SimCenter NHERI

Center for Computational Modeling and Simulation

rWHALE: Regional Workflow for Hazards and Loss Estimation

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NHERI SimCenter

Programming Bootcamp 2019

NSF award: CMMI 1612843

Outline

- **Overview of the Computational Framework**
- **Regional Workflows using rWHALE**
- **Regional Testbed Simulations**
  - San Francisco Testbed
  - Anchorage Testbed
- **Demos & Exercises**
  - Local computer
  - High performance computer (HPC)

NHERI SimCenter

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

SimCenter NHERI
Center for Computational Modeling and Simulation

- **Cloud-enabled research tools, scalable to run on HPC**
- **Emphasis on uncertainty quantification**
- **Educational resources**

Front-end

SimCenter Research Tools

UQ FEM | PBE | EE UQ | WE UQ

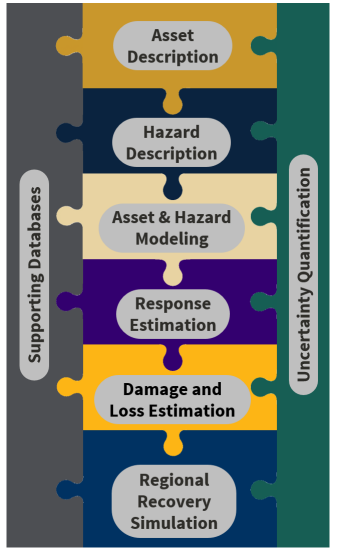
Agave Platform

Back-end

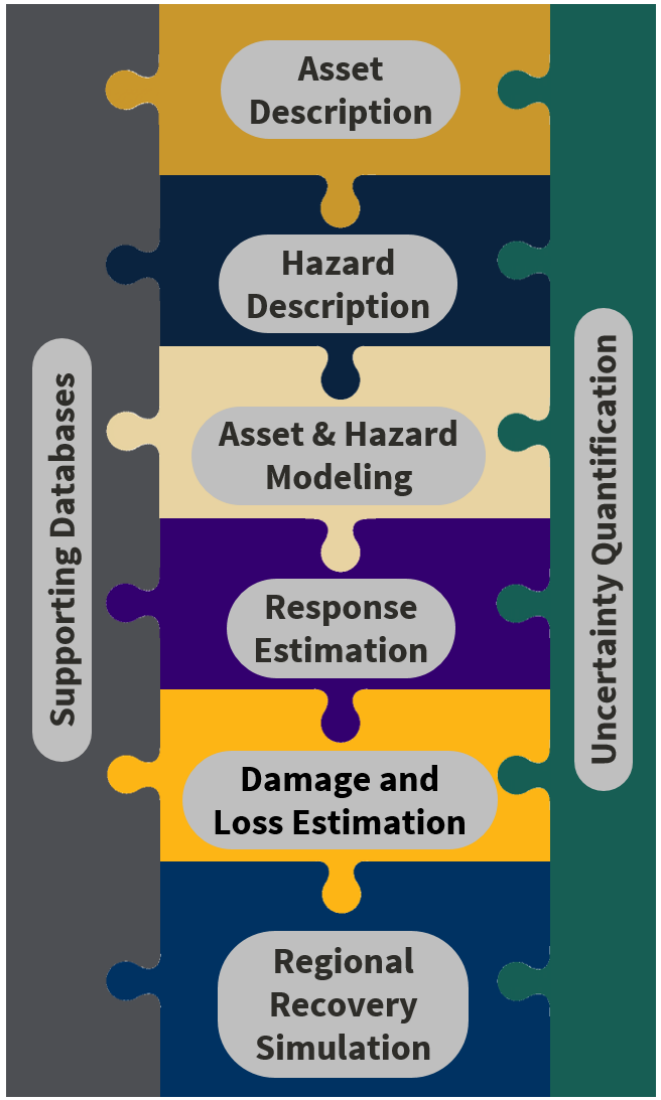
DESIGNSAFE-CI
NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

- **Data storage and HPC access**

SimCenter's Application Framework



Framework for Building Workflow Applications



describe the region
specify characteristics of buildings and infrastructure in the region

describe the hazard
specify the regional distribution of ground shaking, wind, or water

for each random region-hazard sample:
propagate uncertain characteristics of the regional assets and the hazard

for each asset in the region:

describe the asset
create stochastic models for response, damage, and loss estimation — CWE, EE-UQ

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

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

estimate asset response to the event
describe the response with engineering demand parameters — UQ-FEM

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

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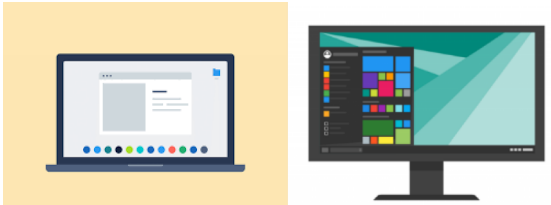
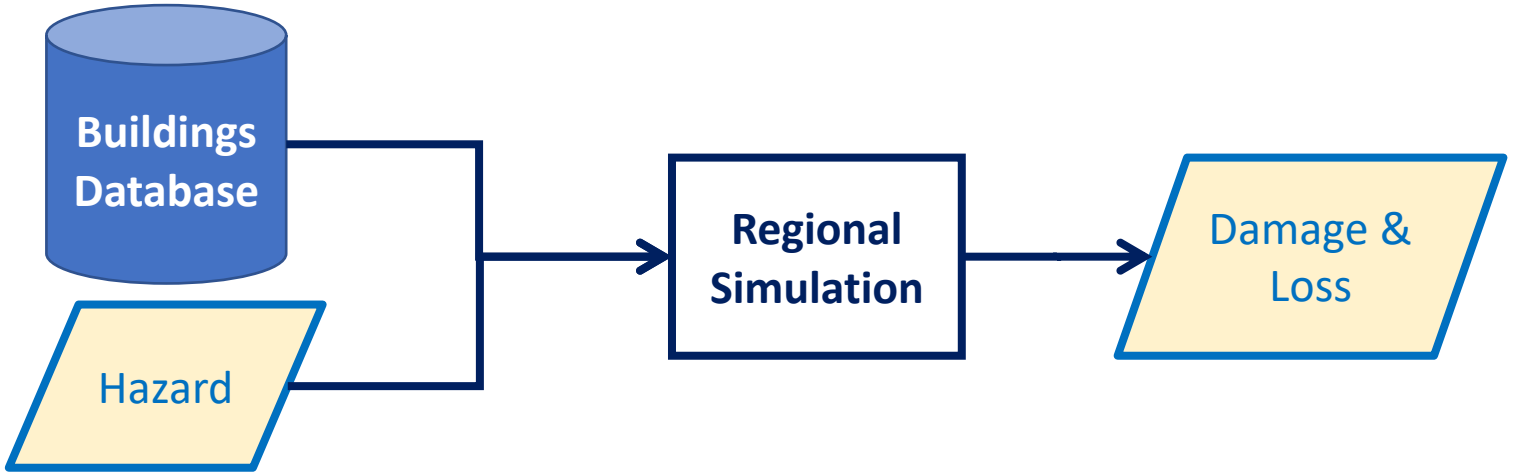
Run in the cloud
OR
Run Locally

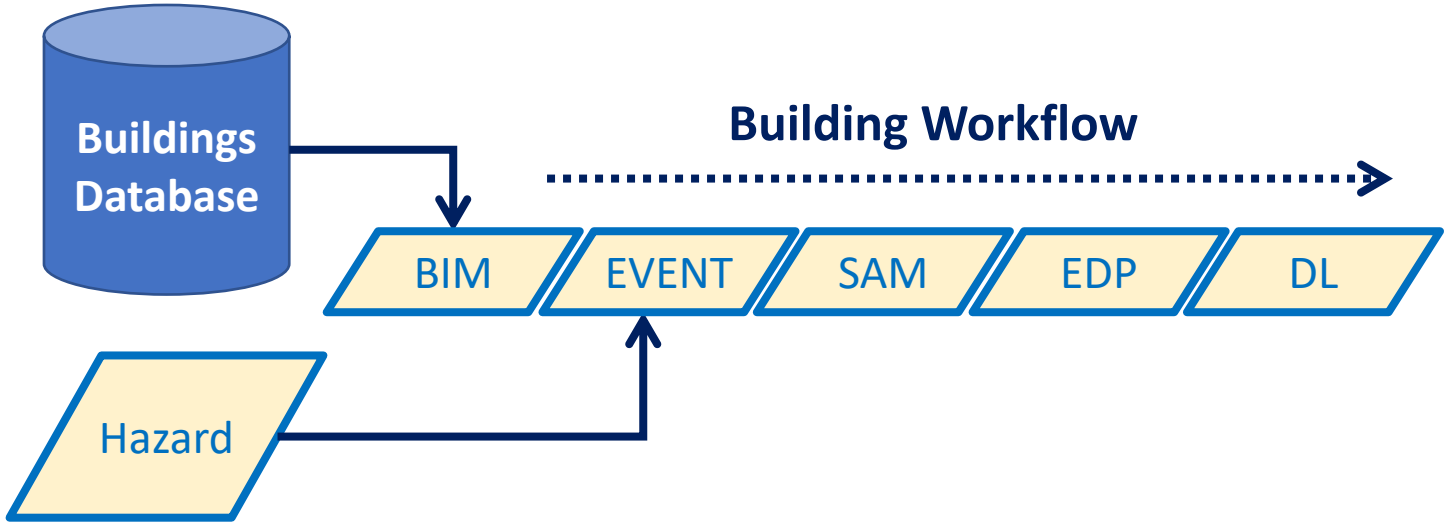


Computations Workflow

- **Regional workflow**



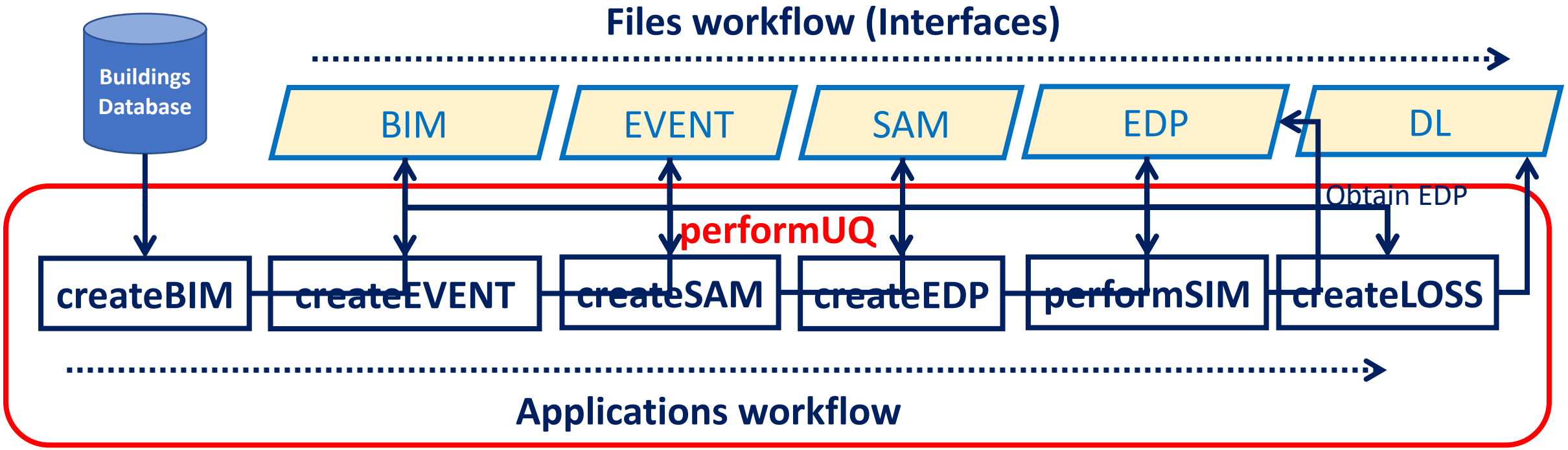
- **Single building workflow**



BIM: **B**uilding **I**nformation **M**odel
SAM: **S**tructural **A**nalysis **M**odel
EDP: **E**ngineering **D**emand **P**arameters
DL: **D**amage & **L**oss

Workflow Overview

- **Applications & Interfaces**

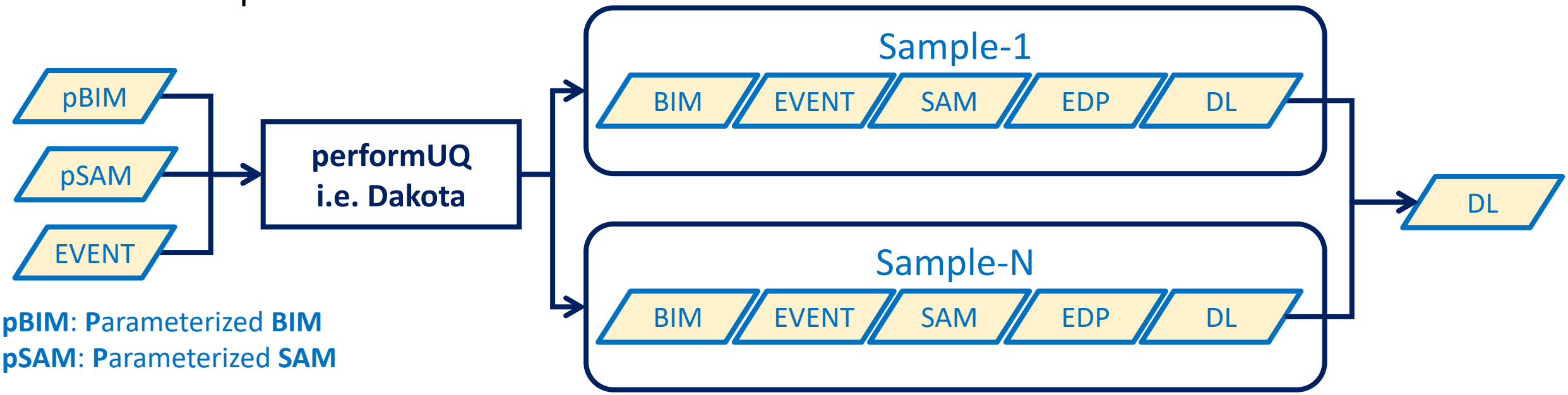


BIM: **B**uilding **I**nformation **M**odel
SAM: **S**tructural **A**nalysis **M**odel
EDP: **E**ngineering **D**emand **P**arameters
DL: **D**amage & **L**oss

lighter text are Inputs/Outputs
darker text are applications

Forward Uncertainty Propagation

- Uncertainties are handled using Dakota
- Each workflow application is called initially to define random variables
- Dakota samples the random variables and runs the workflow applications for each sample



pBIM: **P**arameterized **BIM**
pSAM: **P**arameterized **SAM**

Adams, B.M., Bauman, L.E., Bohnhoff, W.J., Dalbey, K.R., Ebeida, M.S., Eddy, J.P., Eldred, M.S., Hough, P.D., Hu, K.T., Jakeman, J.D., Stephens, J.A., Swiler, L.P., Vigil, D.M., and Wildey, T.M., "Dakota, A Multilevel Parallel Object-Oriented Framework for Design Optimization, Parameter Estimation, Uncertainty Quantification, and Sensitivity Analysis: Version 6.8 Theory Manual," Sandia Technical Report SAND2014-4253, May 2018.

Registered Applications For Regional Earthquake Simulations

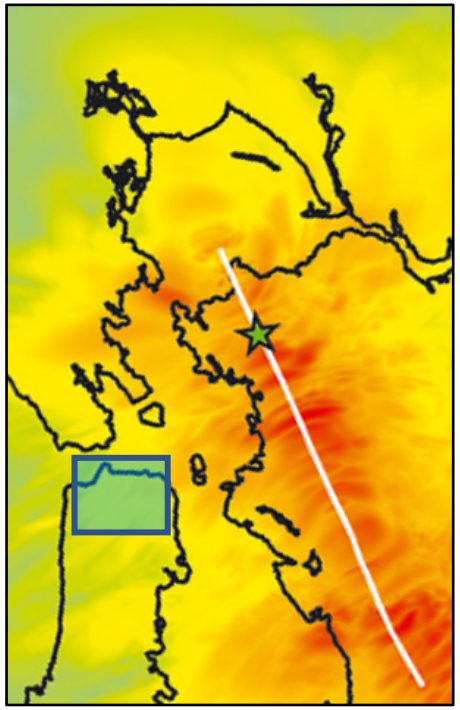
Type	Name	Description
createBIM	GenericBimDatabase	Creates a simple BIM from a building flat file (csv)
	UrbanSimDatabase	Creates a simple BIM from UrbanSim simulation outputs
createEVENT	LLNL_SW4	Gets Event input from SW4 outputs
	SHA-GM	Computes event input using SHA and record selection/scaling
createSAM	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 P-58 procedure
performUQ	DakotaFEM	Propagates uncertainty in all applications using Dakota

Registered Applications For Regional Wind Simulations

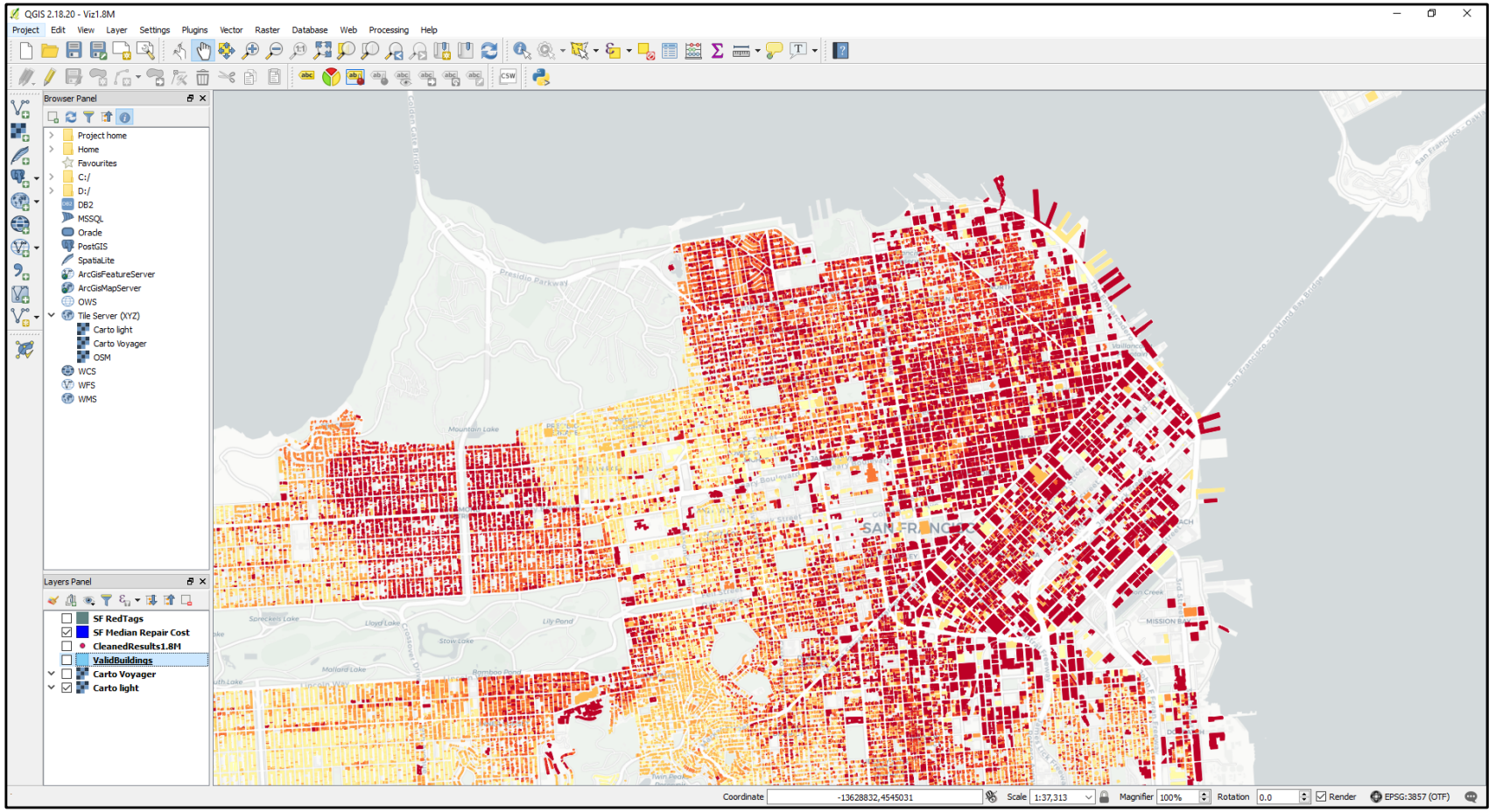
Type	Name	Description
createBIM	GenericBimDatabase	Creates a simple BIM from a building flat file (csv)
	UrbanSimDatabase	Creates a simple BIM from UrbanSim simulation outputs
createEVENT	ASCE 7-10	Generate wind loading using ASCE7-10 procedure
	Stochastic Wind	Generate wind loading using stochastic process models
createSAM	MDOF_LU	Creates a MDOF shear building model
createEDP	StandardWindEDP	Defines the standard EDPs used for a wind event (e.g. pressure)
performSIM	OpenSeesSimulation	Performs simulation using OpenSees and calculates the EDPs
createLOSS	PELICUN(Hazus)	Calculates damage and loss estimates using Hazus methodology
performUQ	DakotaFEM	Propagates uncertainty in all applications using Dakota

Regional Simulation Tools

San Francisco Bay Area Testbed



M7.0 Hayward

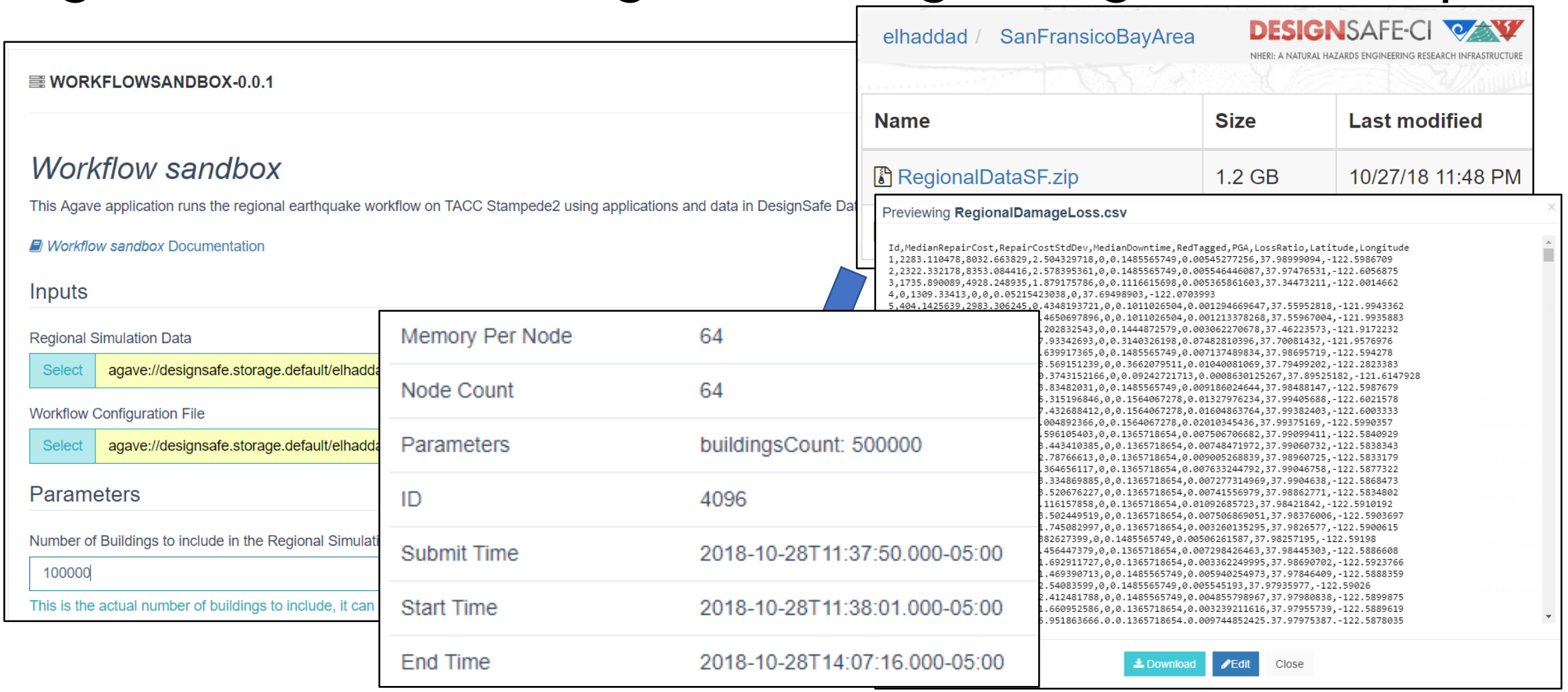


Building Inventory

Hazard Consequences

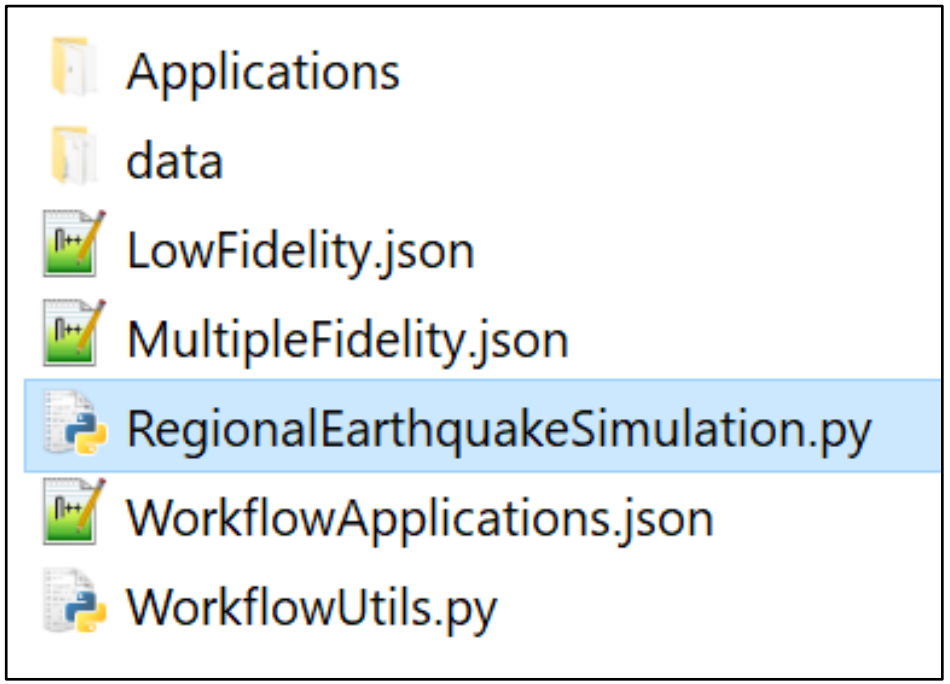
Regional Simulation Tools

Regional simulation using HPC through DesignSafe Workspace

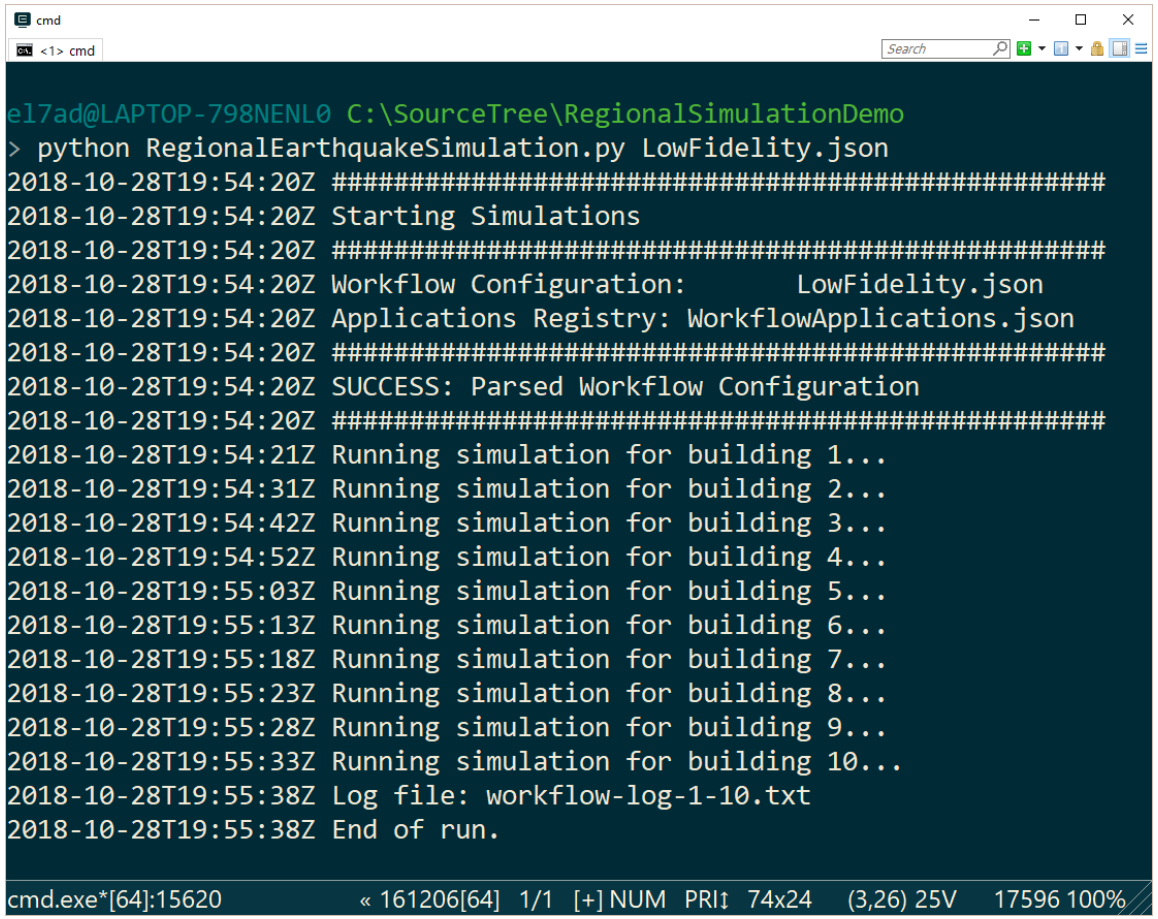


Regional Simulation Tools

Small scale simulation using Local Computer



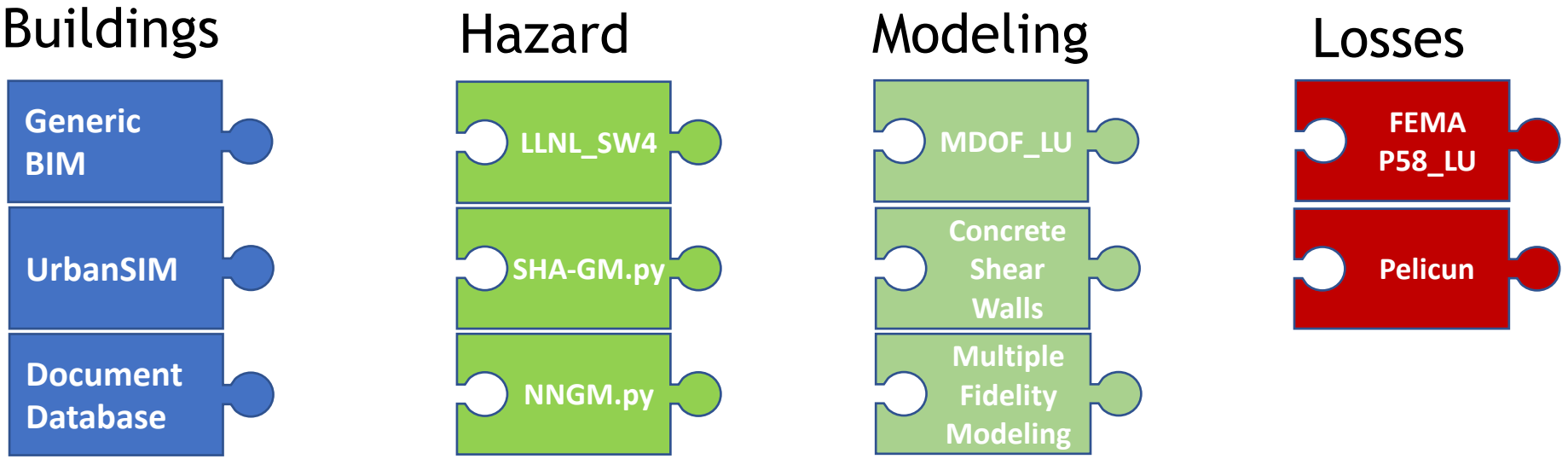
Applications,
Sample Data &
Examples



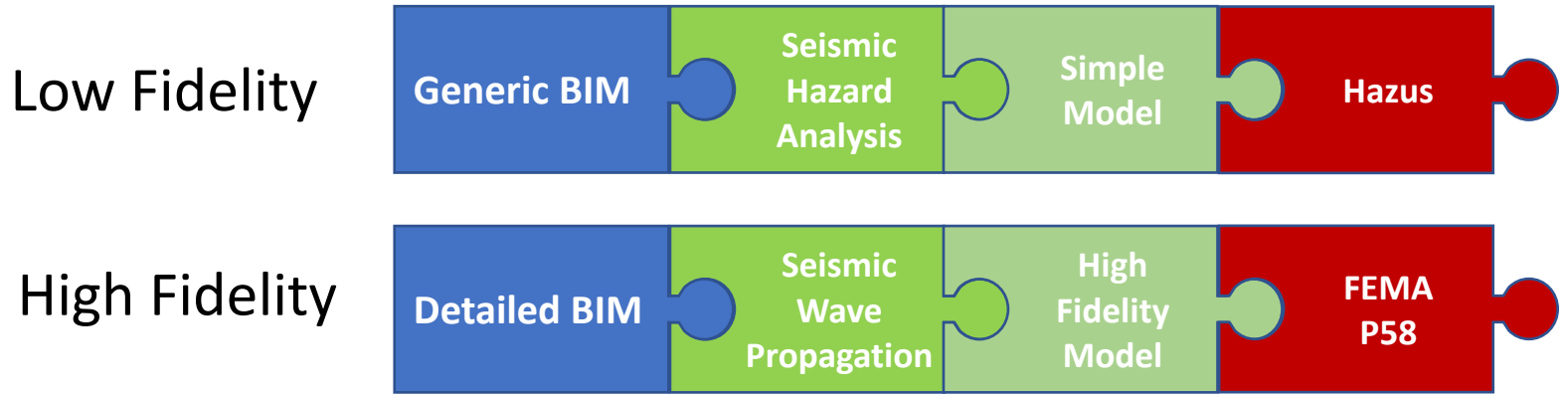
Runs Locally as a console application

Regional Simulation Tools

The Framework provides applications with standard interfaces

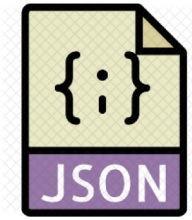


Earthquake Simulation Workflows



Regional Simulation Configuration

Configuration File

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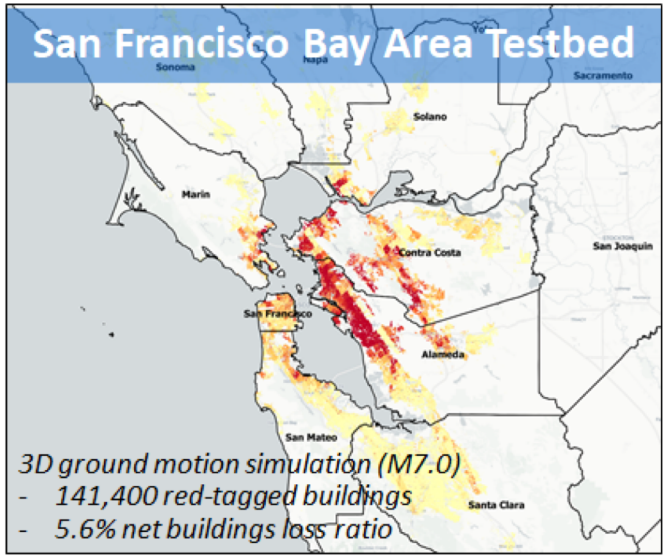
{
    "Name": "Workflow5",
    "Author": "Wael Elhaddad",
    "WorkflowType": "Regional Simulation",
    "buildingFile":"buildings.json",
    "Applications": {
        "Buildings": {…
        },
        "Events": […
        ],
        "Modeling": {…
        },
        "EDP": {…
        },
        "Simulation":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

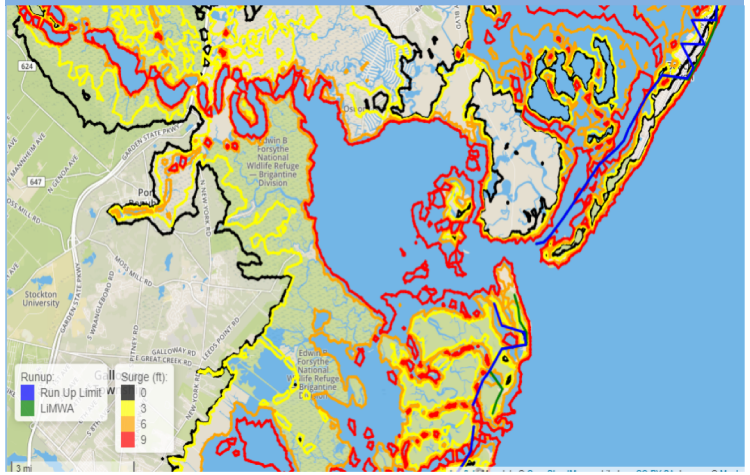
Regional Testbeds Using rWHALE

San Francisco Bay Area Testbed

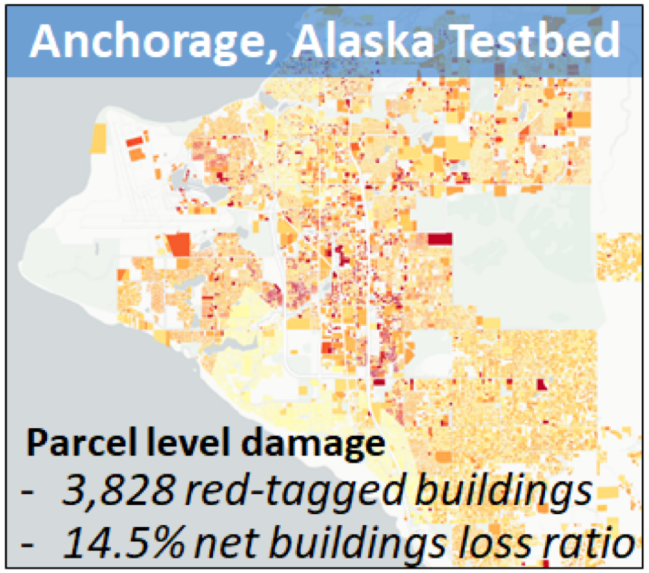


3D ground motion simulation (M7.0)
- *141,400 red-tagged buildings*
- *5.6% net buildings loss ratio*

Atlantic City, NJ Storm Testbed

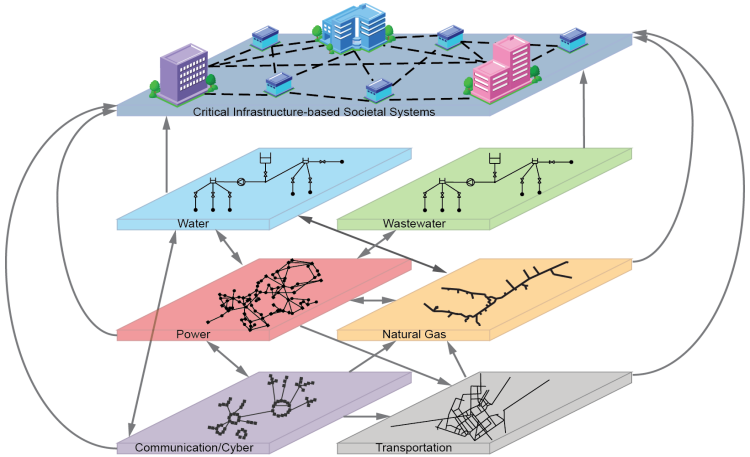


Anchorage, Alaska Testbed



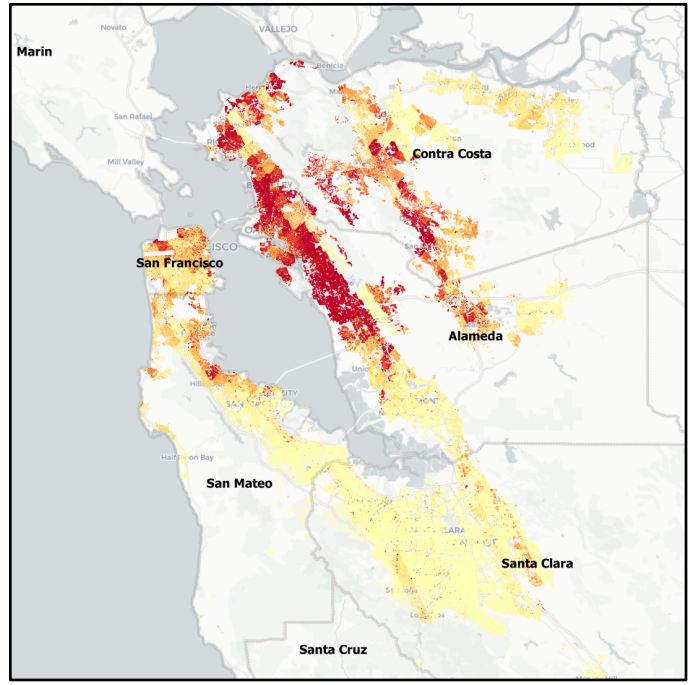
Parcel level damage
- *3,828 red-tagged buildings*
- *14.5% net buildings loss ratio*

Memphis, TN Lifelines Testbed



Example Simulation: Earthquake in San Francisco Bay Area

- M7.0 Rupture along the Hayward fault modeled using SW4 [1]
- **1,843,351 buildings** were included in the Simulation
- Building information is based on UrbanSim data
- Damage and Loss calculation using FEMAP58_LU [2]
- Structural analysis models are based on MDOF_LU [3]
- Red tagged buildings: **141,459**
- Buildings damage: **$84.1 billion**
- Net buildings damage ratio: **5.6%**

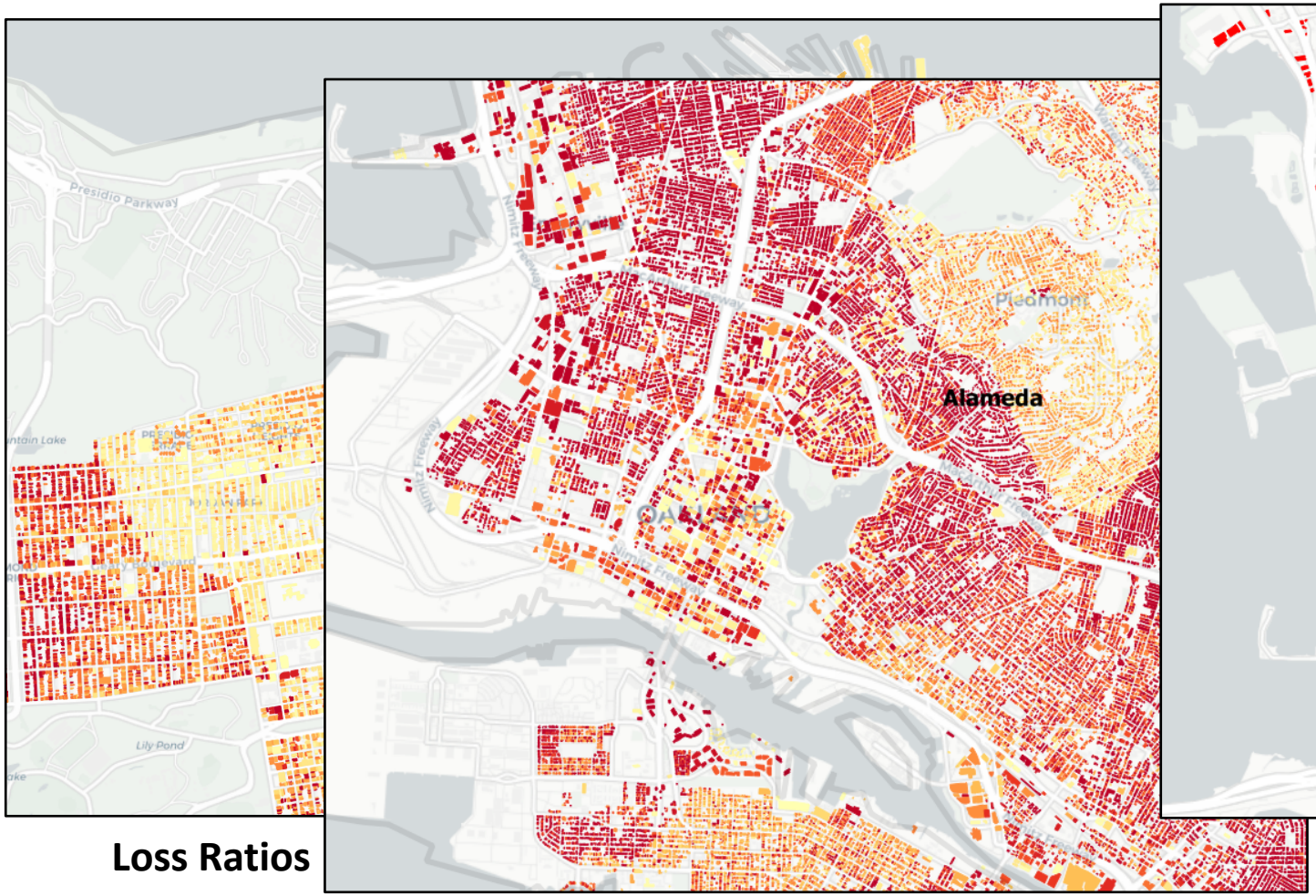


Building Loss Ratio

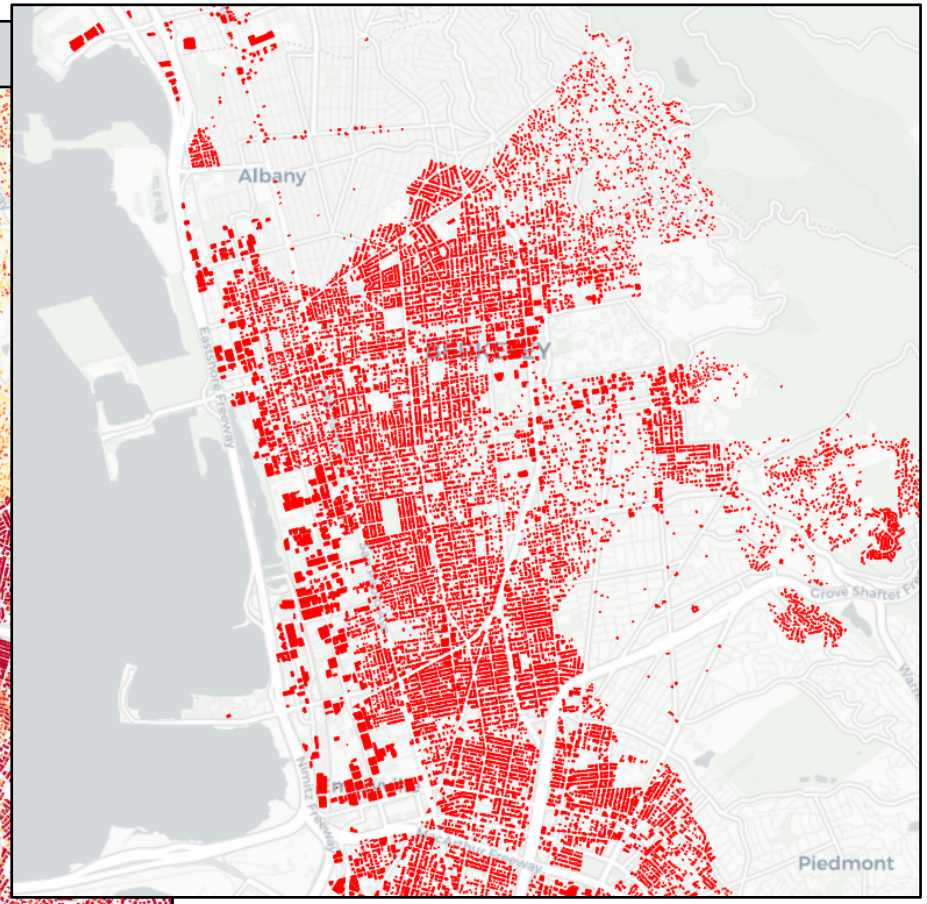
[1] A. J. Rodgers, A. Pitarka, N. A. Petersson, B. Sjögreen and D. B. McCallen, "Broadband (0–4 Hz) ground motions for a magnitude 7.0 Hayward fault earthquake with three-dimensional structure and topography," *Geophysical Research Letters,* vol. 45, p. 739–747, 2018.
[2] Zeng X., Lu X.Z., Yang T., Xu Z., "Application of the FEMA-P58 methodology for regional earthquake loss prediction", Natural Hazards (2016), 10.1007/s11069-016-2307-z
[3] X. Lu, B. Han, M. Hori, C. Xiong and Z. Xu, "A coarse-grained parallel approach for seismic damage simulations of urban areas based on refined models and GPU/CPU cooperative computing," *Advances in Engineering Software,* vol. 70, pp. 90-103, 2014.

Visualization

- Visualization on parcel level results can be done in GIS tools (e.g. QGIS)

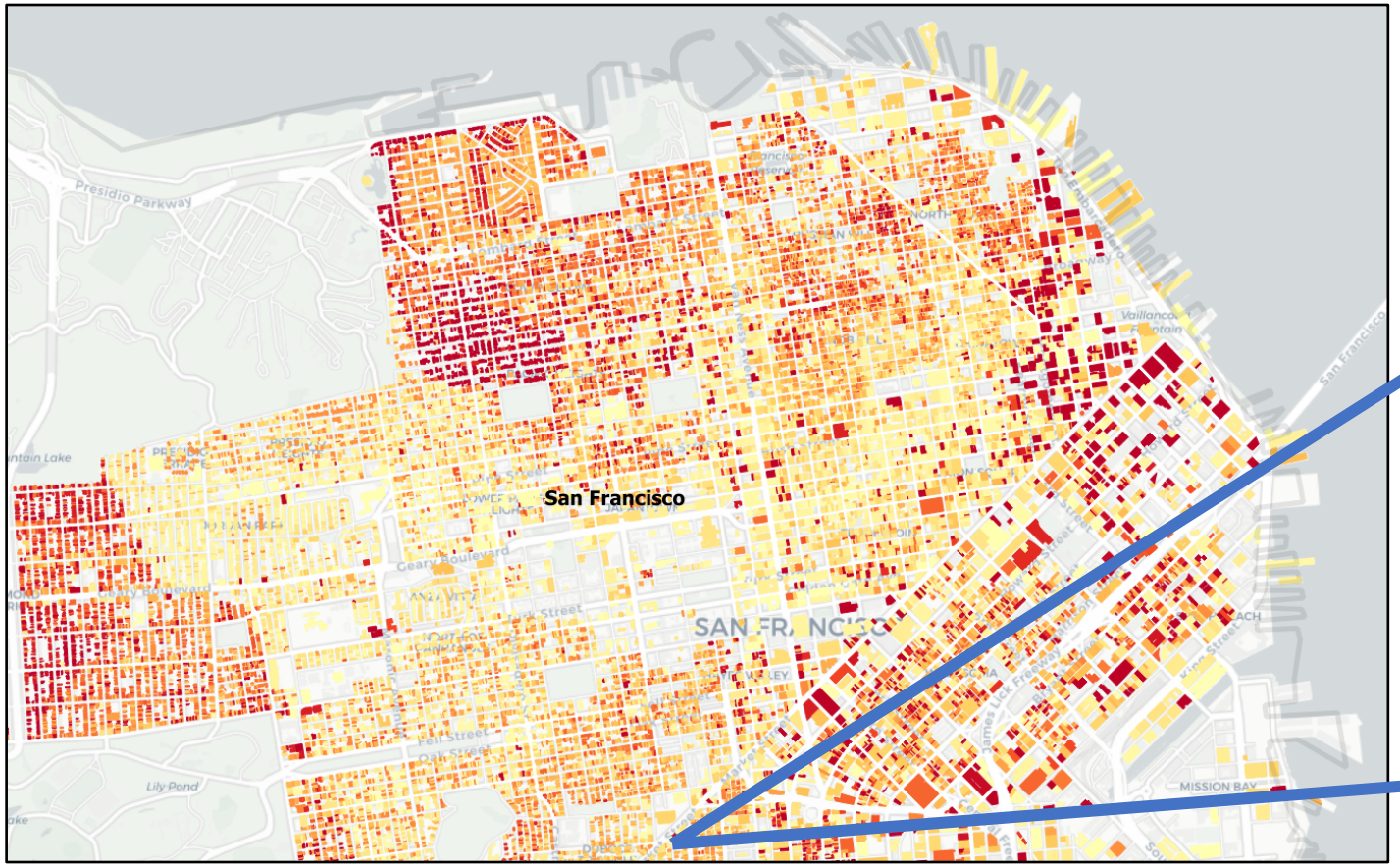


Loss Ratios

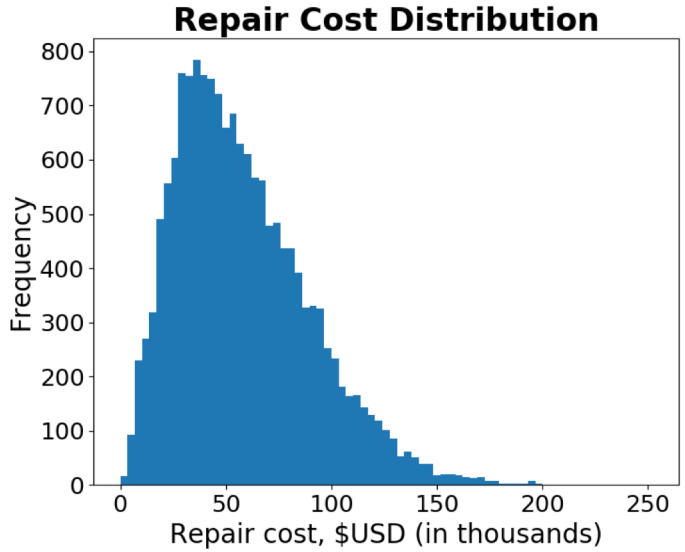


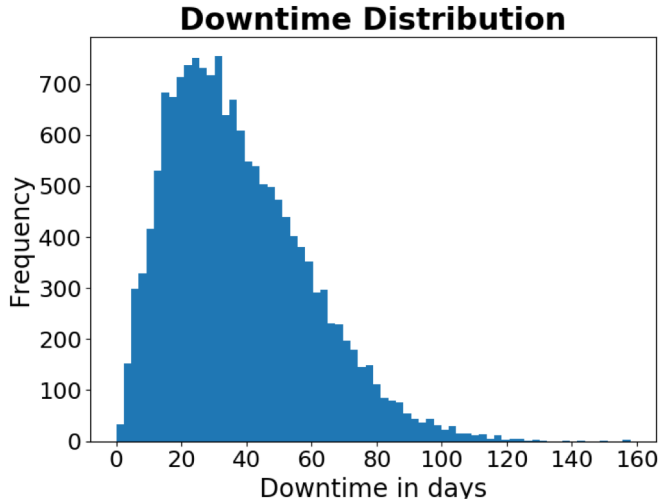
Red Tagged Buildings

Parcel Level Results



Loss Ratios





Comparison To HayWired Scenario

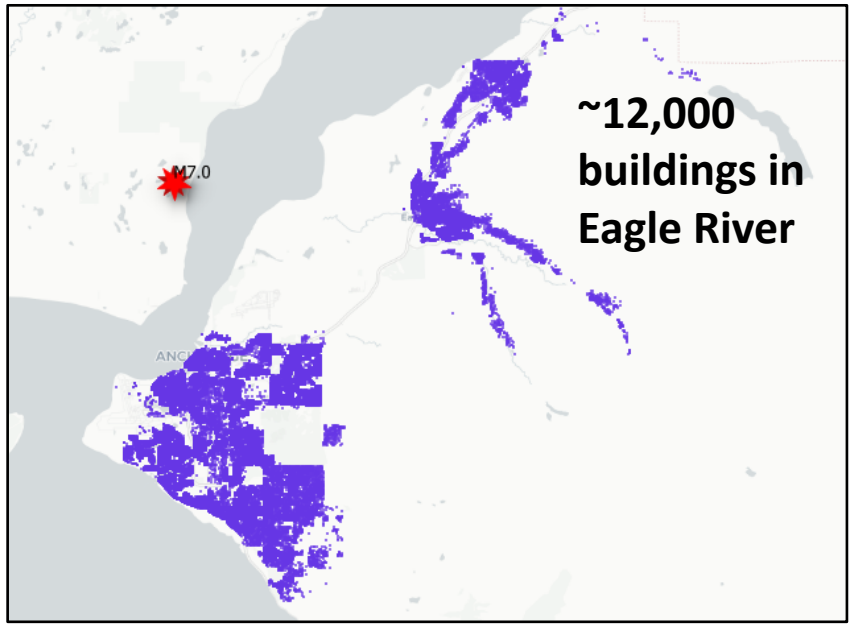
- **HayWired Scenario:** A study lead by USGS, involving approximately 60 partners, to simulate the effects and consequences of a hypothetical, yet scientifically realistic, magnitude M7.0 earthquake on the Hayward fault.

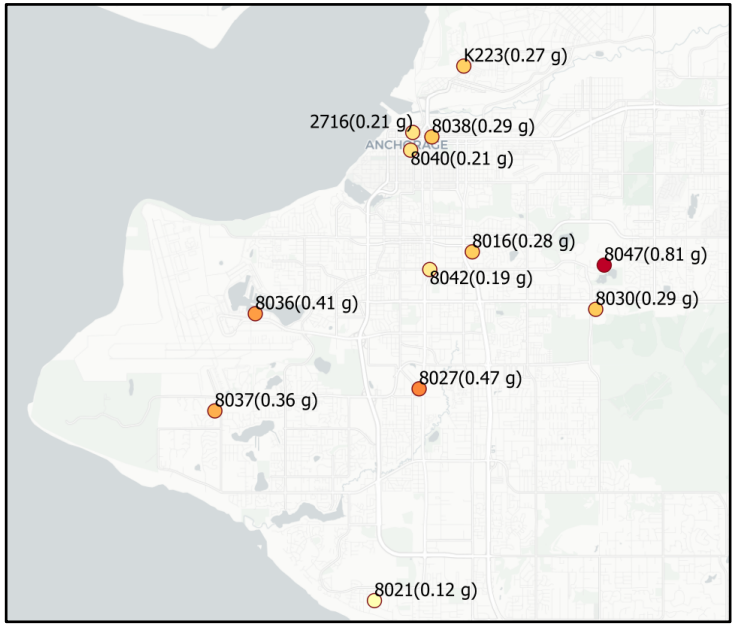
	HayWired Scenario	SimCenter Testbed
Number of Buildings	3 Million	1.84 Million
Red Tagged Buildings	101,000	141,459
Building Damage	$30.3 Billion	$84.1 Billion
Net Damage Ratio	2.91%	5.6%
Total Buildings Cost	$1.04 Trillion	$1.5 Trillion

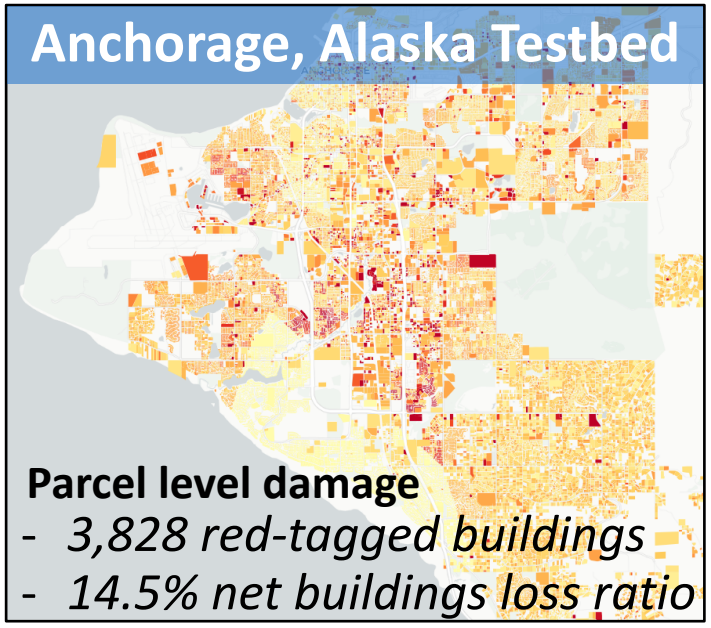
Detweiler, S.T., and Wein, A.M., eds., 2018, The HayWired earthquake scenario—Engineering implications: U.S. Geological Survey Scientific Investigations Report 2017–5013–I–Q, 429 p., https://doi.org/10.3133/sir20175013v2.

Anchorage Earthquake Testbed

- **Tax data for 97,421 buildings/parcels** (Municipality of Anchorage appraisal records)
- **Data was processed to obtain BIM for 84,435 buildings**
  - 78,509 Residential and 7,926 Commercial buildings
- **Event:** Magnitude 7.0 earthquake near Anchorage, Alaska Nov 30th 2018
  - 12 Recorded ground motions available through CESMD





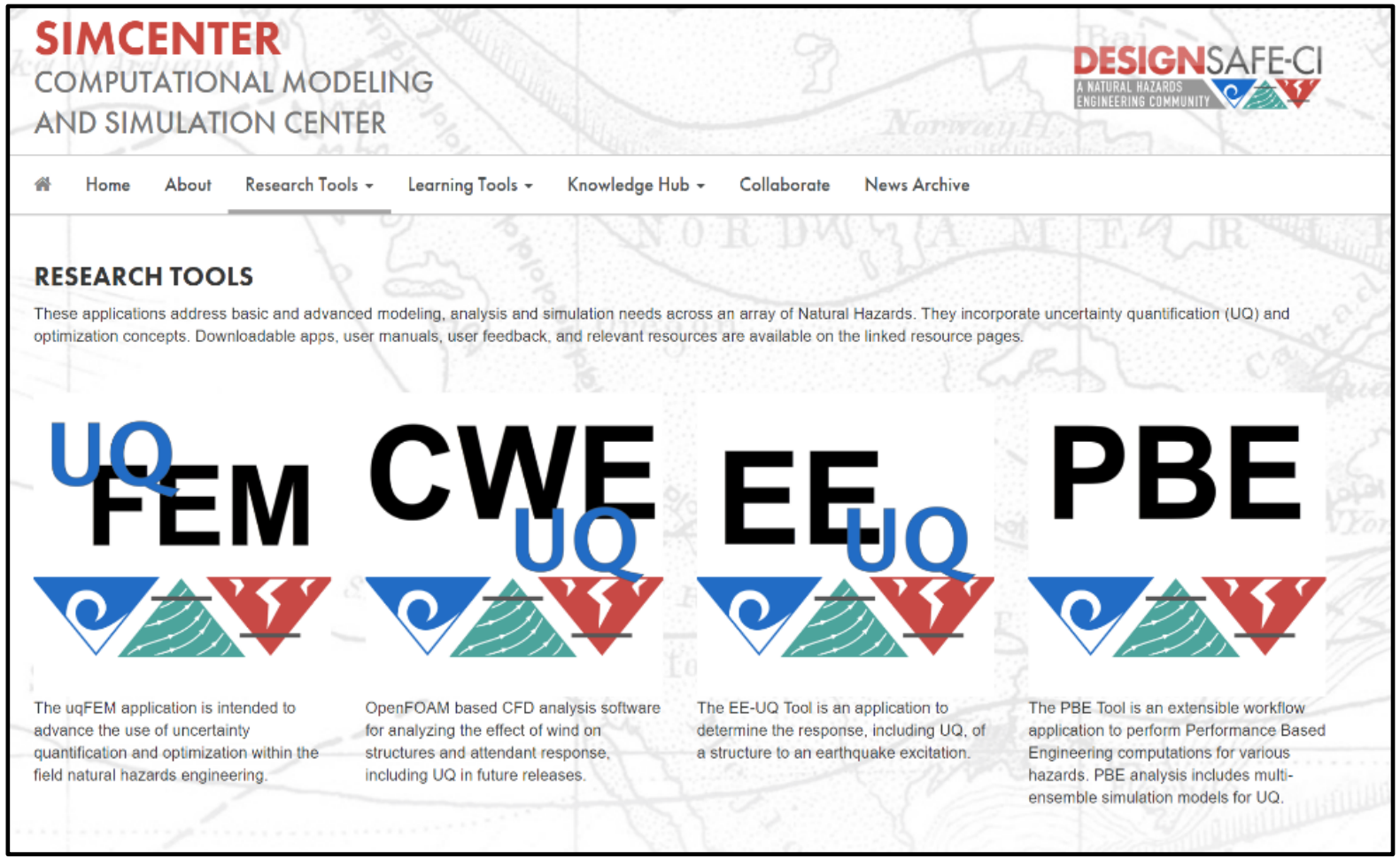


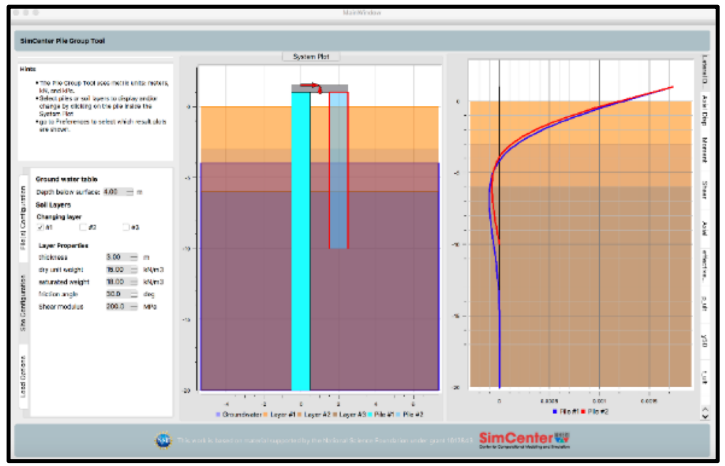
Demos

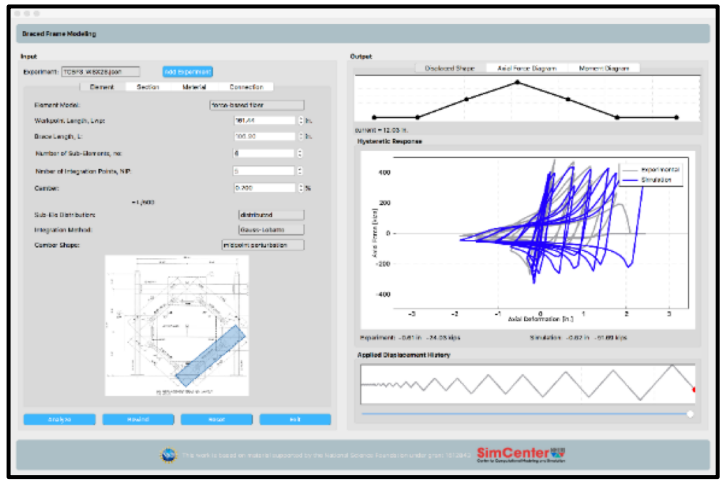
Questions & Discussion

Extra Slides

Research and Educational Tools







MDOF

EvW

PGT

BFM

SimCenter Research Tools

SimCenter Educational Apps

Open source software: https://github.com/NHERI-SimCenter

ECO Activities

Community Engagement

- Regional Hazard Testbeds
- Open-source, Community Driven Software
- SimCenter Tool Training Workshop (~June 2019)
- Summer Programming Bootcamp (~July 2019)
- SimCenter Webinars
- Dedicated Slack discussions
- Multi-disciplinary REU program

Join the Community

https://simcenter.designsafe-ci.org/join-community/