SimCenter NHERI

Center for Computational Modeling and Simulation

# SimCenter Recap

**Frank McKenna**

University of California, Berkeley


NSF award: CMMI 1612843

# Outline

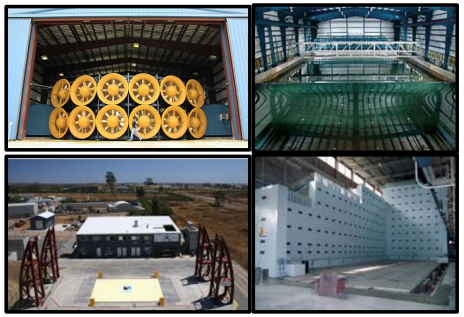
Introduction to SimCenter

Research Applications

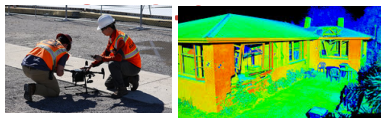
Education & Outreach

# NSF NHERI (Natural Hazards Engineering Research Infrastructure)

NCO

Experimental



Rapid facility

DESIGNSAFE-CI
A NATURAL HAZARDS ENGINEERING COMMUNITY

Data Storage

HPC

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

UQ FEM | PBE | EE-UQ | CWE-UQ

We are a Virtual EF

# Leadership Group

**Sanjay Govindjee**
UC Berkeley

**Ahsan Kareem**
Notre Dame

**Laura Lowes**
Washington

**Greg Deierlein**
Stanford

**Satish Rao**
UC Berkeley

**Frank McKenna**
UC Berkeley

**Matt Schoettler**
UC Berkeley

# Software Development Team

**Peter (UW), Michael, Adam (Stanford), Frank, Charles, Wael, Pedro (UW)**

**Qian**

**Ziad**

**Jiawai (ND)**

**Barbara**

# 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


Camille Crittenden


Filip Filippou


Ewa Deelman


Kincho Law


Ertugrul Taciroglu


Stella Yu


Eduardo Miranda


Andrew Kennedy

# Mission

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

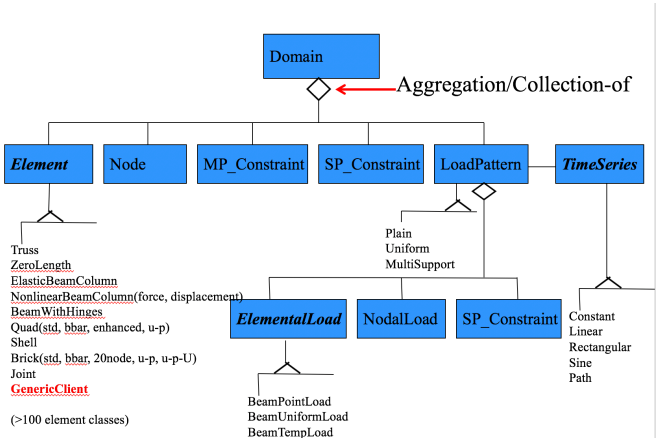
**Grounded in the present**

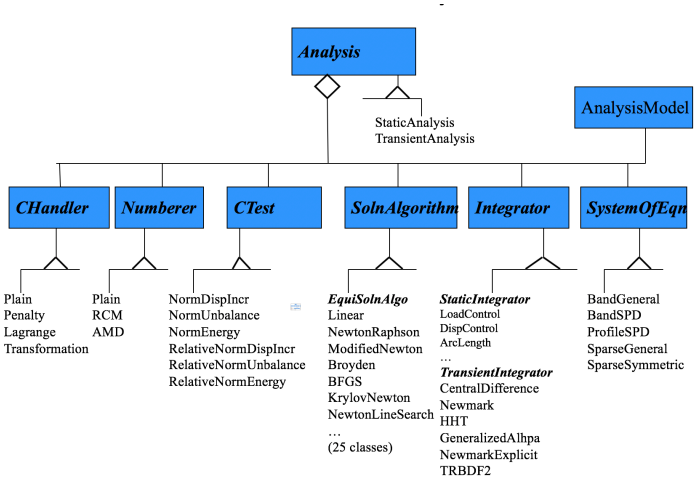
**Five year focus**

**Ten year vision**

# SimCenter Mission to Produce Extensible Software that Researchers in Natural Hazards Engineering can use in their research

- Develop an **open-source computational framework** for **building workflow applications** to support decision-making to enhance community resilience to natural hazards **in the face of uncertainty**;
- **Design a framework** that is sufficiently **flexible, extensible, and scalable** so that any component of it can be enhanced to improve the analysis and thereby better meet the needs of the community;
- **Seed the framework** with enough **data** and **interfaces to existing simulation tools** so that it can be used in the near-term using SimCenter developed Applications;
- **Release tools/applications built using this framework** that meets 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.




OpenSees.exe
OpenSeesMP.exe
OpenSeesMP.exe
PGT
MDOF
EvW
BFM
WE-UQ
EE-UQ

# Outline

Introduction to SimCenter

Research Applications

Education & Outreach

# Some Released Software For Looking at Effect of Hazard At Individual Building Level





Unique Features

- Uncertainty Quantification
- Local or Remote Execution
- Event Selection

# Applications ARE NOT Deterministic Applications

i.e. they do not produce a single output result for every response parameter

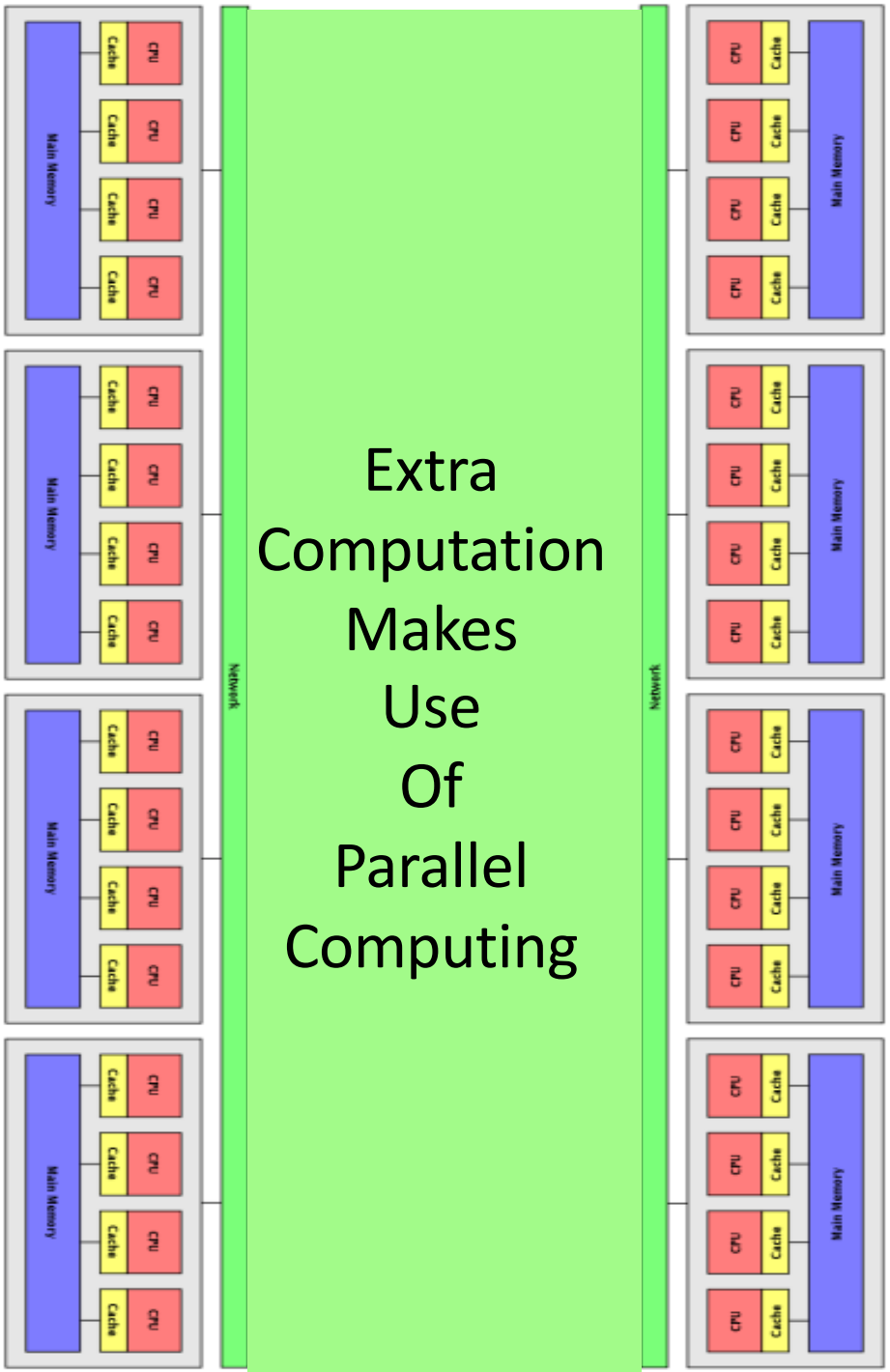
# Applications ARE UQ Applications

i.e. for each output response they produce information on the response and some measure on the uncertainty in the computed response, e.g. mean and std. dev

**This Requires Extra Input From User**

User has to identify certain parameters as being **Random Variables**

User then has to define the **Distribution** associated with these Random Variable




- Applications can run these computations in parallel using the cores of your local computer;
- They also allow you to run the simulations through the Cloud on the HPC resources provided through DesignSafe-ci.

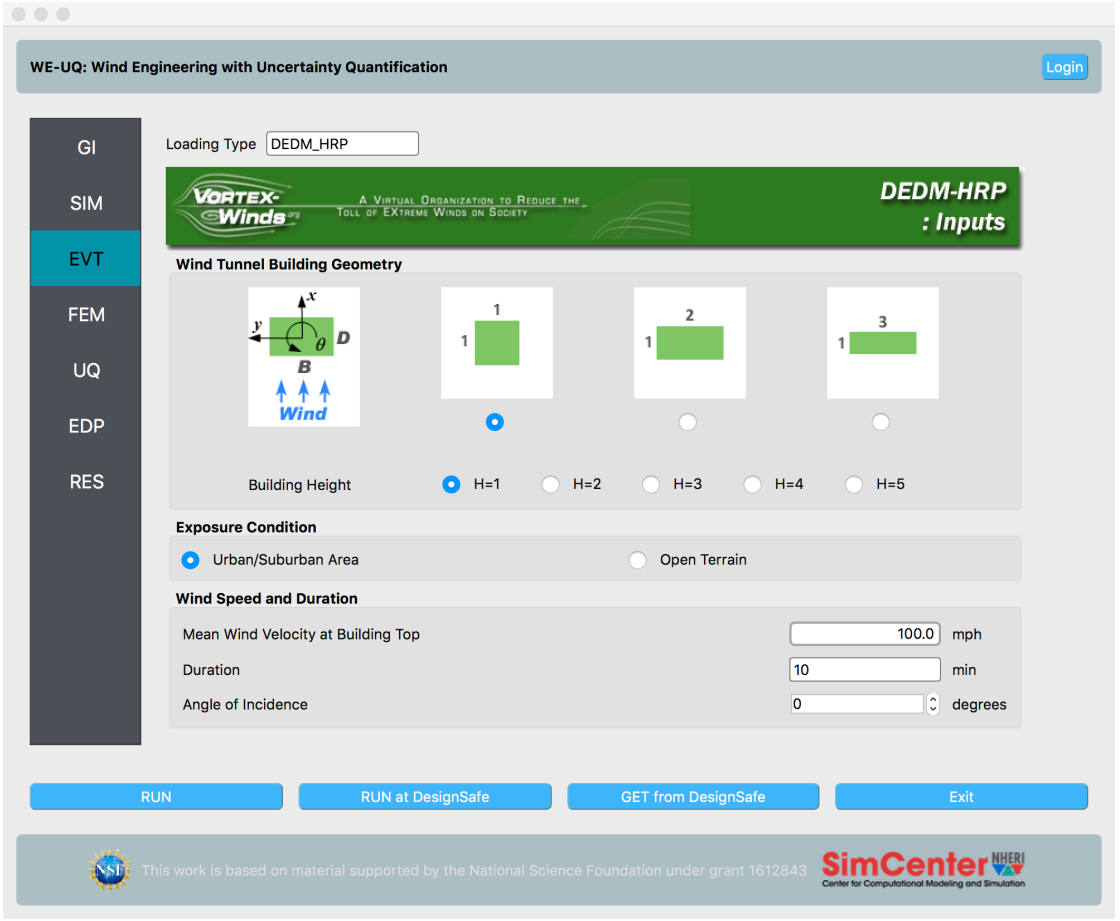
Applications split into 2 applications:

Front End UI

Backend Workflow

- Front end is an application runs on your desktop
- Backend workflow applications run on either your desktop or HPC at TACC

# Frontend - UI




UI Creates an INPUT File for Backend and:

a. UI Invokes Python Application in Backend
b. UI Sends to DesignSafe and Invokes Agave App

# Backend –

## A Scientific Workflow Application

*Python Application Runs the Workflow using Subprocess

* Inputs & Outputs from Applications are in a JSON file format

# Definition

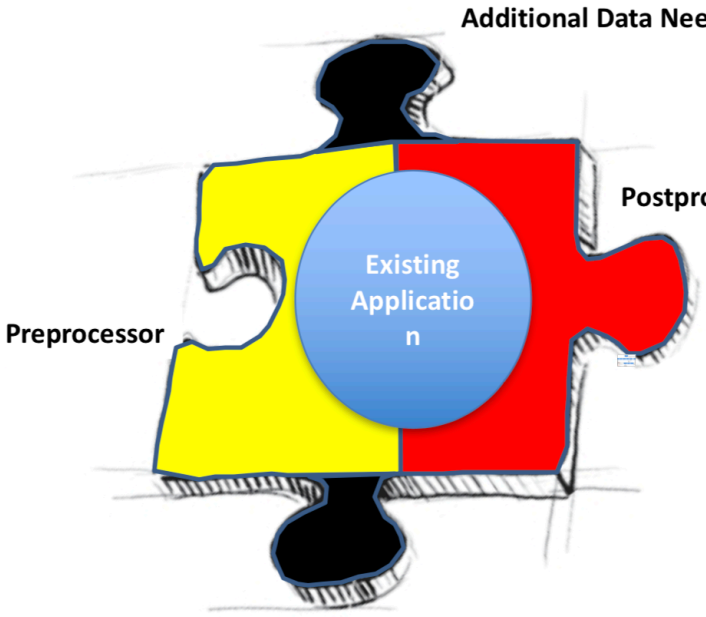
**Scientific Workflow Application:** A scientific workflow is the **automation** of a process in which information is passed from **one application to the next**.

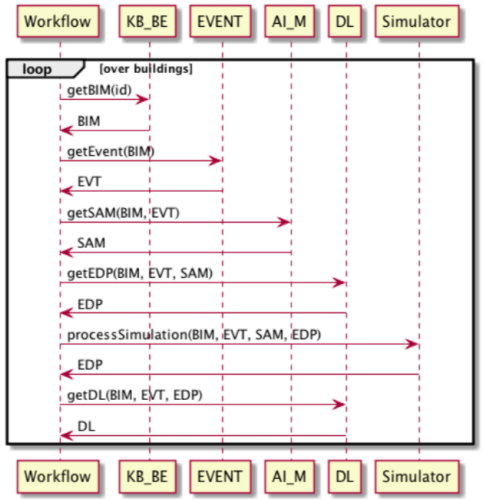
SimCenter classes
are
Applications

# Existing Applications, which of course do not work together

SimCenter defining interfaces they must meet!

# And Writing Code to incorporate Existing Applications into Workflow

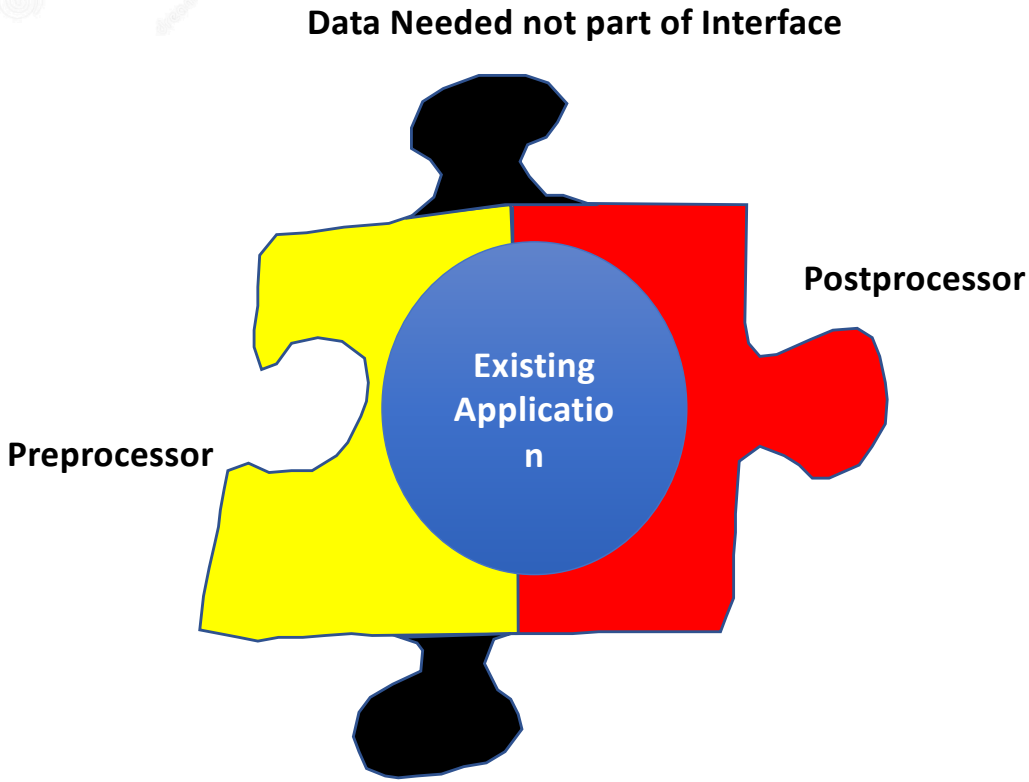


# JSON input/output causes problems for Existing Code

## Existing Software & APIs

**OpenFOAM, OpenSEES, Dakota, PEER NGA, Vortex-Winds**



# Input file for Backend is a JSON file

dakota.json

```
{
    "Applications": {
        "EDP": {
            "Application": "StandardWindEDP",
            "ApplicationData": {
            }
        },
        "Events": [
            {
                "Application": "StochasticWindInput-WittigSinha1975",
                "ApplicationData": {
                },
                "EventClassification": "Wind"
            }
        ],
        "Modeling": {
            "Application": "MDOF_BuildingModel",
            "ApplicationData": {
            }
        },
        "Simulation": {
            "Application": "OpenSees-Simulation",
            "ApplicationData": {
```

dakota.json

# Configuration File is a JSON file

WorkflowApplications.json

```
"EventApplications": {
  "API": {
    "Inputs": [
    {
        "id": "filenameBIM",
        "type": "string",
        "default": "BIM.json"
    }
    ],
    "Outputs": [
    {
        "id": "filenameEVENT",
        "type": "string",
        "default": "EVENT.json"
    }
    ]
  },
  "Applications": [
    {
      "Name": "StochasticWindInput-KwonKareem2006",
      "ExecutablePath": "applications/createEVENT/NOWS1/NOWS1",
      "ApplicationSpecificInputs":[]
    },
    {
      "Name": "DEDM_HRP",
      "ExecutablePath": "applications/createEVENT/DEDM_HRP/DEDM_HRP.py",
      "ApplicationSpecificInputs":[]
    },
```

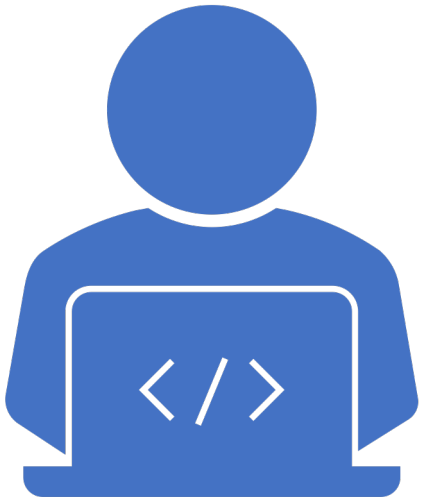
# UQ: Forward Uncertainty Propagation

- 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.

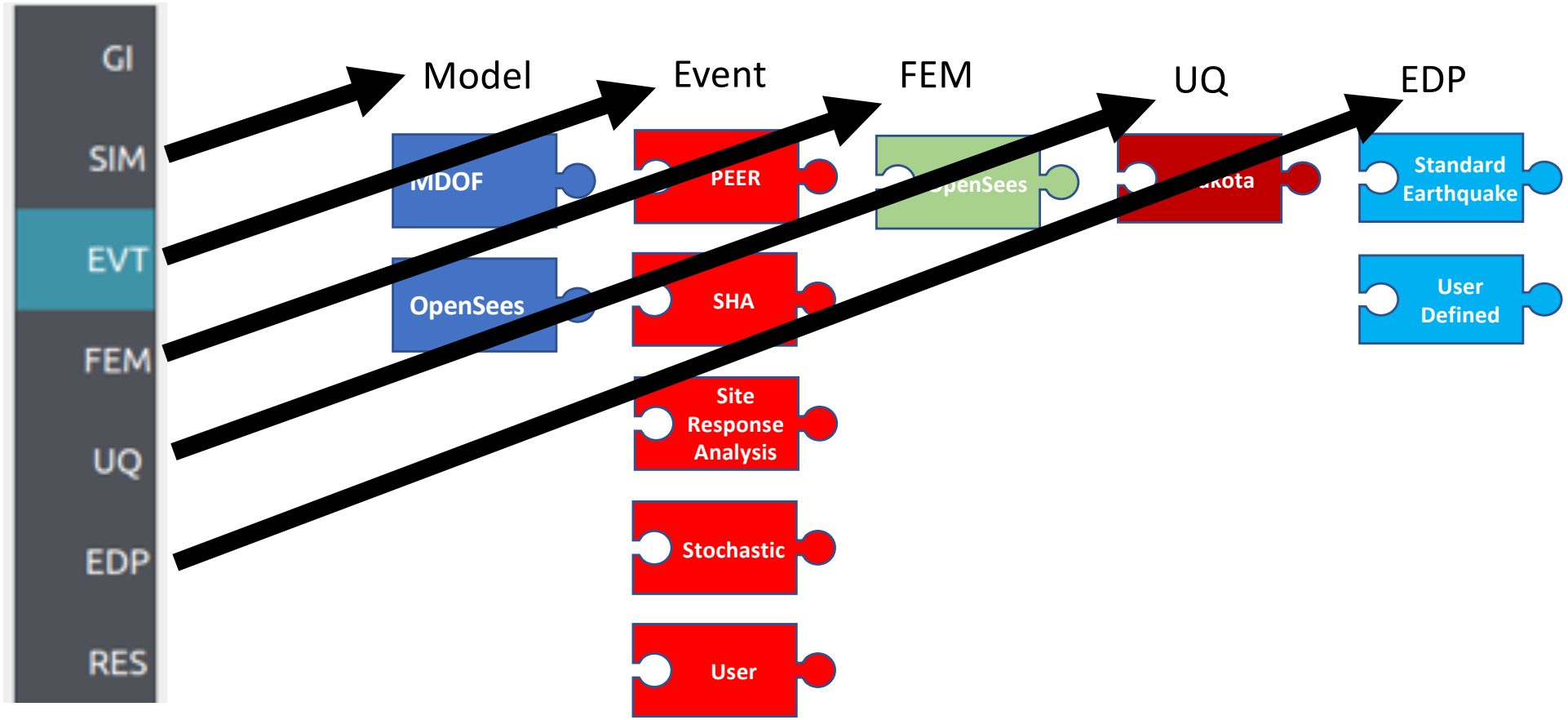
Applications are in actuality

# Scientific Workflow System



- they provide an interface to allow user to select from different applications to run in a scientific workflow
- The interface also allows users to specify specific inputs, schedule and run the workflow, and to monitor the progress.

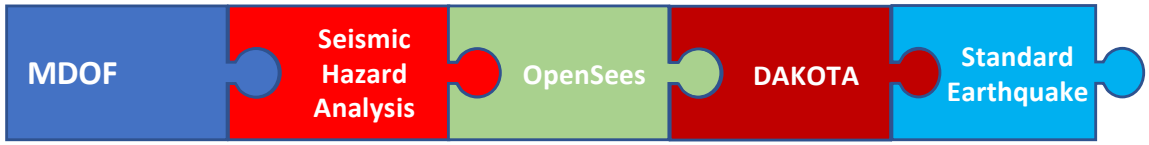
# Applications Present Users With a Lot of Options



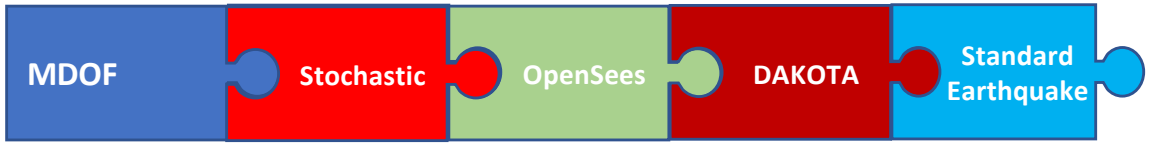
# Which allows User to Mix and Match

Chain a set of applications into a building workflow

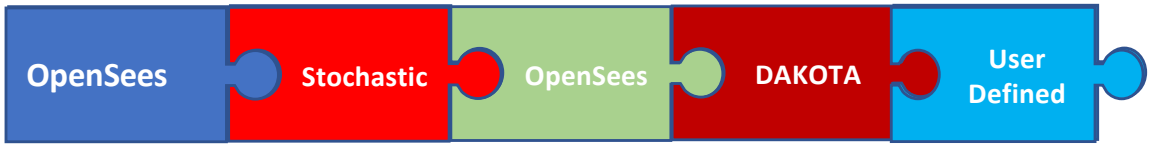
Workflow 1




Workflow 2

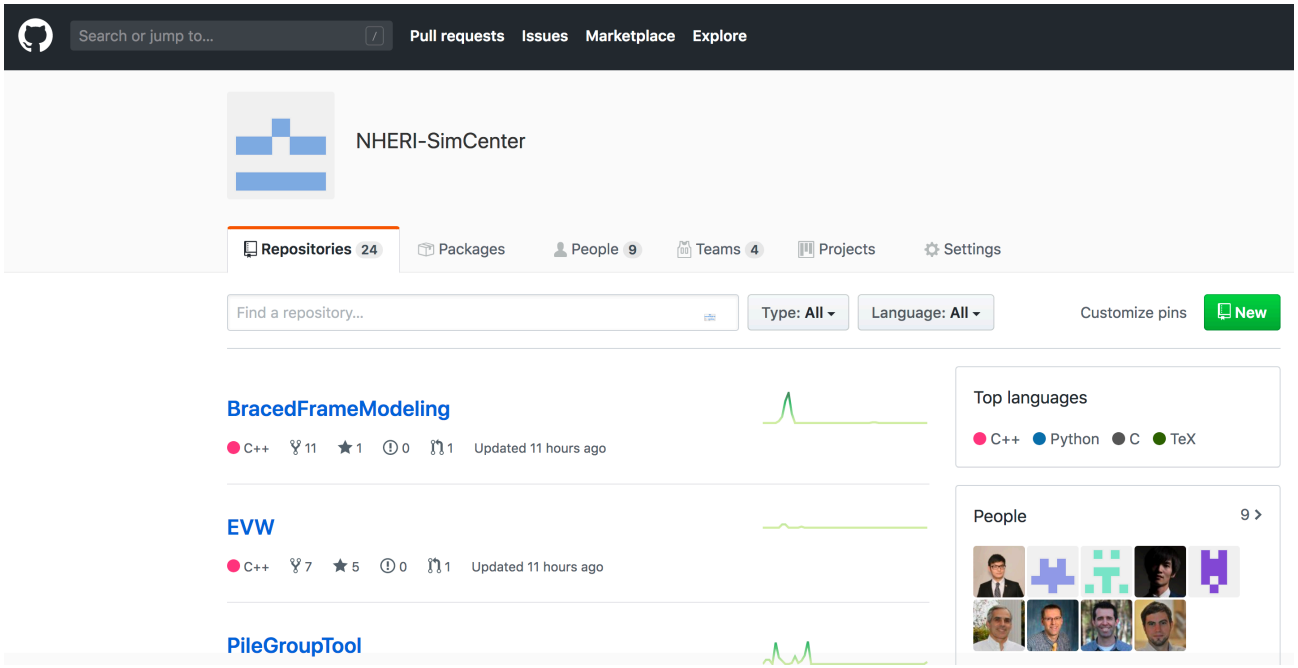



Workflow 3



# Research Applications Are Designed To Be Flexible & Extensible

# Open-Source Source Code




- PELICUN: Probabilistic estimation of losses, injuries and community resilience under natural disasters

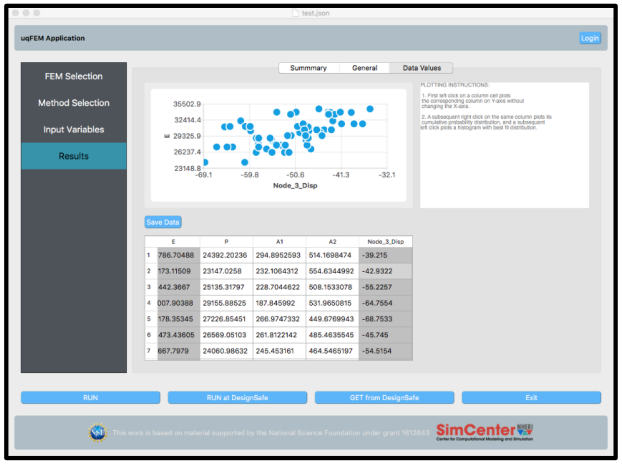
  Miranda, Terzic, Baker, Kijewski-Correa, Adam Zsarnóczay
- SMELT: Stochastic, Modular and Extensible Library for Time history generation

  Michael Gardner
- S3hark Site Response

  Deodatis, Bray, Arduino, Baker, Taciroglu, Charles Wang
- AI Tools

  **Yu**, Law, Taciroglu, Charles Wang

# UQFEM (to be renamed quoFEM)




Govindjee, Conte, Kennedy & Taflanidis

Frank McKenna & Ziad Ghauch

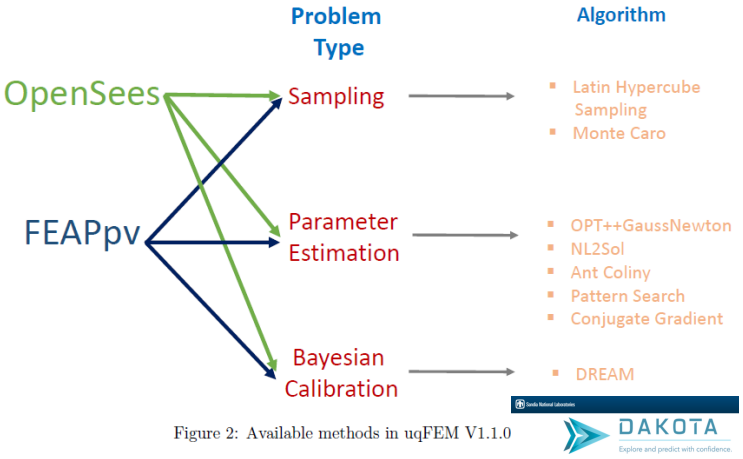


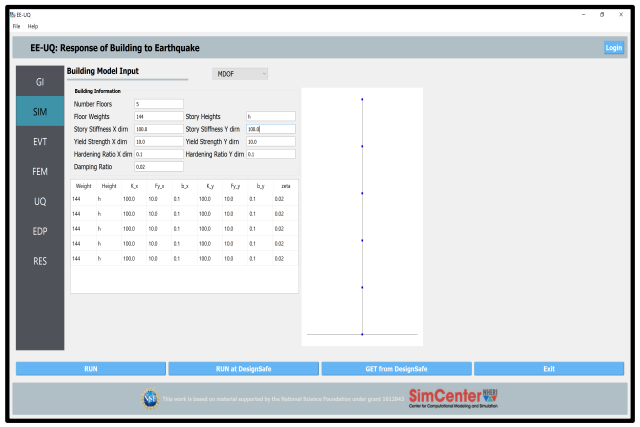

Figure 2: Available methods in uqFEM V1.1.0

**Current Release V1.1 (Oct 2018)**

- Correlation matrix for sampling methods
- Computation for Sobolev indices for sampling algorithms
- Specifying user-defined probability distribution functions for random variables (for sampling methods)
- Fitting of probability distribution functions for sampling results
- Conjugate gradient for calibration problems
- Pattern search for calibration problems

**Future Release V2.0 (Sept 2019)**

- Summary Statistics
- Correlation Matrix Testing with multiple events options
- User Defined Distribution




Arduino, Baker, Bray, Conte, Deodatis, Taciroglu & Taflanidis

**Frank McKenna**, Wael Elhaddad, Charles Wang & Michael Gardner

**Current Release V1.1 (March 2019)**

- Loading:
  - PEER Motions
  - Site Response 2D/1D motion, Effective Stress
  - Stochastic Loading – Vlachos et al.
  - Site Hazard Analysis
- Shear Building Model & OpenSees Models
- Earthquake & User Defined EDP

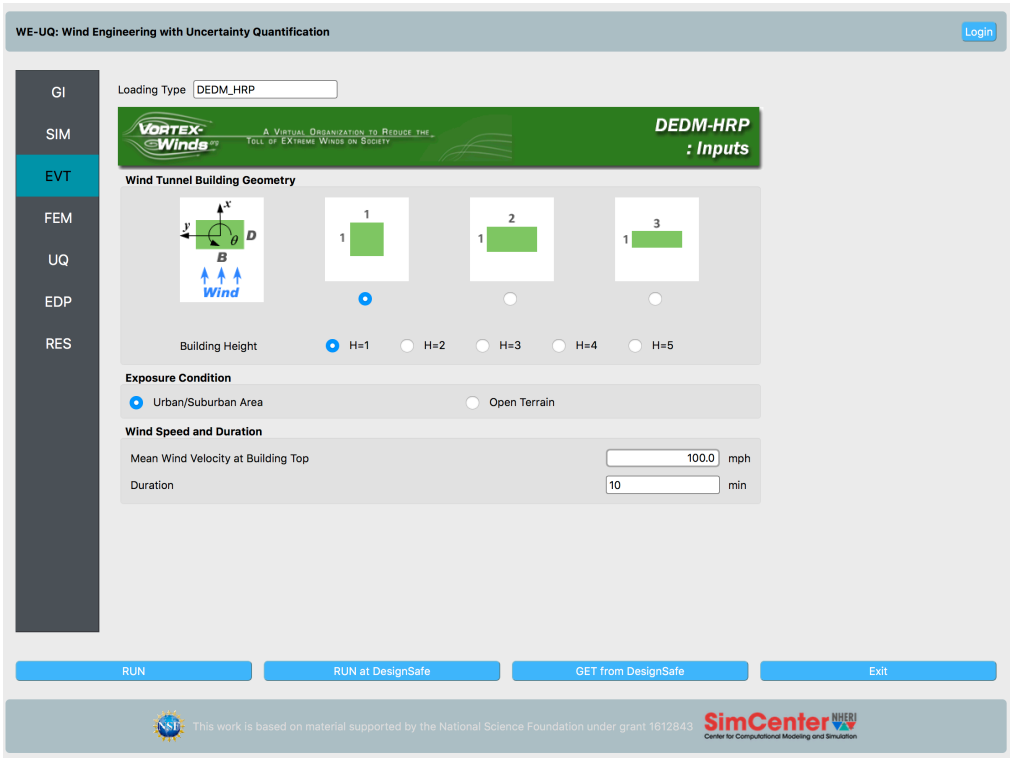
**Future Releases**

**V1.2 (June 2019)**

- Loading - Soil Column - 2d Motion, Effective Stress

**V2.0 (Sept 2019)**

- Loading:
  - Random Field Vertical
  - Stochastic Loading – Dobaghi
- Building:
  - Expert System for Walls, Moment Frames and Braces
  - Conditional Spectrum




Kareem, Kennedy, Motley & Taflanidis

Frank McKenna, Peter Mackenzie-Helnwein, Jiawei Wan, Wael Elhaddad, Charles Wang & Michael Gardner

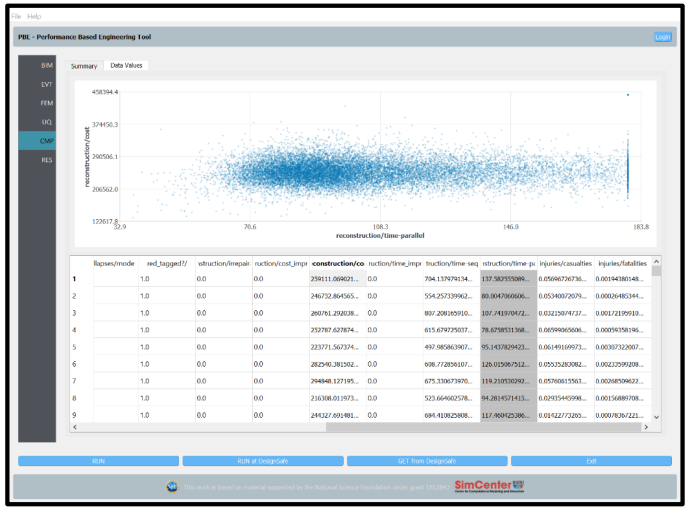
**Initial Release V1.0 (June 2019)**

- Wind Engineering Tool to consider UQ
  - Random Variables in all but CFD
  - Sampling Methods
- Loading
  - Stochastic loads.
  - Interface to Vortex Winds (HighRise).
  - CFD
    - User defined meshes.
    - Inflow for the initial conditions

**Release V1.1 (Sept 2019)**

- UQ for CFD
- Basic Meshing
- Low Rise Buildings

# PBE




Deierlein, Baker, Taflanidis & Terzic

Frank McKenna & Adam Zsarnóczay

**Current Release V1.1 (March 2019)**

- Incorporates EE-UQ features for building system analyses
- Enabled component-group-based (FEMA P58-style) loss assessment for earthquake hazard.

**Future Release V2.0 (Sept 2019)**

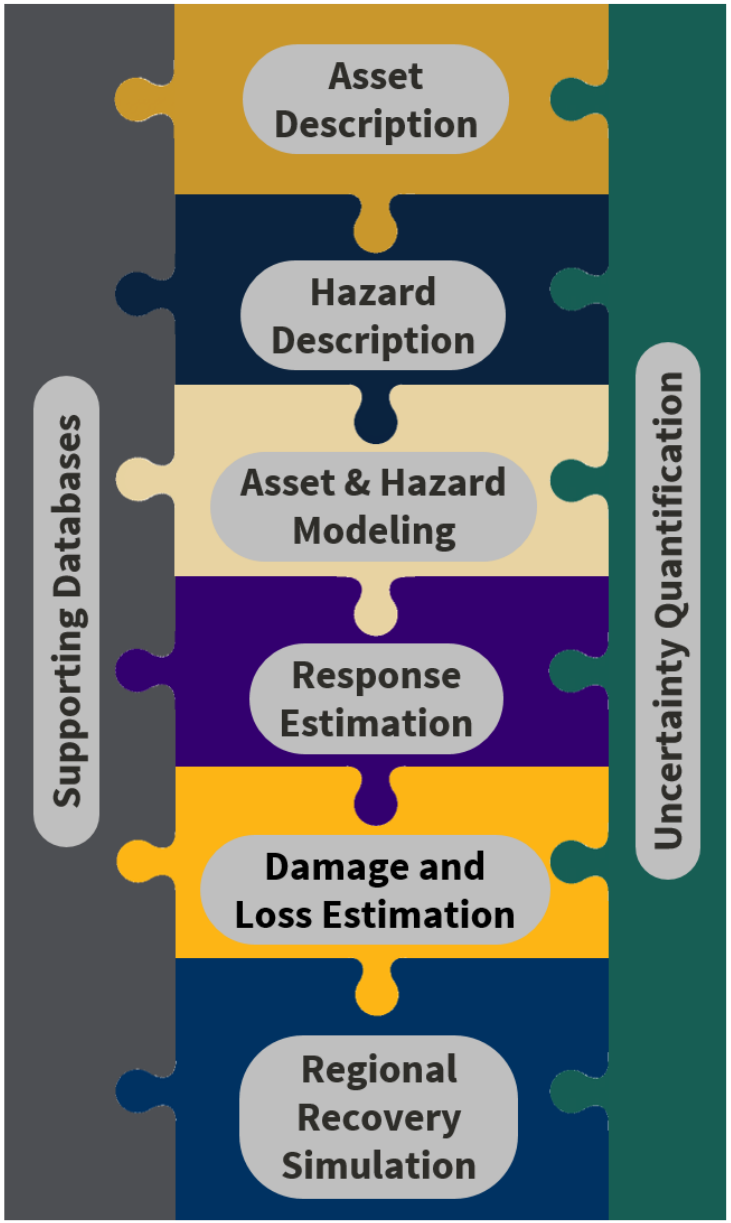
- Extend to incorporate damage and loss functions for wind and storm surge (HAZUS).
- Enable response estimation without simulation (HAZUS-style simplified approach typically using a simple formula), Business interruption (HAZUS).
- More sophisticated injury characterization (HAZUS).
- Downtime (REDi)
- Alternative UQ propagation methods for combining collapse and damage

# Major Upcoming Applications (within next year)

RDT

If we can do a building why not extend to a region!

# Resiliency Decision Tool




**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

**describe the event at the site**
specify hazard-consistent loads for response estimation

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

**estimate asset response to the event**
describe the response with engineering demand parameters

**estimate asset damage and its consequences**
prepare a stochastic description of damage and loss for the asset

**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

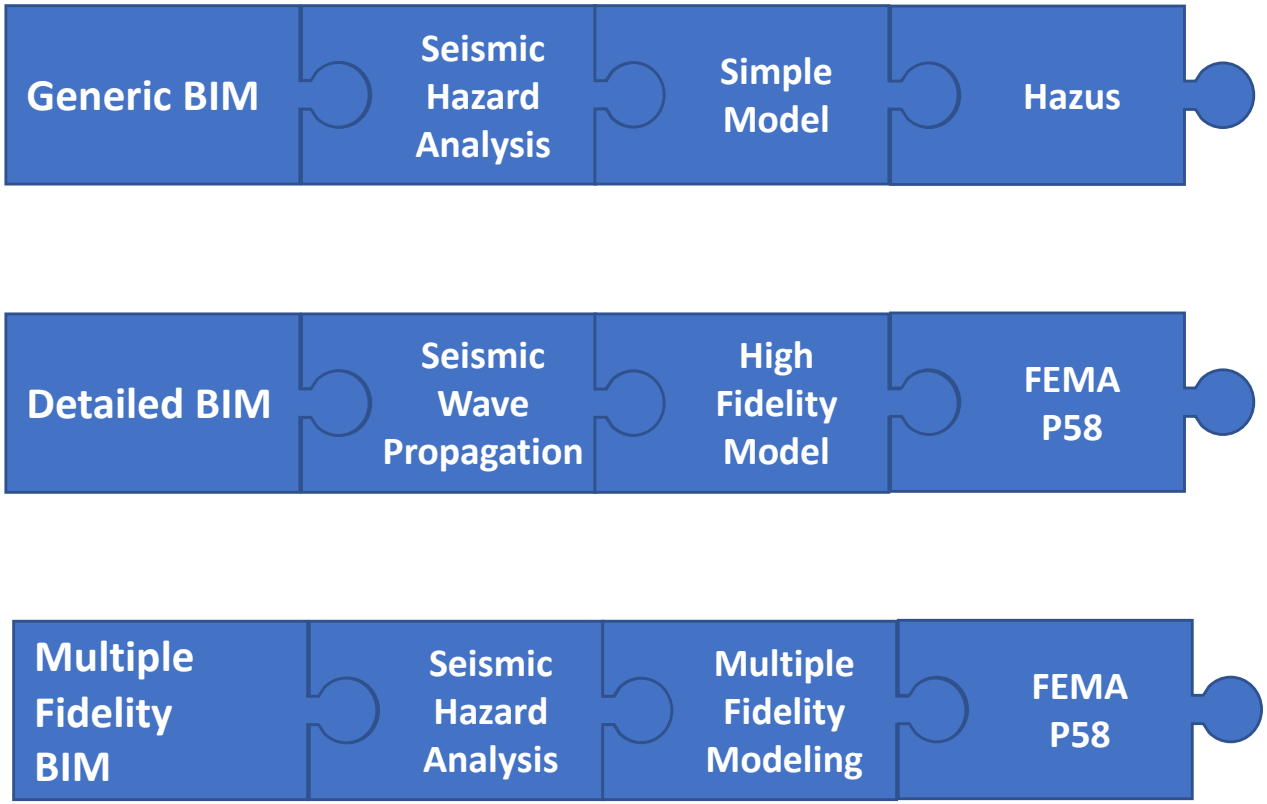
**simulate regional recovery**
estimate the temporal and spatial variation in the recovery of communities

CWE
EE
FEM
PBE

# Regional Workflow for Hazard And Loss Estimation

rWHALE

**Deierlein**, Kareem, Conte, Deelman, Deodatis, Kijewski-Correa, Taflanidis & Tien
Frank McKenna & Wael Elhaddad




**Current Release V1.1 (Feb 2019)**

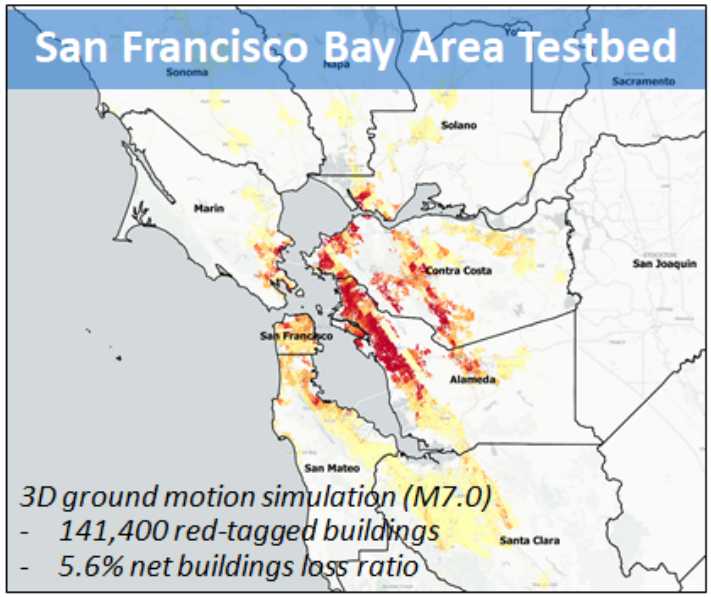
- Regional earthquake workflow
- Various hazard representations

**Future Release V2.0 (Sept 2019)**

- Regional storm workflow
- Initial version to consider ASCE7 wind loading and HAZUS type damage and loss

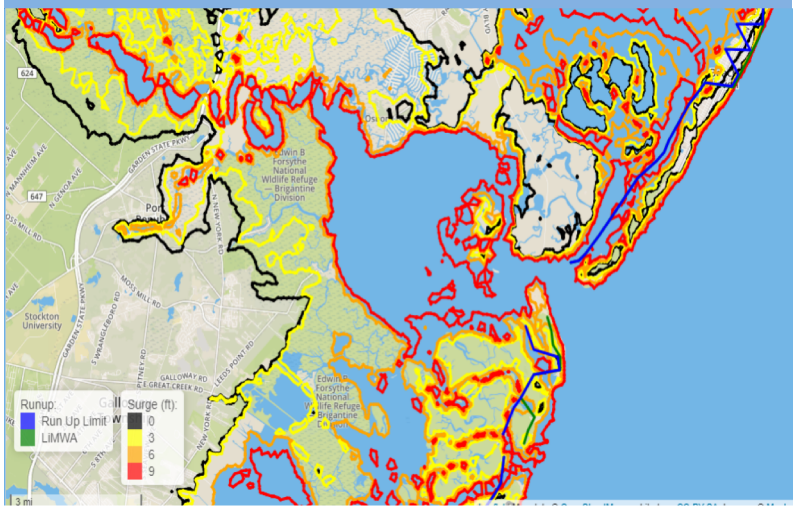
# Regional Workflow Testbeds to Verify rWhale

## San Francisco Bay Area Testbed

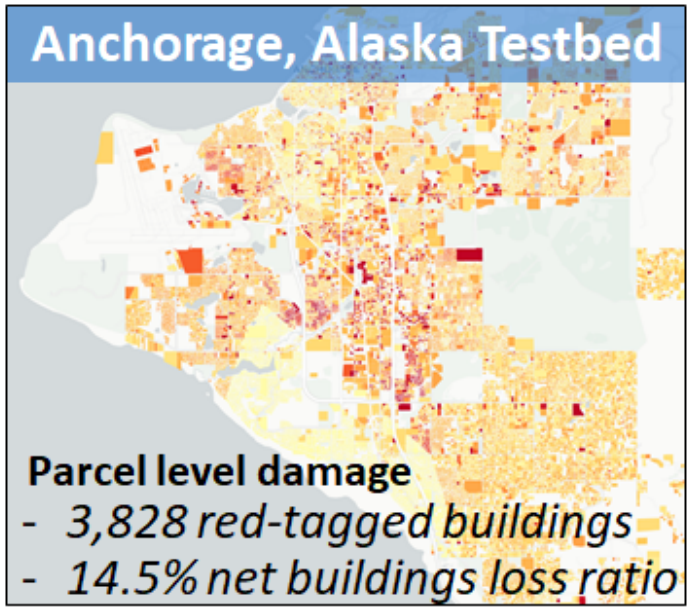



*3D ground motion simulation (M7.0)*
- *141,400 red-tagged buildings*
- *5.6% net buildings loss ratio*

## Atlantic City, NJ Storm Testbed

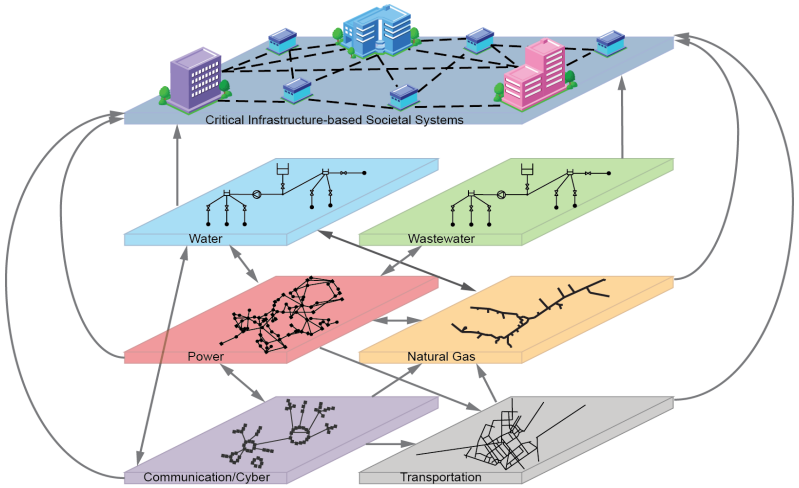



## Anchorage, Alaska Testbed

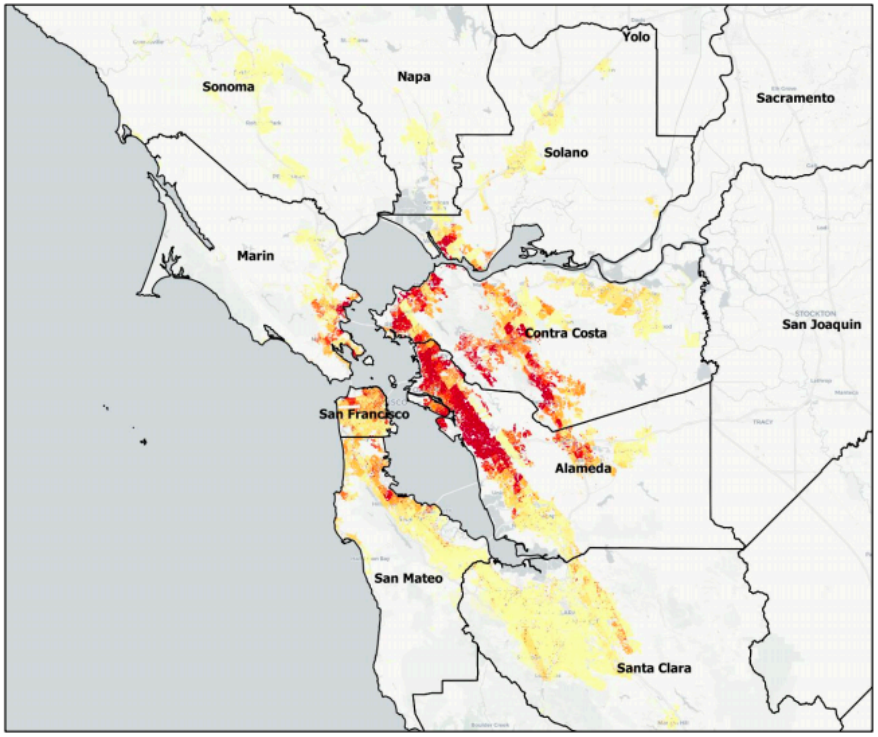


**Parcel level damage**
- *3,828 red-tagged buildings*
- *14.5% net buildings loss ratio*

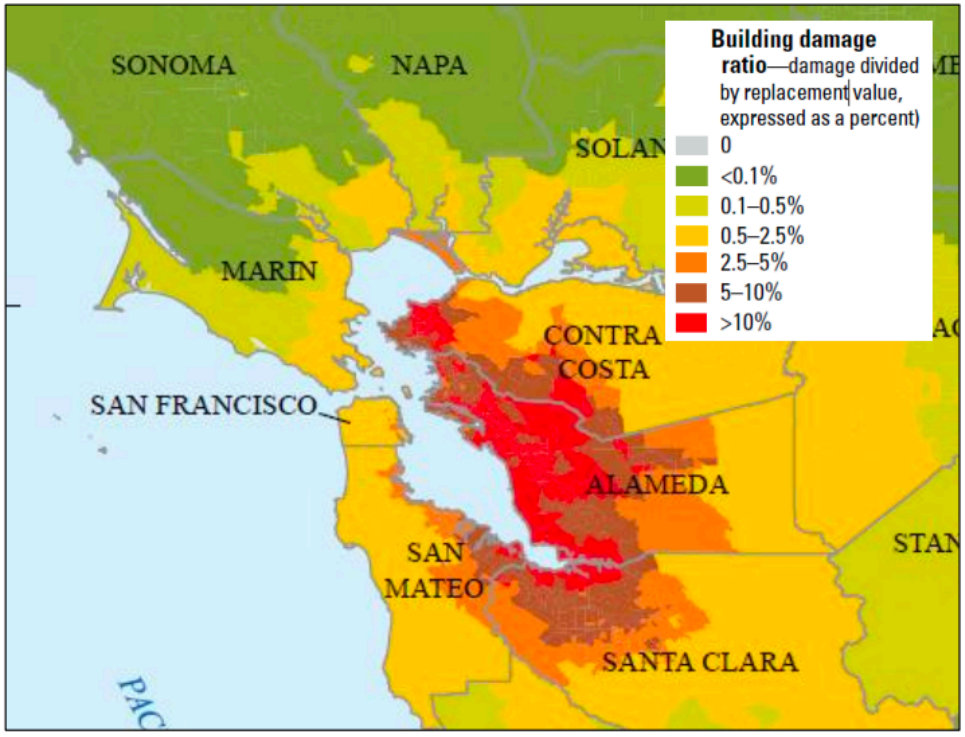
## Memphis, TN Lifelines Testbed



# It's NOT HAZUS




SimCenter Workflow

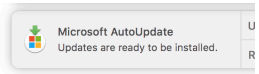



USGS Haywired

If know area, to east of fault there are hills and no construction! **SimCenter Info at parcel level**

# There is Of Course the Small Matter of where we get the Data!

## Web Services




- **ATC API**
  - Hazard by Location API: https://hazards.atcouncil.org/api
  - Example: https://api-hazards.atcouncil.org/wind.json?lat=35.4676&lng=-97.5164

- **USGS APIs (NSHMP-ws)**
  - Hazard Service: https://earthquake.usgs.gov/nshmp-haz-ws/
  - Design Maps: https://earthquake.usgs.gov/ws/designmaps/

- **FDNS**
  - Earthquake Catalog: https://earthquake.usgs.gov/fdsnws/event/1/
  - Examples:

    Ridgecrest, CA
    https://earthquake.usgs.gov/fdsnws/event/1/query?format=geojson&starttime=2019-01-01&endtime=2019-07-24&latitude=35.6225&longitude=-117.6709&maxradiuskm=50&minmagnitude=6
    Anchorage, AK
    https://earthquake.usgs.gov/fdsnws/event/1/query?format=geojson&starttime=2018-11-30&endtime=2018-12-01&latitude=61.2181&longitude=-149.9003&maxradiuskm=50&minmagnitude=6

- **DataSF Portal**
  - Tall Building Inventory
    - Map: https://data.sfgov.org/Housing-and-Buildings/Map-of-Tall-Buildings/xnf9-cudk
    - Inventory: https://data.sfgov.org/Housing-and-Buildings/Tall-Building-Inventory/5kya-mfst
    - Request: https://data.sfgov.org/resource/5kya-mfst.json

- **Census API**
  - https://www.census.gov/data/developers/data-sets.html

# Well Then Collecting The Data!

## Python Libraries

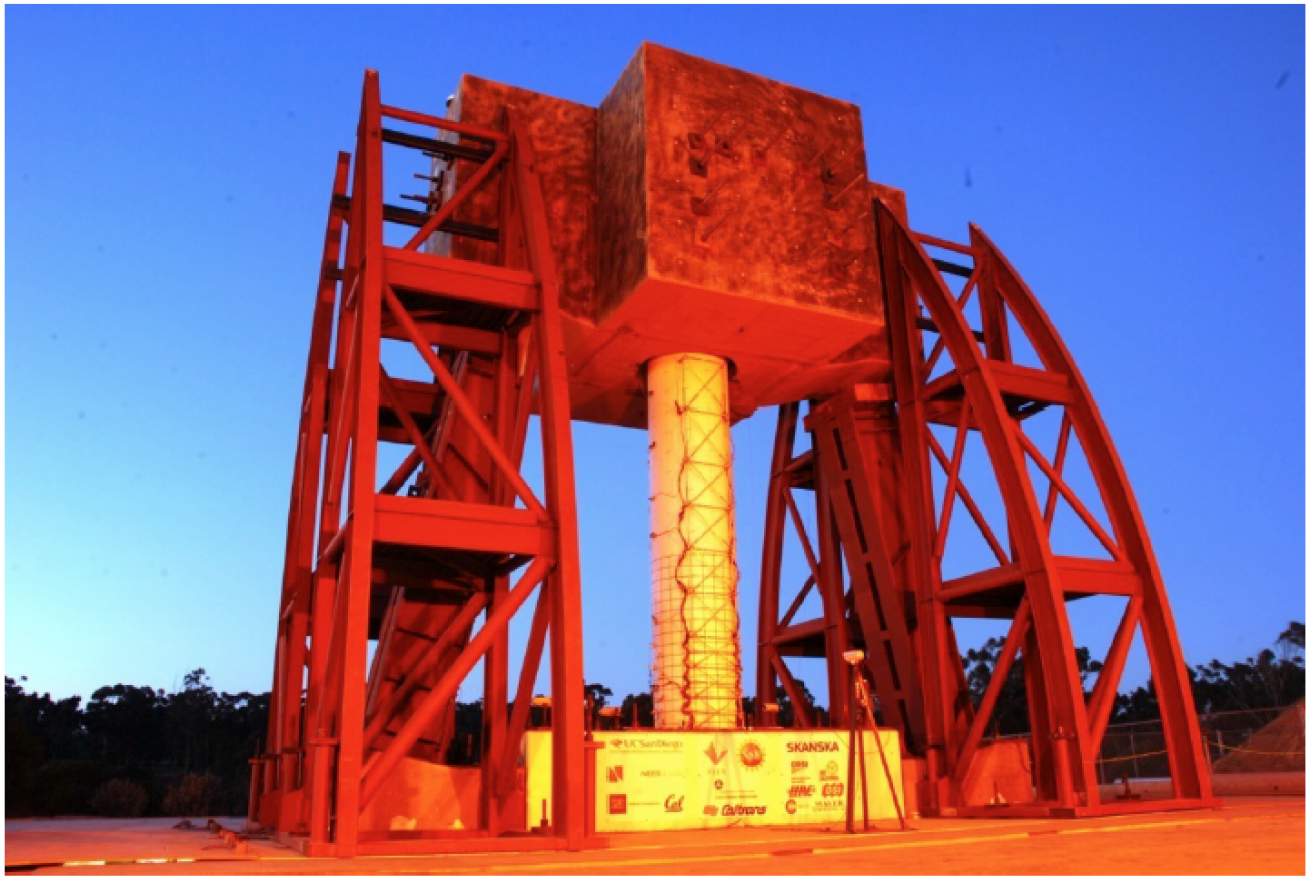
- **Requests**
  - Submit HTTP requests and get the response
  - Documentation: https://2.python-requests.org/en/master/
- **Selenium**
  - Webdriver to control the web browser
  - Documentation: https://selenium-python.readthedocs.io/getting-started.html
- **BeautifulSoup, lxml**
  - Packages to facilitate processing html
  - Documentation: https://www.crummy.com/software/BeautifulSoup/bs4/doc/#quick-start
- **Census, US**
  - Python package to facilitate querying Census data
  - Documentation: https://github.com/datamade/census

And (as you will see) we are also making the Data Freely Available @ DesignSafe.

Our Intention is Not To Release Tools That Do Everything .. Our Intent is to Provide Tools that Represent State-of-the-Art and Ensuring that the Design of Them Will Allow Researchers Such as Yourselves to Make your Own Contributions

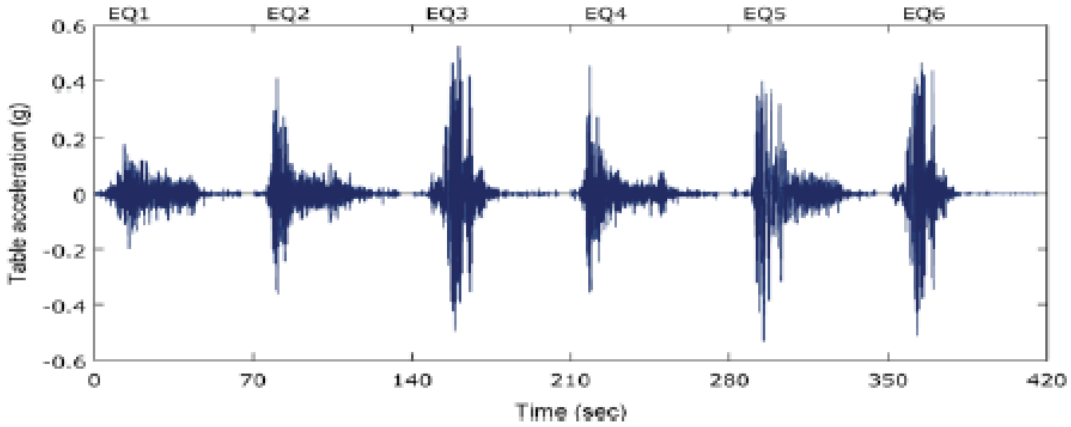

# For Where Are We?

**Today:**
**PEER Bridge Column Benchmark @ UCSD**

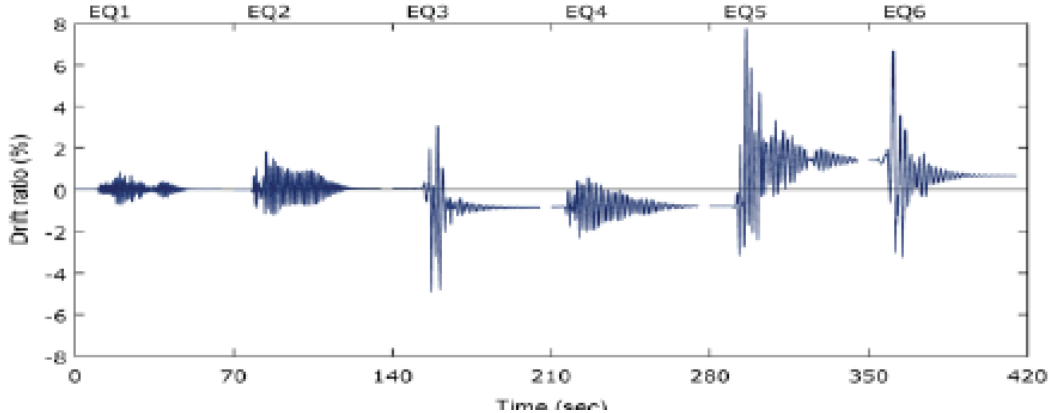


# Today:
# PEER Bridge Column Benchmark @ UCSD

- Earthquake acceleration time histories

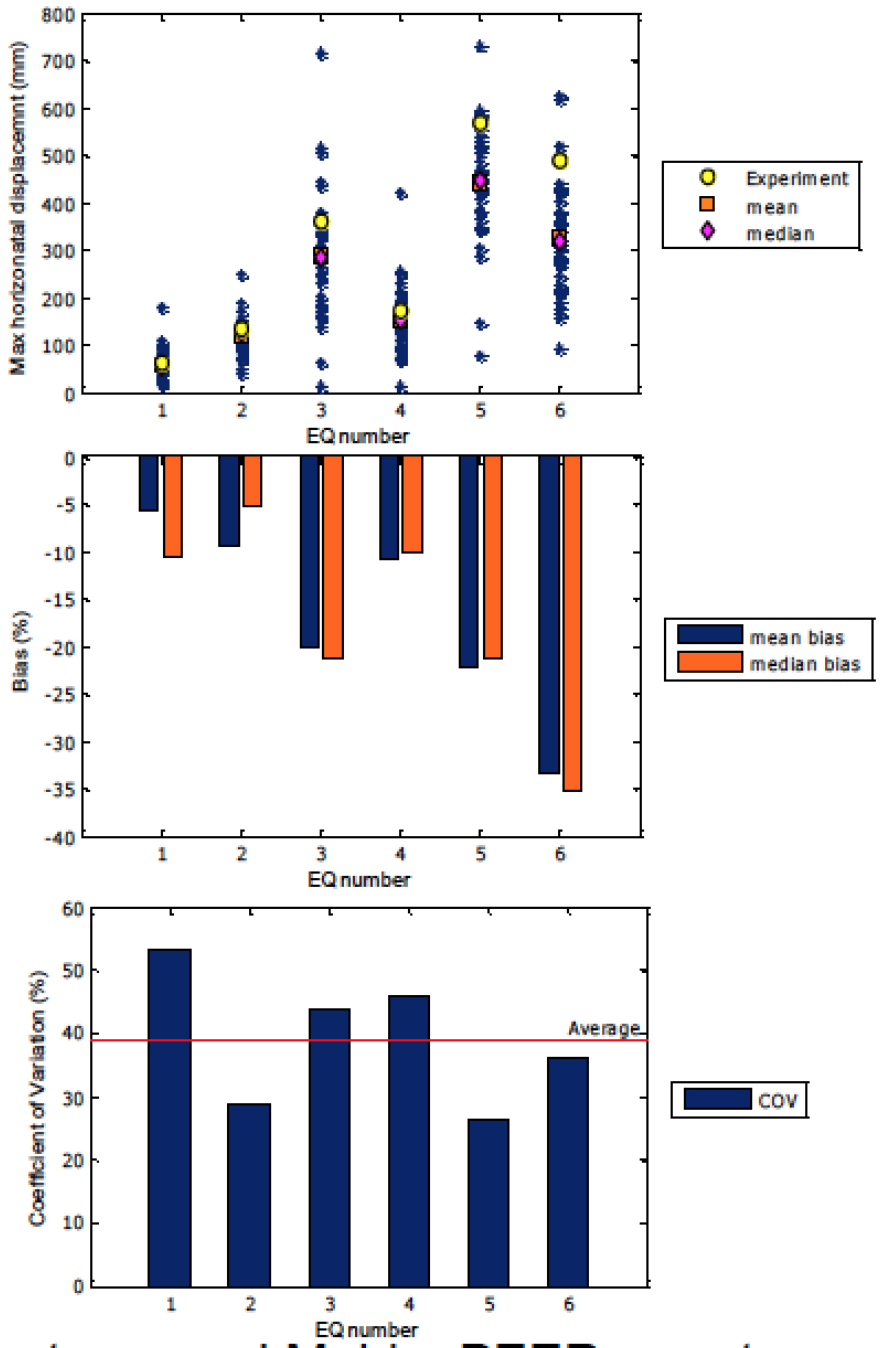



- Drift ratio time histories



# Today

- Prediction of the relative displacement of the top of the column:
  - Very large scatter among the 41 simulations
  - Bias is negative (model underestimates the benchmark) and growing with increase of earthquake intensity
  - CoV is, on average, 39%

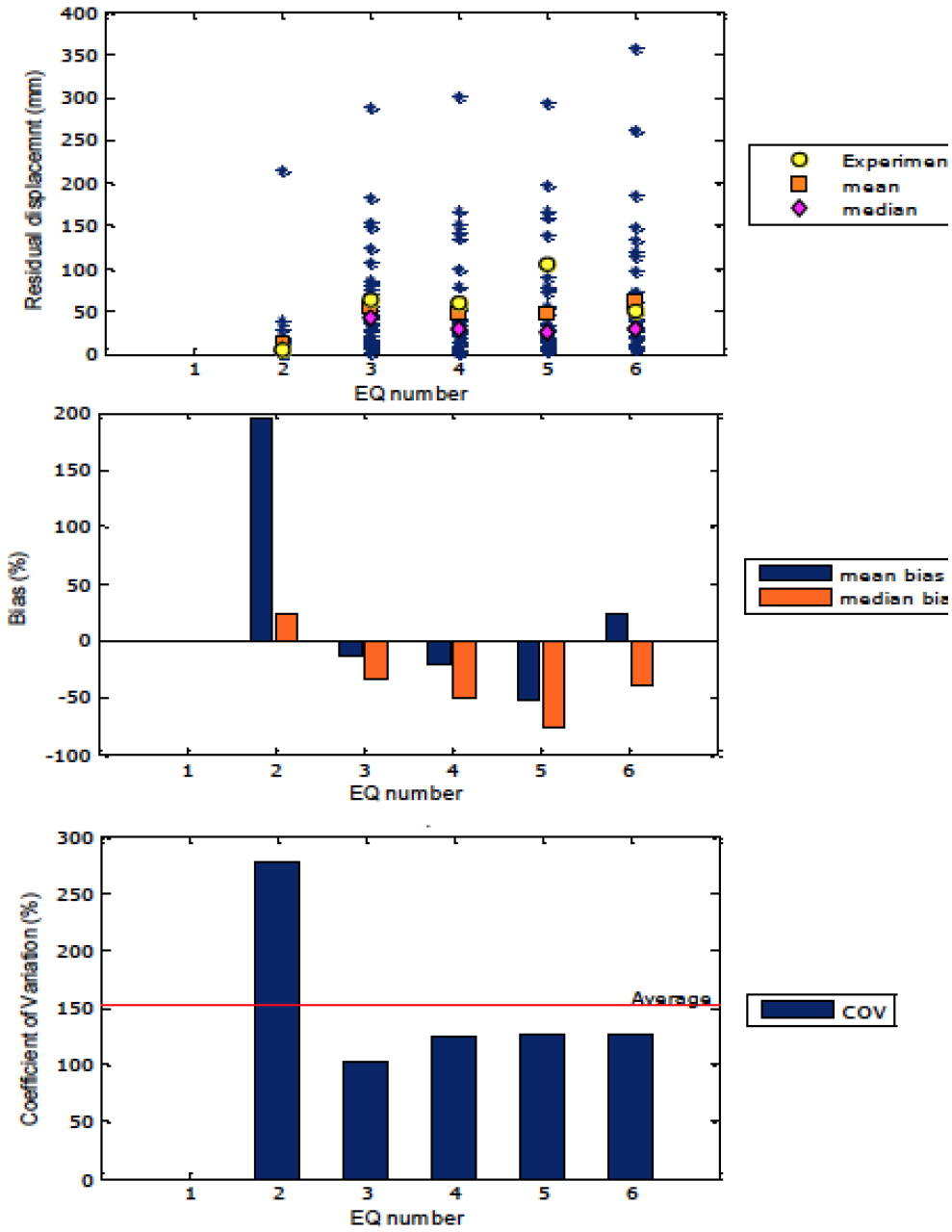



source: Prof. B. Stojadinovic

Terzic, Schoettler, Restrepo and Mahin, PEER report

# Today

- Prediction of the residual displacement of the top of the column:
  - HUGE scatter among the 41 simulations
  - Bias is mostly negative (model underestimates the benchmark) and there is no pattern
  - CoV is, on average, larger than 100%




source: Prof. B. Stojadinovic



Terzic, Schoettler, Restrepo and Mahin, PEER report

# Outline

Introduction to SimCenter

Research Applications

Education & Outreach

# SimCenter ECO Activities

- Training
  - Online Webinars
  - Workshops
    - Tool Training
    - Programming Bootcamp
  - NHERI Summer REU Program
  - State-of-the-Art Report
- Education
  - Educational App's
- Learn about the SimCenter
  - NHERI Summer Institute
  - Subscribe to SimCenter news and join Slack channels

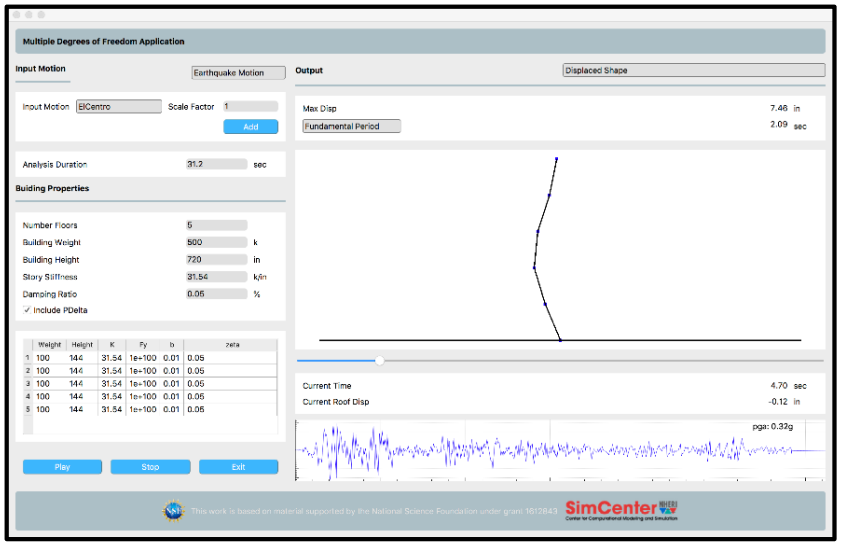
  https://simcenter.designsafe-ci.org/join-community/

# Training Activities: Workshops

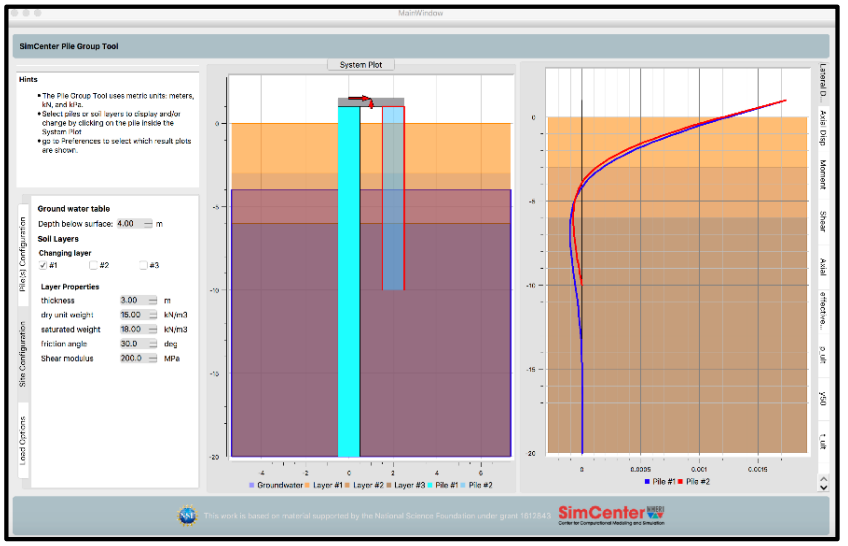
- SimCenter Tool Training Workshop (June 13-14 2019)
  - Hands-on software training and instruction in SimCenter Tools and their useful applications in natural hazards engineering (45 registered)
- Summer Programming Bootcamp (July 22-26, 2019)
  - Goal is to train NHERI researchers in the programming paradigms not covered in traditional civil engineering coursework, but required to advance NHE simulation capabilities (30 registered)

# Educational Applications (Years 1&2)

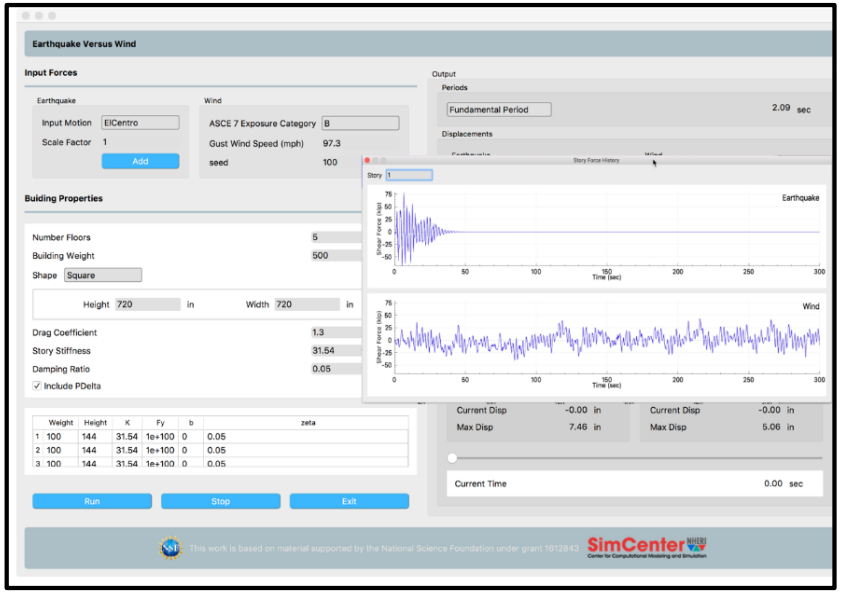
MDOF




PGT




EvW




BFM