



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**”



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

Front-end

SimCenter Research Tools

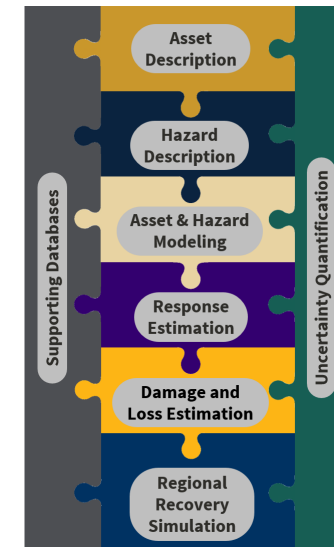


Back-end



- Data storage and HPC access

SimCenter’s Application Framework

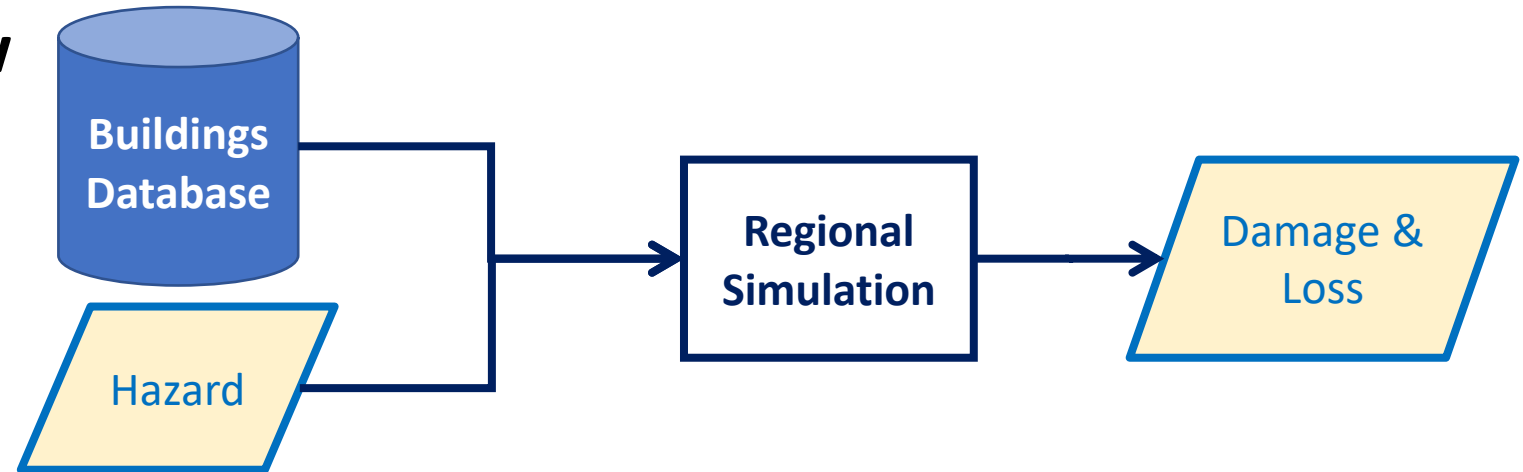


Framework for Building Workflow Applications

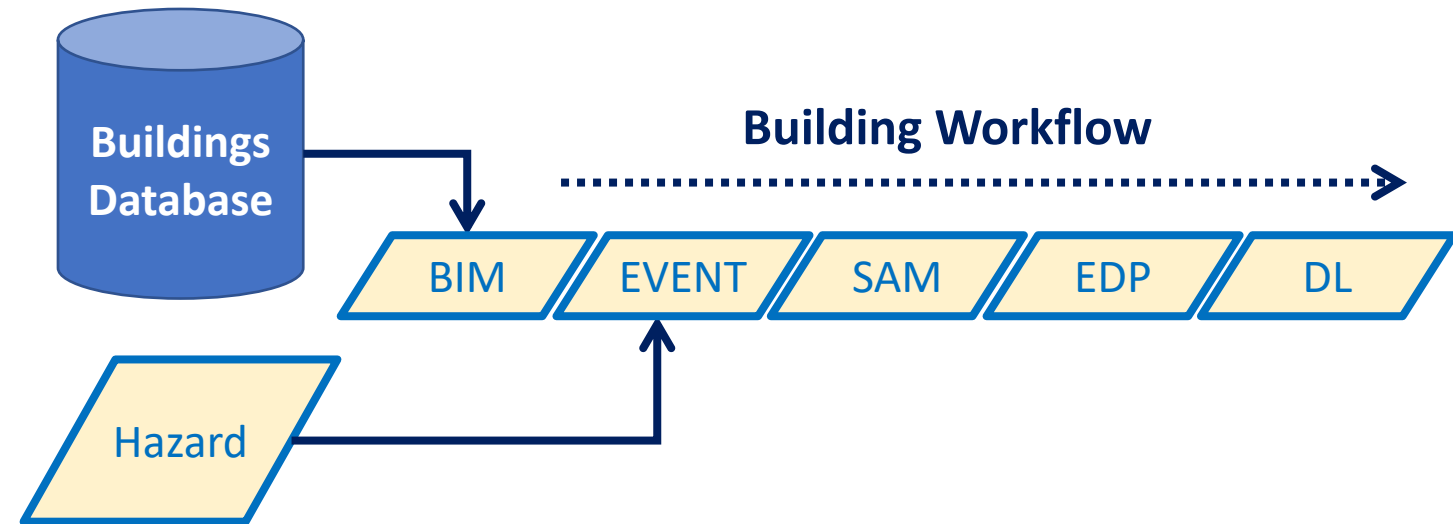


Computations Workflow

Regional workflow



Single building workflow



BIM: Building Information Model

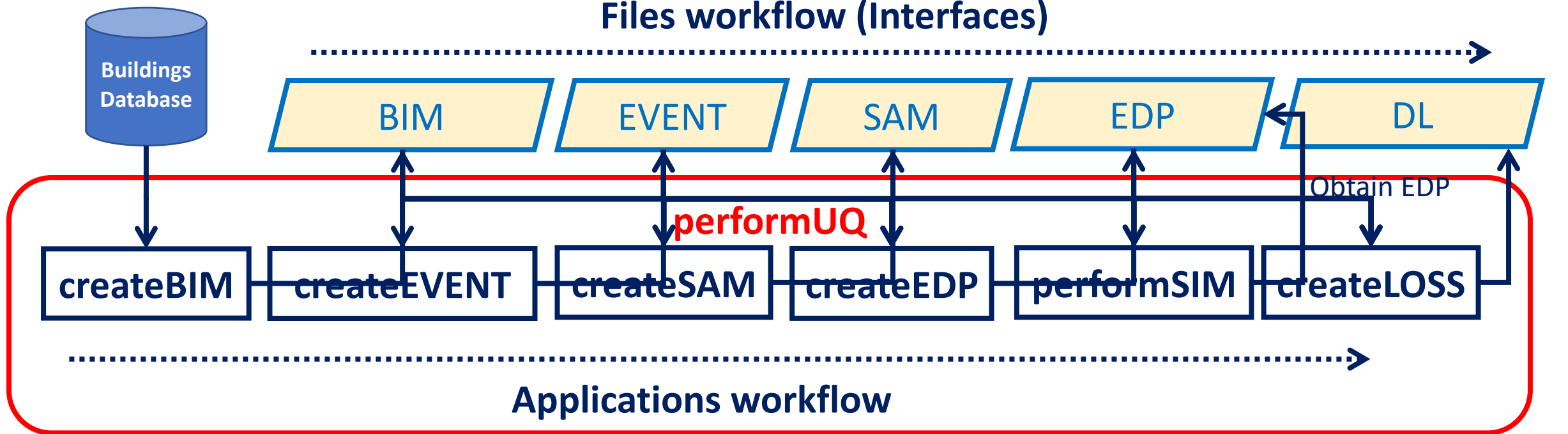
SAM: Structural Analysis Model

EDP: Engineering Demand Parameters

DL: Damage & Loss

Workflow Overview

Applications & Interfaces



BIM: Building Information Model

SAM: Structural Analysis Model

EDP: Engineering Demand Parameters

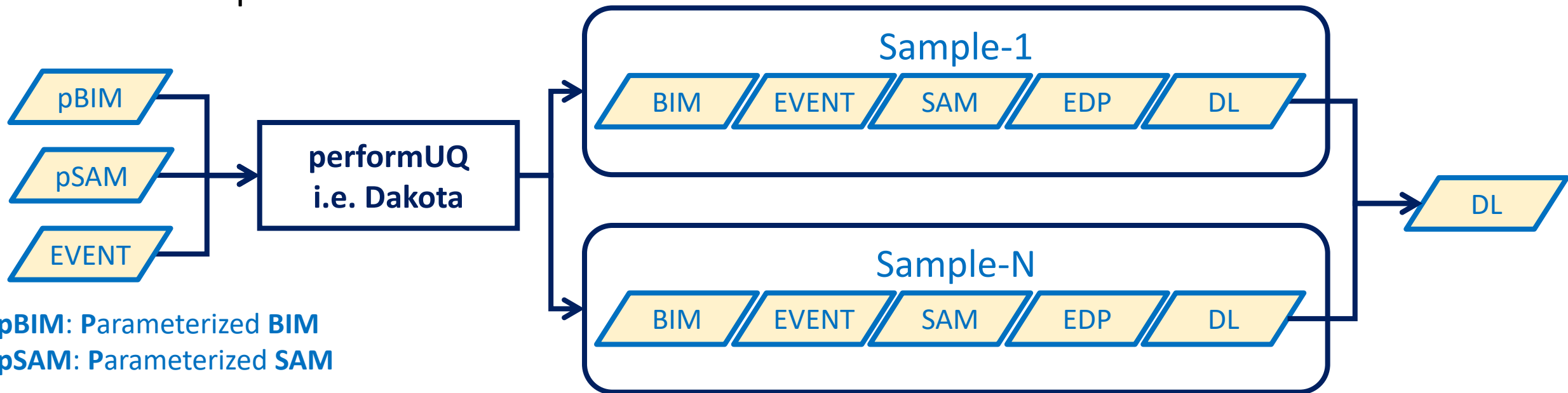
DL: Damage & Loss

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



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

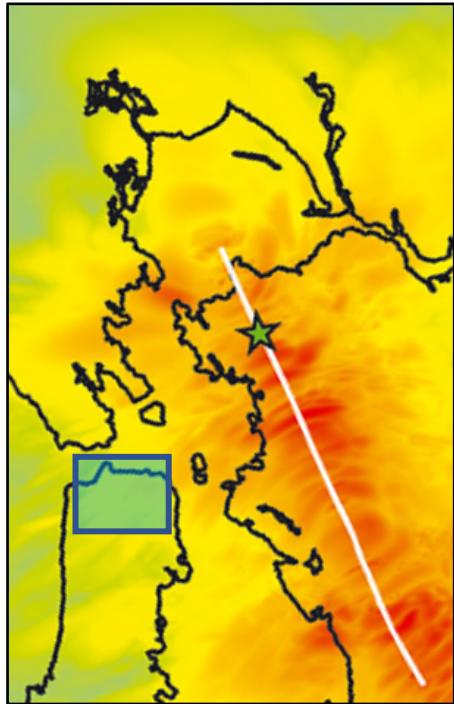
Type	Name	Description
createBIM	GenericBimDatabase	Creates a simple BIM from a building flat file (csv)
	UrbanSimDatabase	Creates a simple BIM from UrbanSim simulation outputs
createEVENT	LLNL_SW4	Gets Event input from SW4 outputs
	SHA-GM	Computes event input using SHA and record selection/scaling
createSAM	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

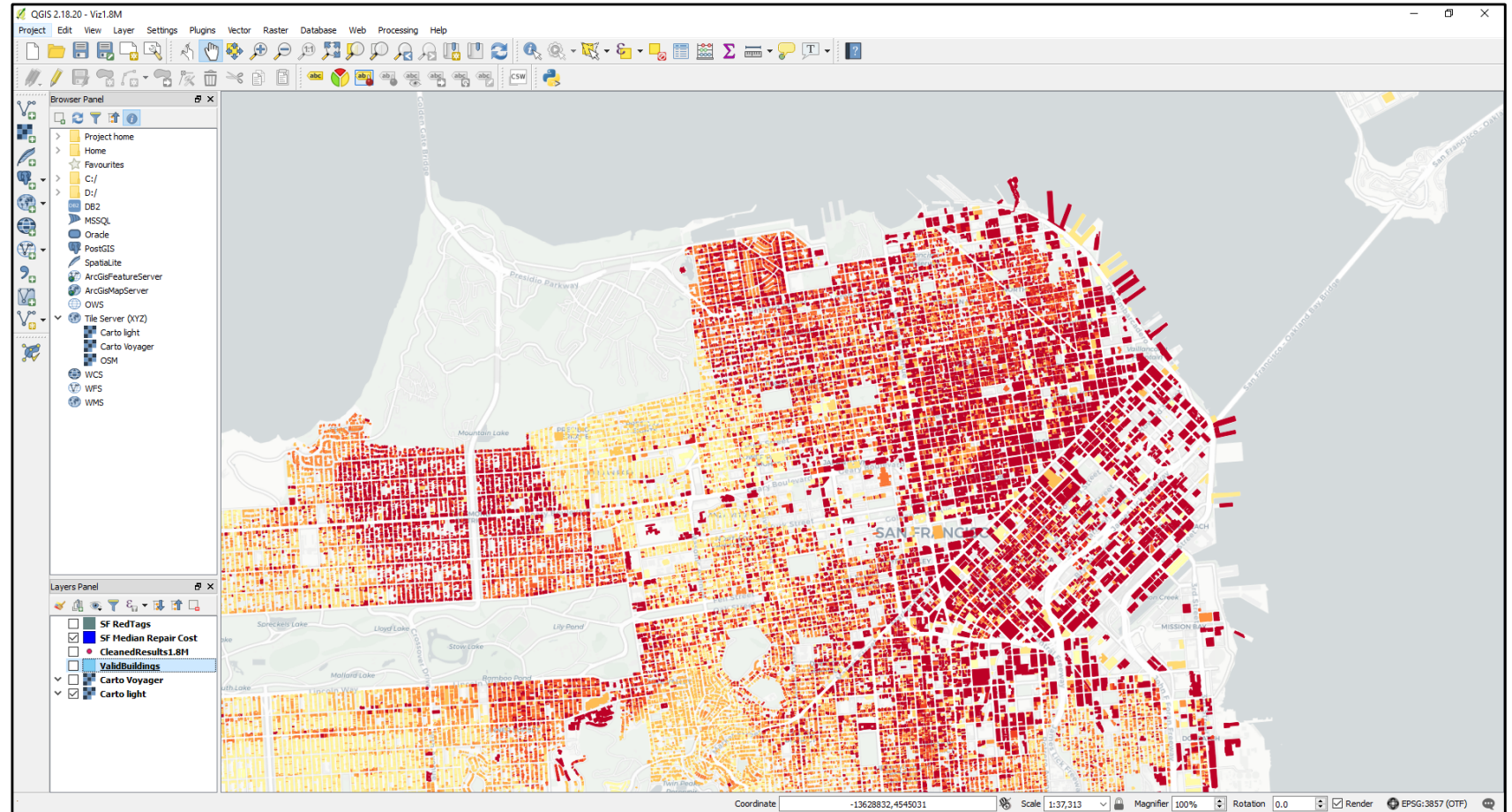
Type	Name	Description
createBIM	GenericBimDatabase	Creates a simple BIM from a building flat file (csv)
	UrbanSimDatabase	Creates a simple BIM from UrbanSim simulation outputs
createEVENT	ASCE 7-10	Generate wind loading using ASCE7-10 procedure
	Stochastic Wind	Generate wind loading using stochastic 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

WORKFLOWSANDBOX-0.0.1

Workflow sandbox

This Agave application runs the regional earthquake workflow on TACC Stampede2 using applications and data in DesignSafe Data

[Workflow sandbox Documentation](#)

Inputs

Regional Simulation Data
 agave://designsafe.storage.default/elhaddad/SanFranciscoBayArea/RegionalDataSF.zip

Workflow Configuration File
 agave://designsafe.storage.default/elhaddad/SanFranciscoBayArea/RegionalSimulationWorkflowConfigurationFile.csv

Parameters

Number of Buildings to include in the Regional Simulation

This is the actual number of buildings to include, it can be different from the number of buildings in the input data

elhaddad / SanFranciscoBayArea **DESIGNSAFE-CI**
NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

Name	Size	Last modified
RegionalDataSF.zip	1.2 GB	10/27/18 11:48 PM

Previewing **RegionalDamageLoss.csv**

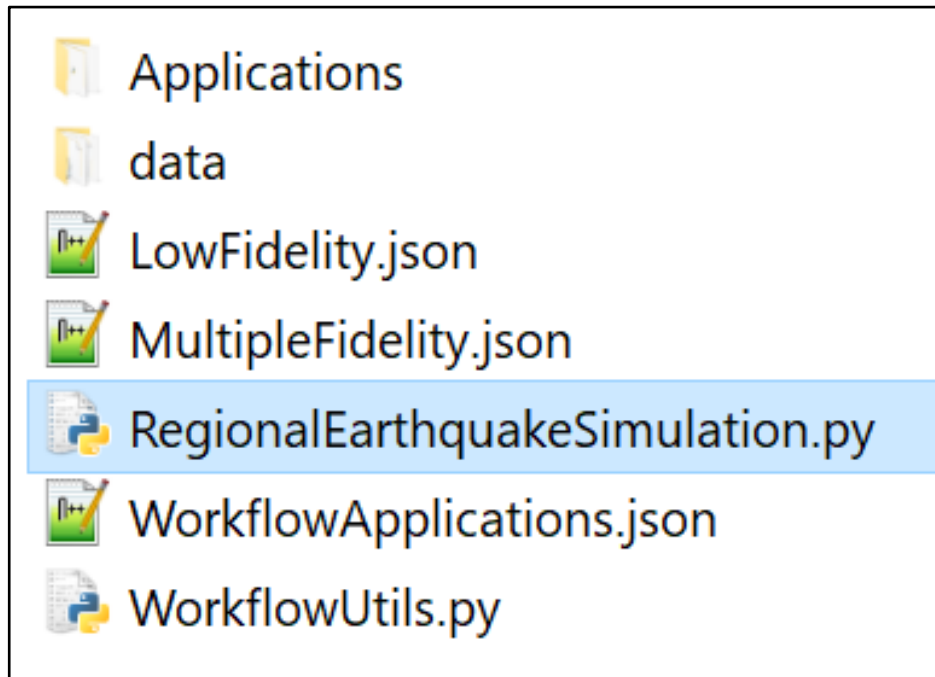
```

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
4.650697896,0,0.1011026504,0.001213378268,37.55967004,-121.9935883
1.202832543,0,0.1444872579,0.003062270678,37.46223573,-121.9172232
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8.569151239,0,0.3662079511,0.01040081069,37.79499202,-122.2823383
0.3743152166,0,0.09242721713,0.0008630125267,37.89525182,-121.6147928
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004892366,0,0.1564067278,0.02010345436,37.99375169,-122.5990357
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1.660952586,0,0.1365718654,0.003239211616,37.97955739,-122.5889619
6.951863666,0,0.1365718654,0.009744852425,37.97975387,-122.5878035
                    
```

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	

Regional Simulation Tools

Small scale simulation using Local Computer



Applications,
Sample Data &
Examples

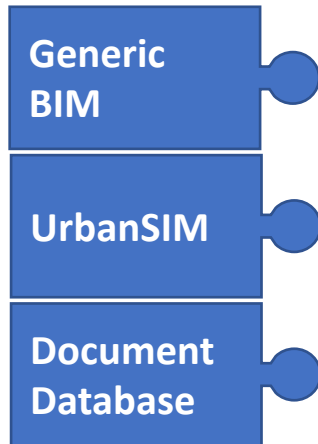
```
cmd
C:\SourceTree\RegionalSimulationDemo
> python RegionalEarthquakeSimulation.py LowFidelity.json
2018-10-28T19:54:20Z #####
2018-10-28T19:54:20Z Starting Simulations
2018-10-28T19:54:20Z #####
2018-10-28T19:54:20Z Workflow Configuration:      LowFidelity.json
2018-10-28T19:54:20Z Applications Registry: 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

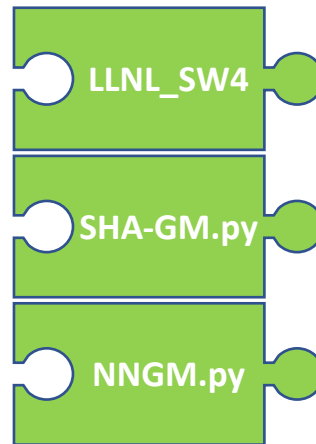
Regional Simulation Tools

The Framework provides applications with standard interfaces

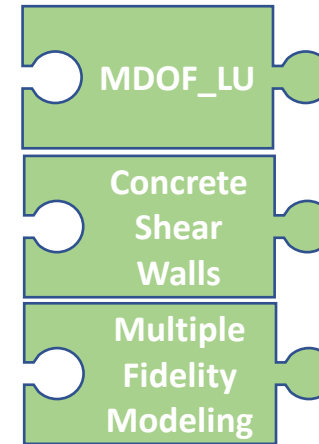
Buildings



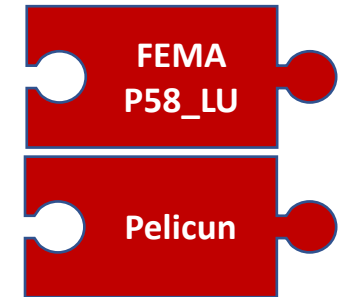
Hazard



Modeling



Losses



Earthquake Simulation Workflows

Low Fidelity

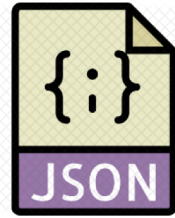


High Fidelity



Regional Simulation Configuration

Configuration File

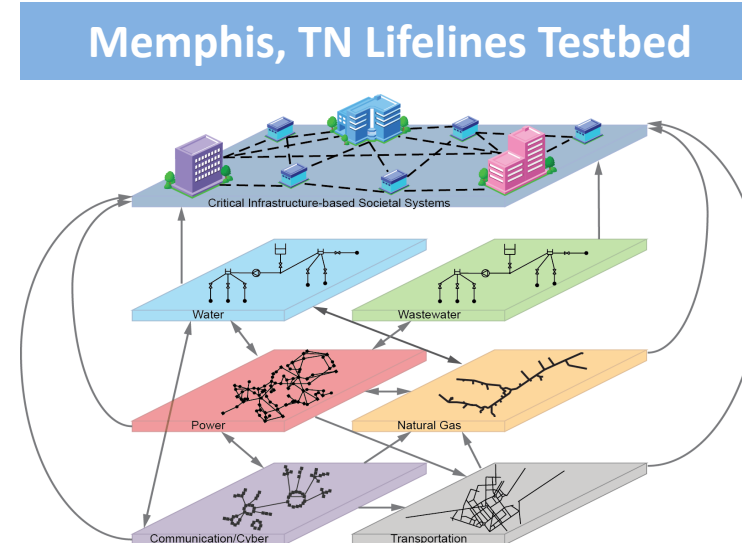
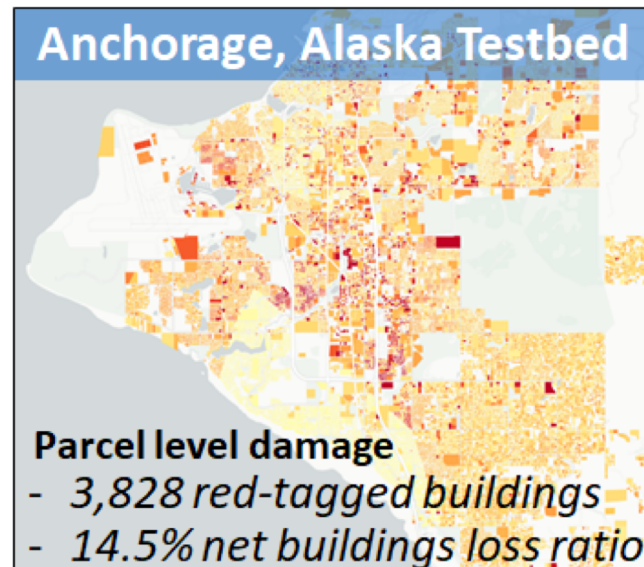
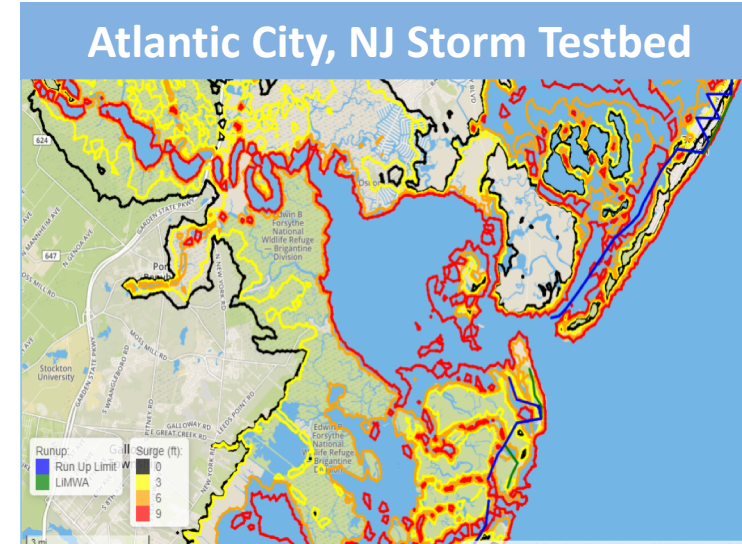
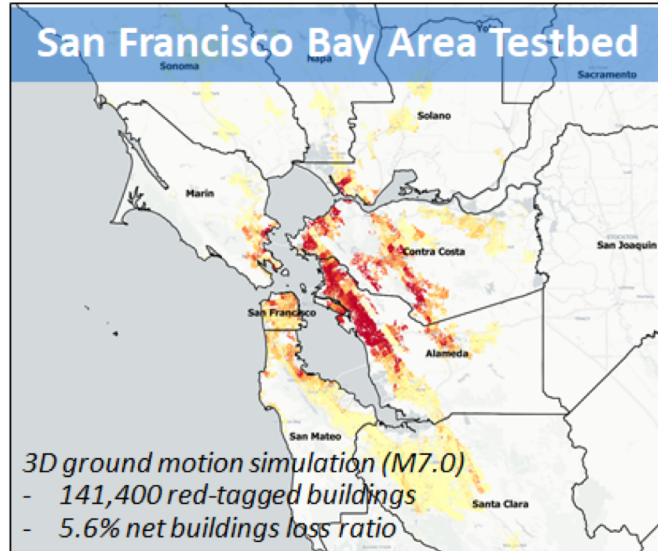


```
{
  "Name": "Workflow5",
  "Author": "Wael Elhaddad",
  "WorkflowType": "Regional Simulation",
  "buildingFile": "buildings.json",
  "Applications": {
    "Buildings": { ...
  },
  "Events": [ ...
  ],
  "Modeling": { ...
  },
  "EDP": { ...
  },
  "Simulation": { ...
  },
  "UQ-Simulation": { ...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

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

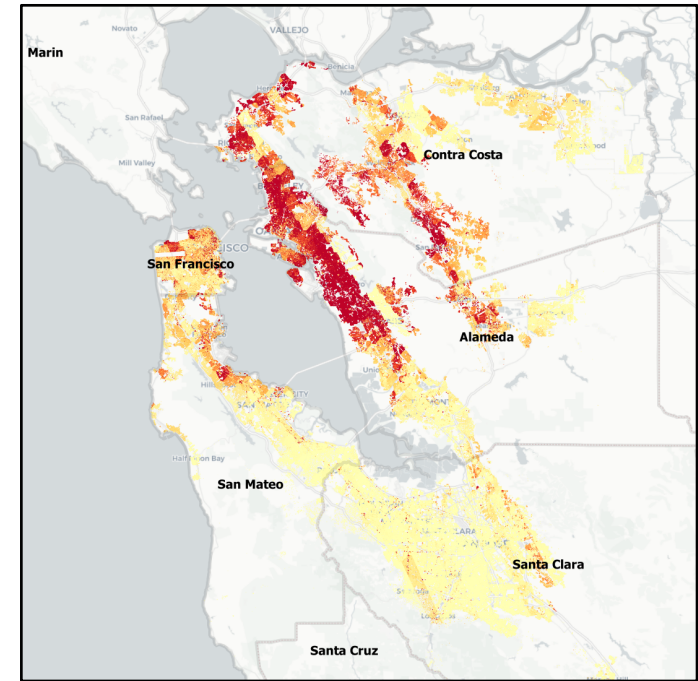
```
"Damage&Loss": {
  "Damage&LossApplication": "FemaP58-LU",
  "ApplicationData": {
    "filenameSettings": "../build/data/settings.ini",
    "pathCurves": "../build/data/ATCCurves/",
    "pathNormative": "../build/data/normative/"
  }
}
```

Regional Testbeds Using rWHALE



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

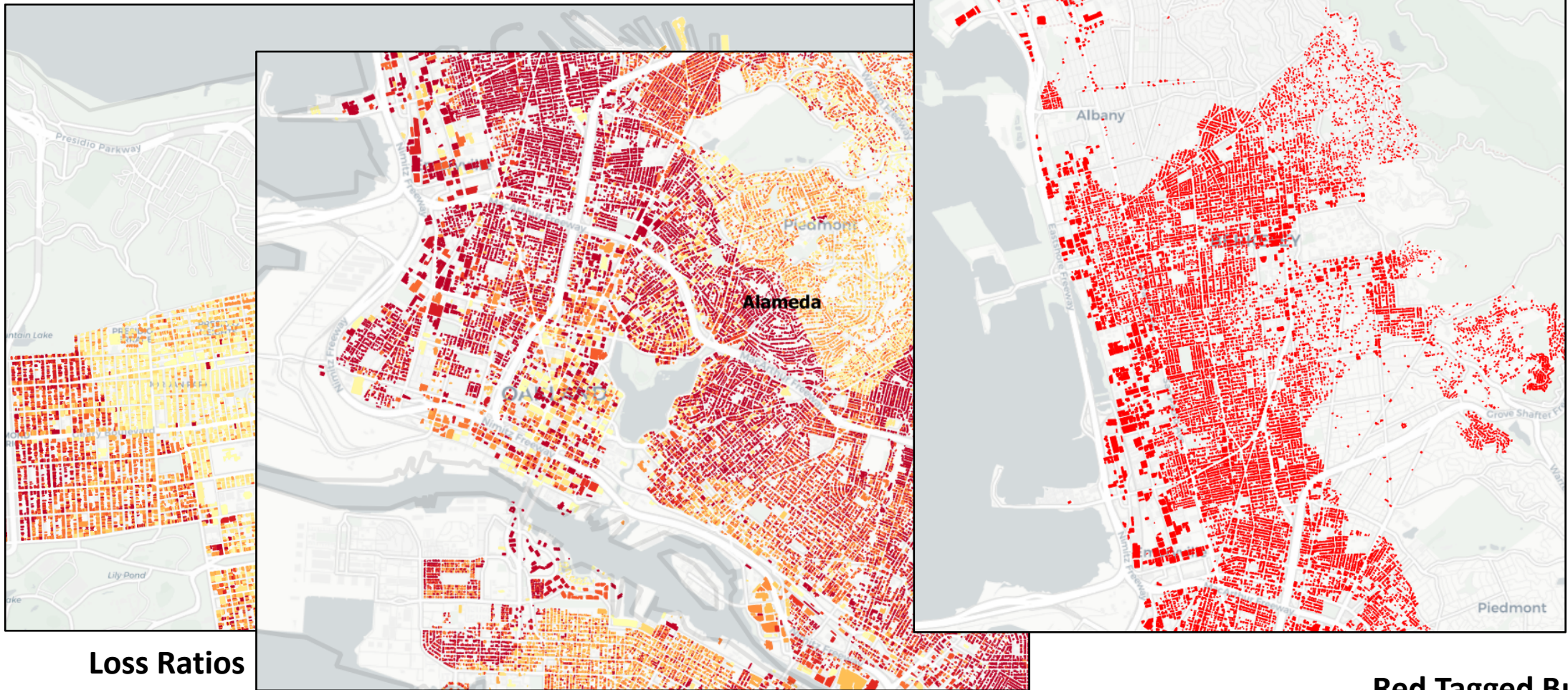
[1] A. J. Rodgers, A. Pitarka, N. A. Petersson, B. Sjögreen and D. B. McCallen, "Broadband (0–4 Hz) ground motions for a magnitude 7.0 Hayward fault earthquake with three-dimensional structure and topography," *Geophysical Research Letters*, vol. 45, p. 739–747, 2018.

[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

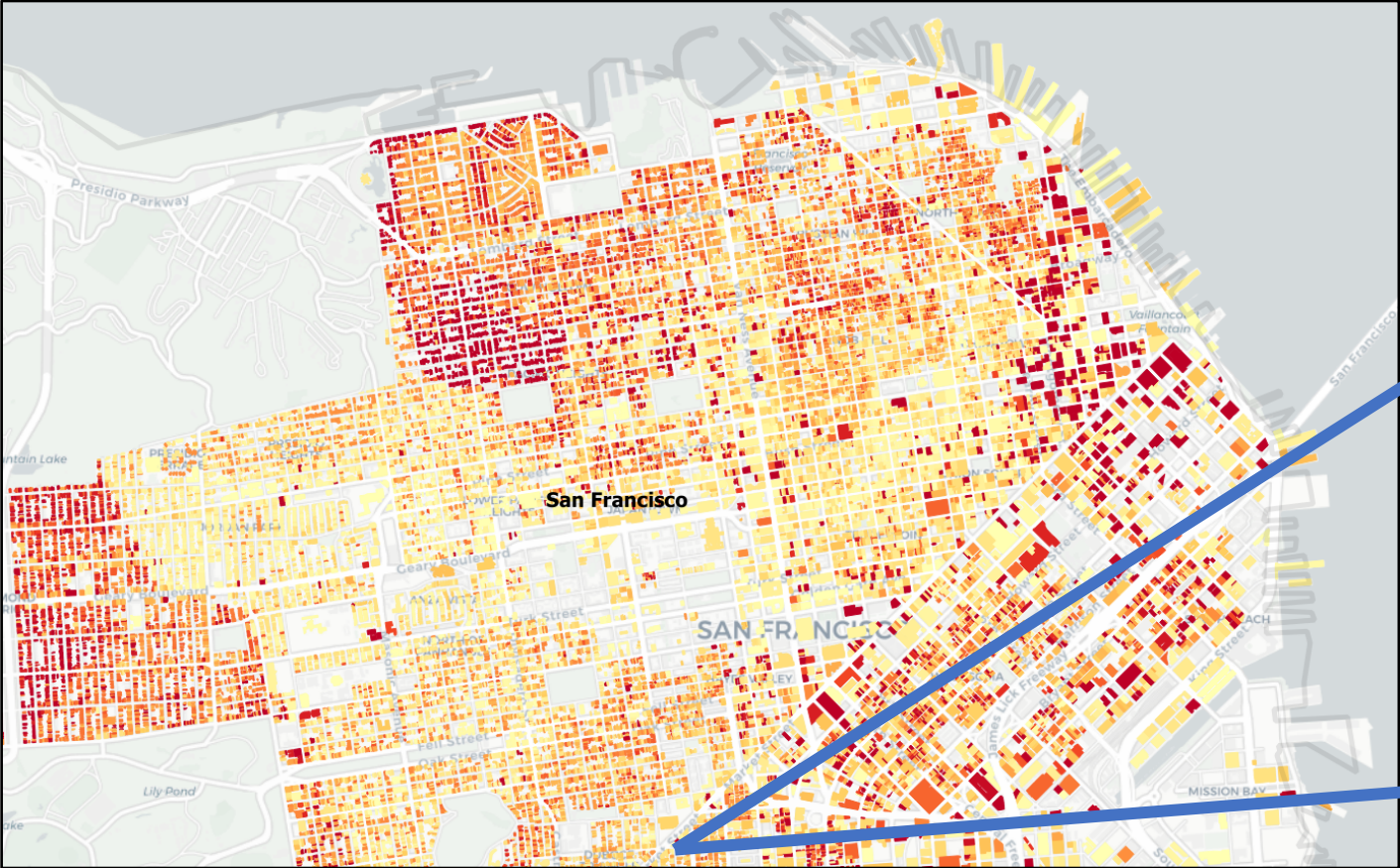
- Visualization on parcel level results can be done in GIS tools (e.g. QGIS)



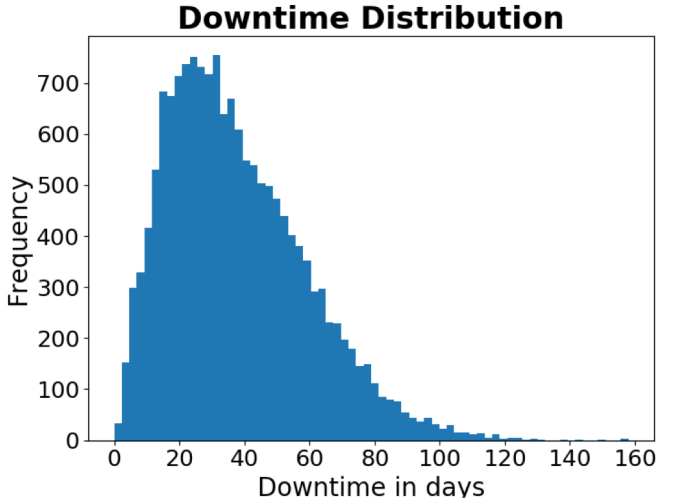
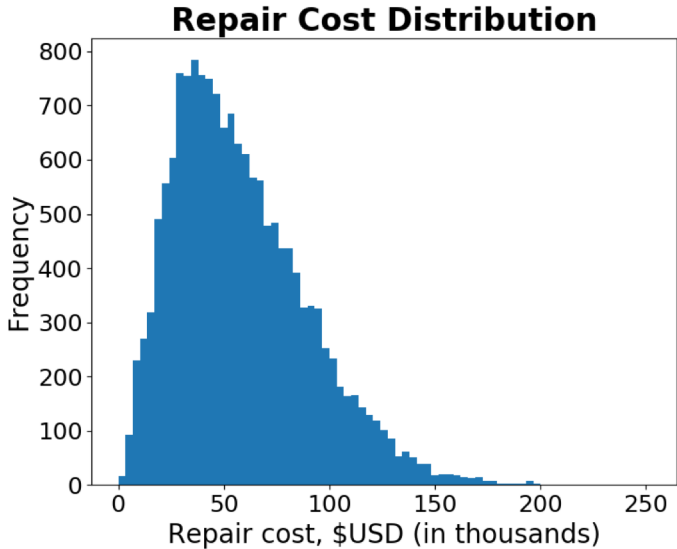
Loss Ratios

Red Tagged Buildings

Parcel Level Results



Loss Ratios



Comparison To HayWired Scenario

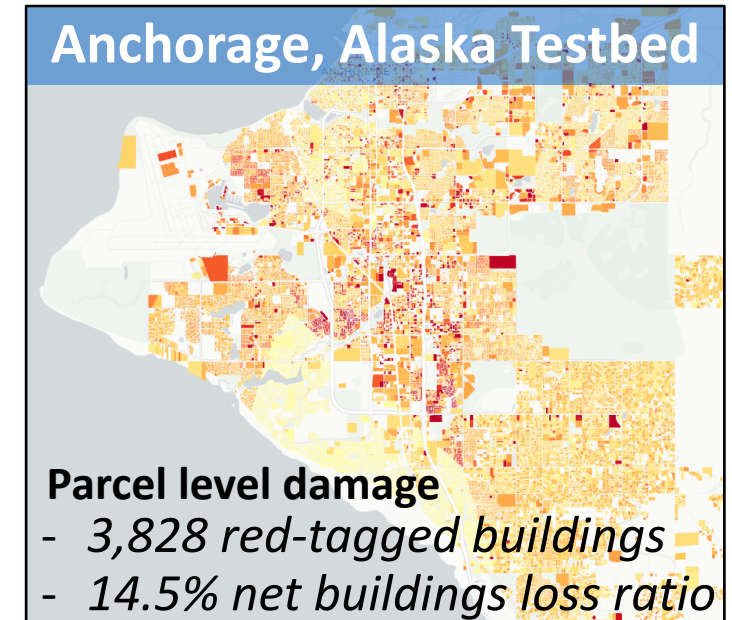
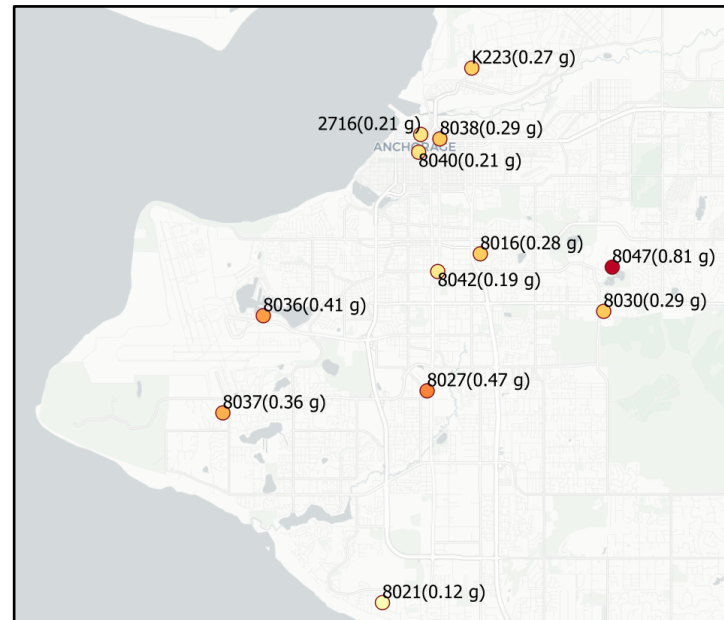
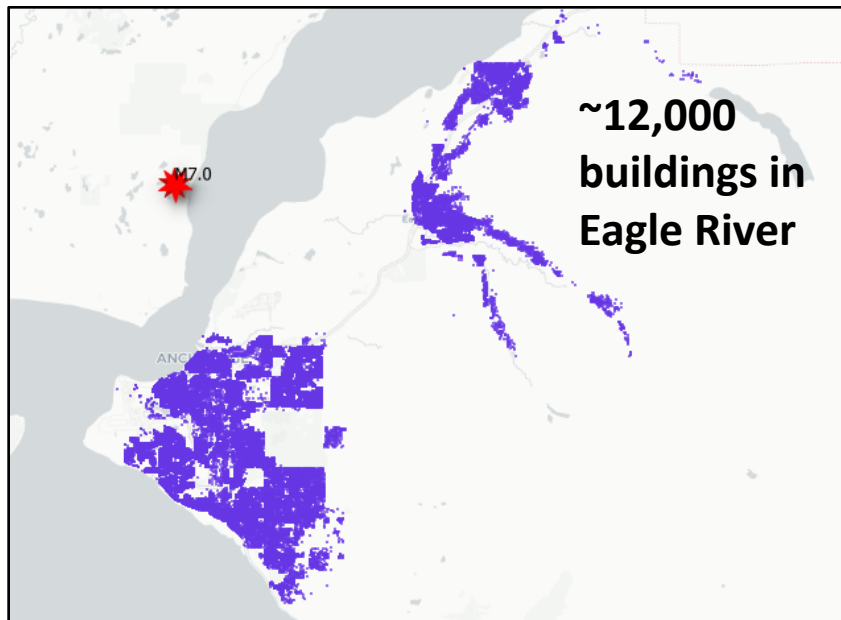
- **HayWired Scenario:** A study lead by USGS, involving approximately 60 partners, to simulate the effects and consequences of a hypothetical, yet scientifically realistic, magnitude M7.0 earthquake on the Hayward fault.

	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

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COMPUTATIONAL MODELING
AND SIMULATION CENTER




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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




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

CWE UQ




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

EE UQ



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

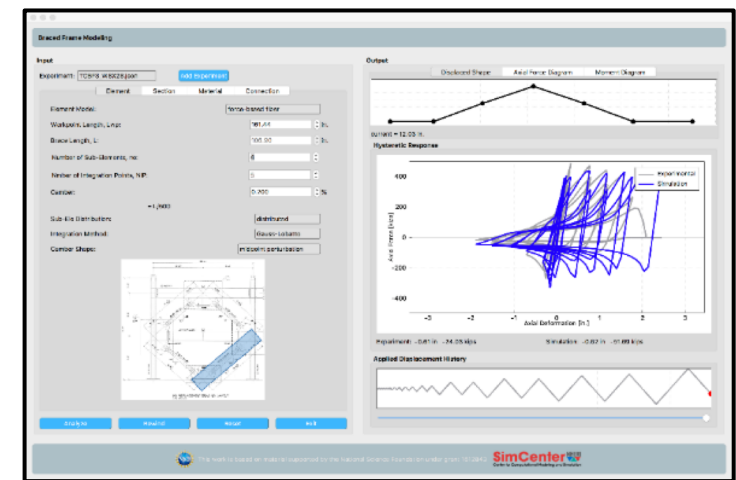
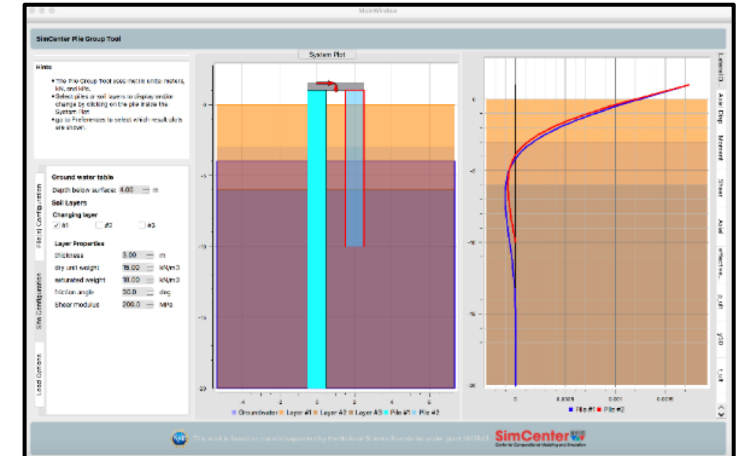
PBE



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

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



SimCenter Educational Apps



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



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