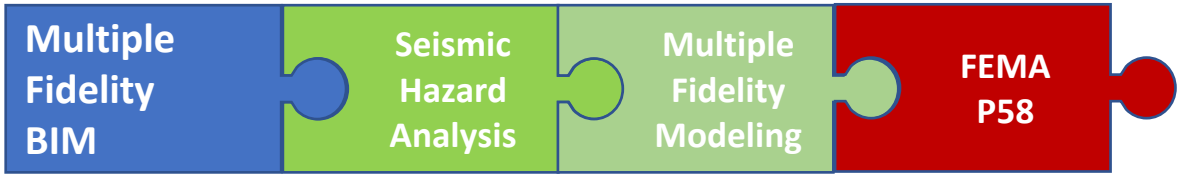
Low Fidelity Configuration



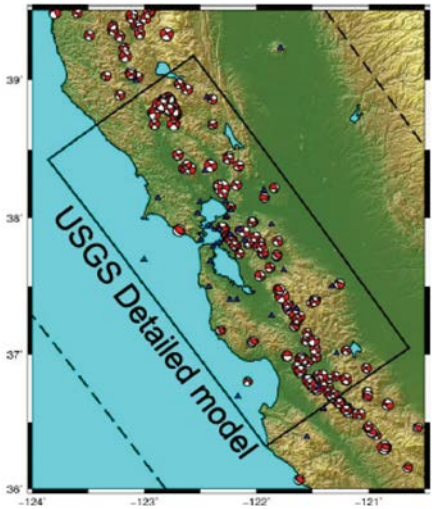
High Fidelity Configuration



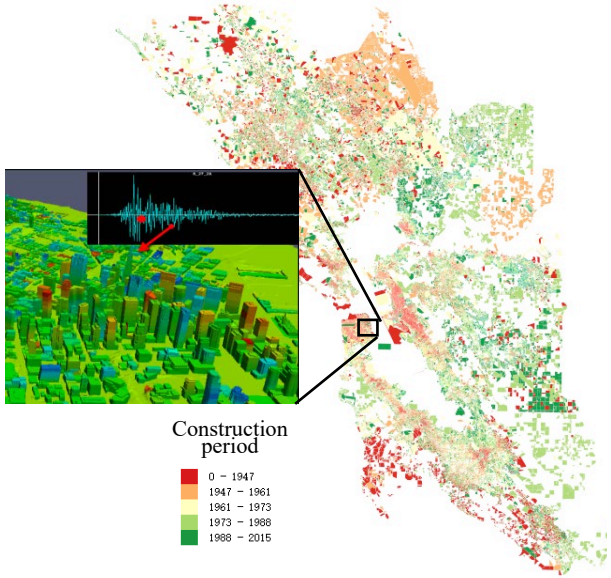
Multiple Fidelity Configuration



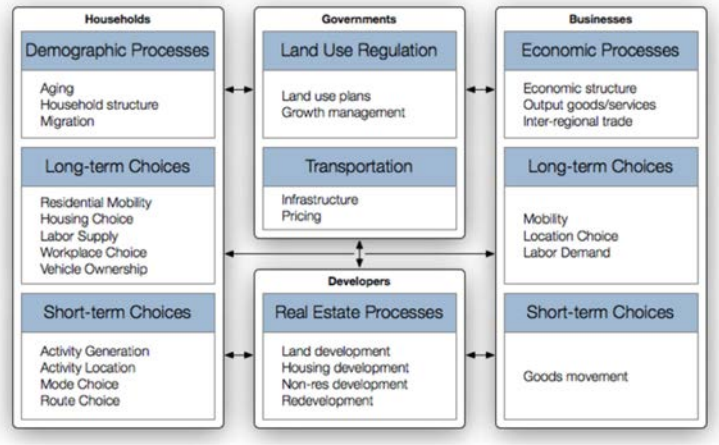
Regional End-to-End EQ Testbed



M7.0 Hayward Fault



1.8 million buildings in SF Bay Area

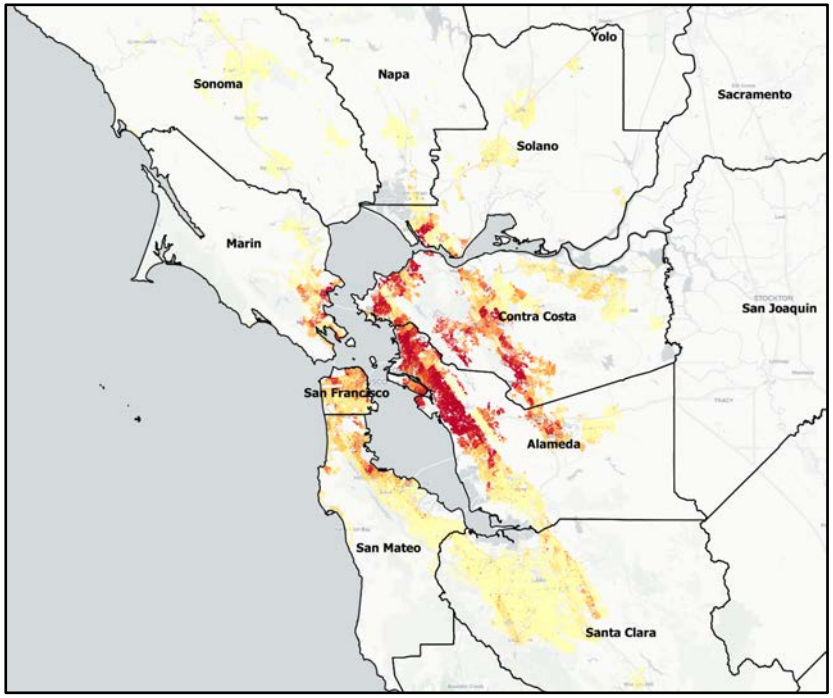


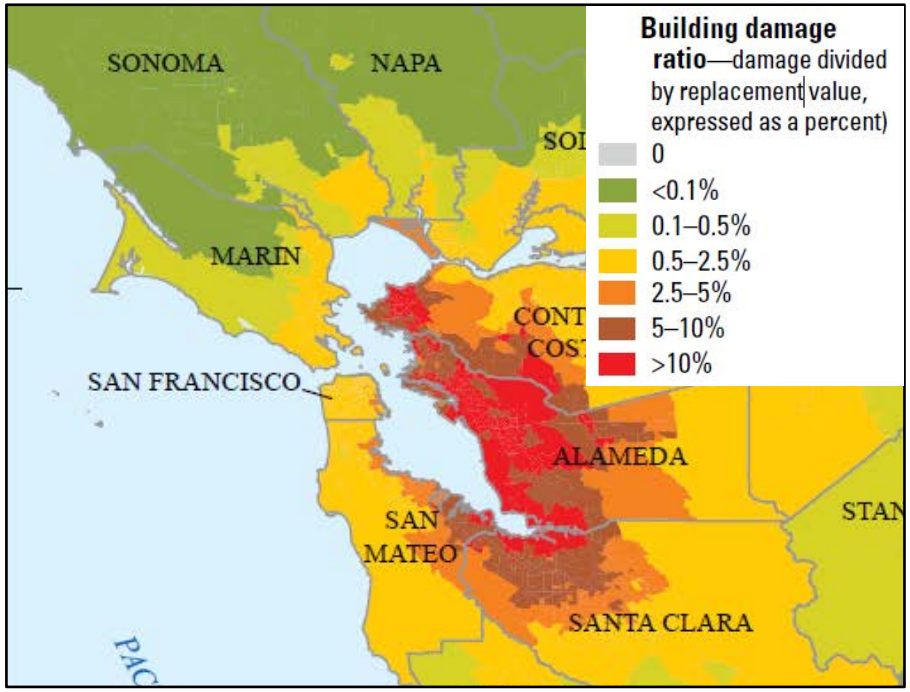
Policy/Planning: *building losses & downtime in 2010 and 2040*

Objective: *develop/exercise a computational workflow for a significant simulation that can engage broad NEHRI community*

Ground Motions: 3D simulation, GM's at 2km grid (Rodgers, Pitarka & Petersson)
Building Inventory: UrbanSim and DataSF Portal; geometry, age, occupancy
Building Analyses: OpenSees, simplified NL MDOF, FEMA P58 (w/Cheng & Lu, Tsinghua)
Visualization: Q-GIS, UrbanSim
Interpretation: UrbanSim - urban growth, damage/loss, displaced occupants/population

Comparison of Building Damage





SimCenter Workflow

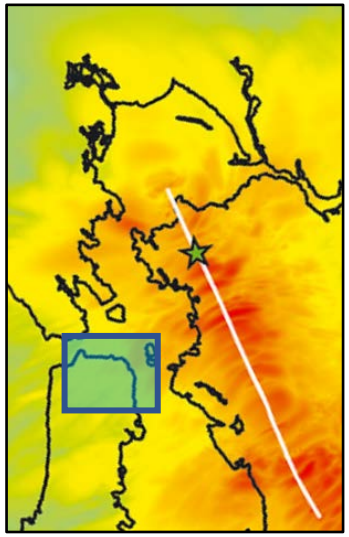
- *Red-tagged buildings 141,400*
- *Net buildings damage ratio 5.6%*

USGS HayWired

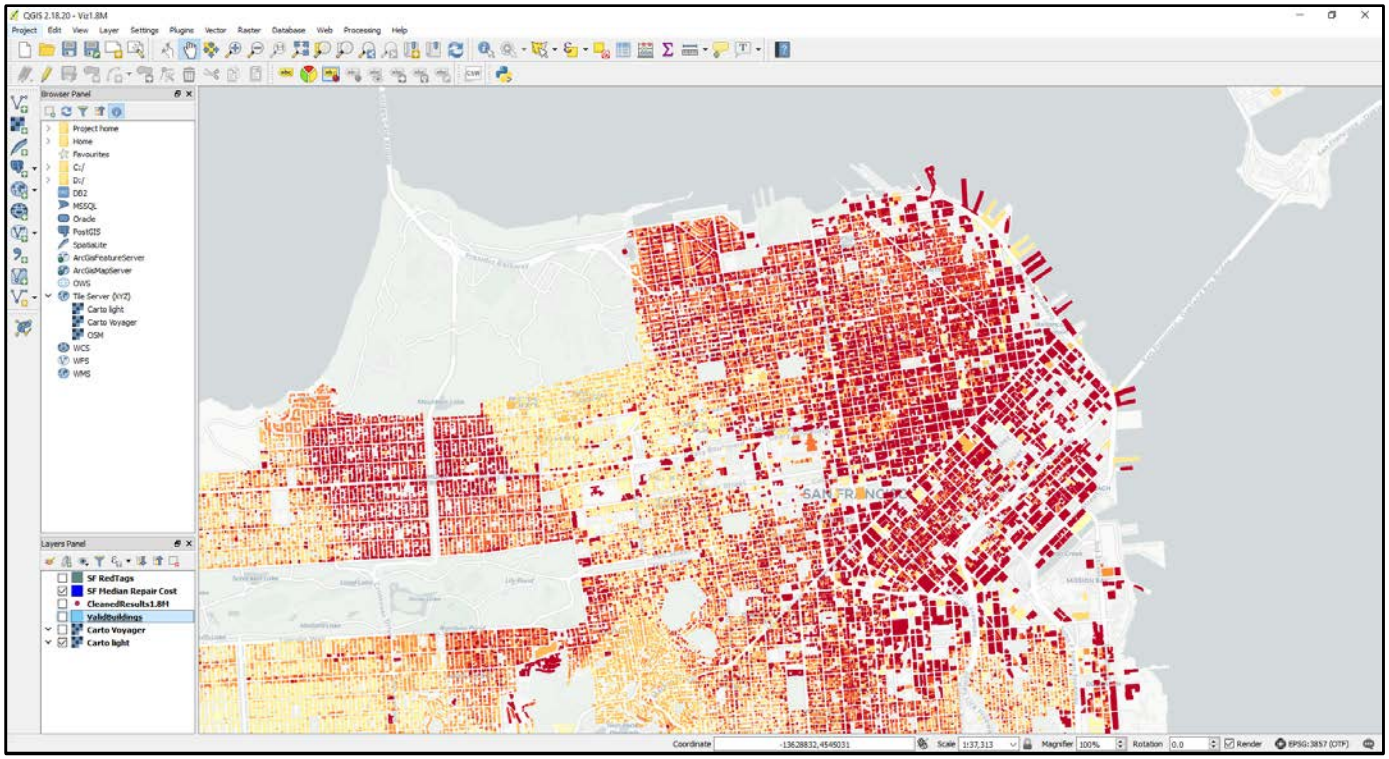
- *Red-tagged buildings 101,000*
- *Net buildings damage ratio 2.9%*

Regional Simulation

San Francisco Bay Area Testbed



M7.0 Hayward



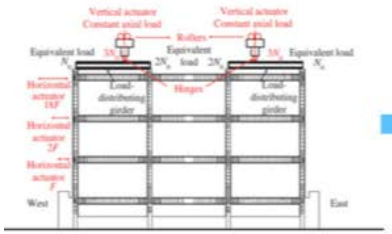
Building Inventory

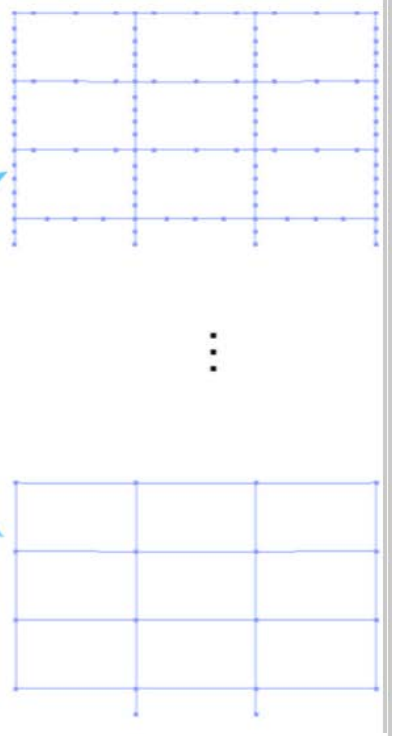
Hazard Consequences

Opportunities to evaluate planning and policy decisions (land use, retrofit, etc.)

AI Applications: BIM to SAM

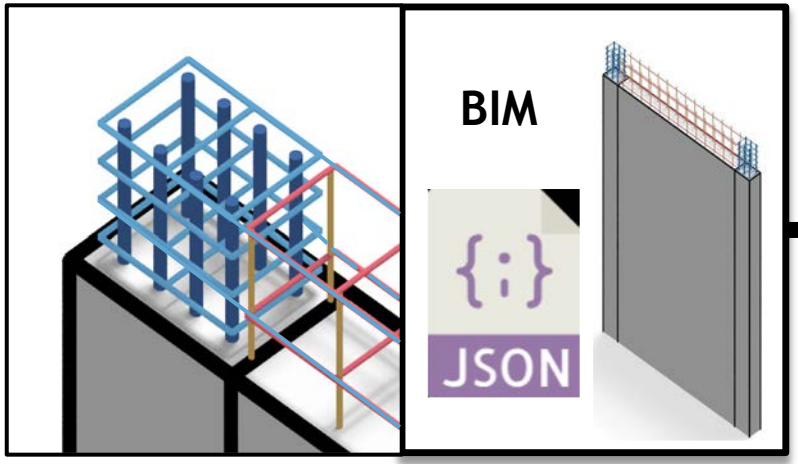
Structural Engineers

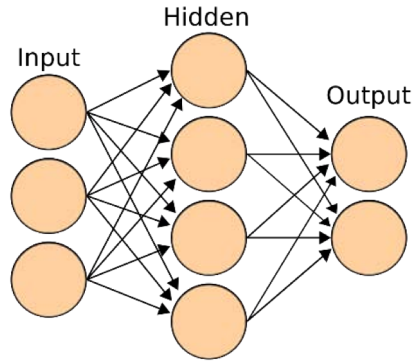


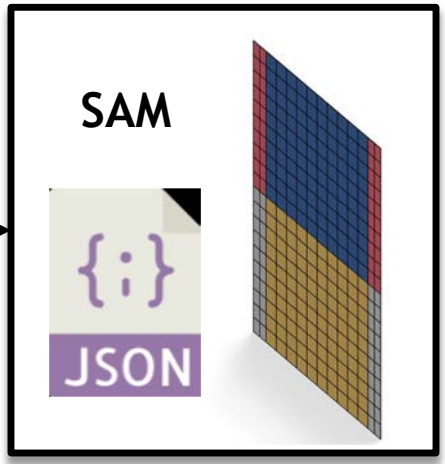


Future Virtual Engineer

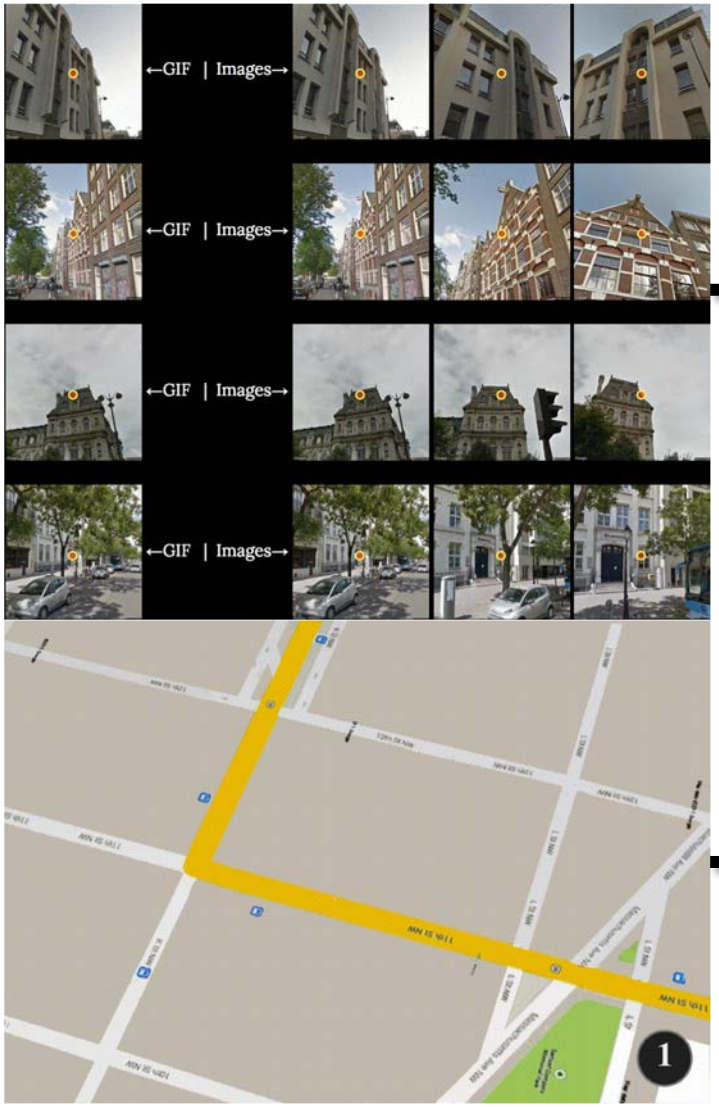
Dataset: 87 walls
Training: 98% accurate
Testing: 93% accurate







In the Future: AI for Data to BIM



Future Virtual Engineer

images

Machine Learning

- Height
- Construction type
- Number of stories
- ……

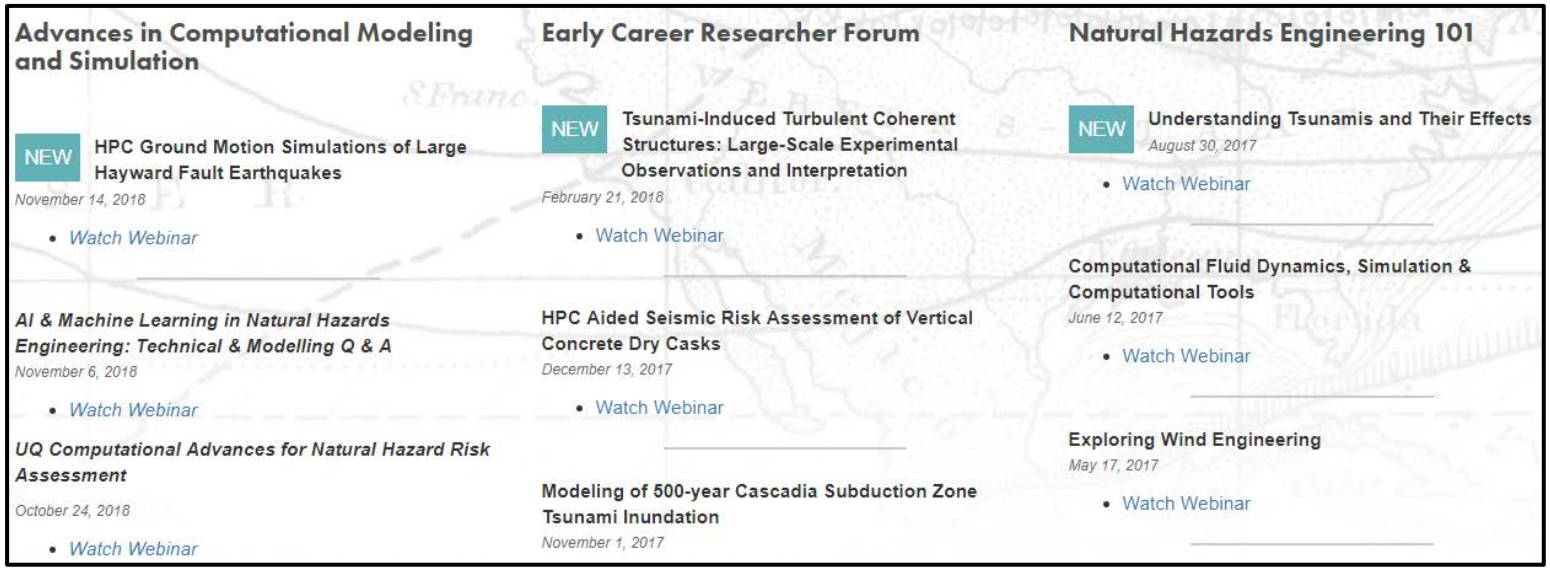
building properties

camera pose
3D models

- SF building footprints: 117023 buildings, height, GPS coordinates, …
- SF building permits: 1+ million records, #stories, construction types, GPS coordinates, …
- SF land use: 115,468 records, land use types, year built, GPS coordinates, …

ECO Activities

- SimCenter Online Webinars



- NHERI Summer Institute (June 5-7)
- Subscribe to SimCenter news and join Slack channels
  - https://simcenter.designsafe-ci.org/join-community/
- Letters of Support and collaboration questions
  - https://simcenter.designsafe-ci.org/about/collaborate/

ECO Activities

- SimCenter Tool Training Workshop (Summer 2019)

- Summer Programming Bootcamp (Summer 2019)

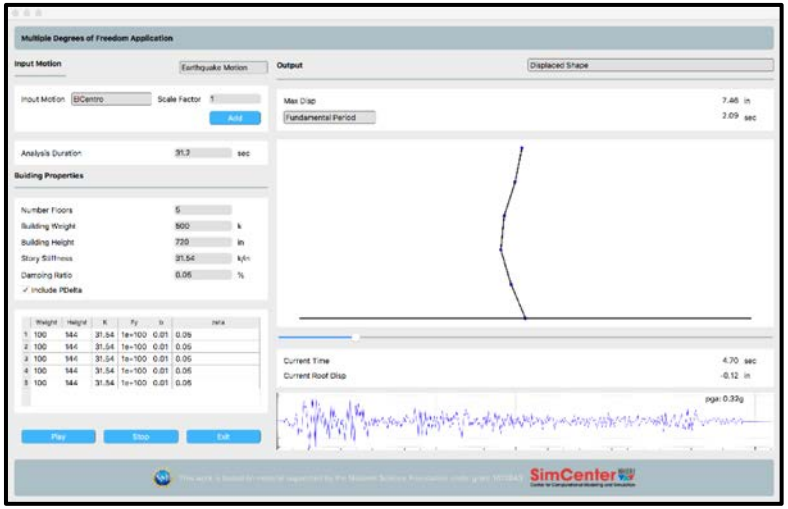
- Summer REU Program

https://www.designsafe-ci.org/learning-center/reu/

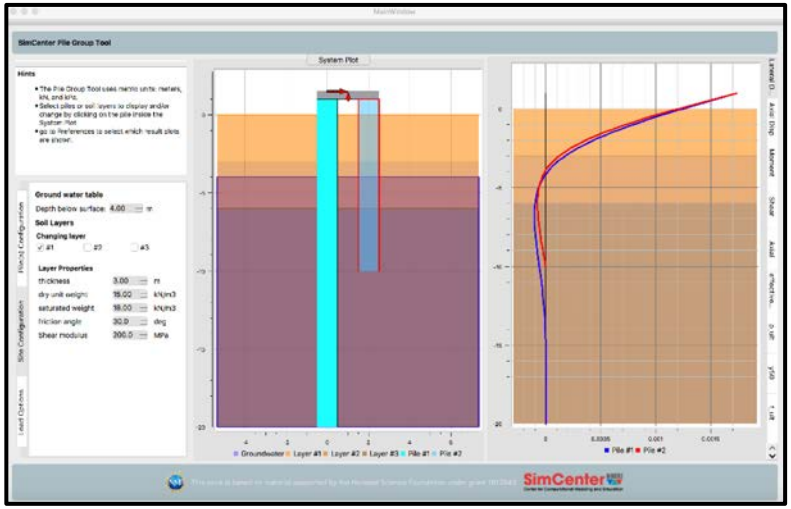
Applications due February 1, 2019

Educational Applications

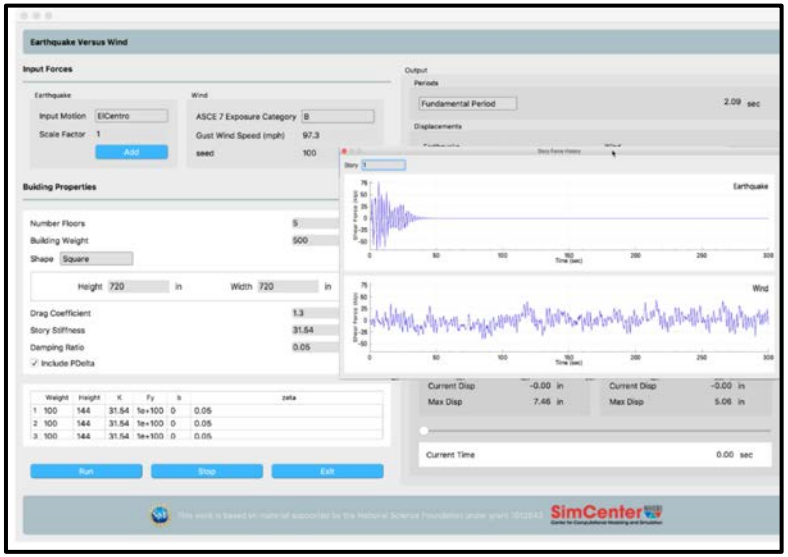
MDOF



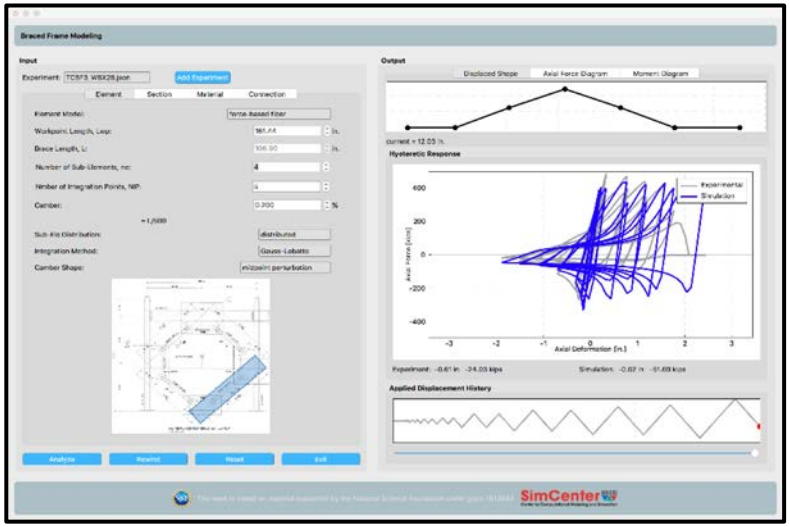
PGT



EvW



BFM



Acknowledgments

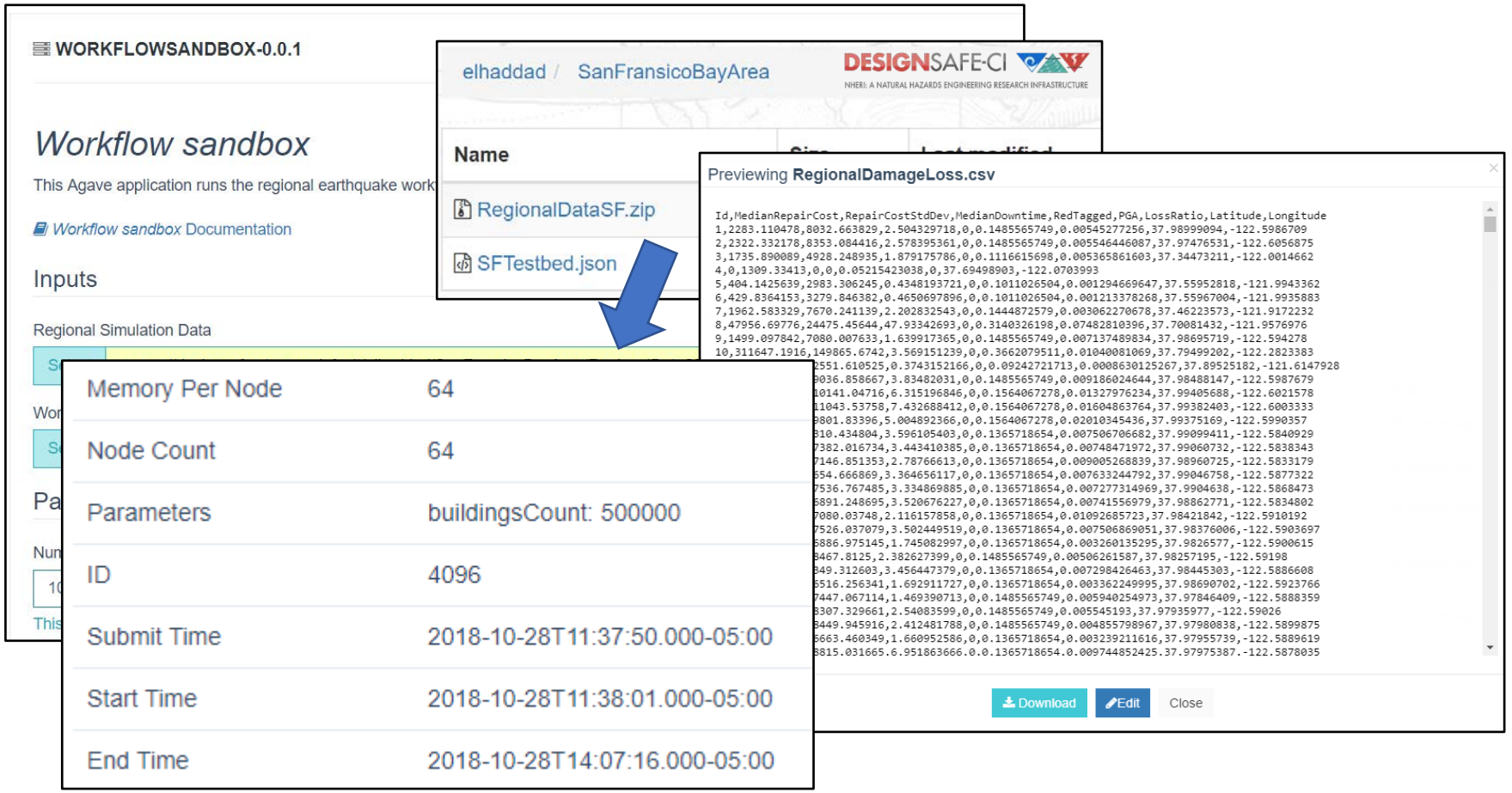
- The SimCenter is supported by the **National Science Foundation** under awards 1612843. Any statements in this presentation are those of the presenter and do not necessary represent the views of the National Science Foundation.
- **Dr. Arthur Rodgers and coworkers** at the Lawrence Livermore and Lawrence Berkeley National Laboratories for providing ground motion data incorporated into the San Francisco Bay Area testbed simulations.
- **Prof. Xinzheng Lu and his research group** for contributing structural modeling and FEMA P-58 building loss implementations.
- **OpenSHA**, a library developed by **SCEC** for seismic hazard analysis.
- **Steve Mahin**'s vision for the center.

Regional Simulation Demo

Wael Elhaddad

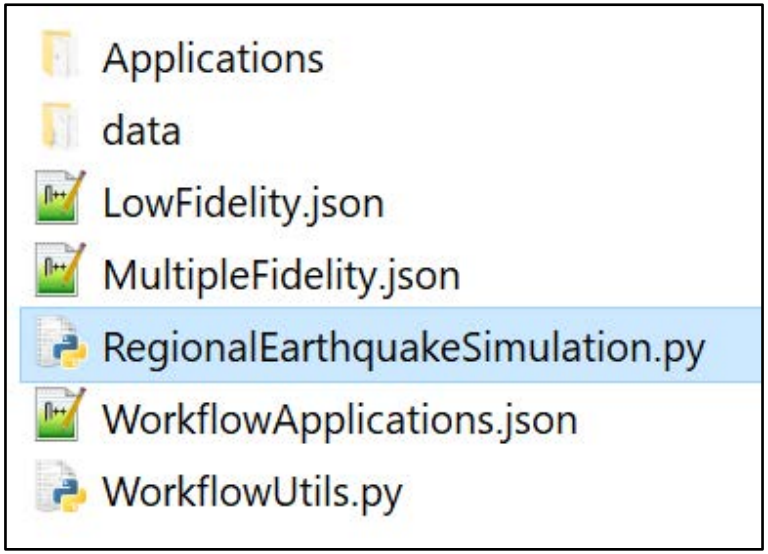
Regional Simulation

Running a regional simulation using DesignSafe

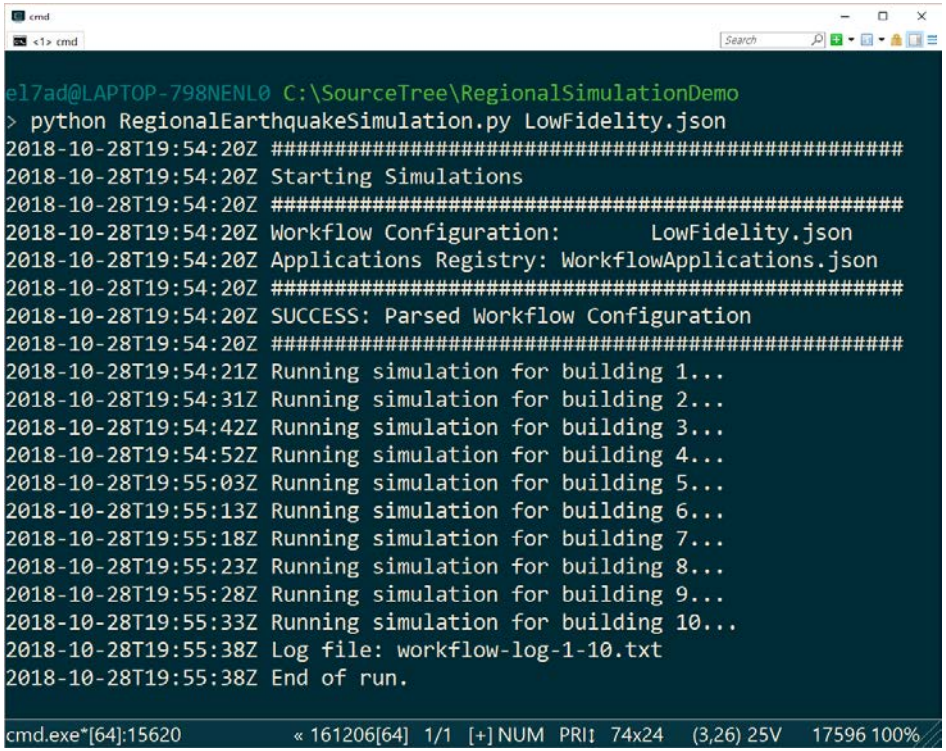


Regional Simulation

Running a regional simulation using on Local Computer



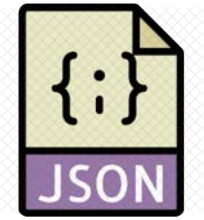
Applications,
Sample Data
& Examples



Runs Locally as a
console application

Regional Simulation

Configuration File

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        "Modeling": {…
        },
        "EDP": {…
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        "Simulation": {…
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        "UQ-Simulation": {…
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        "Damage&Loss": {…
        }
    }
}
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"Events": [
    {
        "EventClassification": "Earthquake",
        "EventApplication": "LLNL-SW4",
        "ApplicationData": {
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            "filenameHFmeta":"../build/data/HFmeta"
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"Damage&Loss": {
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    "ApplicationData": {
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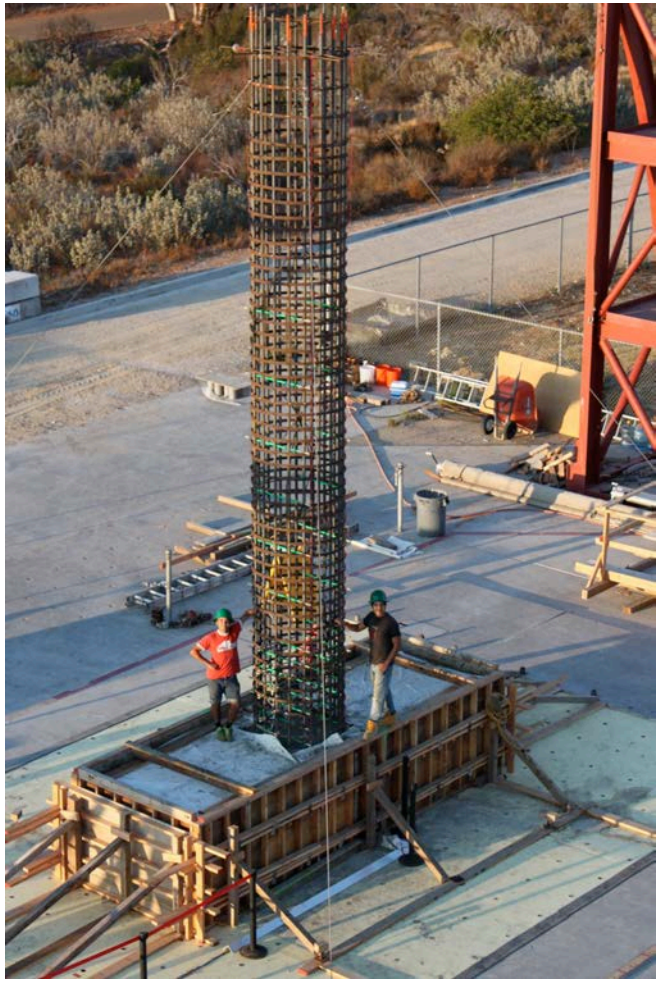
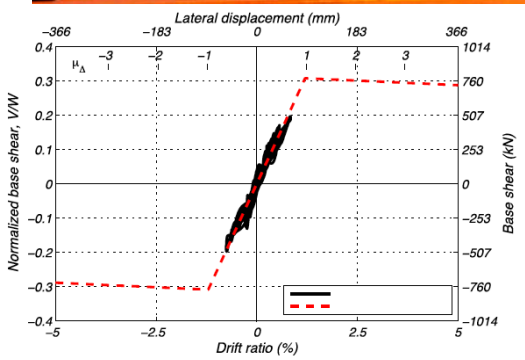
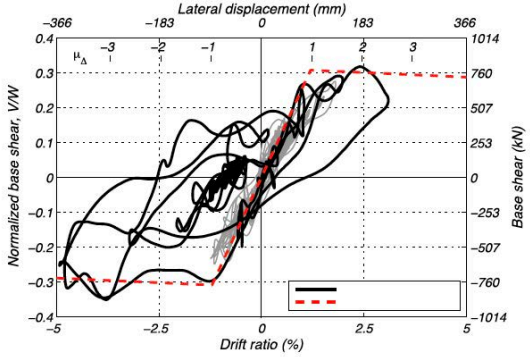
        "pathCurves":"../build/data/ATCCurves/",
        "pathNormative":"../build/data/normative/"
    }
}
```

EE-UQ DEMO




SKANSKA


Lateral displacement (mm)
−366
−183
0
183
366
μΔ
−3
−2
−1
1
2
3
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
1014
760
507
253
0
−253
−507
−760
−1014
Normalized base shear, V/W
Base shear (kN)
−5
−2.5
0
2.5
5
Drift ratio (%)


Lateral displacement (mm)
−366
−183
0
183
366
μΔ
−3
−2
−1
1
2
3
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
1014
760
507
253
0
−253
−507
−760
−1014
Normalized base shear, V/W
Base shear (kN)
−5
−2.5
0
2.5
5
Drift ratio (%)

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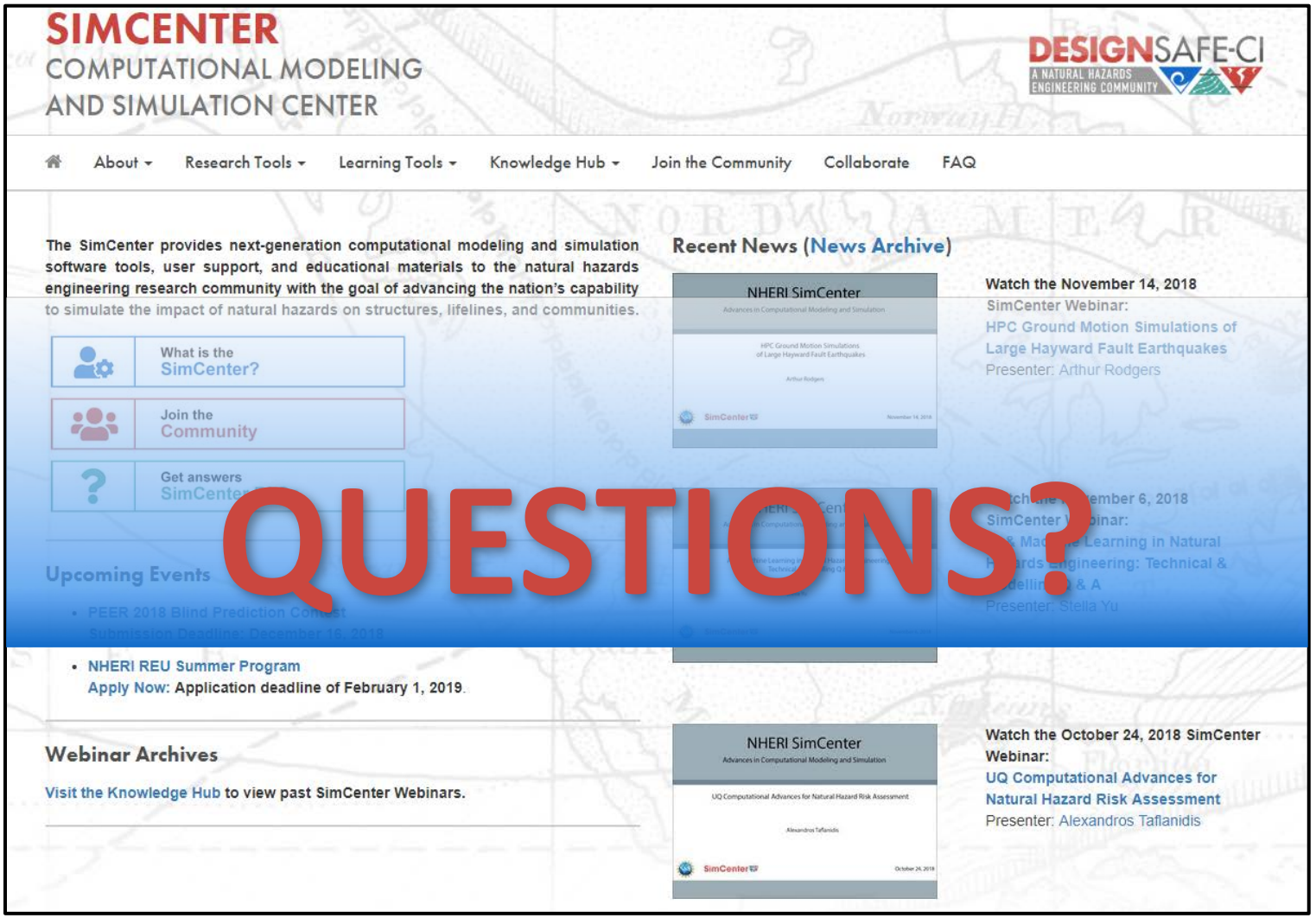

SimCenter Research Tools
https://simcenter.designsafe-ci.org/research-tools

Software Source Codes and Contributions
https://github.com/NHERI-SimCenter