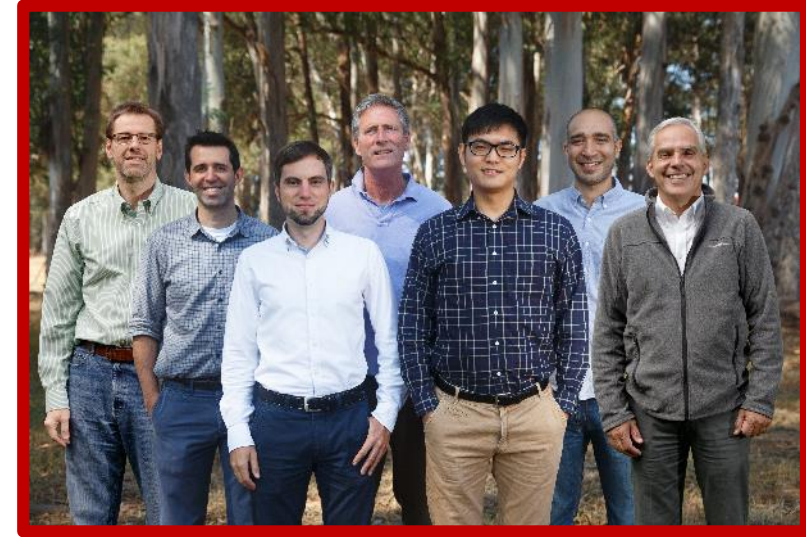


COMPUTATIONAL FRAMEWORK AND TOOLS FOR HIGH-FIDELITY/HIGH RESOLUTION REGIONAL EQ SCENARIOS



Greg Deierlein
& SimCenter Team



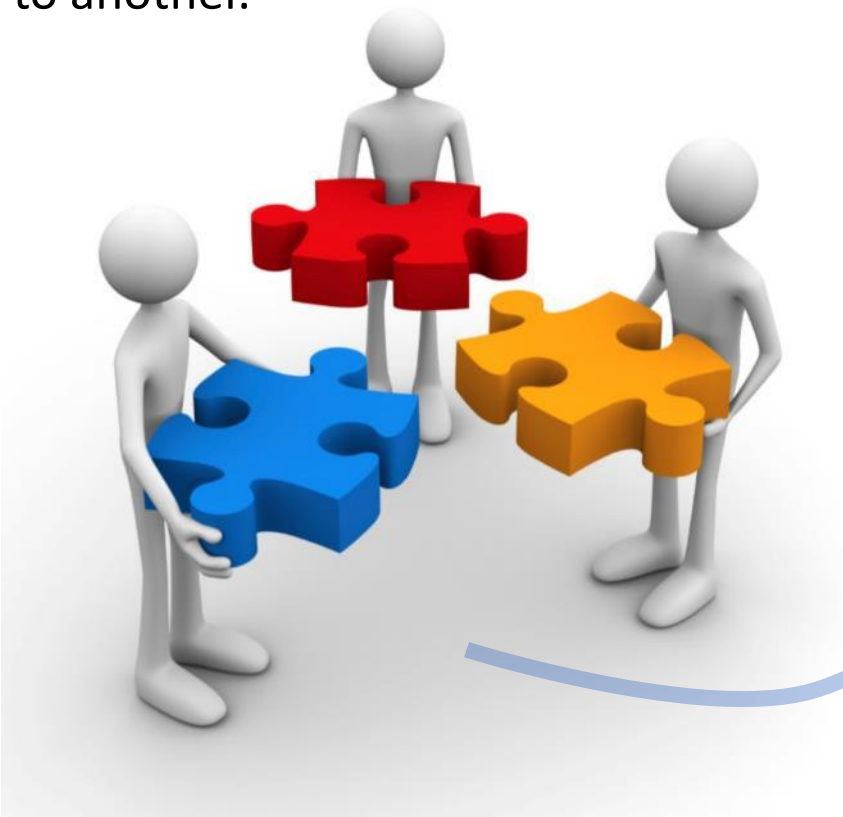
SimCenter **NHERI**
Center for Computational Modeling and Simulation



Our Strategy: Personal computer class software

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.

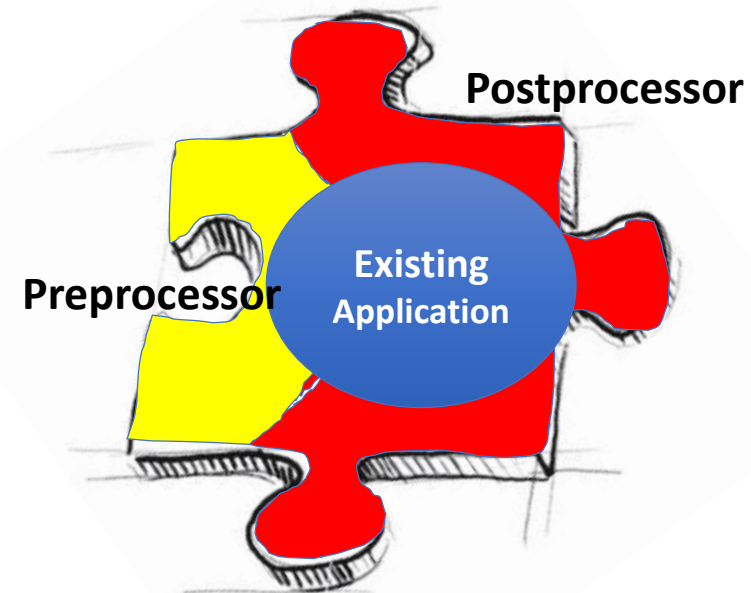
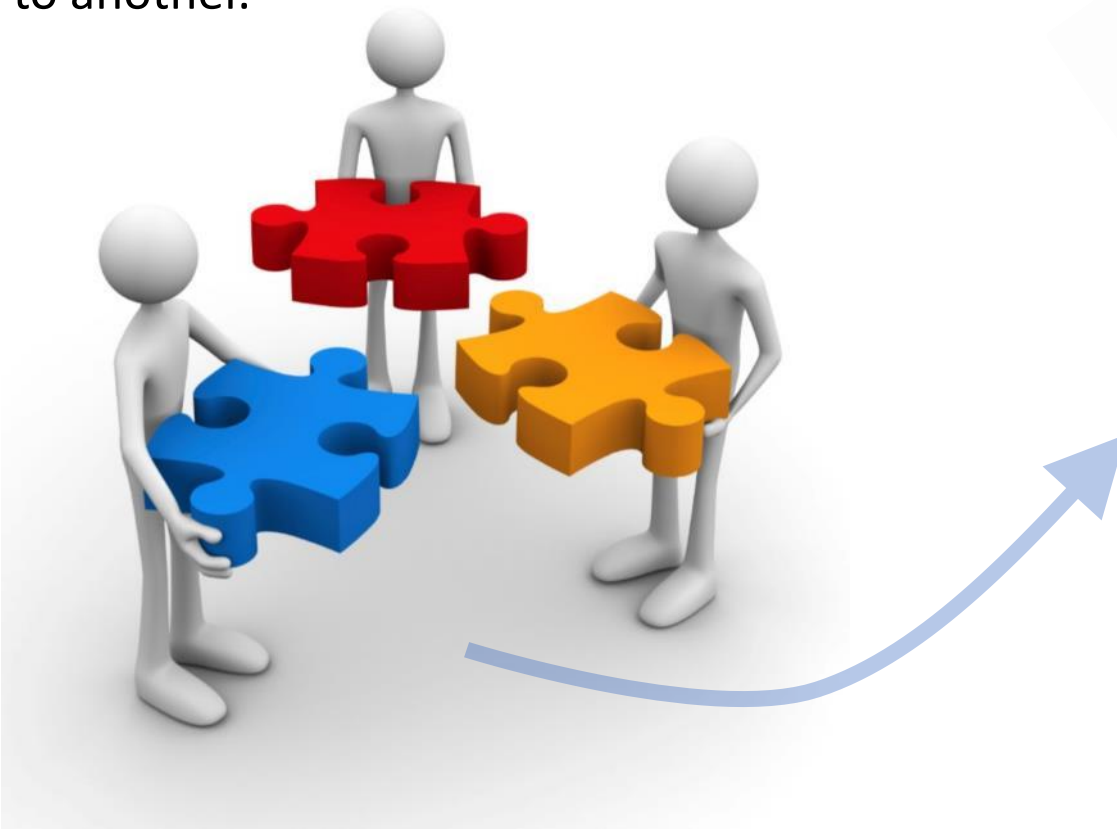


- Move to cloud-based HPC environment,
- Provide integrated “plug and play” capability to link multiple software apps together into workflows

Our Strategy: Personal computer class software

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.

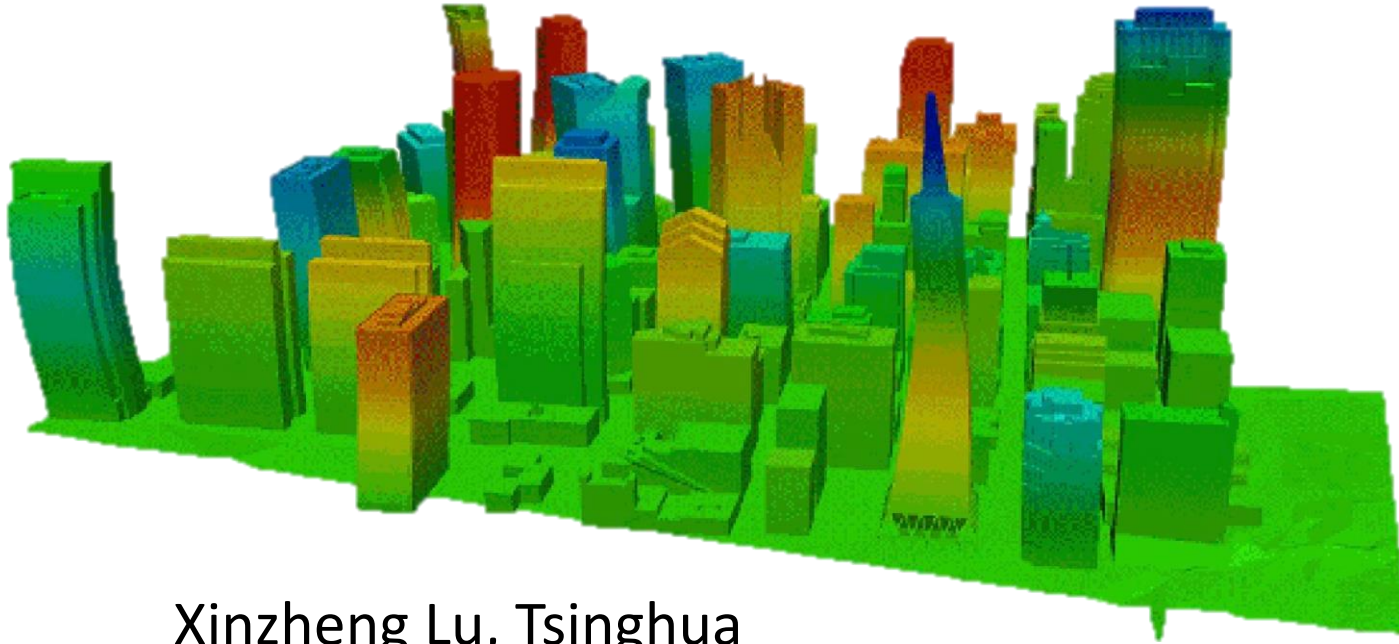


Focus on defining API requirements for data input/output and develop API wrappers to interface existing software

Application of Applications Framework



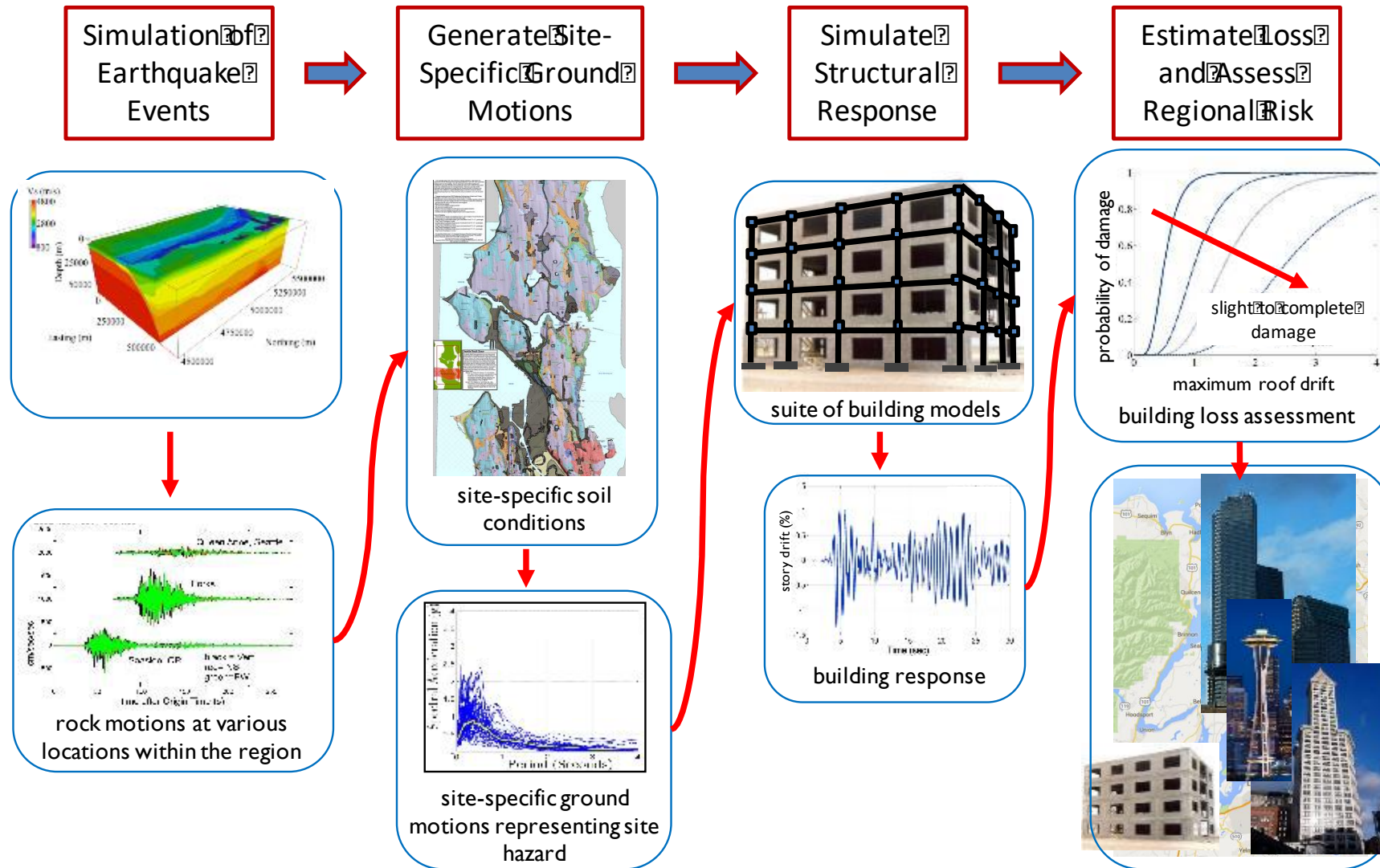
Application of Applications Framework



Xinzheng Lu, Tsinghua

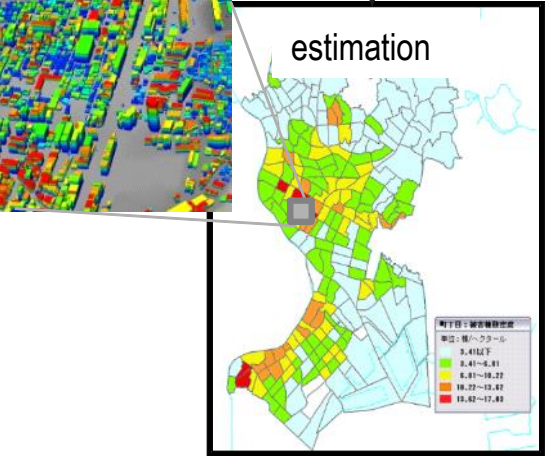
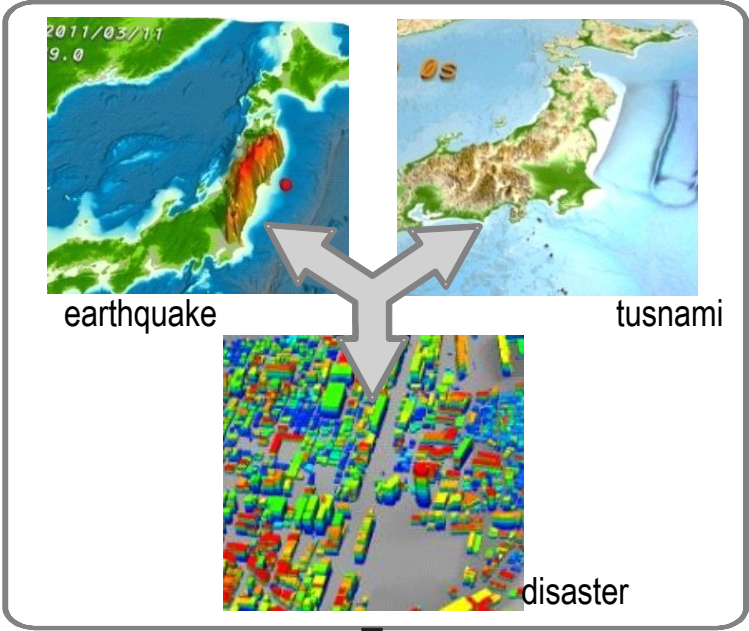
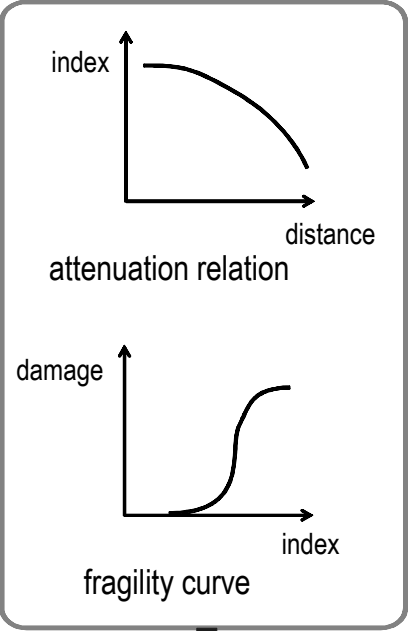


Performance-Based Engineering Approach



Simulation-Based Risk and Resilience Assessment

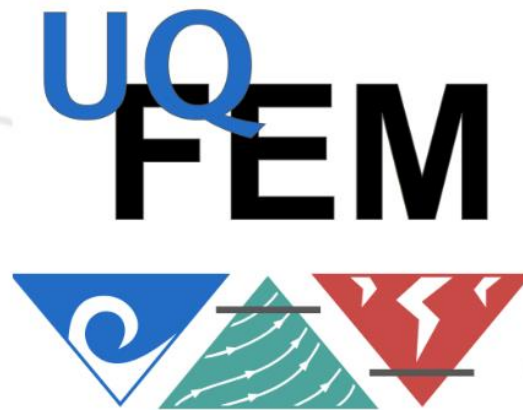
CURRENT (e.g., HAZUS)
Empirical Models
Census Block Inventory



GOAL
Direct Simulation
Detailed Inventory
Multiple models

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.



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.

- probabilistic estimation of losses, injuries and community resilience under natural disasters

- Hazard-agnostic loss-assessment library in 

- Object-oriented and conceptually similar to what OpenSees is for FEM

- Open-source, transparent, cross-platform, easy to install and use

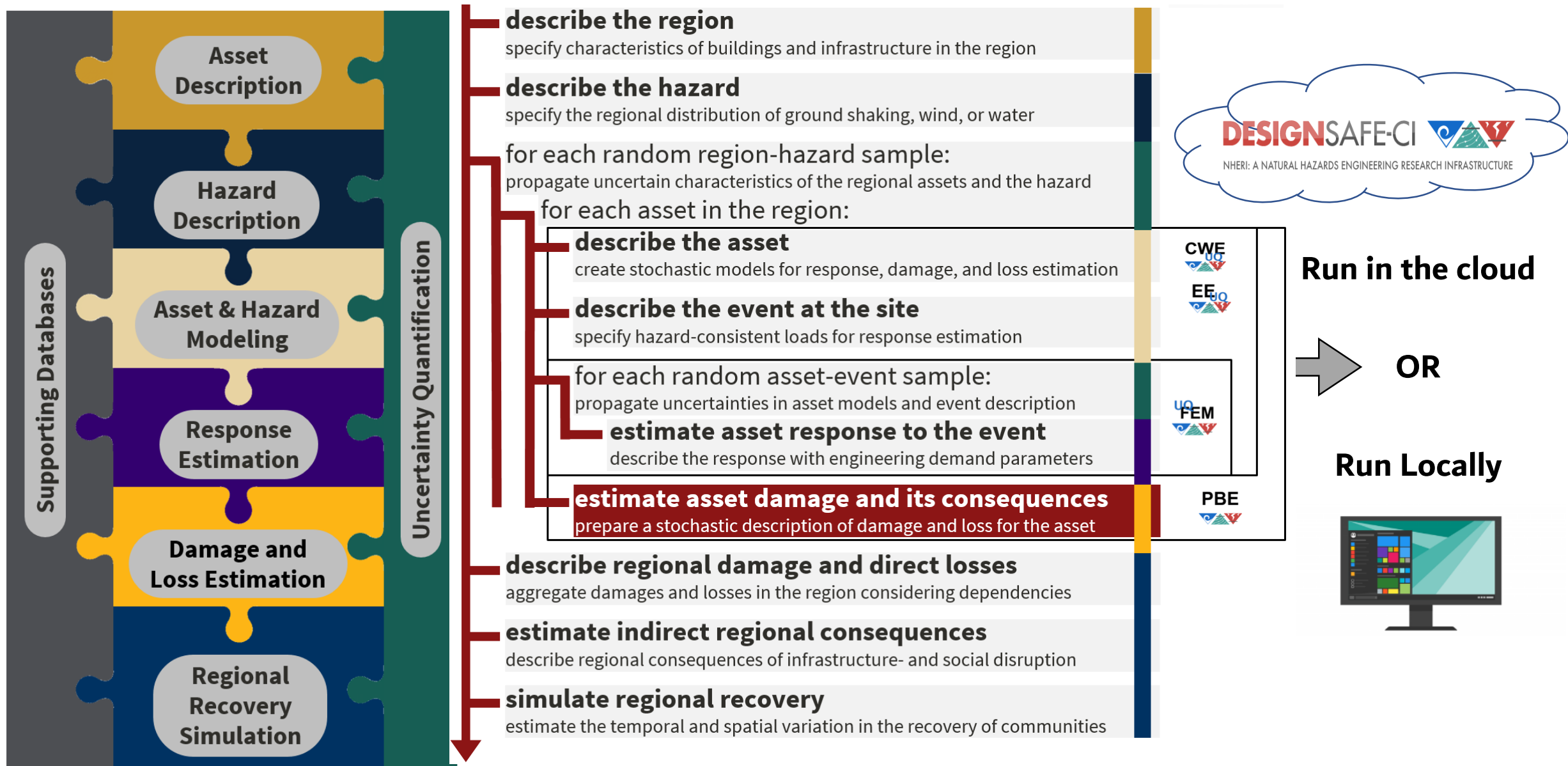


Read *the* Docs

github.com/zsarnoczay/pelican

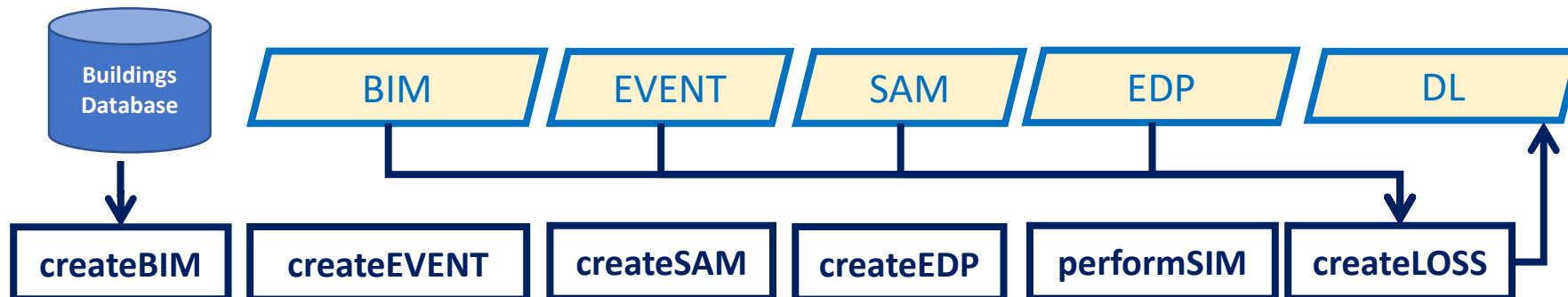
Adam Zsarnoczay

Application Framework & Research Apps

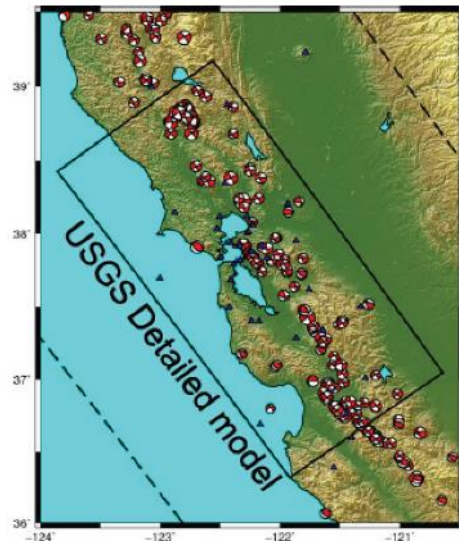


Registered Applications

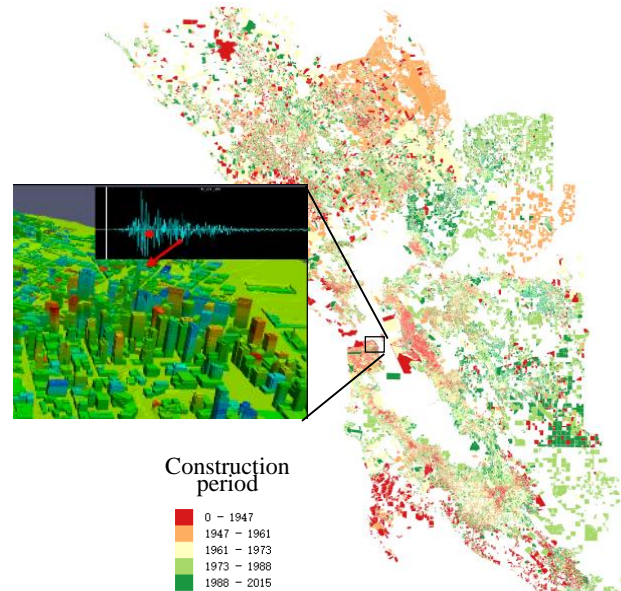
Type	Name	Description
createBIM	GenericBimDatabase	Creates a simple BIM from a building flat file (csv)
	UrbanSimDatabase	Creates a simple BIM from UrbanSim simulation outputs
createEVENT	LLNL_SW4	Gets Event input from SW4 outputs
	SHA-GM	Computes event input using SHA and record selection/scaling
createSAM	MDOF_LU	Creates a MDOF shear building model
createEDP	StandardEarthquakeEDP	Defines the standard EDPs used for a seismic event
performSIM	OpenSeesSimulation	Performs simulation using OpenSees and calculates the EDPs
createLOSS	FEMAP58_LU	Calculates damage and loss estimates using FEMA P58 procedure
performUQ	DakotaFEM	Propagates uncertainty in all applications using Dakota



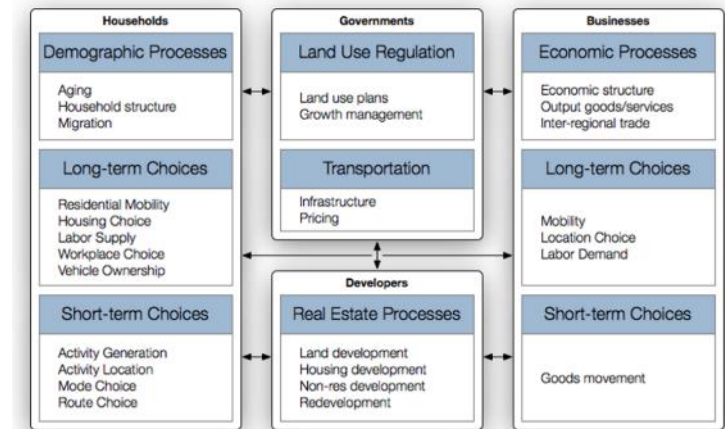
PBEE Regional End-to-End Testbed: SF Bay Area



M7.0 Hayward Fault



1.8 million buildings in SF Bay Area



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

Objective: develop and exercise a workflow to connect software models and systems on a challenging computational model that engages a broad cross-section of NEHRI community

Ground Motions: 3D simulation, GM's at 2km grid (Rodgers, Pitarka & Petersson)

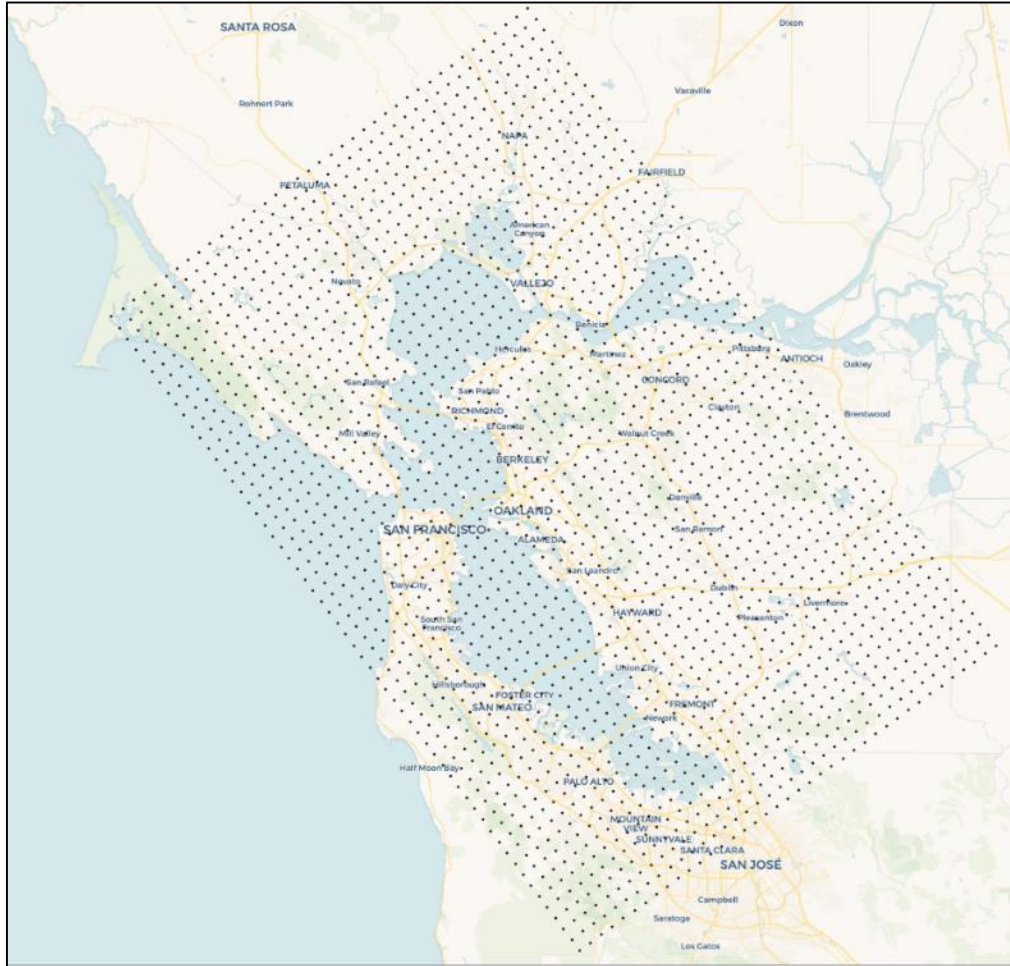
Building Inventory: UrbanSim and DataSF Portal; geometry, age, occupancy

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

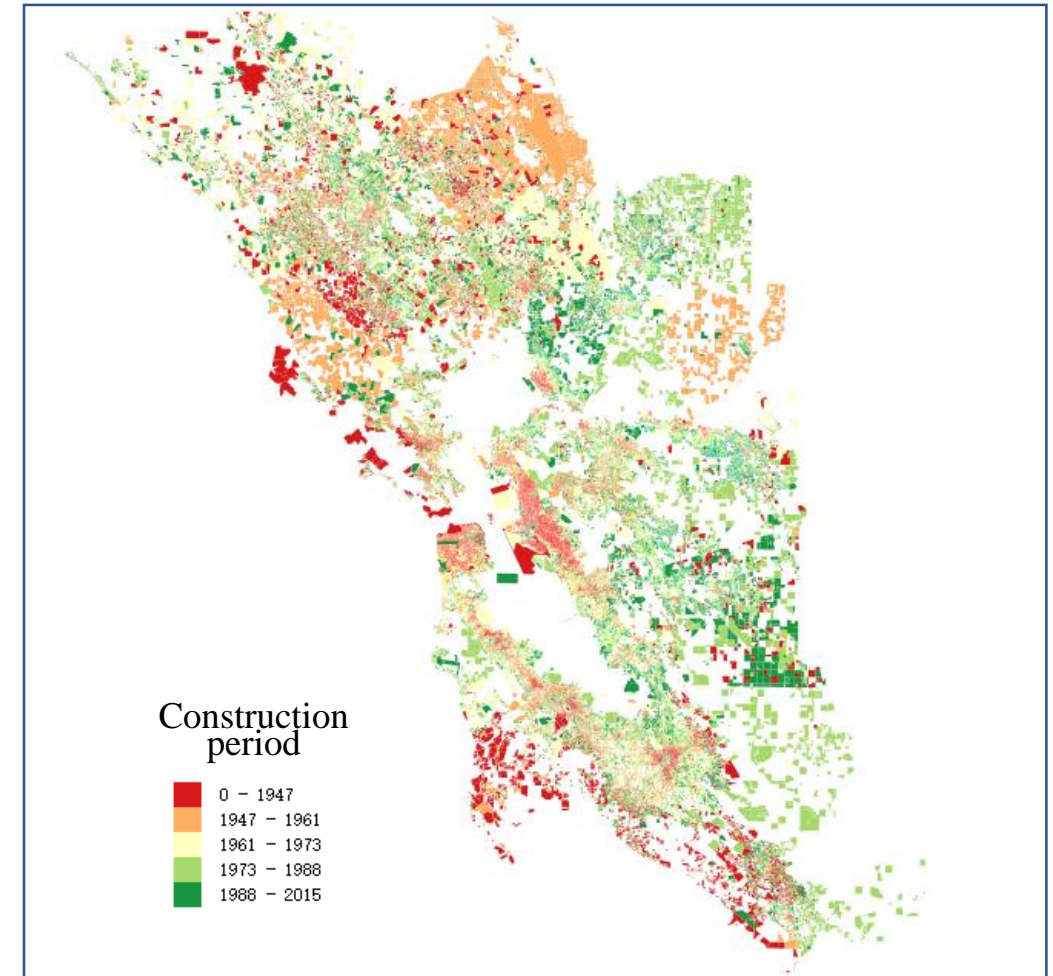
Visualization: Q-GIS, UrbanSim (Waddell)

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

SimCenter SF Bay Area Regional Testbed Study



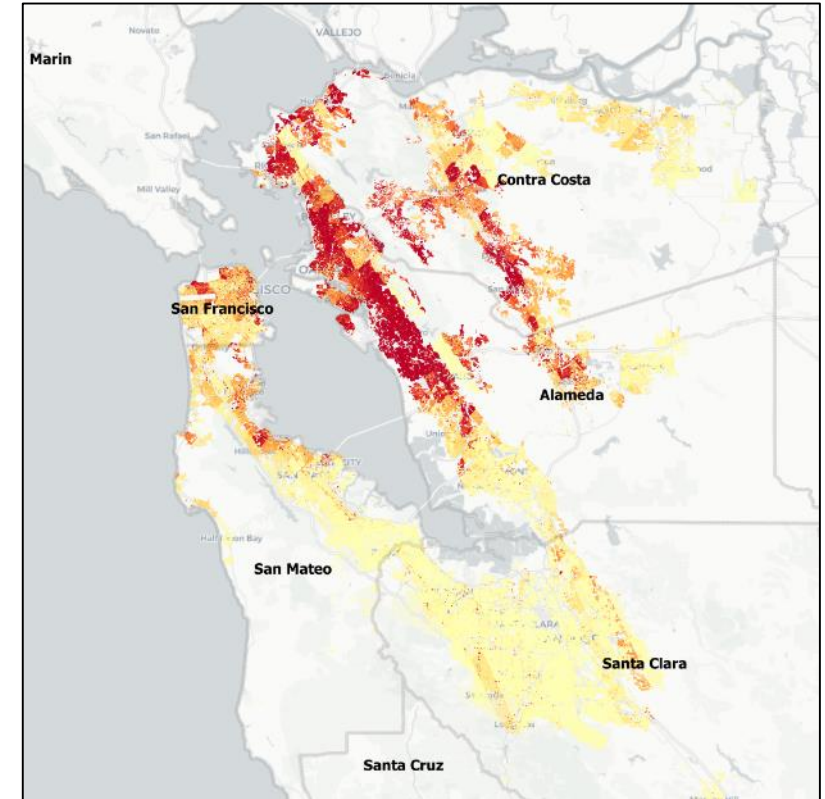
LLNL_SW4 (M7.0 Scenario; 2km grid)



Building Inventory (Parcel by Age)

SimCenter SF Bay Area Regional Testbed Study

- M7.0 Hayward rupture modeled using SW4 [1]
- 1.84 M buildings were included in the simulation
- Building information is based on UrbanSim data
- Damage and Loss is based FEMA_P58_LU [2]
- OpenSees structural analysis models are based on MDOF_LU
- Run on DesignSafe HPC Resources
- Example of Results:
 - *Red-tagged buildings 141,400*
 - *Net buildings damage ratio 5.6%*

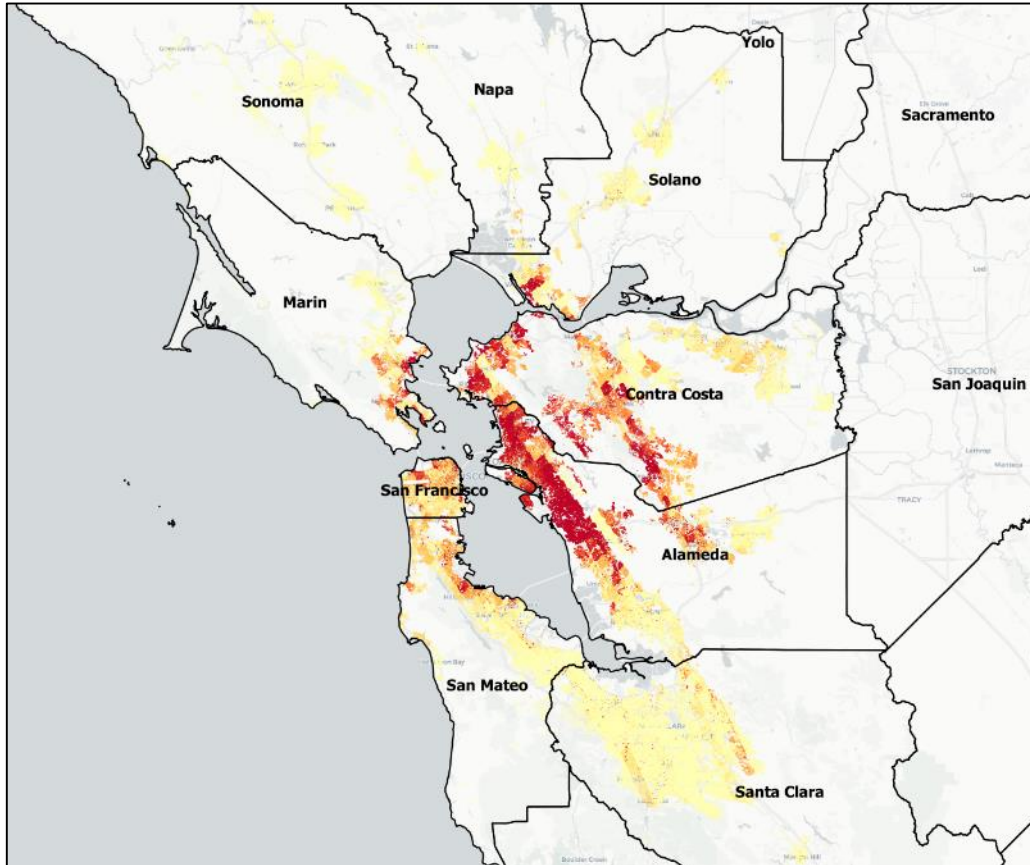


Building Loss Ratio

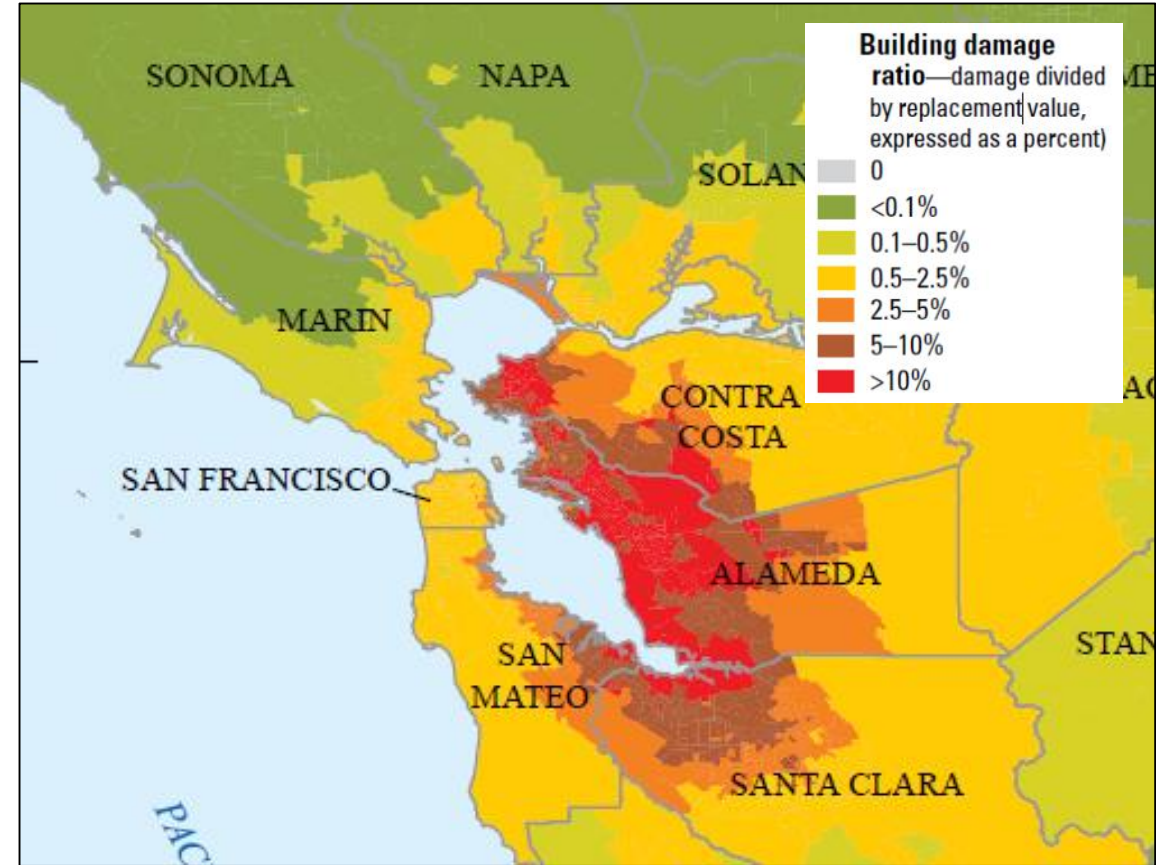
[1] Petersson, N.A.; Sjogreen, B. (2017), SW4, version 2.0 [software], Computational Infrastructure of Geodynamics, doi: 10.5281/zenodo.1045297, url: <https://doi.org/10.5281/zenodo.1045297>

[2] Zeng X., Lu X.Z., Yang T., Xu Z., "Application of the FEMA-P58 methodology for regional earthquake loss prediction", Natural Hazards (2016), 10.1007/s11069-016-2307-z

Hayward 7.0 - Comparison of Building Damage

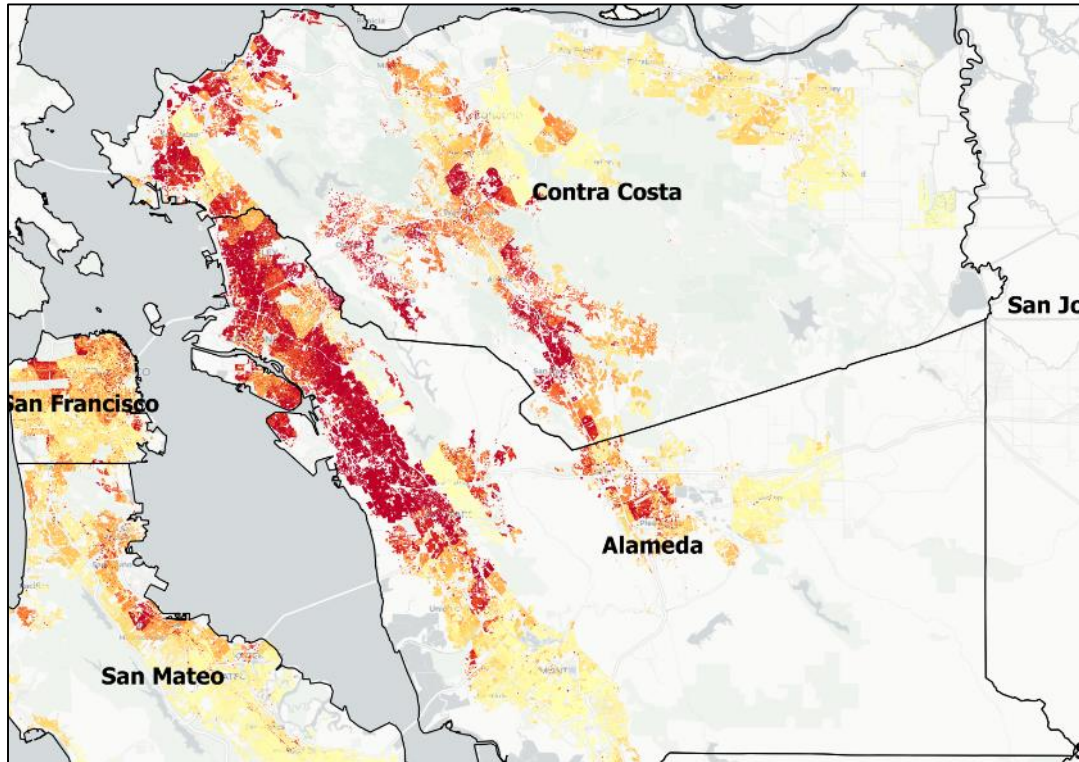


SimCenter Workflow



USGS Haywired

Hayward 7.0 - Comparison of Building Damage

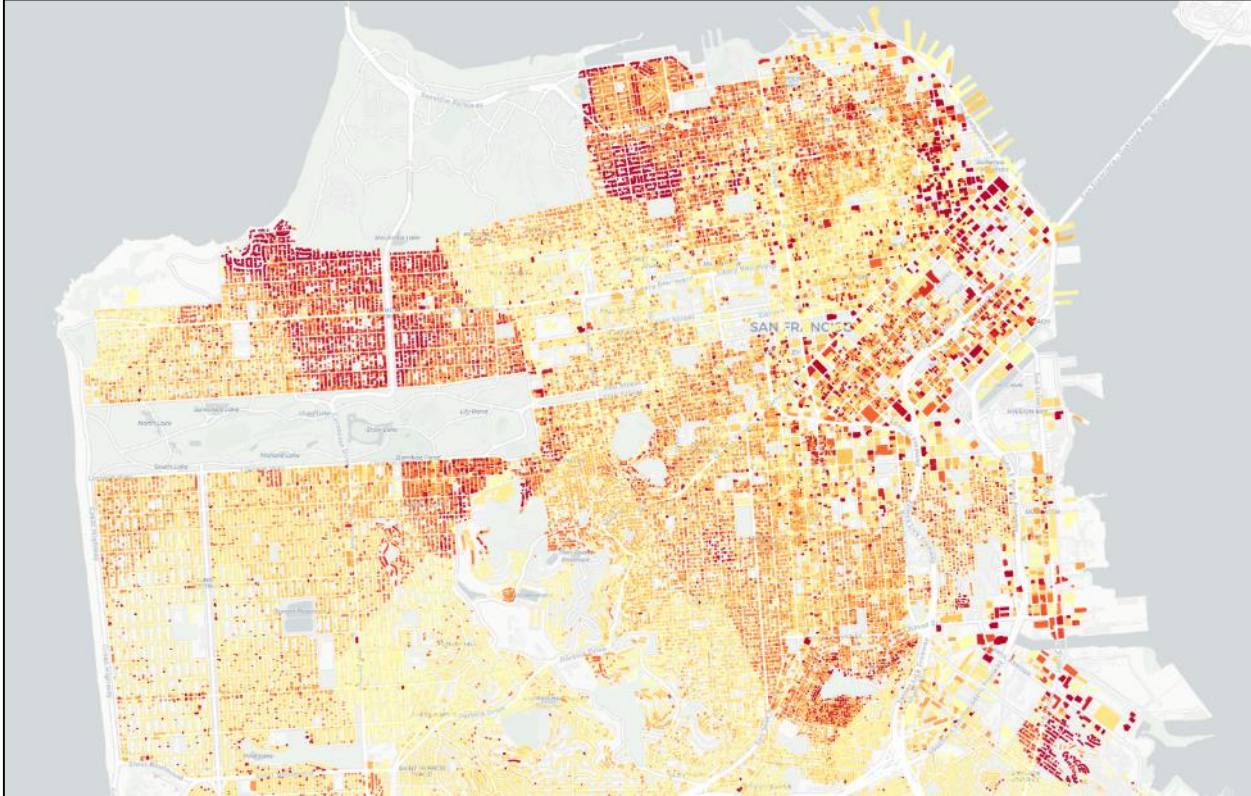


SimCenter Workflow



USGS Haywired

Parcel-level Data of Building Damage



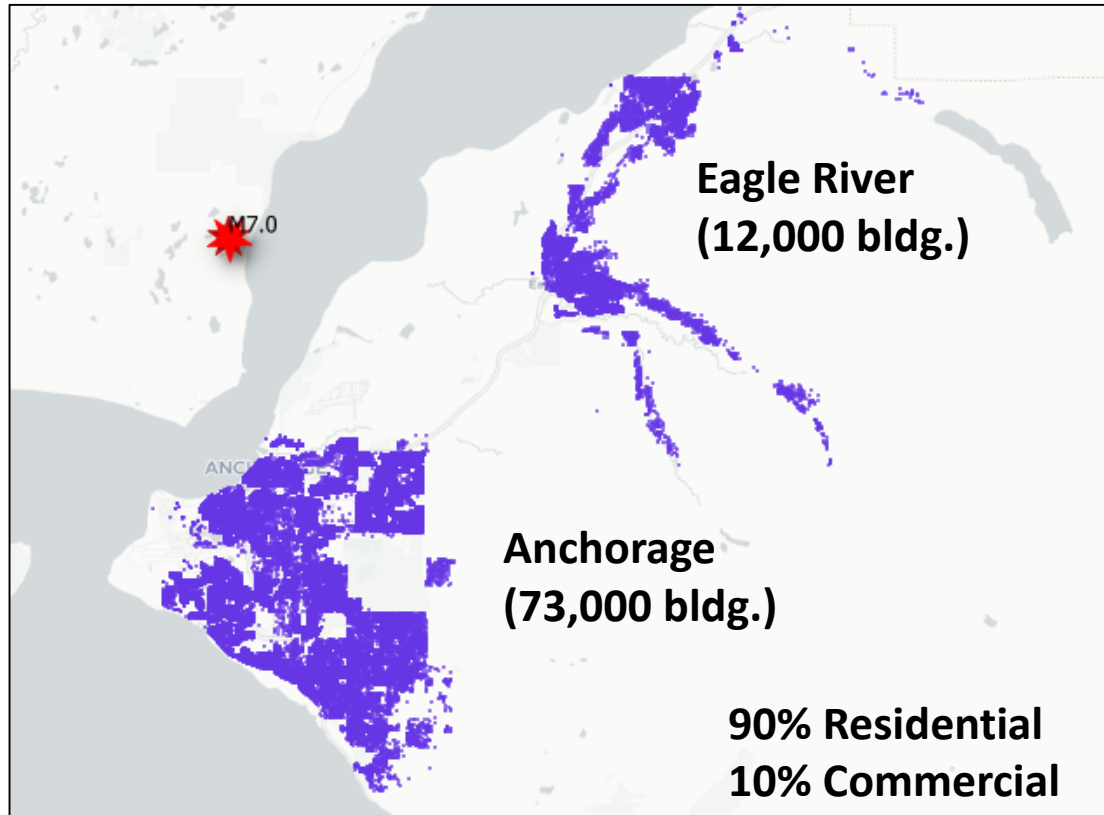
San Francisco



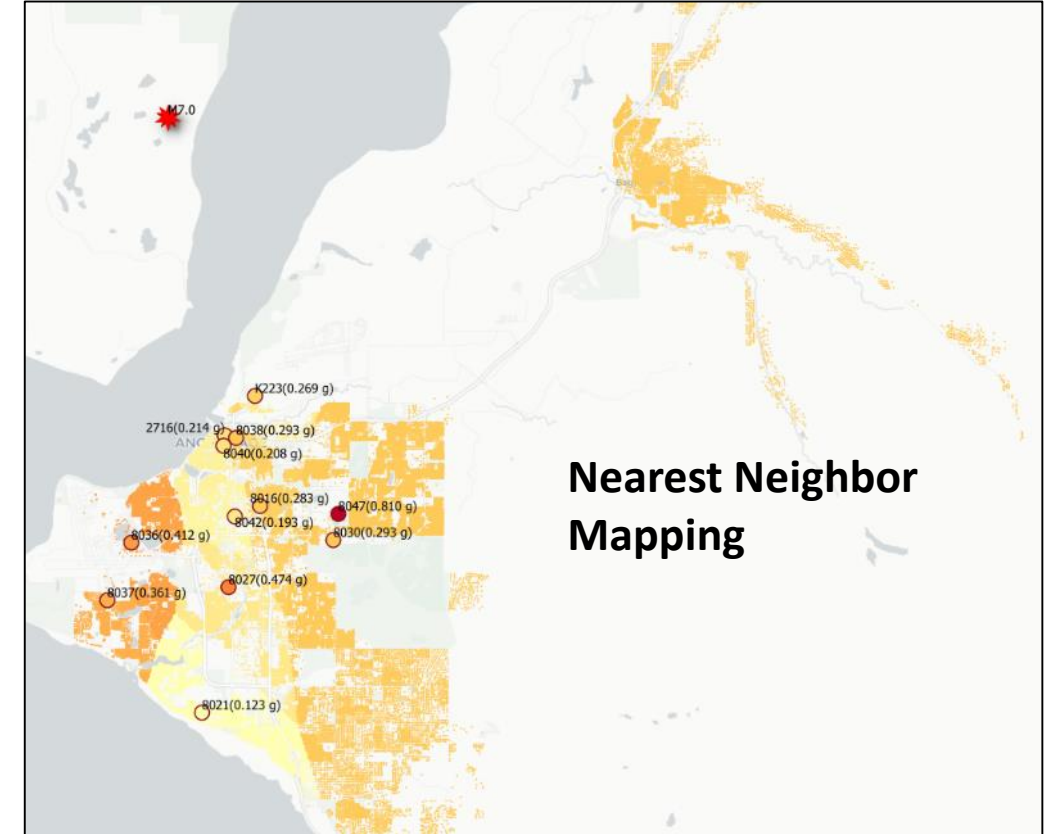
Oakland - Alameda



Anchorage M7 (Nov. 30, 2018)



Building Inventory
(Tax Database to BIM)

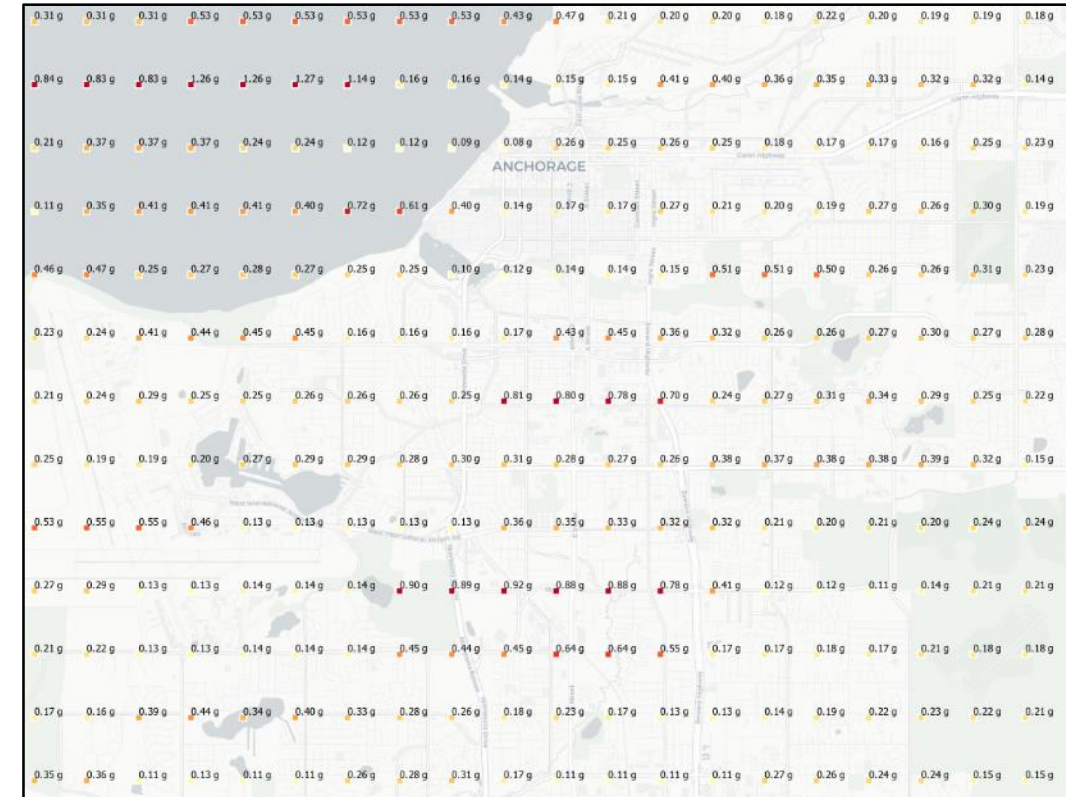


Recorded Motions
(CESMD – 12 processed motions)

Anchorage M7 – Recorded & Simulated Motions

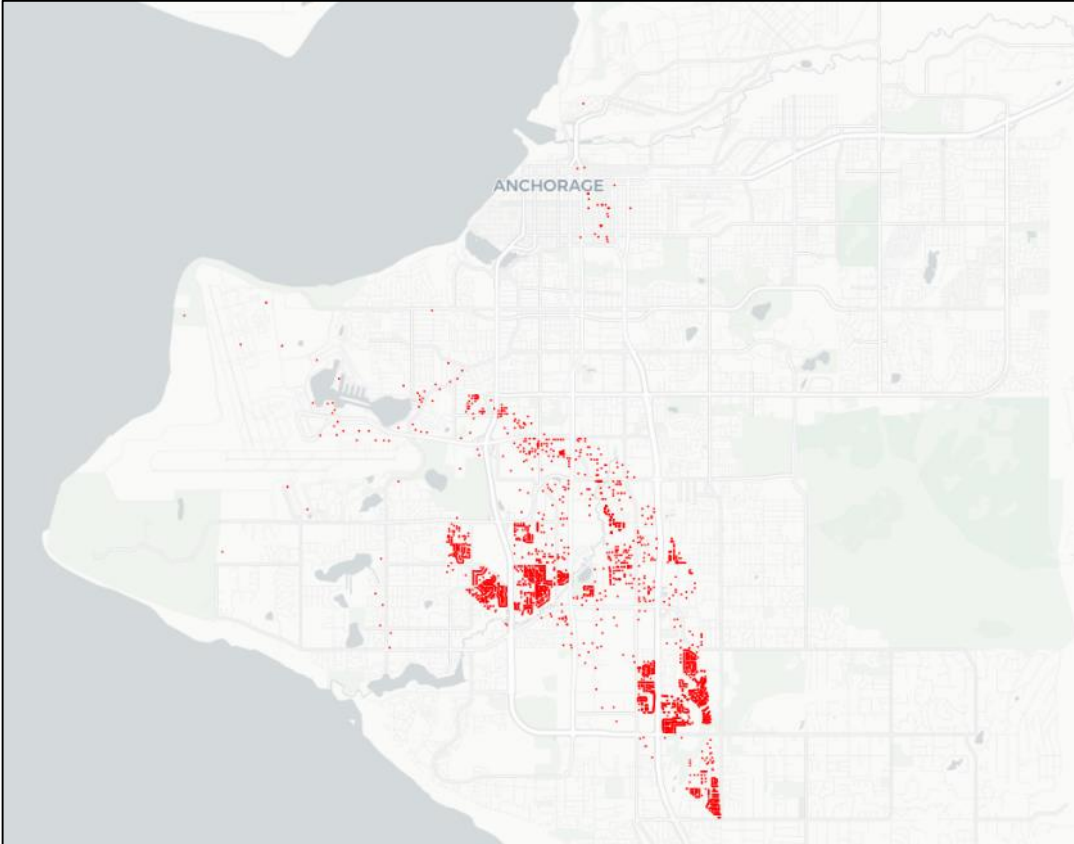


Recorded Motions - 24
(CSMED + Alaska EQ Center)

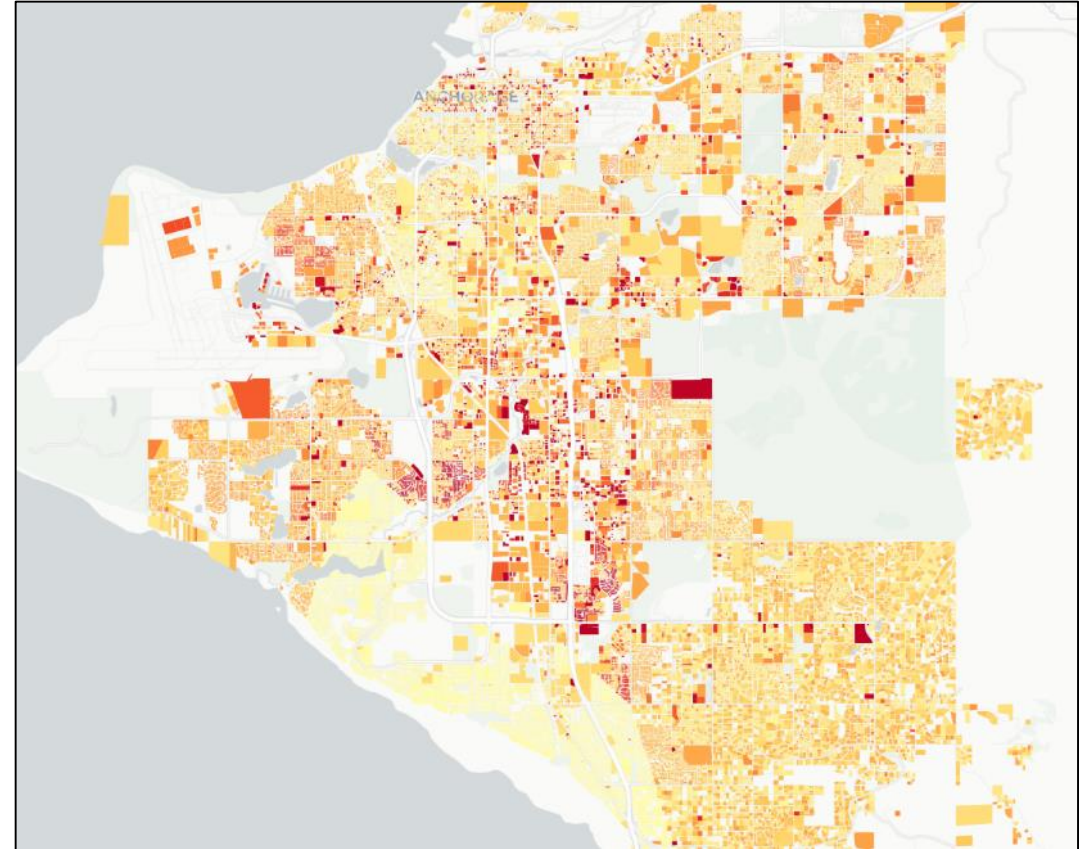


Simulated Motions
(Stochastic Model, Deodatis et al.)

Anchorage – Building Damage

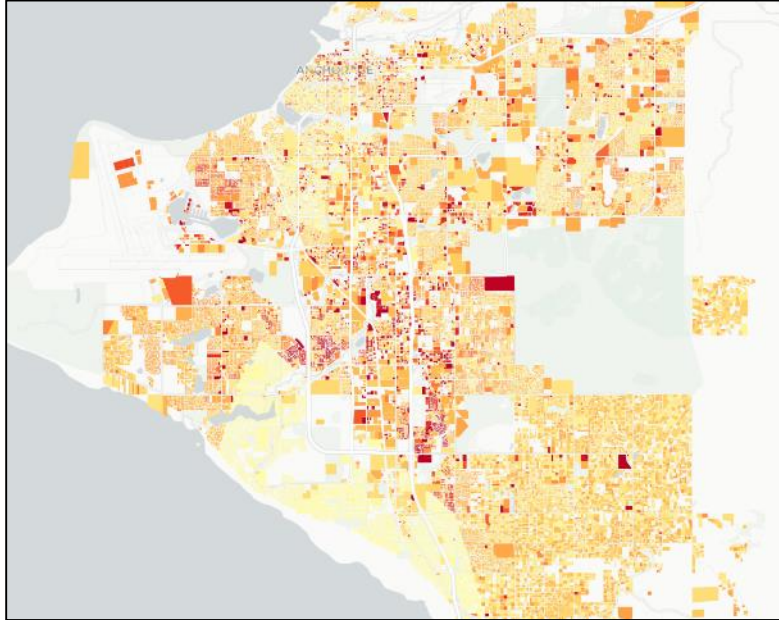


Red Tagged Buildings

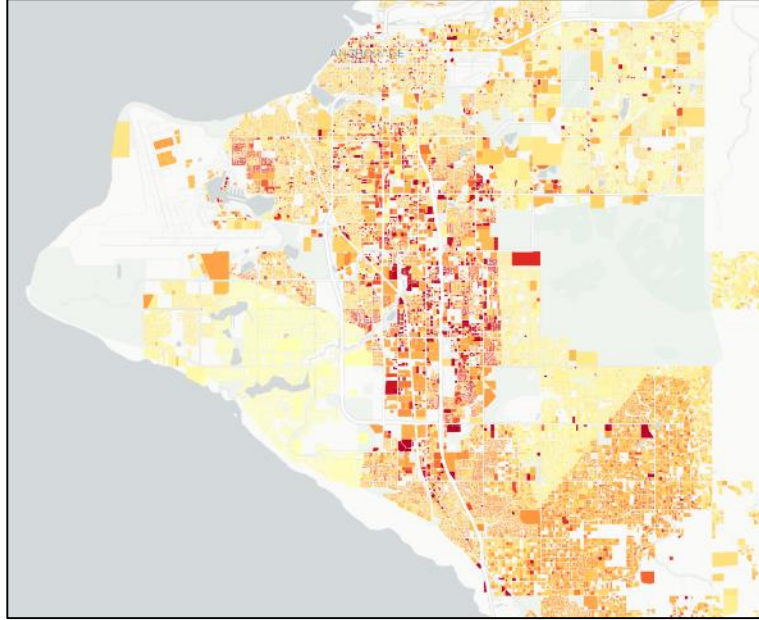


Building Loss Ratios

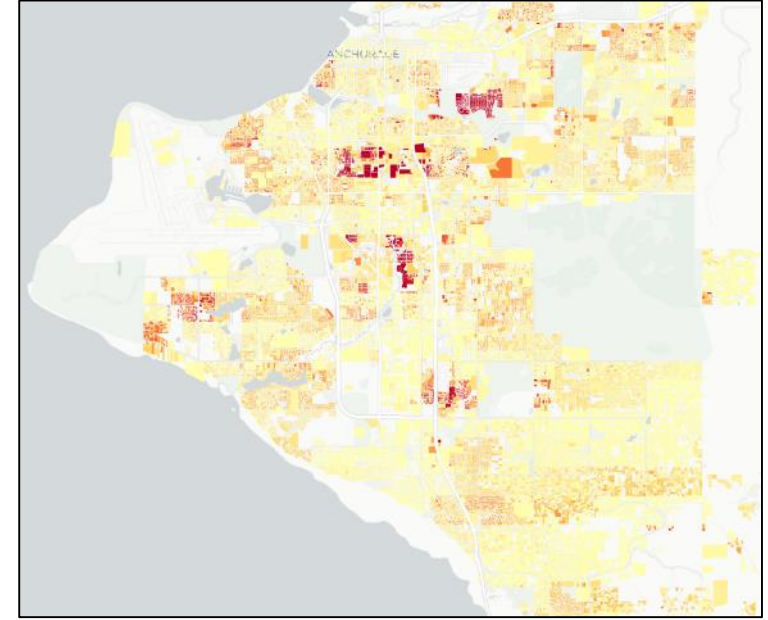
Anchorage – Building Damage



CESMD Motions



Alaska EQ Center



Simulated Motions

Effect on ground motion inputs (estimates) on building damage

Testbed for Wind & Coastal Hazards

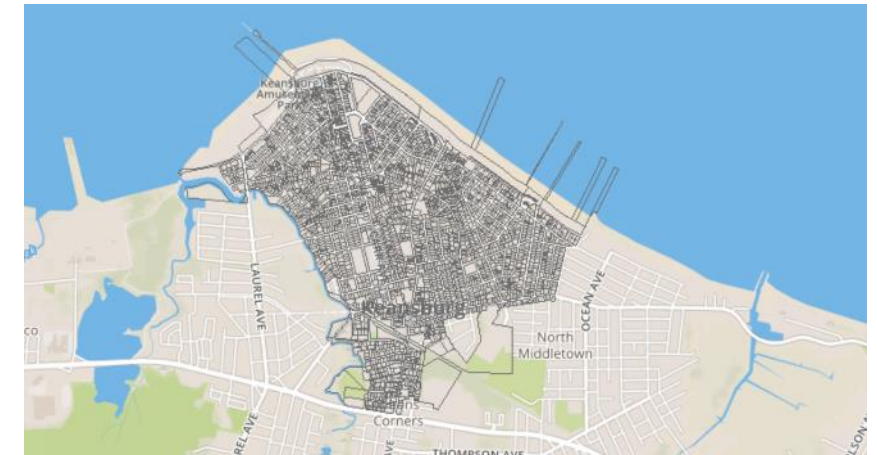
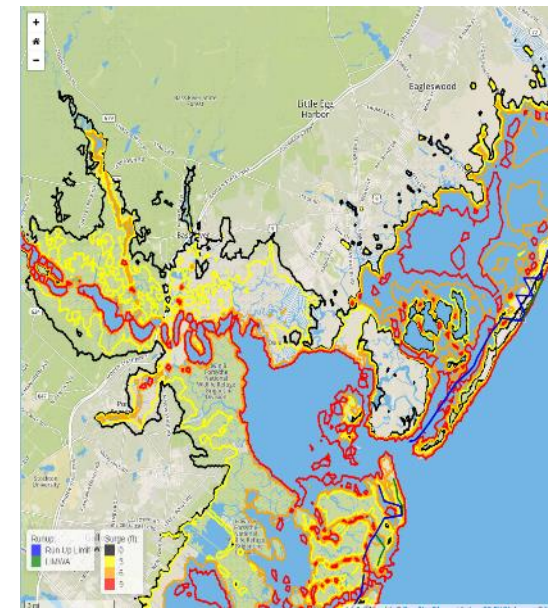
New York/New Jersey Regional Model

- Impact potential comparable to San Francisco
- Northern New Jersey Coast (wood-framed single family coastal construction)
- Manhattan (urban resiliency, complex flow environments, flexible buildings)

Existing Database of High Fidelity Hazard Simulations

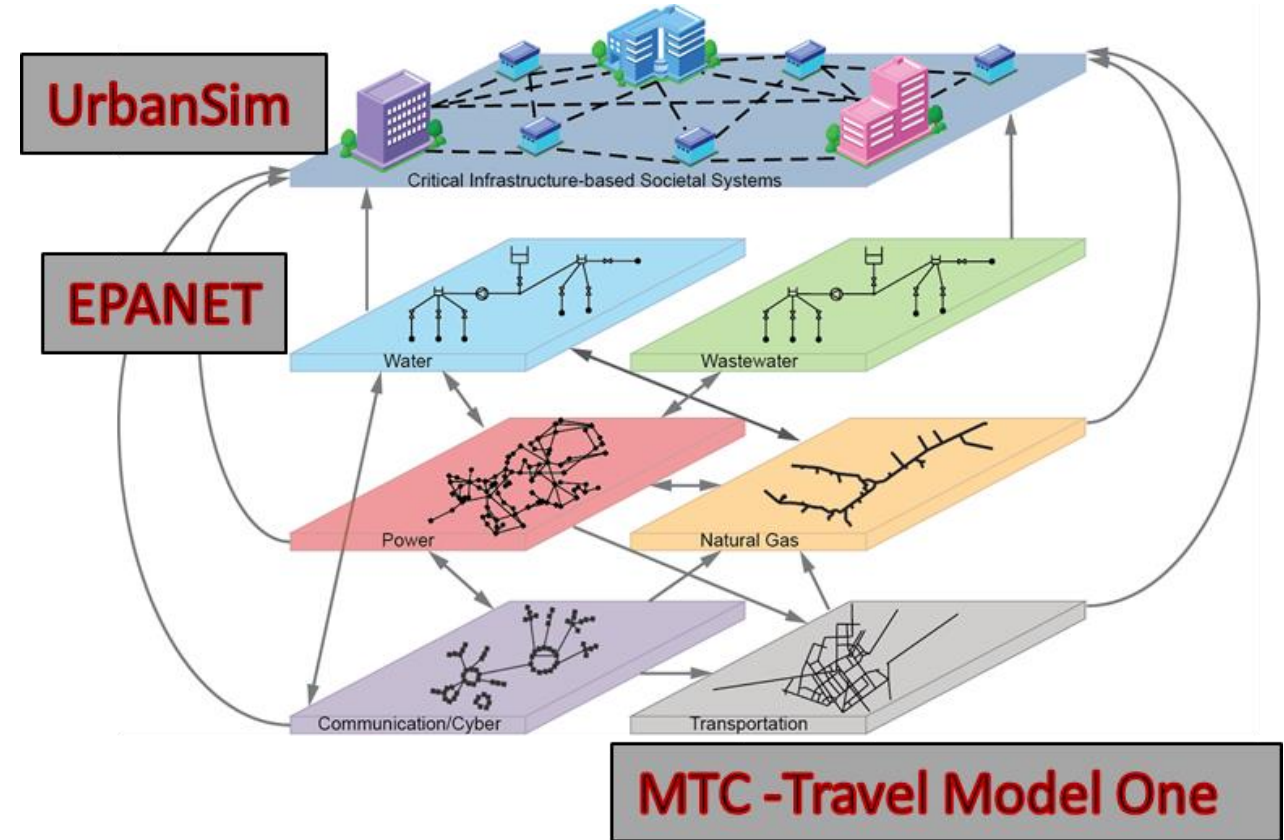
- North Atlantic Coast Comprehensive Study (NACCS): ADCIRC + ST-WAVE
- 1000+ historical and synthetic tracks of hurricanes and nor'easters

Surrogate models allow computationally efficient scenario generation



Regional Workflows – Vision & Plans

- Open source component tools
 - createEvent, createBIM, createSAM
 - PBE Loss/Recovery
- Robust and scalable UQ tools
- Utility & Transportation Systems
- Other Natural Hazards
 - Wind & Storm Surge
 - Tsunami
- Resilience Decision Tool **RDT**
 - V1 (2020) – EQ
 - V2 (2021) - Hurricane (Wind/Surge)
 - V3 (2022) - Tsunami



Integrated Infrastructure Systems

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