



# An Overview of the NHERI SimCenter

*Matthew Schoettler*

*Associate Director for Operations*

UC Berkeley

December 13-14, 2018



# Mission

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“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**

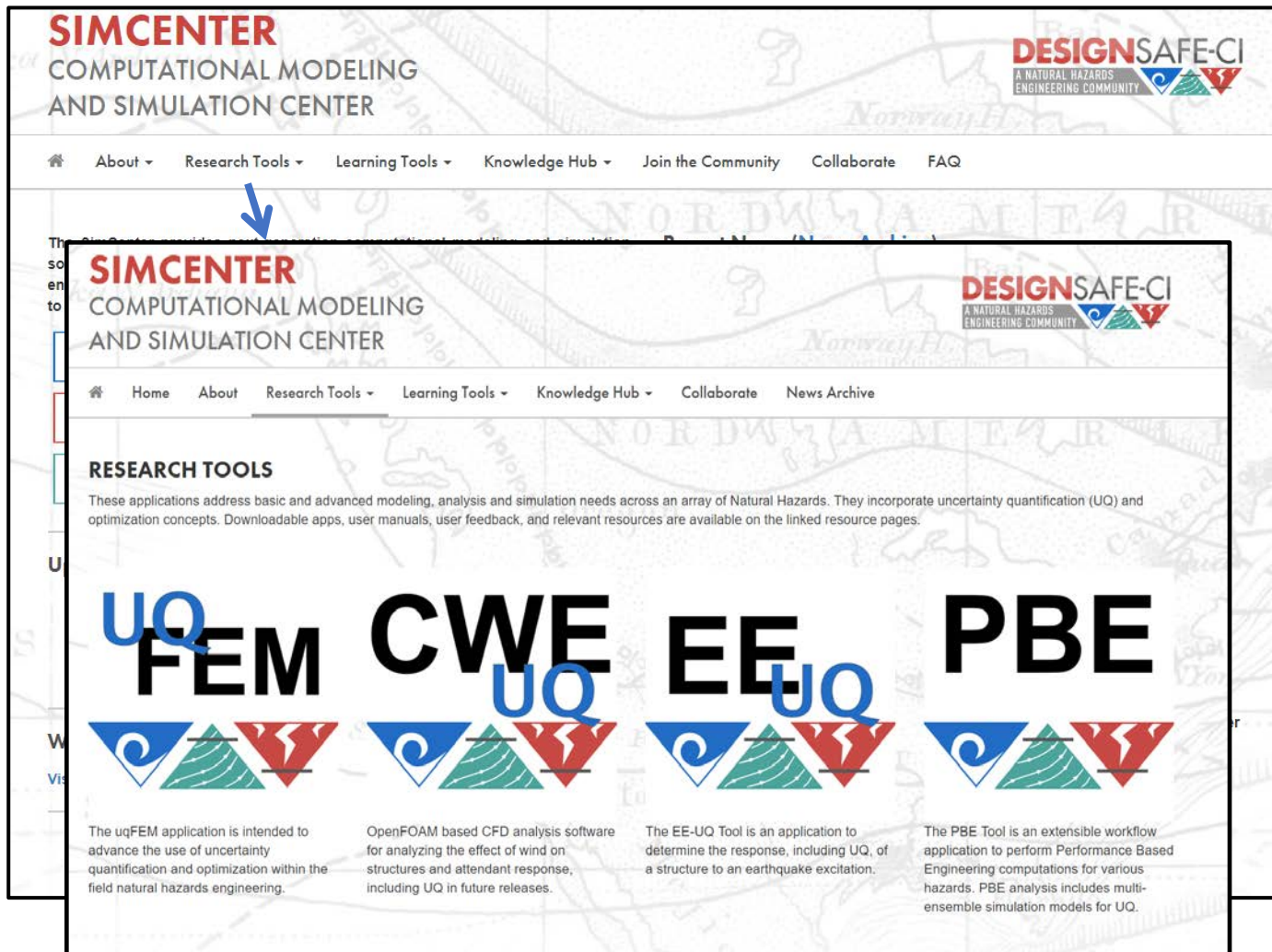
**Five year focus**

**Ten year vision**

# Goals

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- 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.



SimCenter Research Tools

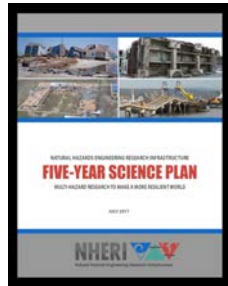
<https://simcenter.designsafe-ci.org/research-tools>

Software Source Codes and Contributions

<https://github.com/NHERI-SimCenter>

# Role in NHERI

## Network Coordination Office



## Experimental and RAPID facilities

[DesignSafe-ci.org](https://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



Back-end

SimCenter Application Framework

DESIGNSAFE-CI  
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



# Leadership Group

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**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.



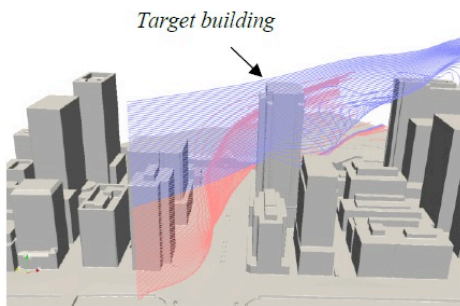
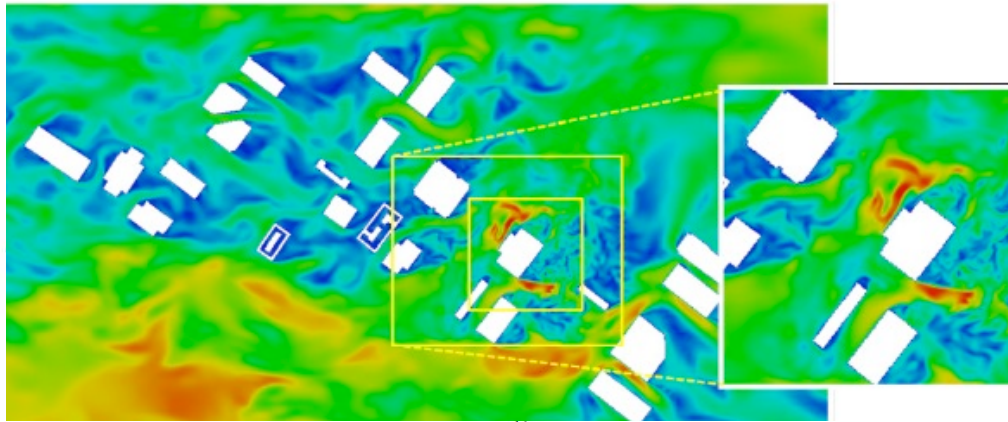
- Move to cloud-based HPC environment,
- Provide integrated “plug and play” capability to link multiple software apps together into workflows

# API Facilitated Application of Applications

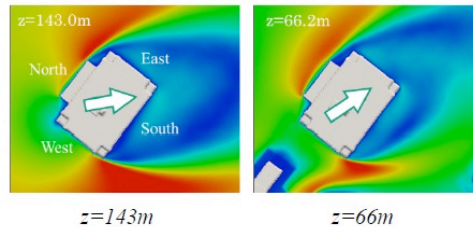
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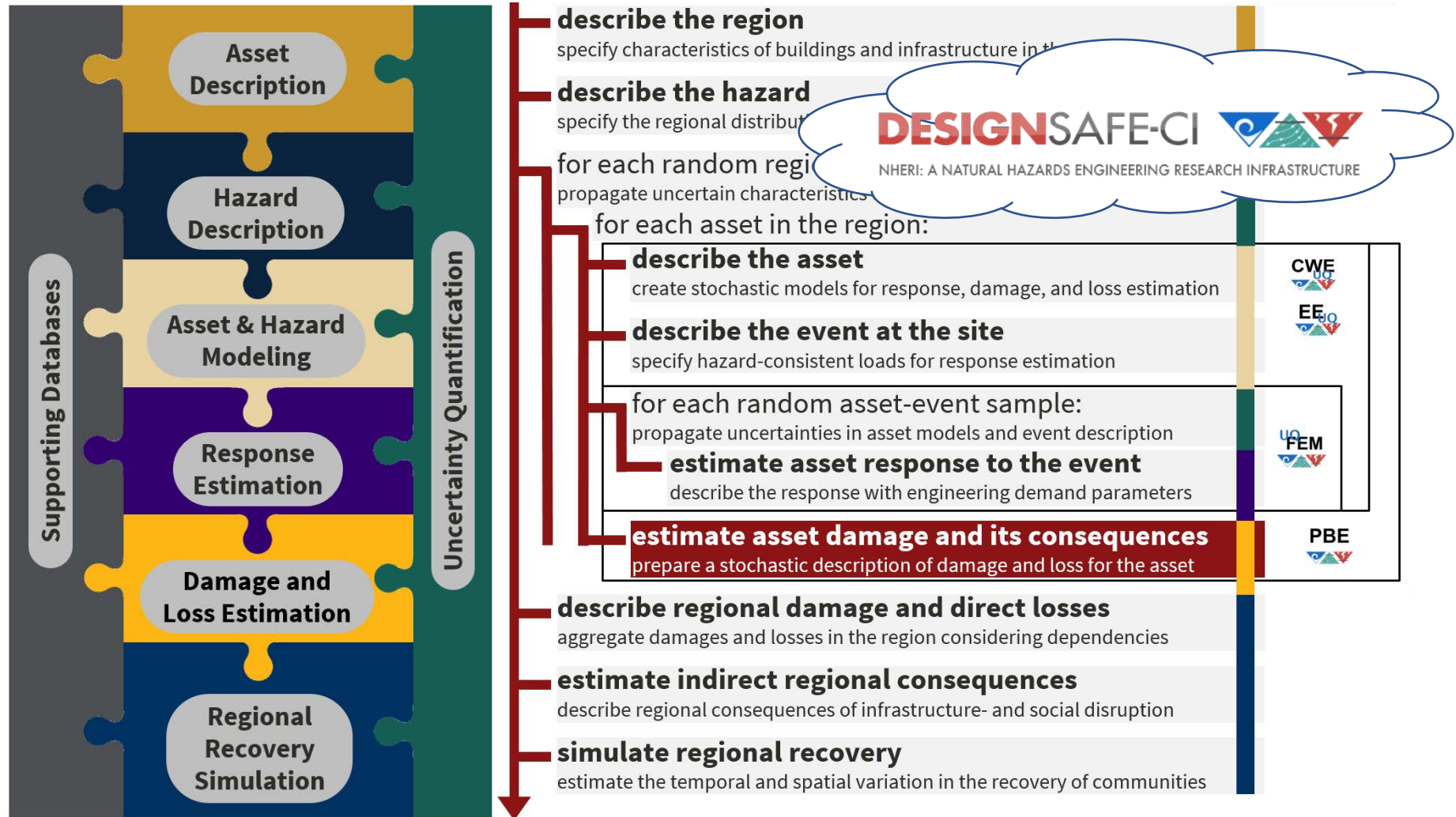
# Desired Outcome



T. Tamura Group TIT



# Application Framework & Research Apps

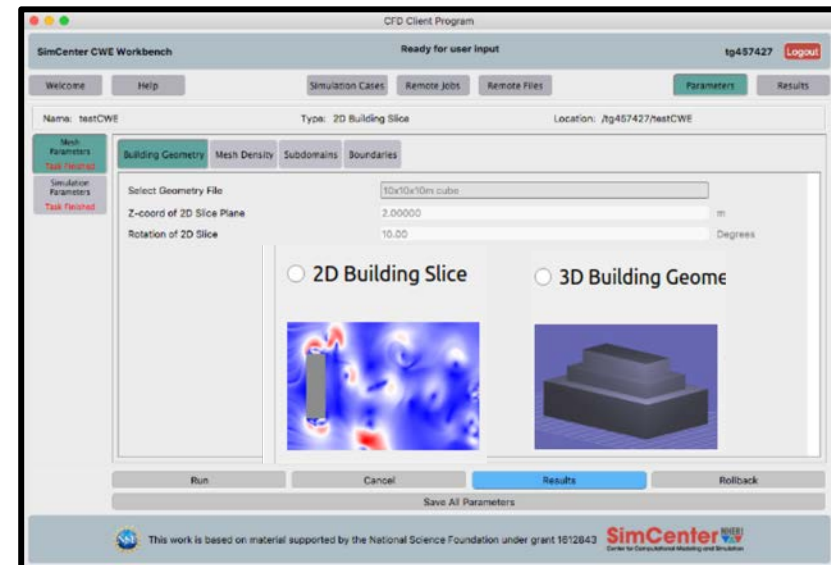
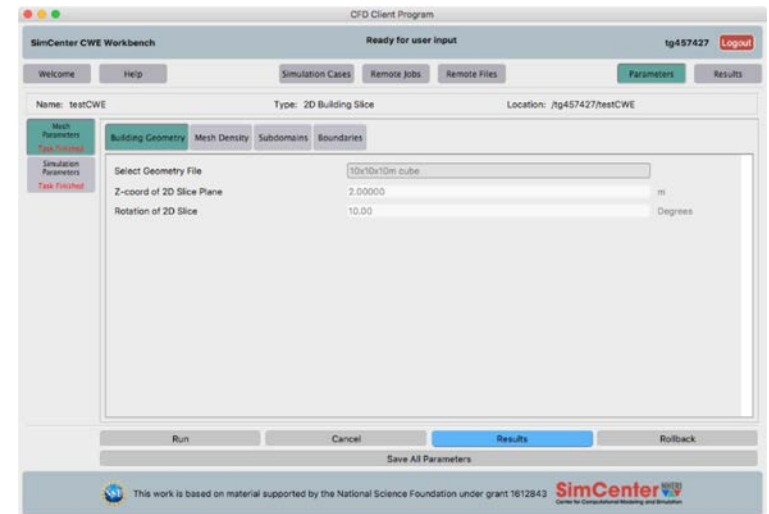


## Application:

- 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



- Quantifies uncertainty in building response subjected to an earthquake

## Application:

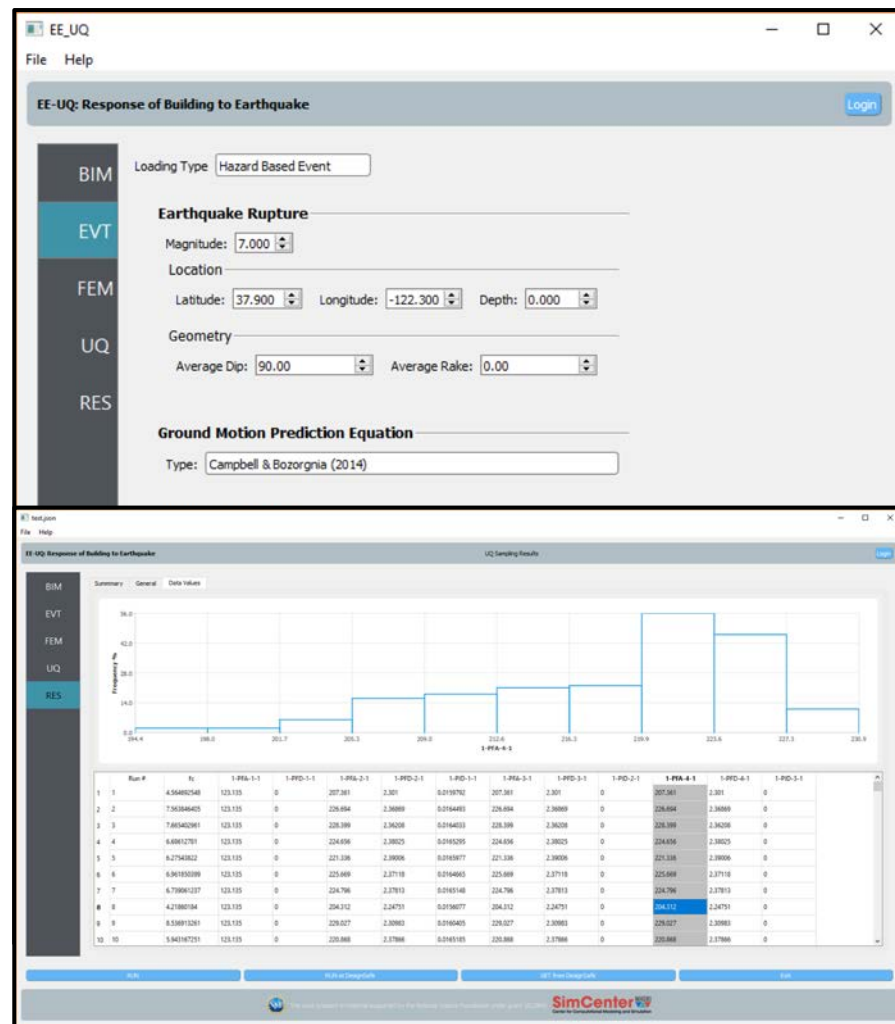
- Inputs:** Building information, earthquake event & uncertainty specification
- Outputs:** Uncertainty measures of building response

## 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



- Integrates Simulation Applications with UQ Engine(s)

## Application:

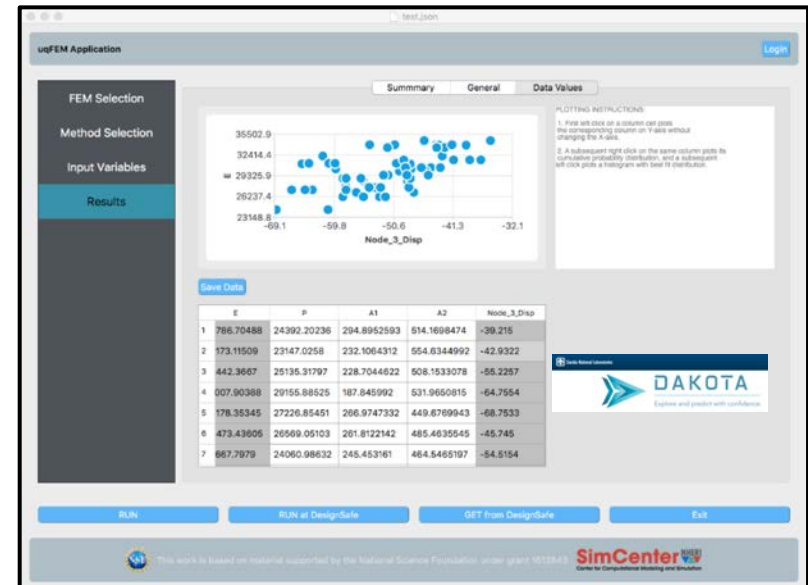
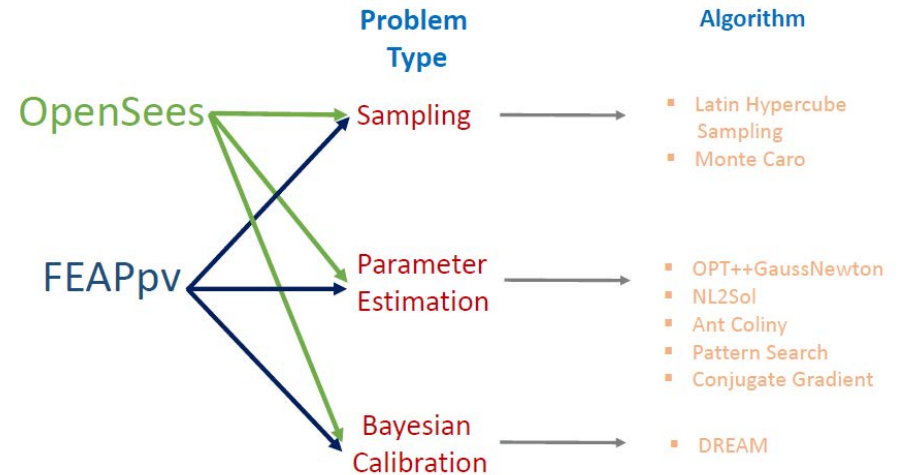
- Inputs:** FEM model, input uncertainty specification, UQ method & post-processing script
- Outputs:** Depends on problem type and post-processing (e.g. Uncertainty measures of outputs)

## 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



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

## Application:

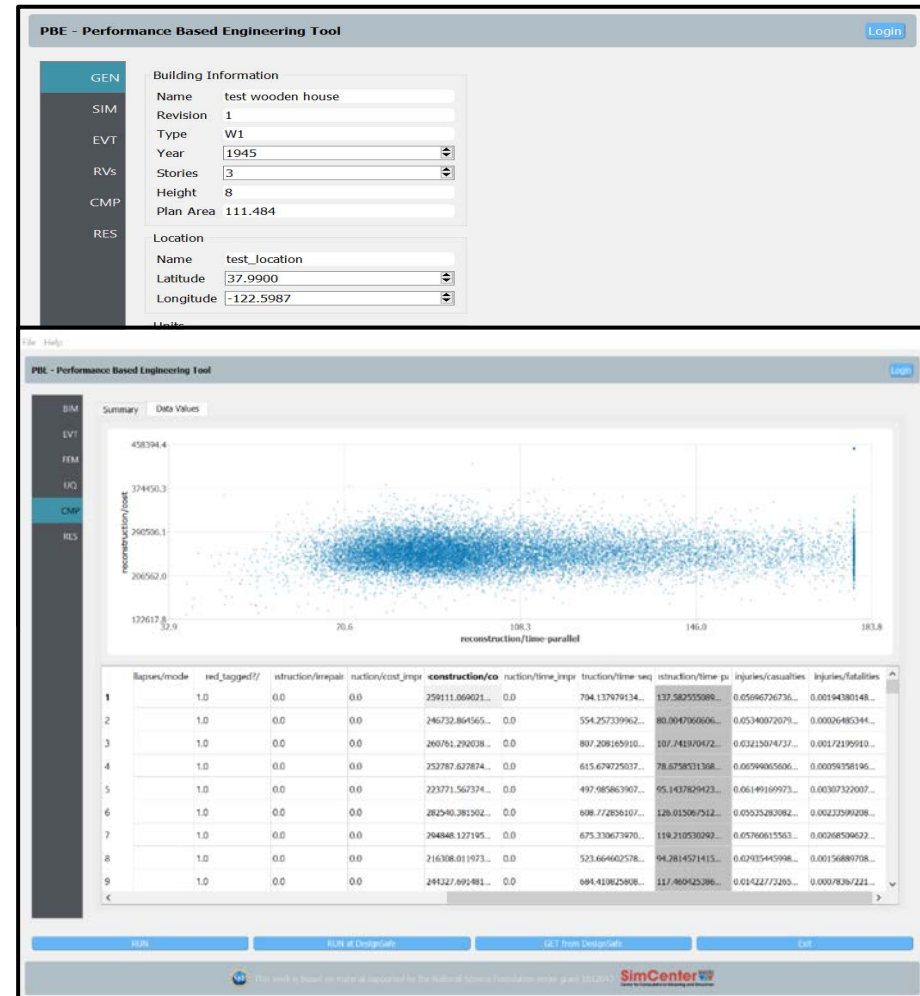
- Inputs:**
  - Building & structural information,
  - Hazard characterization,
  - Contents,
  - Damage & loss functions, e.g. P58, Hazus or user-defined.
- Outputs:** Damage, loss, and consequences

## Release Dates:


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

## Research Opportunities:

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

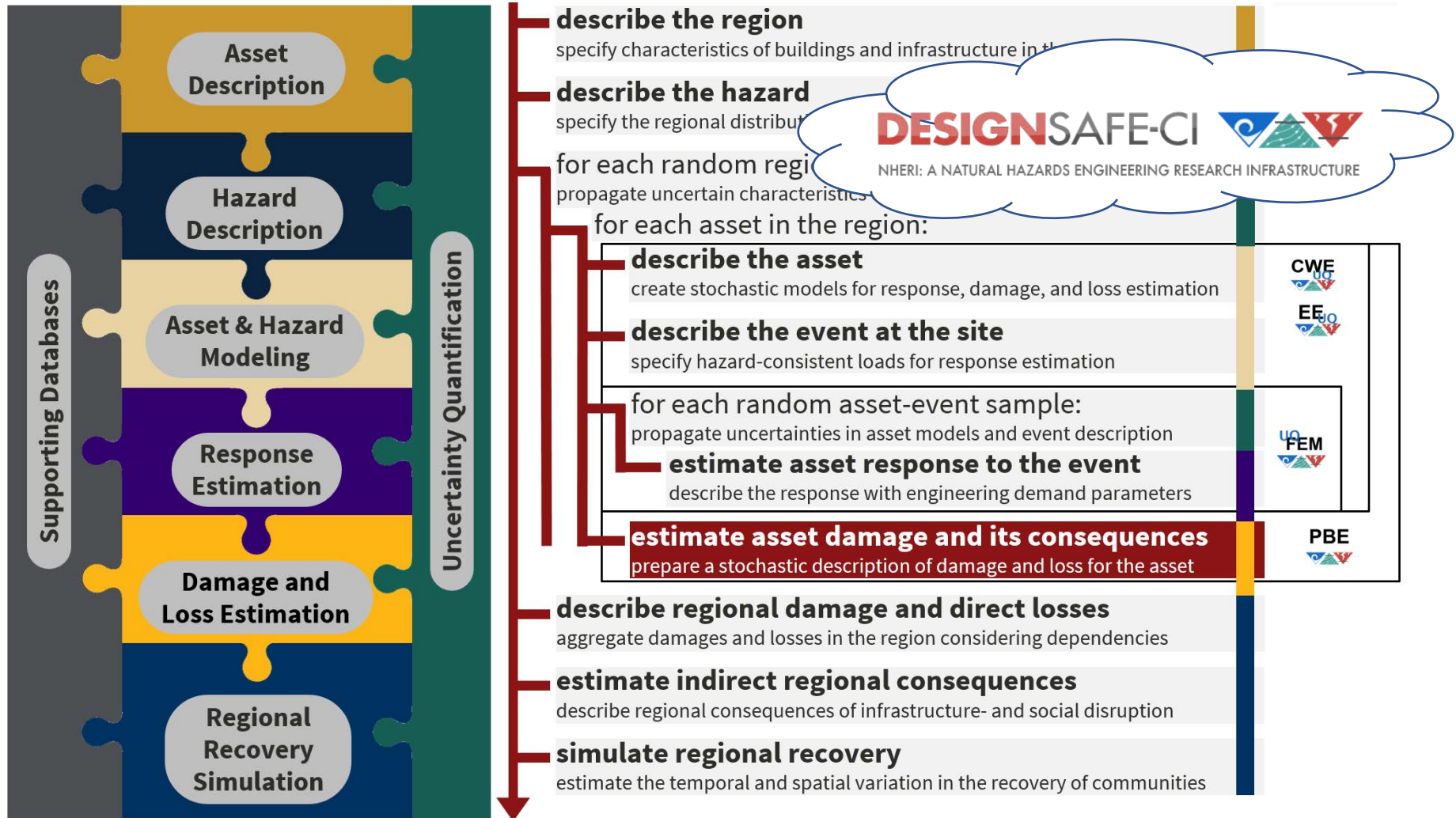


# PELICUN

- 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



# Application Framework & Research Apps

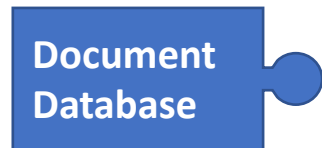
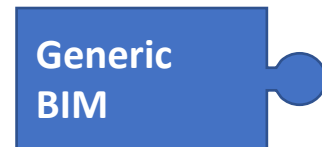


# Regional Simulation

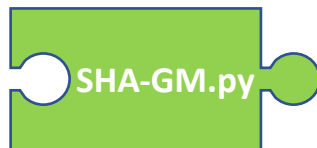
## Applications

The Application Framework provides applications with standard interfaces

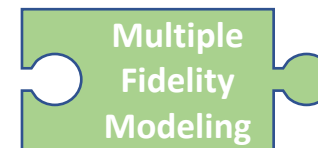
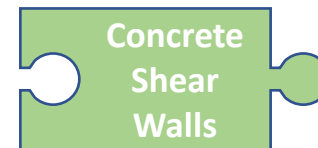
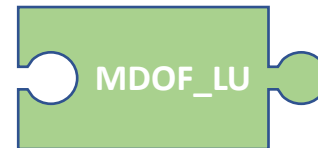
### Buildings



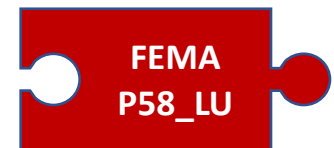
### Hazard



### Modeling



### Losses

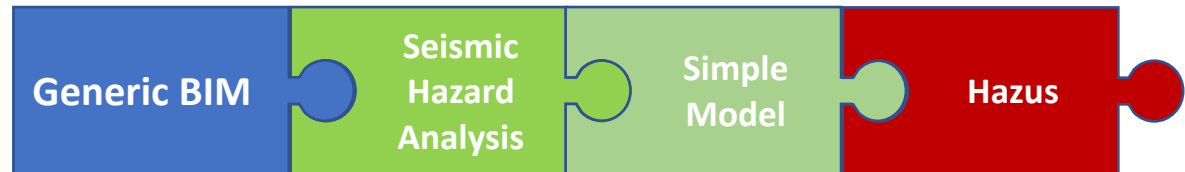


# Regional Simulation

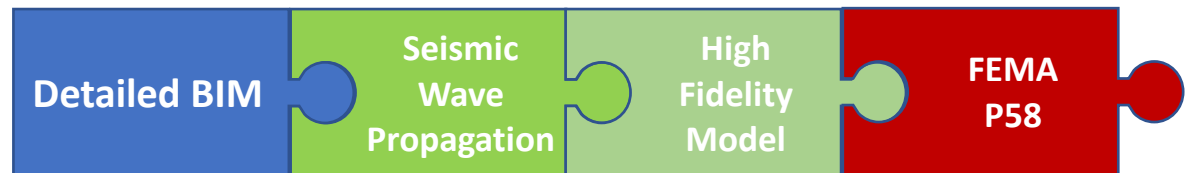
## Configuration

Chain a set of applications into a building workflow

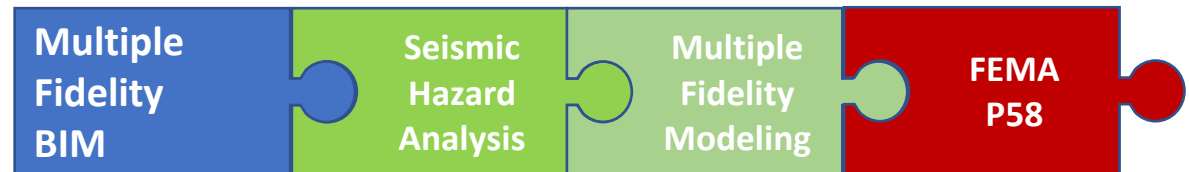
Low Fidelity  
Configuration



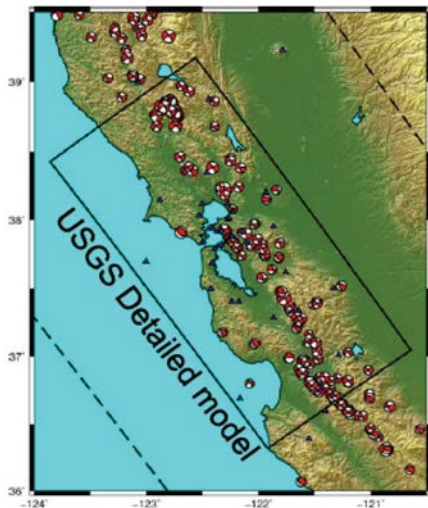
High Fidelity  
Configuration



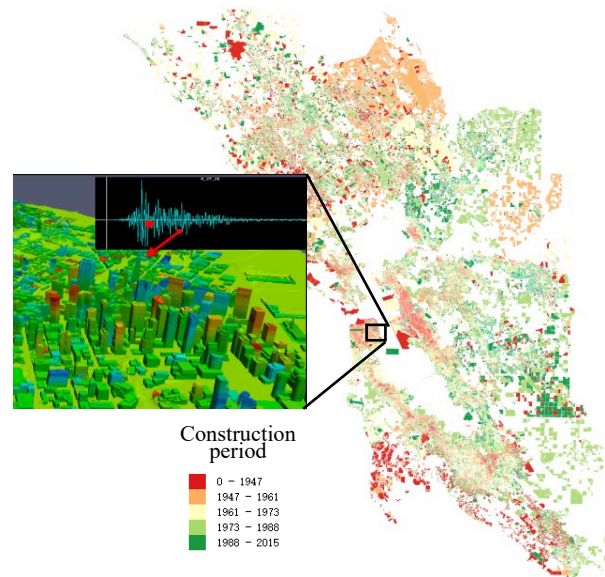
Multiple Fidelity  
Configuration



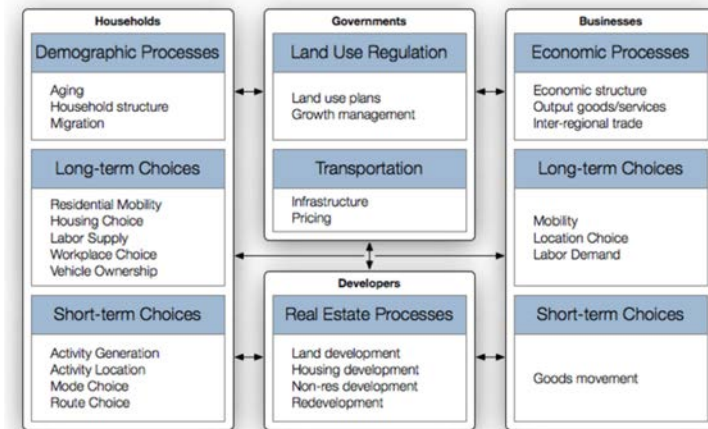
# Regional End-to-End EQ Testbed



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)

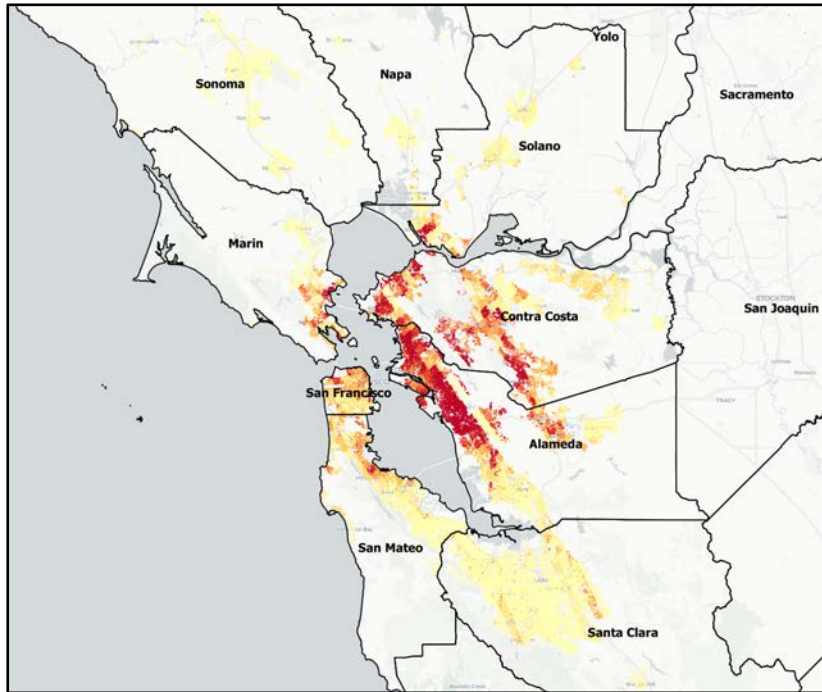
**Building Inventory:** UrbanSim and DataSF Portal; geometry, age, occupancy

**Building Analyses:** OpenSees, simplified NL MDOF, FEMA P58 (w/Cheng & Lu, Tsinghua)

**Visualization:** Q-GIS, UrbanSim

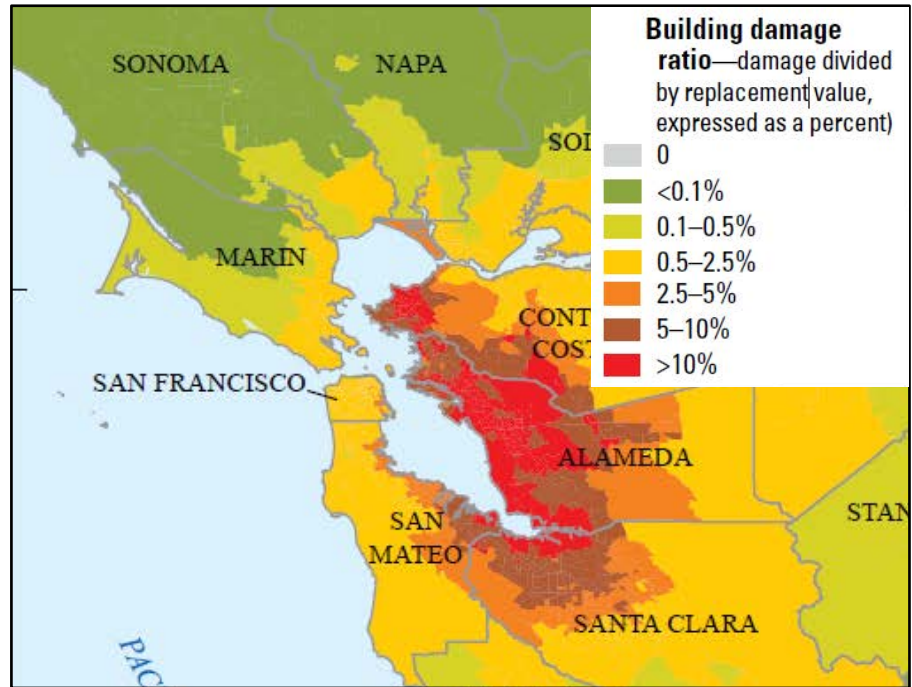
**Interpretation:** UrbanSim - urban growth, damage/loss, displaced occupants/population

# Comparison of Building Damage



## SimCenter Workflow

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

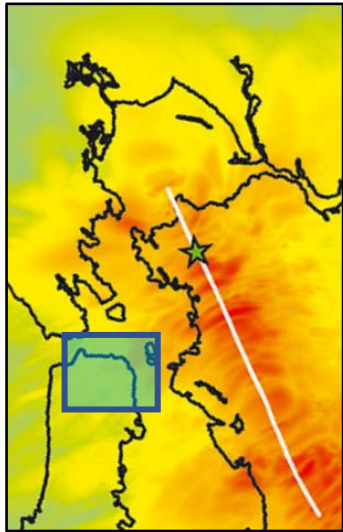


## USGS HayWired

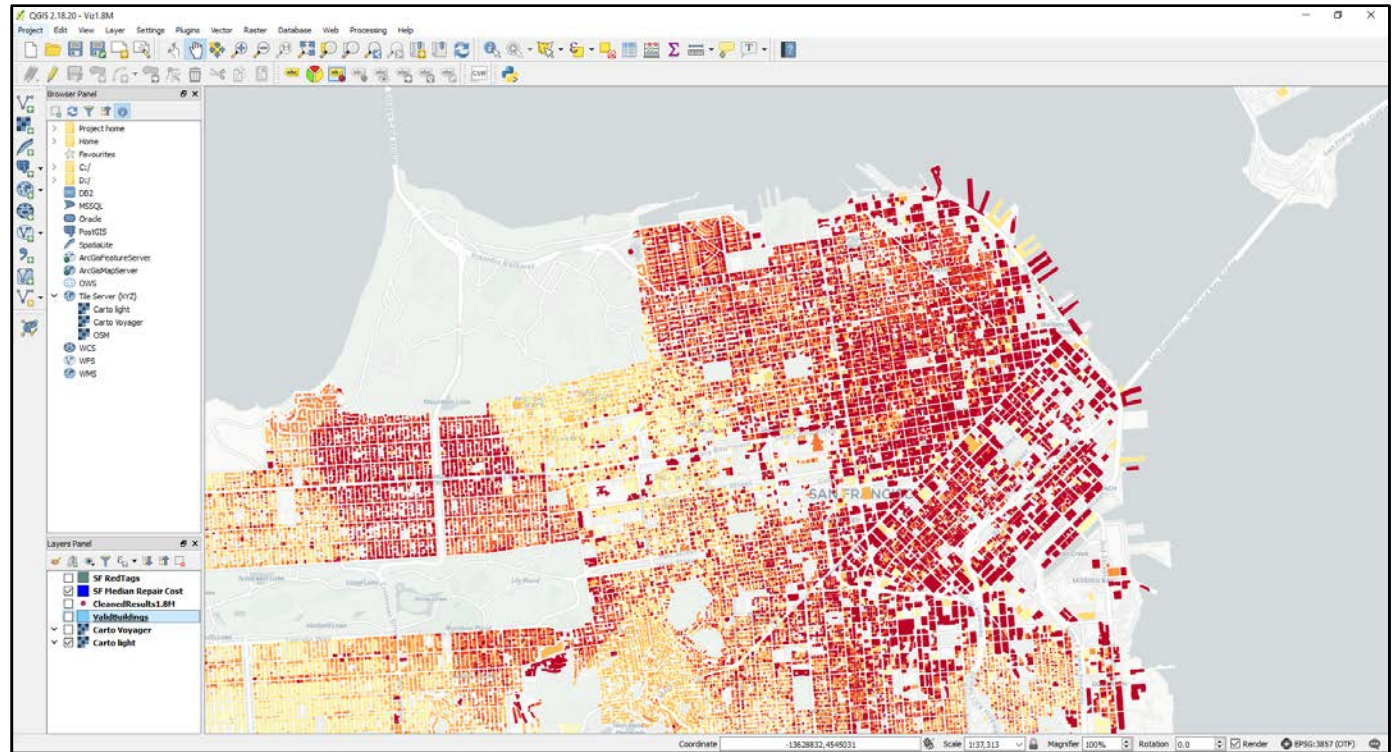
- Red-tagged buildings 101,000
- Net buildings damage ratio 2.9%

# Regional Simulation

## San Francisco Bay Area Testbed



M7.0 Hayward



Building Inventory

Hazard Consequences

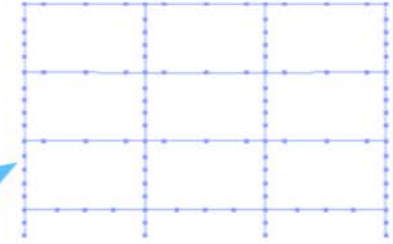
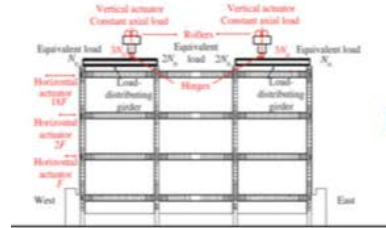
*Opportunities to evaluate planning and policy decisions (land use, retrofit, etc.)*

# AI Applications: BIM to SAM

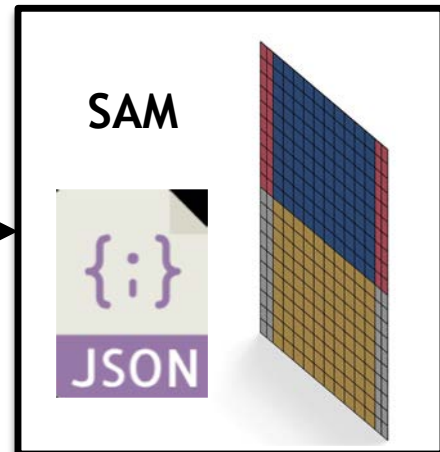
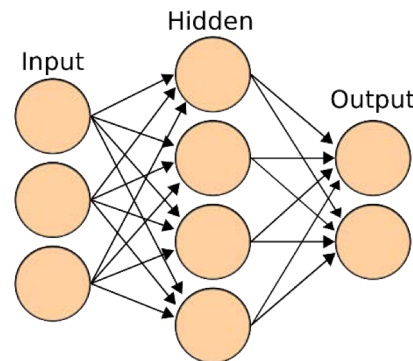
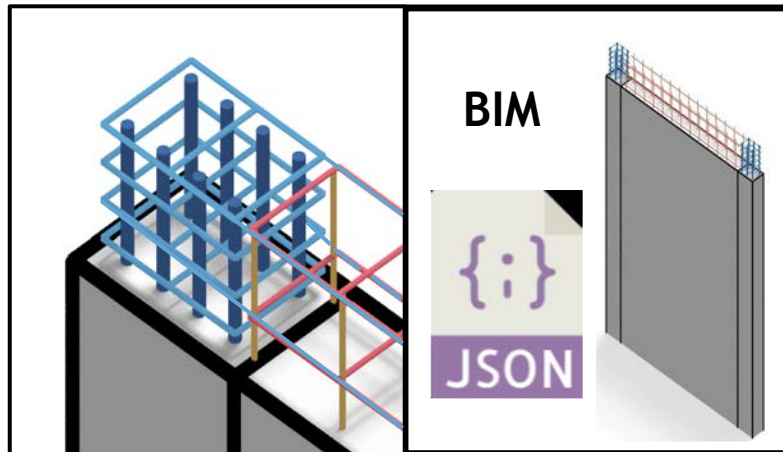
Structural Engineers



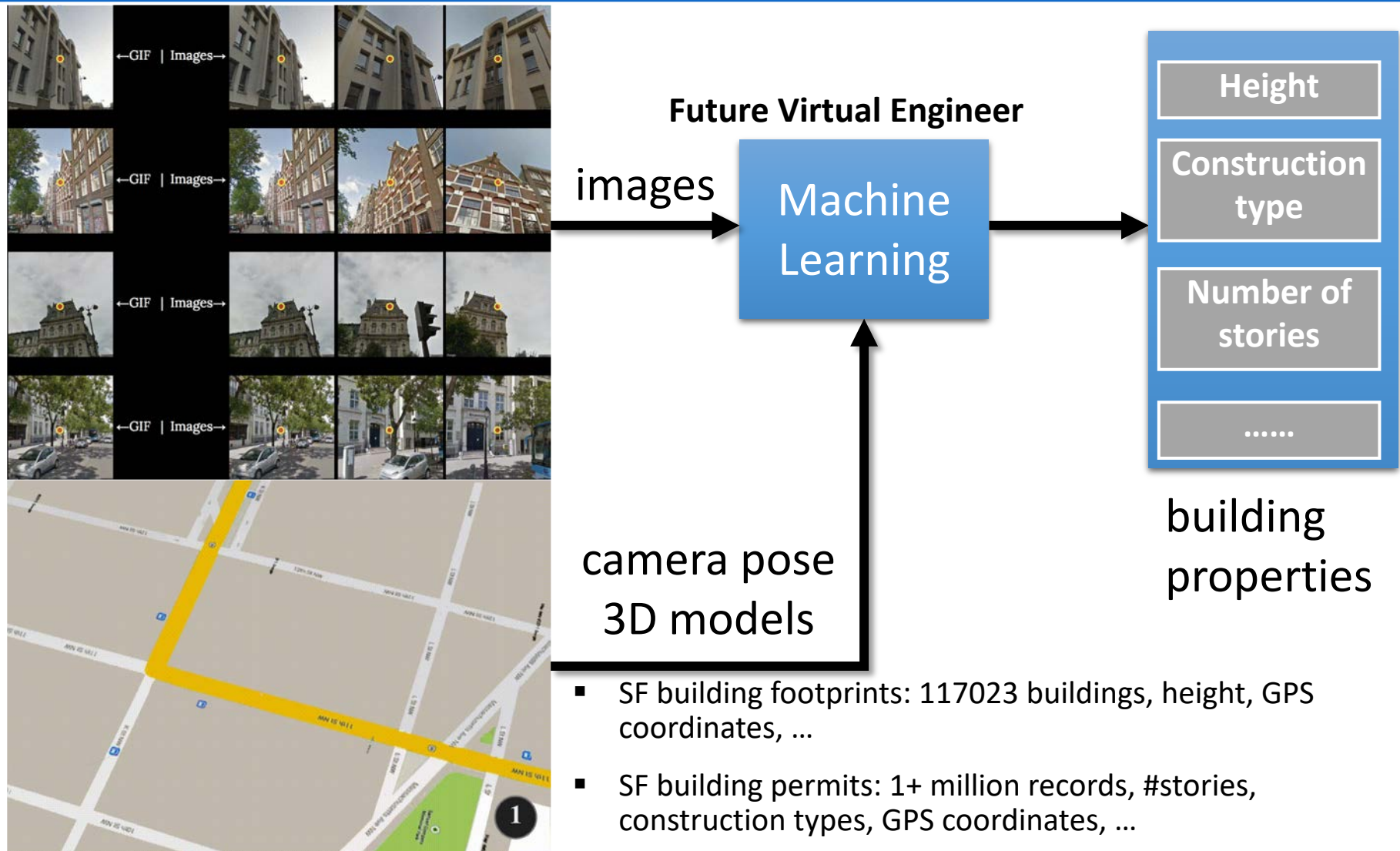
Future Virtual Engineer



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



# In the Future: AI for Data to BIM



- 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

Advances in Computational Modeling and Simulation	Early Career Researcher Forum	Natural Hazards Engineering 101
<b>NEW</b> HPC Ground Motion Simulations of Large Hayward Fault Earthquakes November 14, 2018 • <a href="#">Watch Webinar</a>	<b>NEW</b> Tsunami-Induced Turbulent Coherent Structures: Large-Scale Experimental Observations and Interpretation February 21, 2018 • <a href="#">Watch Webinar</a>	<b>NEW</b> Understanding Tsunamis and Their Effects August 30, 2017 • <a href="#">Watch Webinar</a>
AI & Machine Learning in Natural Hazards Engineering: Technical & Modelling Q & A November 6, 2018 • <a href="#">Watch Webinar</a>	HPC Aided Seismic Risk Assessment of Vertical Concrete Dry Casks December 13, 2017 • <a href="#">Watch Webinar</a>	Computational Fluid Dynamics, Simulation & Computational Tools June 12, 2017 • <a href="#">Watch Webinar</a>
UQ Computational Advances for Natural Hazard Risk Assessment October 24, 2018 • <a href="#">Watch Webinar</a>	Modeling of 500-year Cascadia Subduction Zone Tsunami Inundation November 1, 2017	Exploring Wind Engineering May 17, 2017 • <a href="#">Watch Webinar</a>

- 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)



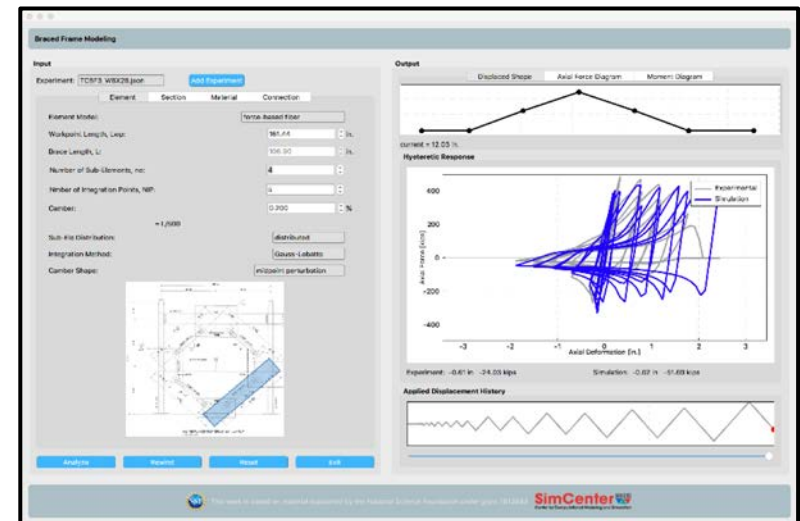
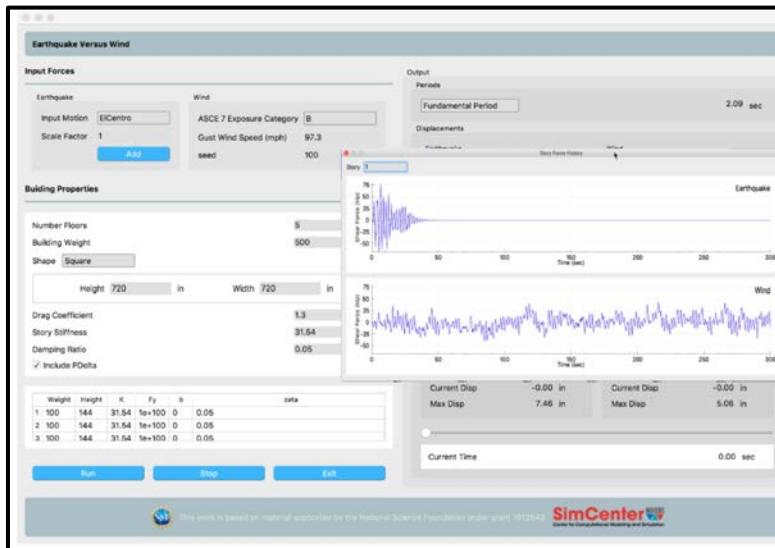
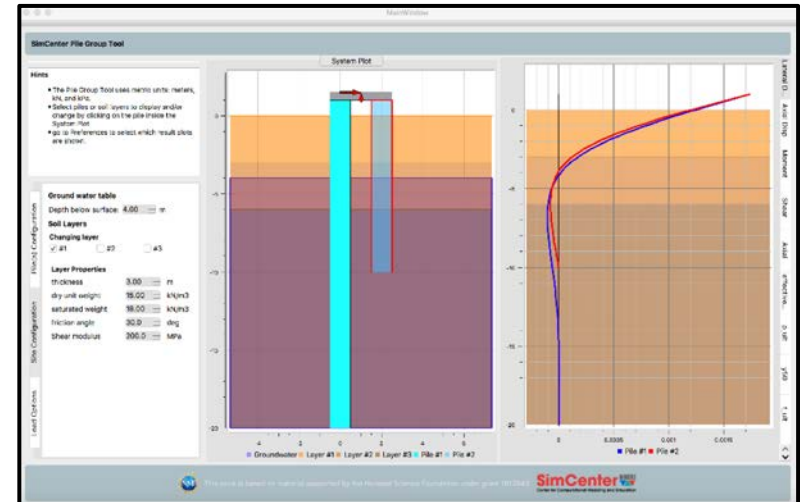
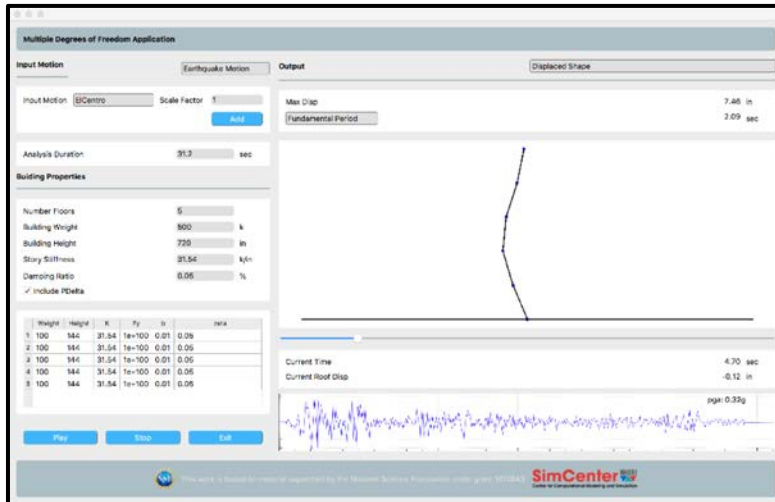
- Summer REU Program



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

Applications due February 1, 2019

# Educational Applications



# Acknowledgments

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- 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 necessarily 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.



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# Regional Simulation Demo

Wael Elhaddad

# Regional Simulation

## Running a regional simulation using DesignSafe

The screenshot displays the DesignSafe CI Workflow Sandbox interface. The main window shows the workflow 'Workflow sandbox' for the project 'elhaddad / SanFranciscoBayArea'. A blue arrow points to the 'SFTestbed.json' file in the 'Inputs' section. A 'Previewing RegionalDamageLoss.csv' window is open, showing a table of simulation results. A 'Memory Per Node' window is also open, displaying simulation parameters and timing.

**Workflow sandbox**  
This Agave application runs the regional earthquake work

[Workflow sandbox Documentation](#)

**Inputs**

- RegionalDataSF.zip
- SFTestbed.json

**Regional Simulation Data**

Memory Per Node	64
Node Count	64
Parameters	buildingsCount: 500000
ID	4096
Submit Time	2018-10-28T11:37:50.000-05:00
Start Time	2018-10-28T11:38:01.000-05:00
End Time	2018-10-28T14:07:16.000-05:00

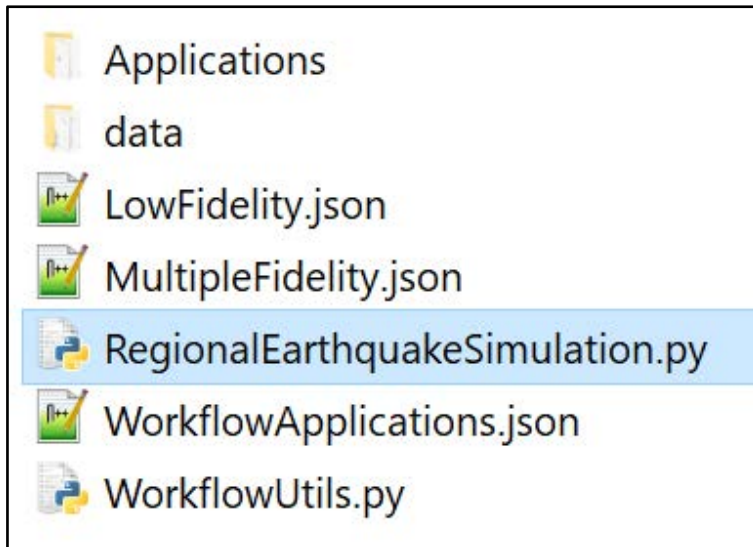
**Previewing RegionalDamageLoss.csv**

Id	MedianRepairCost	RepairCostStdDev	MedianDowntime	RedTagged	PGA	LossRatio	Latitude	Longitude
1,2283	110478	8032.663829	2.504329718	0	0.1485565749	0.00545277256	37.98999094	-122.5986709
2,2322	332178	8353.084416	2.578395361	0	0.1485565749	0.005546446087	37.97476531	-122.6056875
3,1735	890089	4928.248935	1.879175786	0	0.116615698	0.005365861603	37.34473211	-122.0014662
4,0,1309	33413	0	0.05215423038	0	0.37.69498903	-122.0703993		
5,404	1425639	2983.306245	0.4348193721	0	0.1011026504	0.001294669647	37.55952818	-121.9943362
6,429	8364153	3279.846382	0.4650697896	0	0.1011026504	0.001213378268	37.55967004	-121.9935883
7,1962	583329	7670.241139	2.202832543	0	0.1444872579	0.003062270678	37.46223573	-121.9172232
8,47956	69776	24475.45644	47.93342693	0	0.3140326198	0.07482810396	37.70081432	-121.9576976
9,1499	097842	7080.007633	1.639917365	0	0.1485565749	0.007137489834	37.96695719	-122.594278
10,311647	1916	149865.6742	3.569151239	0	0.3662079511	0.01040081069	37.79499202	-122.2823383
2551	610525	0.3743152166	0	0.09242721713	0.0008630125267	37.89525182	-121.6147928	
9036	858667	3.83482031	0	0.1485565749	0.009186024644	37.98488147	-122.5987679	
10141	04716	6.315196846	0	0.1564067278	0.01327976234	37.99405688	-122.6021578	
11043	53758	7.432688412	0	0.1564067278	0.01604863764	37.99382403	-122.6003333	
9801	83396	5.004892366	0	0.1564067278	0.02010345436	37.99375169	-122.5990357	
810	434804	3.596105403	0	0.1365718654	0.007506706682	37.99099411	-122.5840929	
7382	016734	3.443410385	0	0.1365718654	0.00748471972	37.99060732	-122.5838343	
7146	851353	2.78766613	0	0.1365718654	0.009005268839	37.98960725	-122.5833179	
554	666869	3.364656117	0	0.1365718654	0.007633244792	37.99046758	-122.5877322	
7536	767485	3.334869885	0	0.1365718654	0.007277314969	37.99046638	-122.5868473	
8891	248695	3.520676227	0	0.1365718654	0.00741556979	37.98862771	-122.5834802	
7080	03748	2.116157858	0	0.1365718654	0.01092685723	37.98421842	-122.5910192	
7526	037079	3.502449519	0	0.1365718654	0.007506869051	37.98376006	-122.5903697	
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8467	8125	2.382627399	0	0.1485565749	0.00506261587	37.98257195	-122.59198	
849	312603	3.456447379	0	0.1365718654	0.007298426463	37.98445303	-122.5886608	
5516	256341	1.692911727	0	0.1365718654	0.003362249995	37.98690702	-122.5923766	
7447	067114	1.469390713	0	0.1485565749	0.005940254973	37.97846409	-122.5888359	
8307	329661	2.54083599	0	0.1485565749	0.005545193	37.97935977	-122.59026	
8449	945916	2.412481788	0	0.1485565749	0.004855798967	37.97980838	-122.5899875	
6663	460349	1.660952586	0	0.1365718654	0.003239211616	37.97955739	-122.5889619	
8815	031665	6.951862666	0	0.1365718654	0.009744852425	37.97975387	-122.5878035	

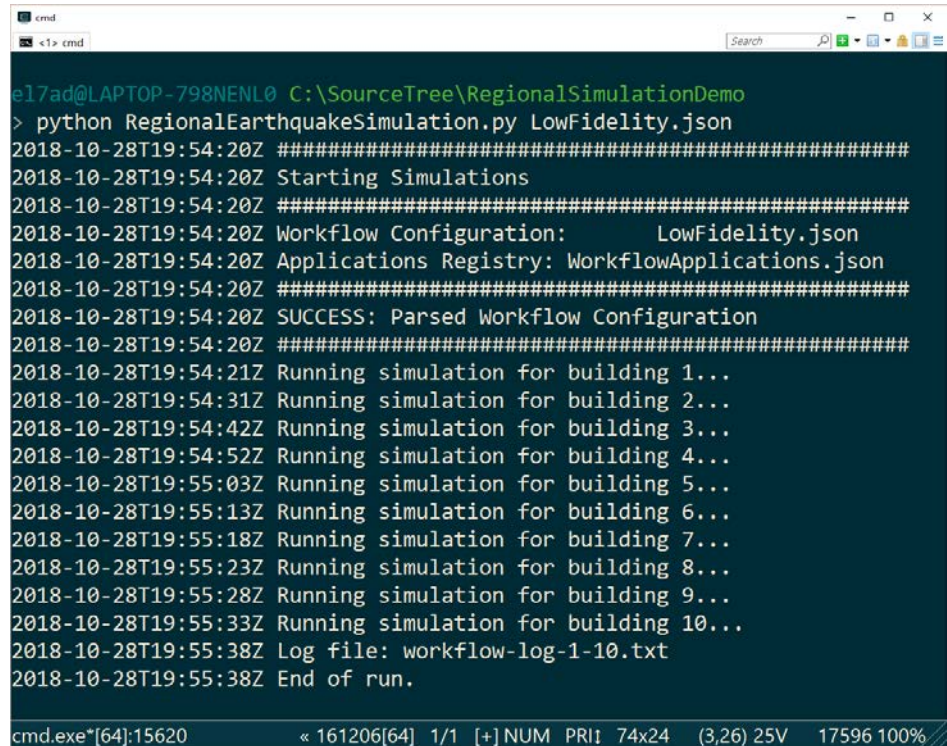
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# Regional Simulation

## Running a regional simulation using on Local Computer



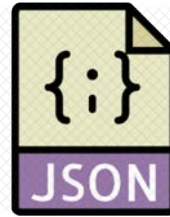
Applications,  
Sample Data  
& Examples

A screenshot of a Windows Command Prompt window. The title bar says "cmd". The command prompt shows the user "el7ad@LAPTOP-798NENL0" at the "C:\SourceTree\RegionalSimulationDemo" directory. The command entered is "python RegionalEarthquakeSimulation.py LowFidelity.json". The output shows a series of timestamps and messages: "2018-10-28T19:54:20Z #####", "2018-10-28T19:54:20Z Starting Simulations", "2018-10-28T19:54:20Z #####", "2018-10-28T19:54:20Z Workflow Configuration: LowFidelity.json", "2018-10-28T19:54:20Z Applications Registry: WorkflowApplications.json", "2018-10-28T19:54:20Z #####", "2018-10-28T19:54:20Z SUCCESS: Parsed Workflow Configuration", "2018-10-28T19:54:20Z #####", "2018-10-28T19:54:21Z Running simulation for building 1...", "2018-10-28T19:54:31Z Running simulation for building 2...", "2018-10-28T19:54:42Z Running simulation for building 3...", "2018-10-28T19:54:52Z Running simulation for building 4...", "2018-10-28T19:55:03Z Running simulation for building 5...", "2018-10-28T19:55:13Z Running simulation for building 6...", "2018-10-28T19:55:18Z Running simulation for building 7...", "2018-10-28T19:55:23Z Running simulation for building 8...", "2018-10-28T19:55:28Z Running simulation for building 9...", "2018-10-28T19:55:33Z Running simulation for building 10...", "2018-10-28T19:55:38Z Log file: workflow-log-1-10.txt", "2018-10-28T19:55:38Z End of run." The status bar at the bottom shows "cmd.exe\*[64]:15620", "« 161206[64] 1/1 [+], NUM PRI: 74x24 (3,26) 25V 17596 100%".

Runs Locally as a  
console application

# Regional Simulation

## Configuration File

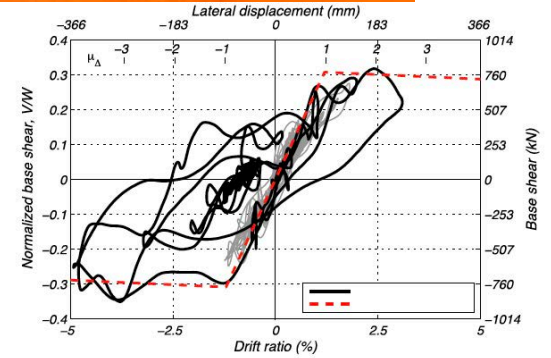
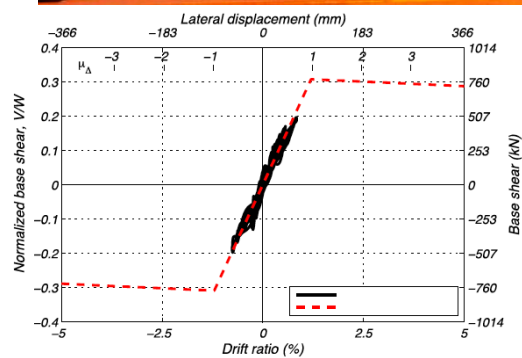
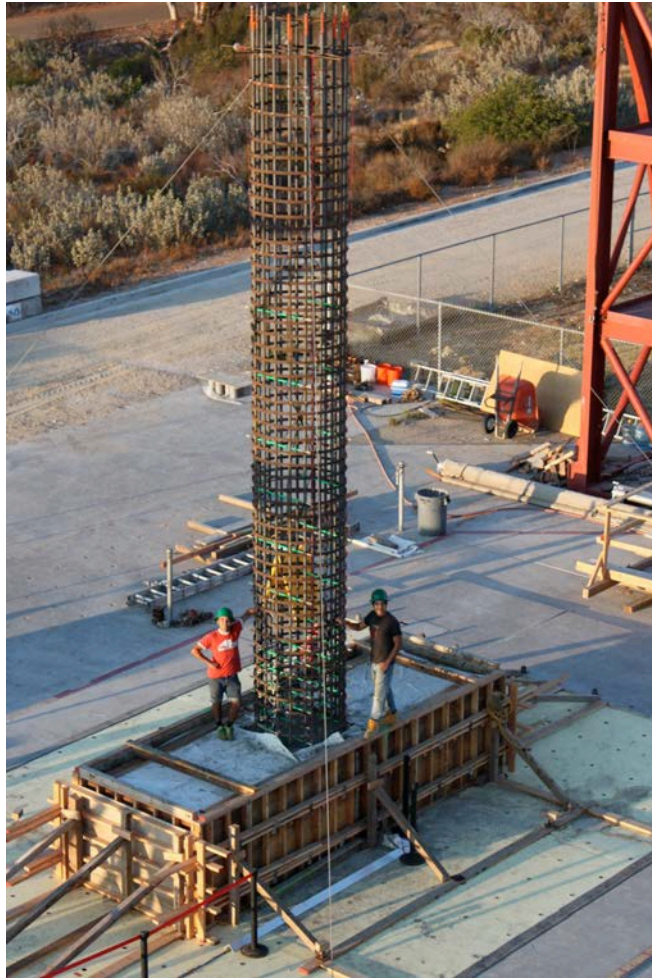


```
{
  "Name": "Workflow5",
  "Author": "Wael Elhaddad",
  "WorkflowType": "Regional Simulation",
  "buildingFile": "buildings.json",
  "Applications": {
    "Buildings": { ...
  },
  "Events": [ ...
  ],
  "Modeling": { ...
  },
  "EDP": { ...
  },
  "Simulation": { ...
  },
  "UQ-Simulation": { ...
  },
  "Damage&Loss": { ...
  }
}
```

```
"Events": [
  {
    "EventClassification": "Earthquake",
    "EventApplication": "LLNL-SW4",
    "ApplicationData": {
      "pathSW4results": "../createEVENT/Hayward7.0/",
      "filenameHFmeta": "../build/data/HFmeta"
    }
  }
]
```

```
"Damage&Loss": {
  "Damage&LossApplication": "FemaP58-LU",
  "ApplicationData": {
    "filenameSettings": "../build/data/settings.ini",
    "pathCurves": "../build/data/ATCCurves/",
    "pathNormative": "../build/data/normative/"
  }
}
```

# EE-UQ DEMO



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**QUESTIONS?**

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