



An Overview of the NHERI SimCenter

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Associate Director for Operations

UC Berkeley

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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.

The screenshot displays the SIMCENTER website interface. At the top, the logo for SIMCENTER (COMPUTATIONAL MODELING AND SIMULATION CENTER) and DESIGNSAFE-CI (A NATURAL HAZARDS ENGINEERING COMMUNITY) is visible. A navigation menu includes links for About, Research Tools, Learning Tools, Knowledge Hub, Join the Community, Collaborate, and FAQ. A blue arrow points to the 'Research Tools' link. Below this, a secondary navigation menu shows Home, About, Research Tools, Learning Tools, Knowledge Hub, Collaborate, and News Archive. The main content area is titled 'RESEARCH TOOLS' and contains a paragraph describing the applications. Below this, four tool categories are presented: UQ FEM, CWE UQ, EE UQ, and PBE. Each category features a stylized logo with a blue 'U' and a red 'Q' and a descriptive paragraph.

SIMCENTER
COMPUTATIONAL MODELING
AND SIMULATION CENTER

DESIGNSAFE-CI
A NATURAL HAZARDS
ENGINEERING COMMUNITY

Home About **Research Tools** Learning Tools Knowledge Hub Collaborate News Archive

RESEARCH TOOLS

These applications address basic and advanced modeling, analysis and simulation needs across an array of Natural Hazards. They incorporate uncertainty quantification (UQ) and optimization concepts. Downloadable apps, user manuals, user feedback, and relevant resources are available on the linked resource pages.

UQ FEM **CWE UQ** **EE UQ** **PBE**

The uqFEM application is intended to advance the use of uncertainty quantification and optimization within the field natural hazards engineering.

OpenFOAM based CFD analysis software for analyzing the effect of wind on structures and attendant response, including UQ in future releases.

The EE-UQ Tool is an application to determine the response, including UQ, of a structure to an earthquake excitation.

The PBE Tool is an extensible workflow application to perform Performance Based Engineering computations for various hazards. PBE analysis includes multi-ensemble simulation models for UQ.

SimCenter Research Tools

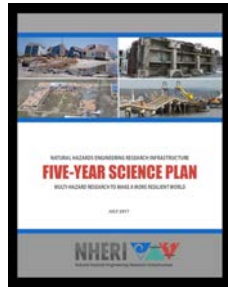
<https://simcenter.designsafe-ci.org/research-tools>

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



- Collaboration Tools



Back-end

SimCenter Application Framework



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



Sanjay Govindjee
UC Berkeley



Ahsan Kareem
Notre Dame



Laura Lowes
Washington



Greg Deierlein
Stanford



Camille Crittenden
UC Berkeley

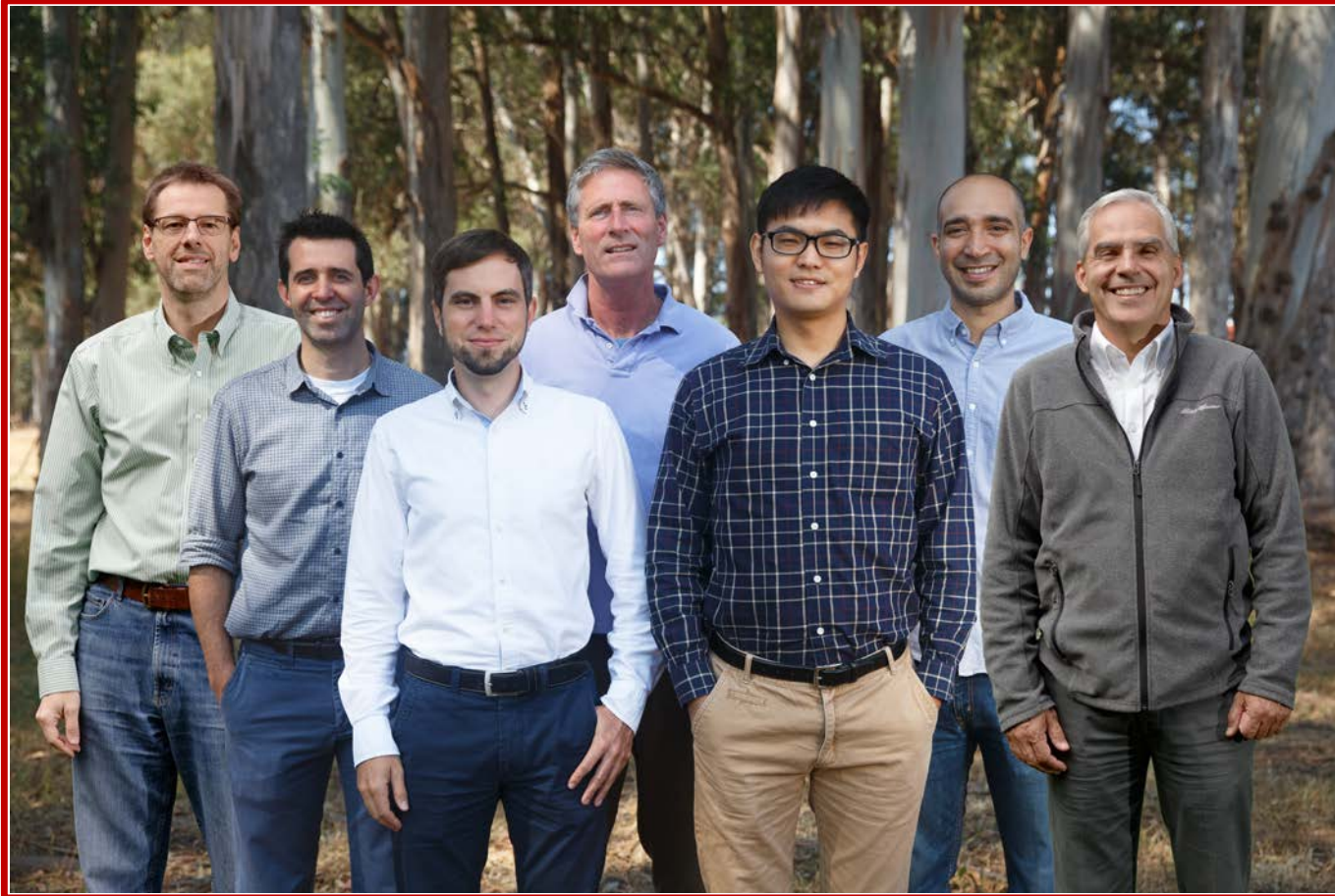


Frank McKenna
UC Berkeley



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.

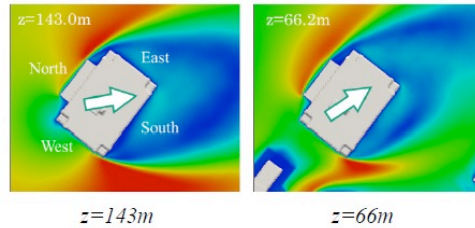
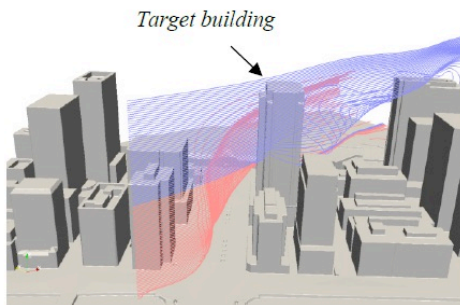
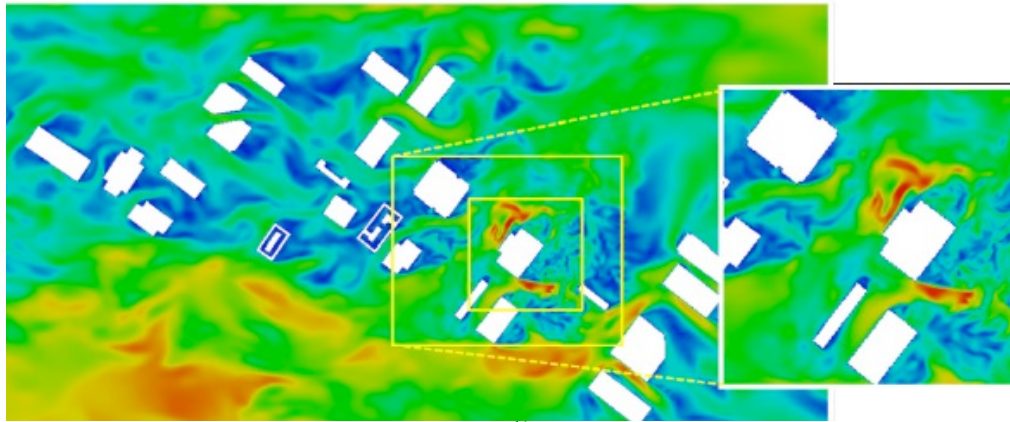


- Move to cloud-based HPC environment,
- Provide integrated “plug and play” capability to link multiple software apps together into workflows

API Facilitated Application of Applications



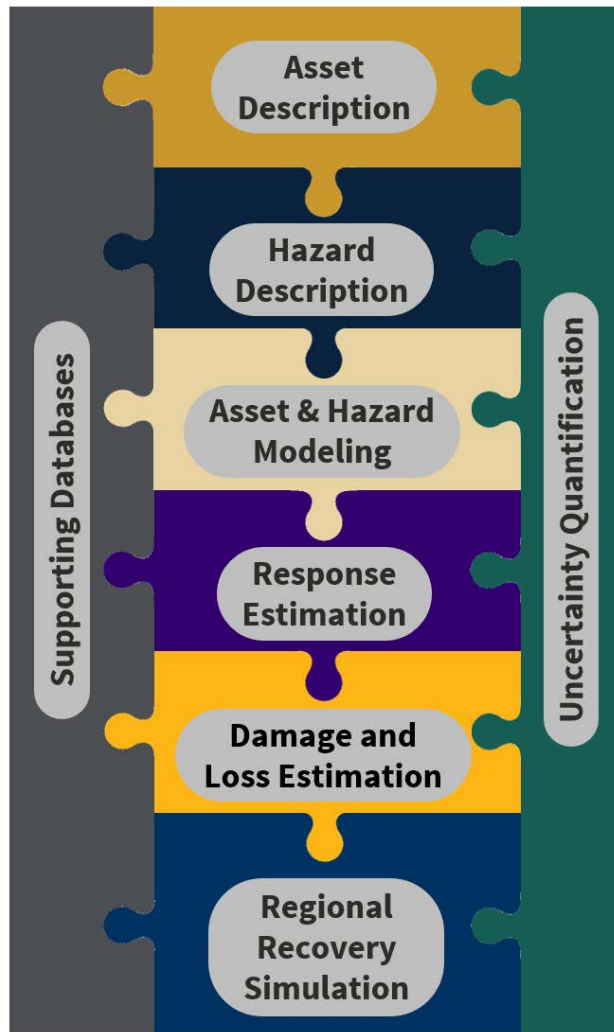
Desired Outcome



T. Tamura Group TIT



Application Framework & Research Apps

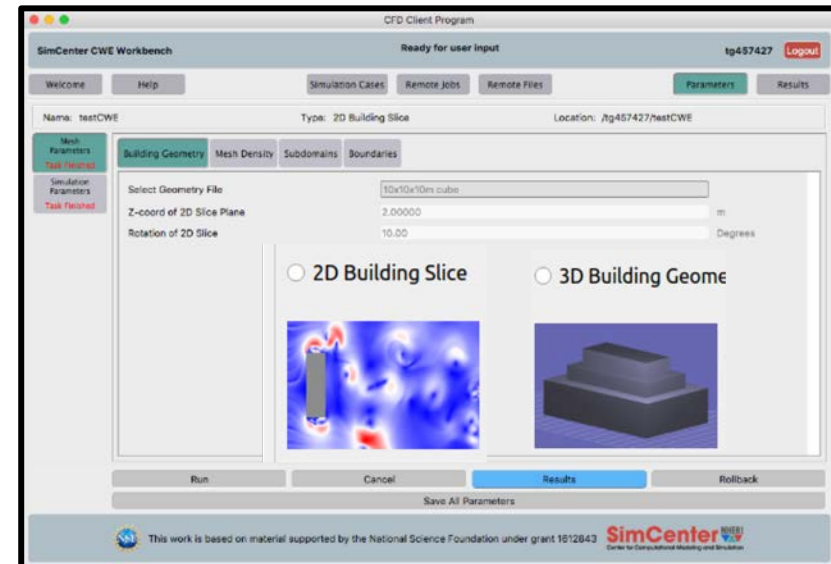
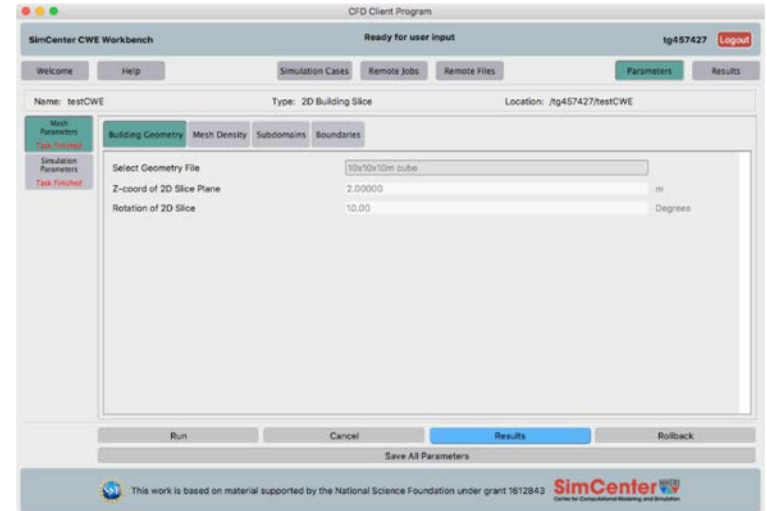


Application:

- 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:

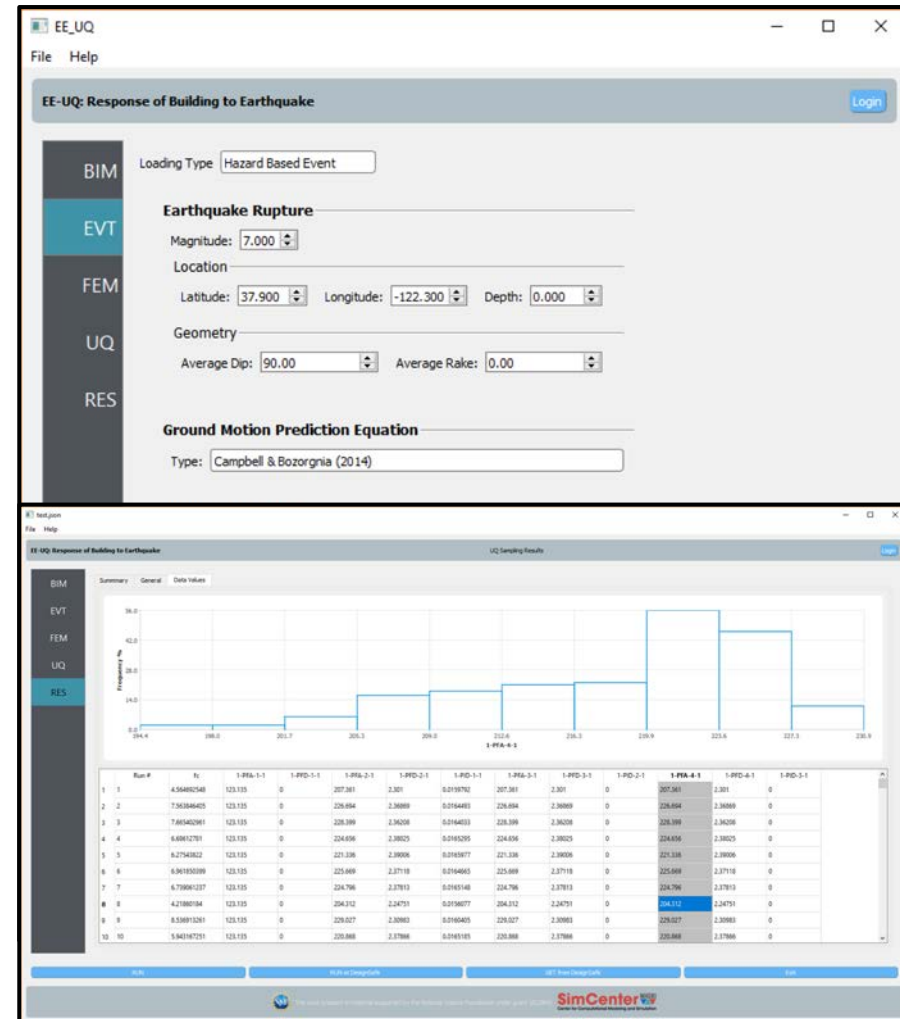
- Inputs:** Building information, earthquake event & uncertainty specification
- Outputs:** Uncertainty measures of building response

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:

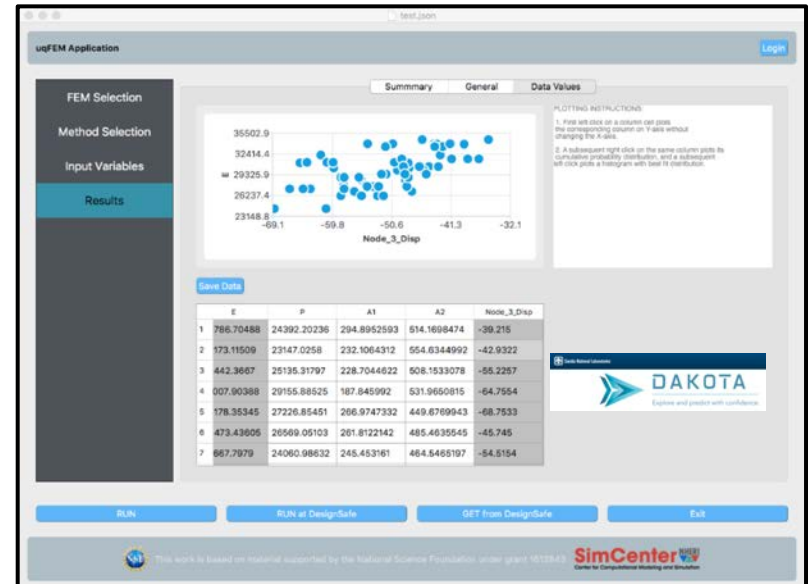
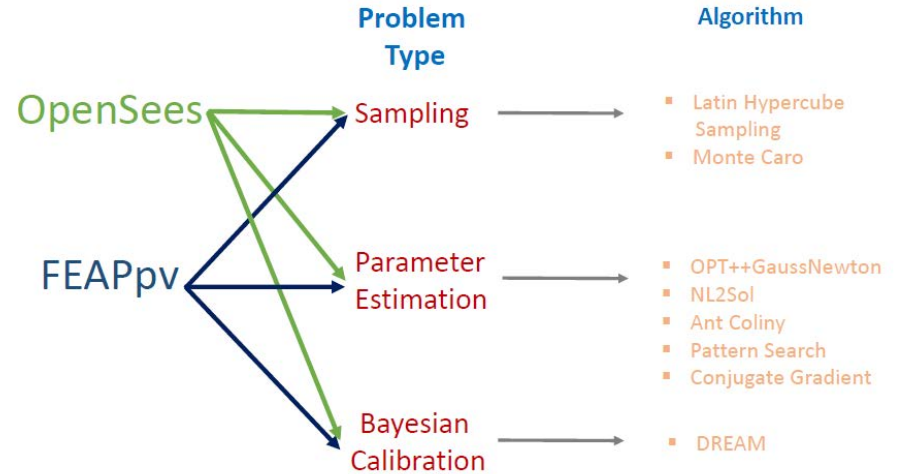
- Inputs:** FEM model, input uncertainty specification, UQ method & post-processing script
- Outputs:** Depends on problem type and post-processing (e.g. Uncertainty measures of outputs)

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:

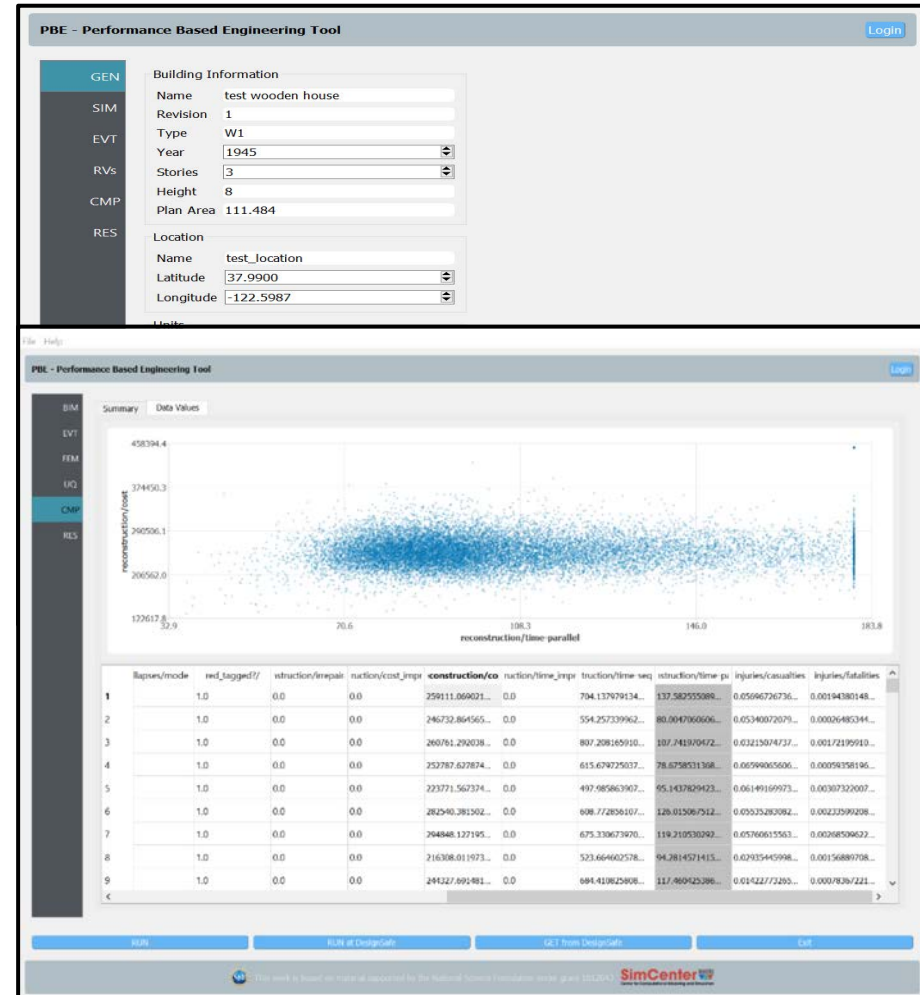
- Inputs:** Building & structural information, Hazard characterization, Contents, Damage & loss functions, e.g. P58, Hazus or user-defined.
- Outputs:** Damage, loss, and consequences

Release Dates:


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

Research Opportunities:

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

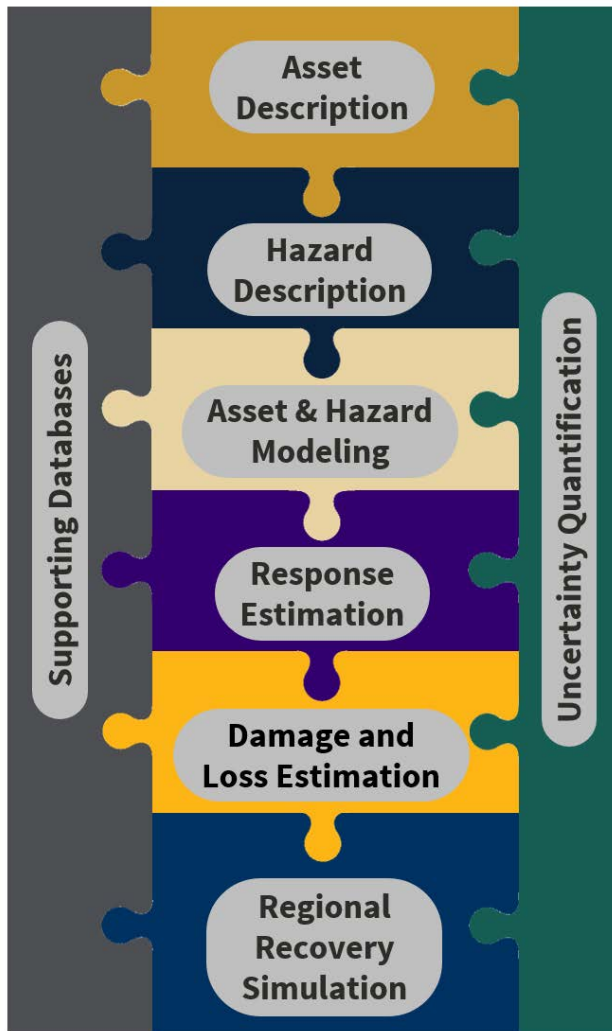


PELICUN

- 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

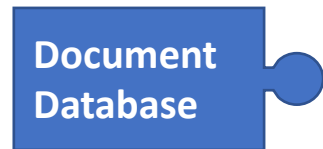
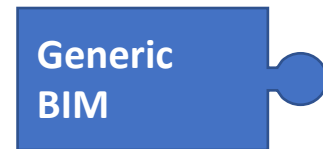


Regional Simulation

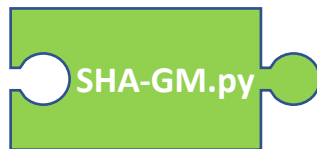
Applications

The Application Framework provides applications with standard interfaces

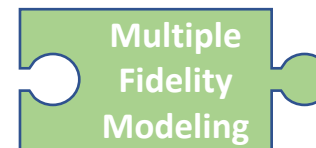
Buildings



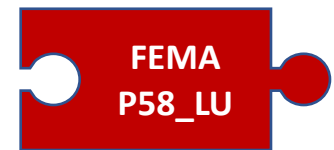
Hazard



Modeling



Losses



Regional Simulation

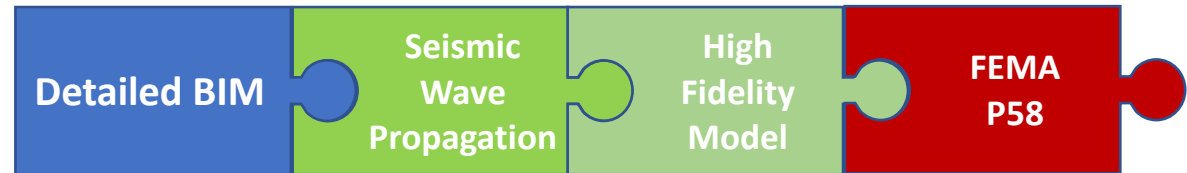
Configuration

Chain a set of applications into a building workflow

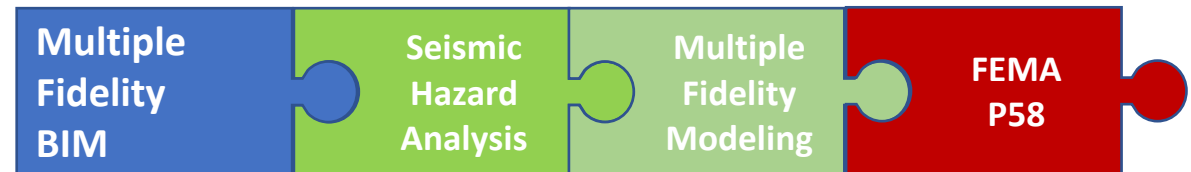
Low Fidelity Configuration



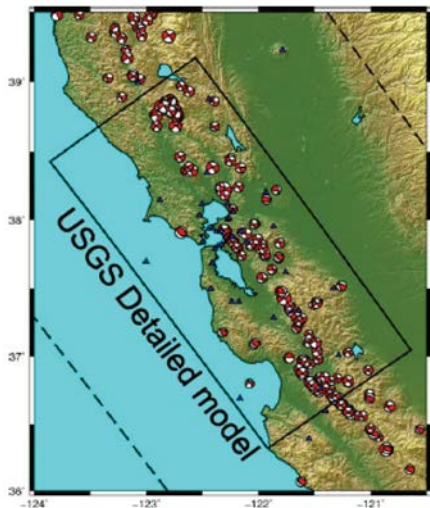
High Fidelity Configuration



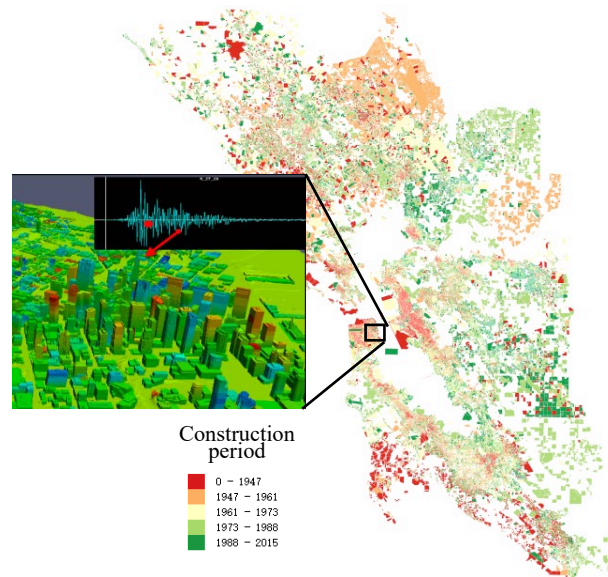
Multiple Fidelity Configuration



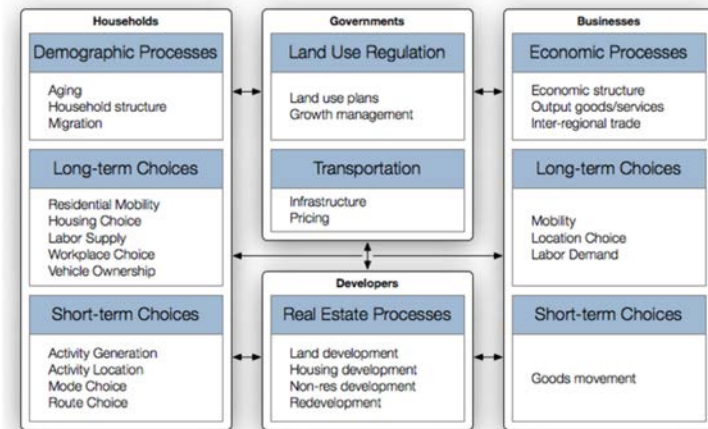
Regional End-to-End EQ Testbed



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)

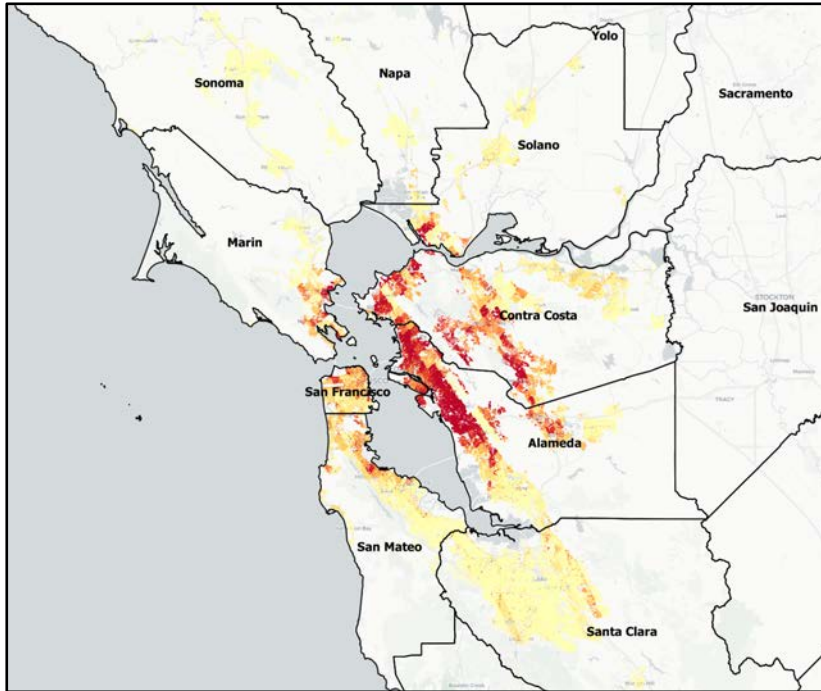
Building Inventory: UrbanSim and DataSF Portal; geometry, age, occupancy

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

Visualization: Q-GIS, UrbanSim

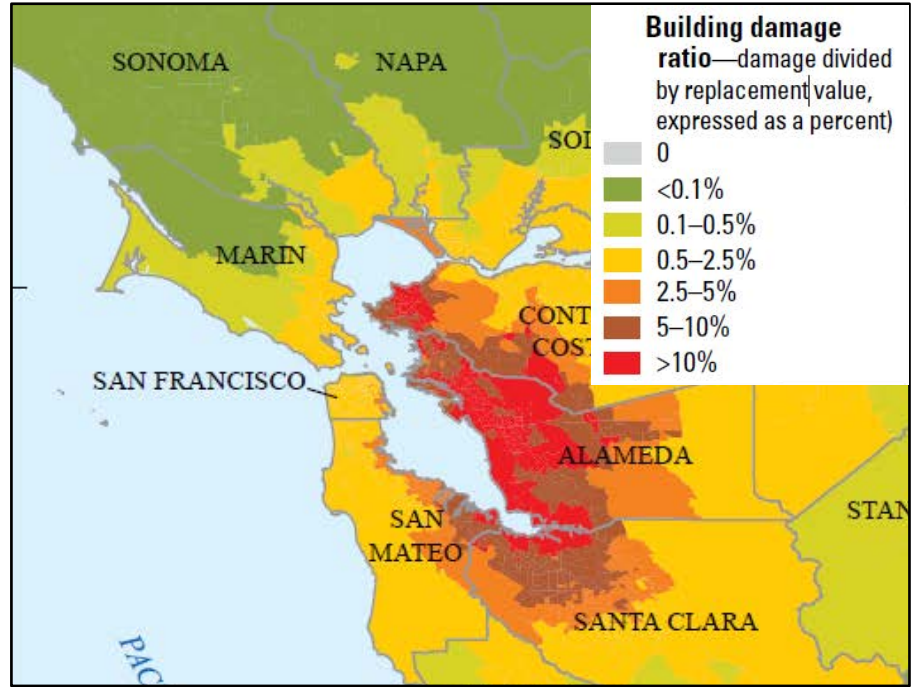
Interpretation: UrbanSim - urban growth, damage/loss, displaced occupants/population

Comparison of Building Damage



SimCenter Workflow

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

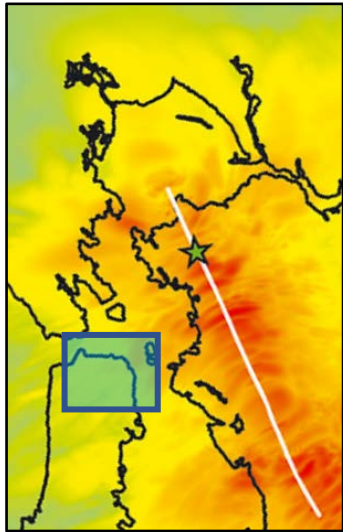


USGS HayWired

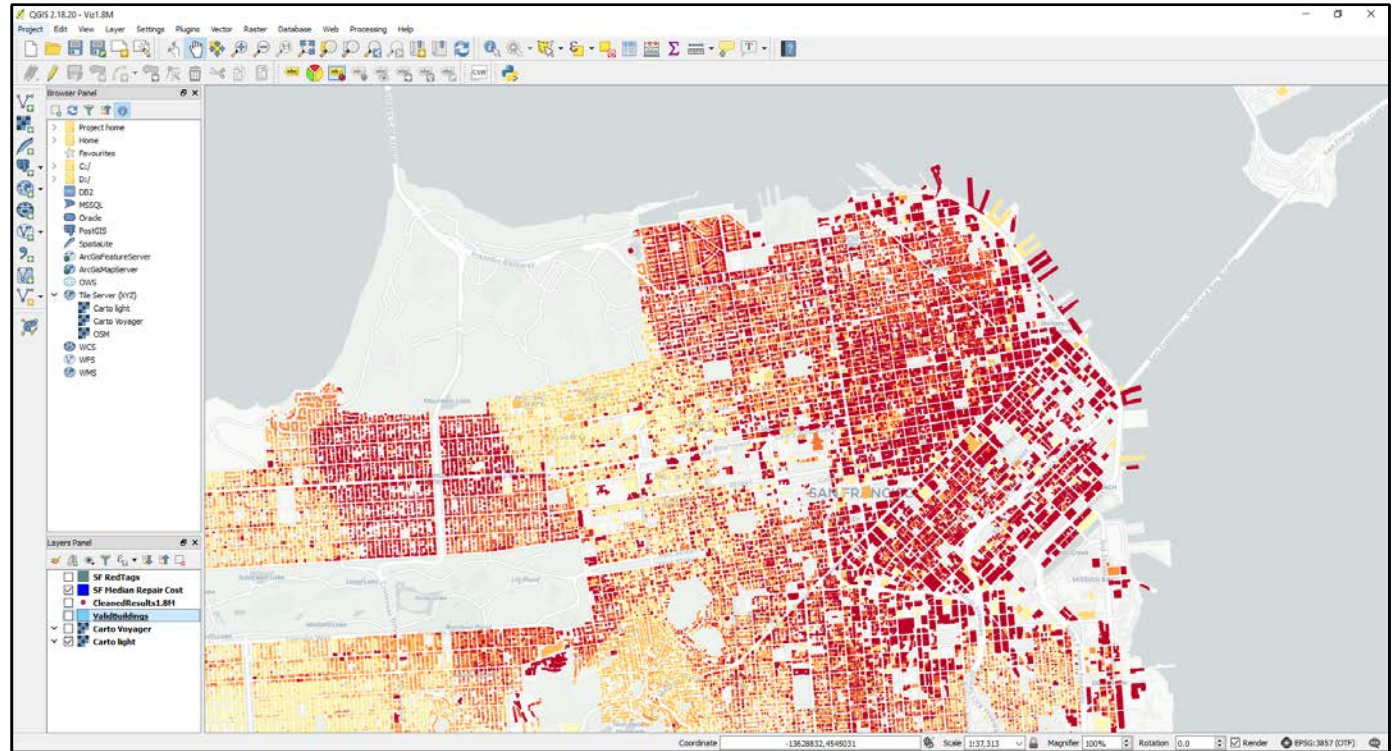
- *Red-tagged buildings 101,000*
- *Net buildings damage ratio 2.9%*

Regional Simulation

San Francisco Bay Area Testbed



M7.0 Hayward



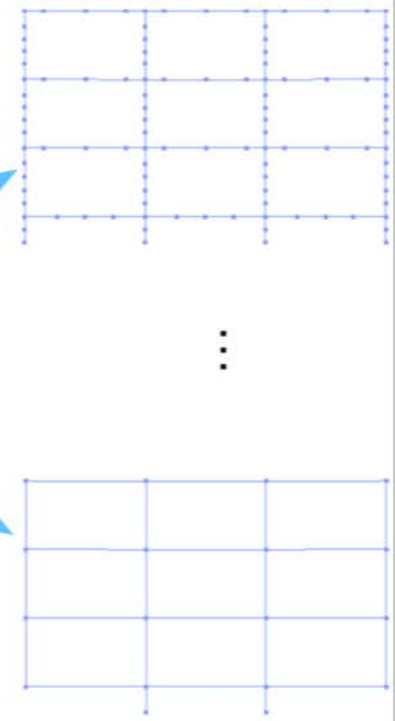
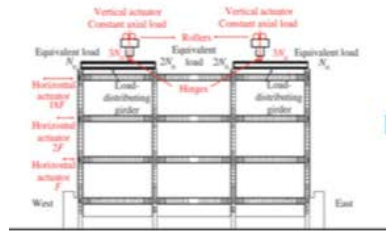
Building Inventory

Hazard Consequences

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

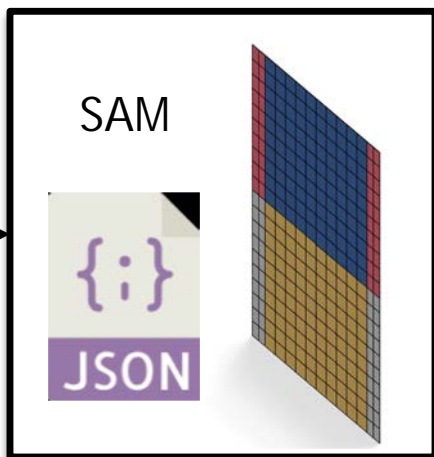
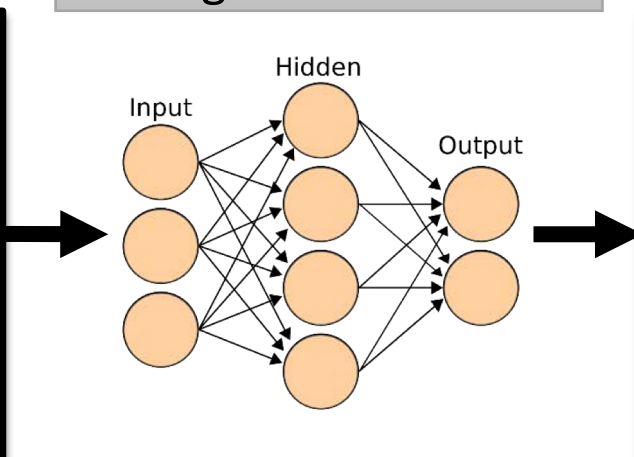
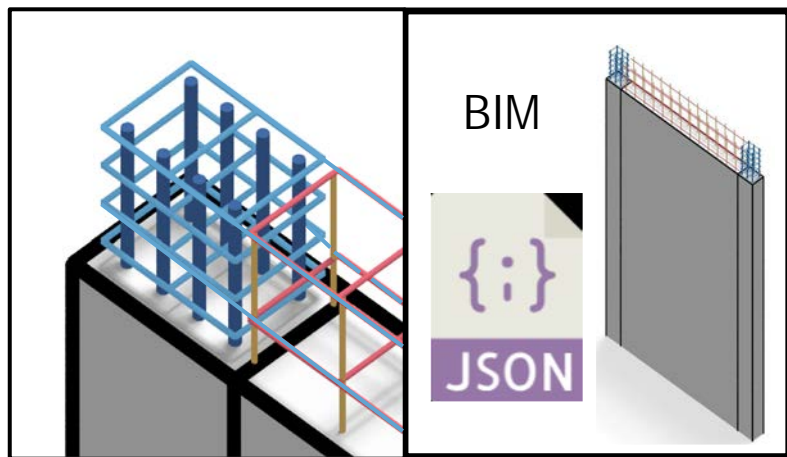
AI Applications: BIM to SAM

Structural Engineers

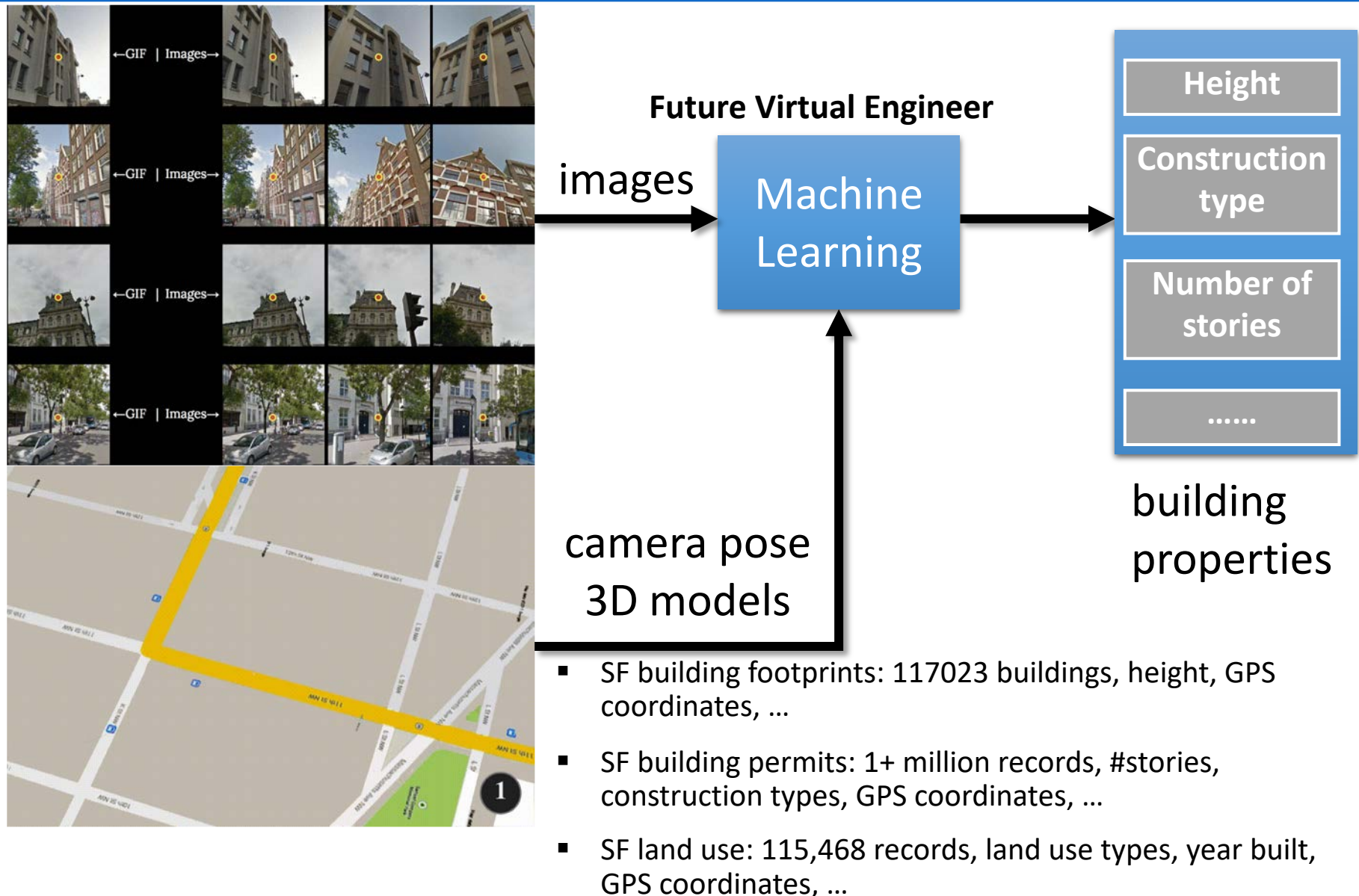


Future Virtual Engineer

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



In the Future: AI for Data to BIM



ECO Activities

■ SimCenter Online Webinars



The screenshot displays a grid of webinar listings under three main categories: Advances in Computational Modeling and Simulation, Early Career Researcher Forum, and Natural Hazards Engineering 101. Each listing includes a title, a date, and a 'Watch Webinar' link. Some listings are marked as 'NEW'.

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

- 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



Multiple Degrees of Freedom Application

Input Motion: Earthquake Motion | Output: Displaced Shape

Input Motion: EICentro | Scale Factor: 1 | Add

Max Disp: 7.48 in
Fundamental Period: 2.09 sec

Analysis Duration: 31.3 sec

Building Properties

Number Floors: 5
Building Weight: 500 k
Building Height: 720 in
Story Stiffness: 31.54 k/in
Damping Ratio: 0.05 %
 Include PDelta

Weight	Height	K	Fy	ix	ix2
1	100	144	31.54	1e+100	0.01
2	100	144	31.54	1e+100	0.01
3	100	144	31.54	1e+100	0.01
4	100	144	31.54	1e+100	0.01
5	100	144	31.54	1e+100	0.01

Current Time: 4.70 sec
Current Roof Disp: -6.12 in
pgs: 0.35g

Play Stop Exit

SimCenter
Center for Computational Modeling and Simulation



SimCenter File Group Tool

System Plot

Hints:

- The File Group Tool uses metric units: meters, kN and kN/m².
- Select piles or soil systems to display and/or change by clicking on the pile inside the System Plot.
- Click on Parameters to select which result plots are shown.

Ground water table: Depth below surface: 4.000 m

Soil Layers

Changing layer: #1 #2 #3 #4

Layer Properties

Thickness: 3.000 m
Dry unit weight: 18.000 kN/m³
apparent weight: 18.000 kN/m³
friction angle: 30.0 deg
shear modulus: 200.0 MPa

Current Time: 4.70 sec
Current Roof Disp: -6.12 in

Play Stop Exit

SimCenter
Center for Computational Modeling and Simulation



Earthquake Versus Wind

Input Forces: Earthquake | Wind

Input Motion: EICentro | Scale Factor: 1 | Add

ASCE 7 Exposure Category: B | Gust Wind Speed (mph): 97.3 | Add

Scale Factor: 1 | Add

Building Properties

Number Floors: 5
Building Weight: 500
Shape: Square
Height: 720 in | Width: 720 in
Drag Coefficient: 1.3
Story Stiffness: 31.54
Damping Ratio: 0.05
 Include PDelta

Weight	Height	K	Fy	ix	ix2
1	100	144	31.54	1e+100	0
2	100	144	31.54	1e+100	0
3	100	144	31.54	1e+100	0

Current Time: 0.00 sec

Run Stop Exit

SimCenter
Center for Computational Modeling and Simulation



Braced Frame Modeling

Input: Experiment: TCR3 W8X25 joist | Add Experiment

Element: Section: Material: Connector:

Frame Model: Vertical-based Fiber

WorkPoint: Length, Lwp: 161.44 in
Brace Length, L: 106.50 in
Number of Sub-Elements, n: 4
Number of Integration Points, NP: 5
Corner: 0.200 %
Corner: +1.000
Sub-Element Position: distributed
Integration Method: Gauss Lobatto
Corner Shape: minimum penetration

Output: Displaced Shape | Axial Force Diagram | Moment Diagram

Current Time: 12.05 s

Hysteretic Response

Experimental: Simulation

Experiment: -0.61 in -24.03 kips | Simulation: -0.62 in -17.69 kips

Applied Displacement History

Play Stop Exit

SimCenter
Center for Computational Modeling and Simulation

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 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.



Regional Simulation Demo

Wael Elhaddad

Regional Simulation

Running a regional simulation using DesignSafe

The screenshot displays the DesignSafe interface for a workflow sandbox. The main window shows the workflow 'Workflow sandbox' and its inputs. A file upload dialog is open, showing 'RegionalDataSF.zip' and 'SFTestbed.json'. A preview window for 'RegionalDamageLoss.csv' is also open, displaying a list of simulation results. A summary table provides key simulation parameters.

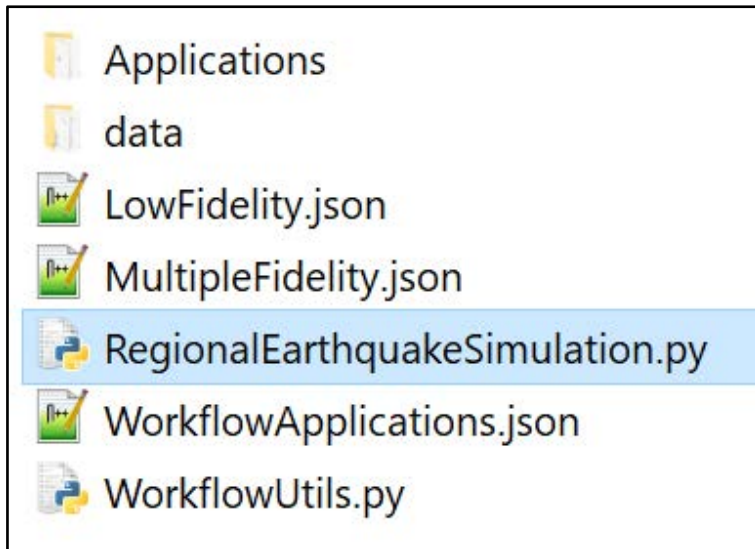
Parameter	Value
Memory Per Node	64
Node Count	64
Parameters	buildingsCount: 500000
ID	4096
Submit Time	2018-10-28T11:37:50.000-05:00
Start Time	2018-10-28T11:38:01.000-05:00
End Time	2018-10-28T14:07:16.000-05:00

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								
3,1735.890089,4928.248935,1.879175786,0,0.1116615698,0.005365861603,37.34473211,-122.0014662								
4,0,1309.33413,0,0,0.05215423038,0,37.69498903,-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								
9,1499.097842,7080.007633,1.639917365,0,0.1485565749,0.007137489834,37.98695719,-122.594278								
10,311647.1916,149865.6742,3.569151239,0,0.3662079511,0.01040081069,37.79499202,-122.2823383								
11,551.610525,0.3743152166,0,0.09242721713,0.0008630125267,37.89525182,-121.6147928								
12,9036.858667,3.83482031,0,0.1485565749,0.009186024644,37.98488147,-122.5987679								
13,10141.04716,6.315196846,0,0.1564067278,0.01327976234,37.99405688,-122.6021578								
14,11043.53758,7.432688412,0,0.1564067278,0.01604863764,37.99382403,-122.6003333								
15,9801.83396,5.004892366,0,0.1564067278,0.02010345436,37.99375169,-122.5990357								
16,810.434804,3.596105403,0,0.1365718654,0.007506706682,37.99099411,-122.5840929								
17,7382.016734,3.443410385,0,0.1365718654,0.00748471972,37.99060732,-122.5838343								
18,7146.851353,2.78766613,0,0.1365718654,0.009005268839,37.98960725,-122.5833179								
19,554.666869,3.364656117,0,0.1365718654,0.007633244792,37.99046758,-122.5877322								
20,7536.767485,3.334869885,0,0.1365718654,0.007277314969,37.99046638,-122.5868473								
21,8891.248695,3.520676227,0,0.1365718654,0.00741556979,37.98862771,-122.5834802								
22,7080.03748,2.116157858,0,0.1365718654,0.01092685723,37.98421842,-122.5910192								
23,7526.037079,3.502449519,0,0.1365718654,0.007506869051,37.98376006,-122.5903697								
24,8886.975145,1.745082997,0,0.1365718654,0.003260135295,37.9826577,-122.5900615								
25,8467.8125,2.382627399,0,0.1485565749,0.00506261587,37.98257195,-122.59198								
26,849.312603,3.456447379,0,0.1365718654,0.007298426463,37.98445303,-122.5886608								
27,5516.256341,1.692911727,0,0.1365718654,0.003362249995,37.98690702,-122.5923766								
28,7447.067114,1.469390713,0,0.1485565749,0.005940254973,37.97846409,-122.5888359								
29,8307.329661,2.54083599,0,0.1485565749,0.005545193,37.97935977,-122.59026								
30,8449.945916,2.412481788,0,0.1485565749,0.004855798967,37.97980838,-122.5899875								
31,6663.460349,1.660952586,0,0.1365718654,0.003239211616,37.97955739,-122.5889619								
32,8815.031665,6.951862666,0,0.1365718654,0.009744852425,37.97975387,-122.5878035								

Regional Simulation

Running a regional simulation using on Local Computer



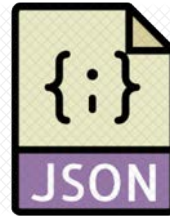
Applications,
Sample Data
& Examples

```
cmd
C:\SourceTree\RegionalSimulationDemo
> python RegionalEarthquakeSimulation.py LowFidelity.json
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.
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

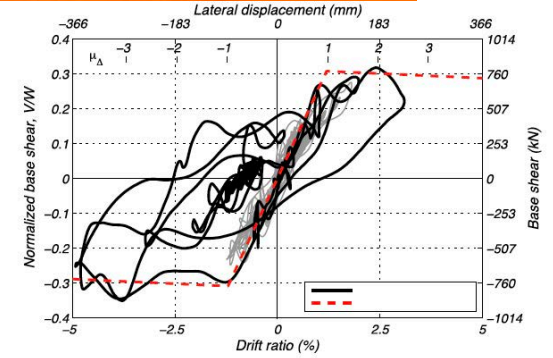
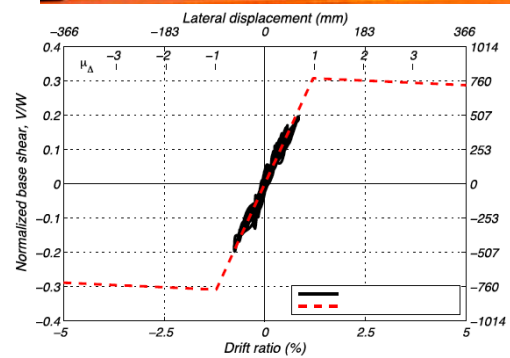
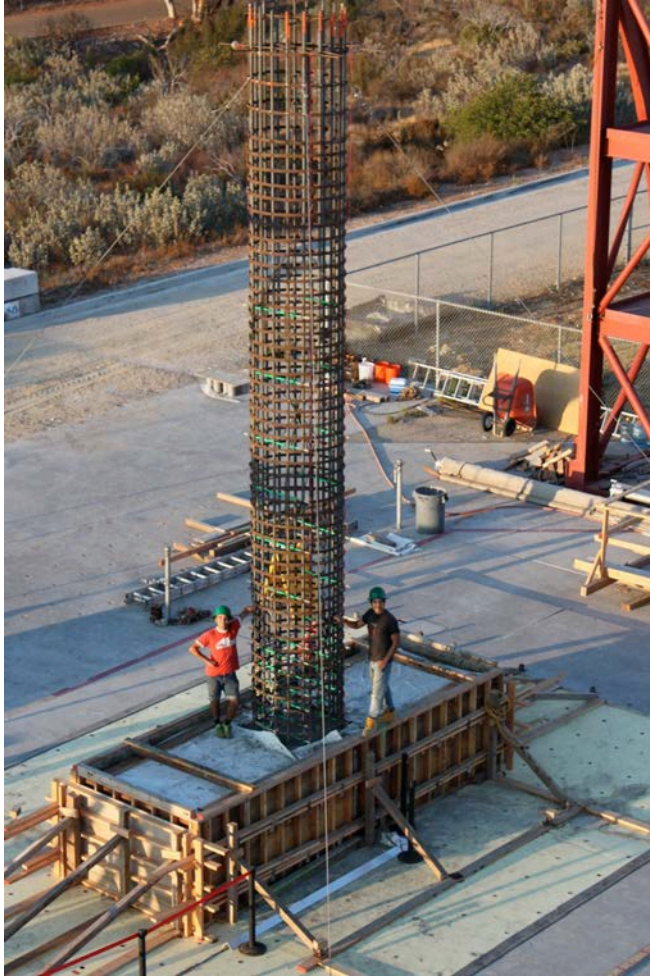


```
{
  "Name": "Workflow5",
  "Author": "Wael Elhaddad",
  "WorkflowType": "Regional Simulation",
  "buildingFile": "buildings.json",
  "Applications": {
    "Buildings": { ...
  },
  "Events": [ ...
  ],
  "Modeling": { ...
  },
  "EDP": { ...
  },
  "Simulation": { ...
  },
  "UQ-Simulation": { ...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



SIMCENTER
COMPUTATIONAL MODELING
AND SIMULATION CENTER

DESIGNSAFE-CI
A NATURAL HAZARDS
ENGINEERING COMMUNITY

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