



NSF award: CMMI 2022469



NSF award: CMMI 2131111

Machine Learning Training for Natural Hazards Engineering 2022

Frank McKenna
SimCenter

Outline

- Welcome
- Introduction to NHERI
- ML in Earthquake Engineering: Opportunities and Challenges

Presenters



Prof. Henry Burton
UCLA



Prof. Krishna Kumar
UT-Austin



Dr. Barbaros Cetiner
SimCenter

Syllabus

- Day 1: ML in Earthquake Engineering: Opportunities and Challenges
- Day 2: Explainable AI in Earthquake Engineering
- Day 3: Image Classification
- Day 4: Semantic Segmentation
- Day 5: Inventory Generation with BRAILS

These last 3 days are very hands on.
They REQUIRE you to watch videos
before the day presentation starts

Resources

GitHub Repo:

https://github.com/NHERI-SimCenter/SimCenter_DesignSafe_ML_2022

Workshop Website:

https://nheri-simcenter.github.io/SimCenter_DesignSafe_ML_2022/

Programming Help:

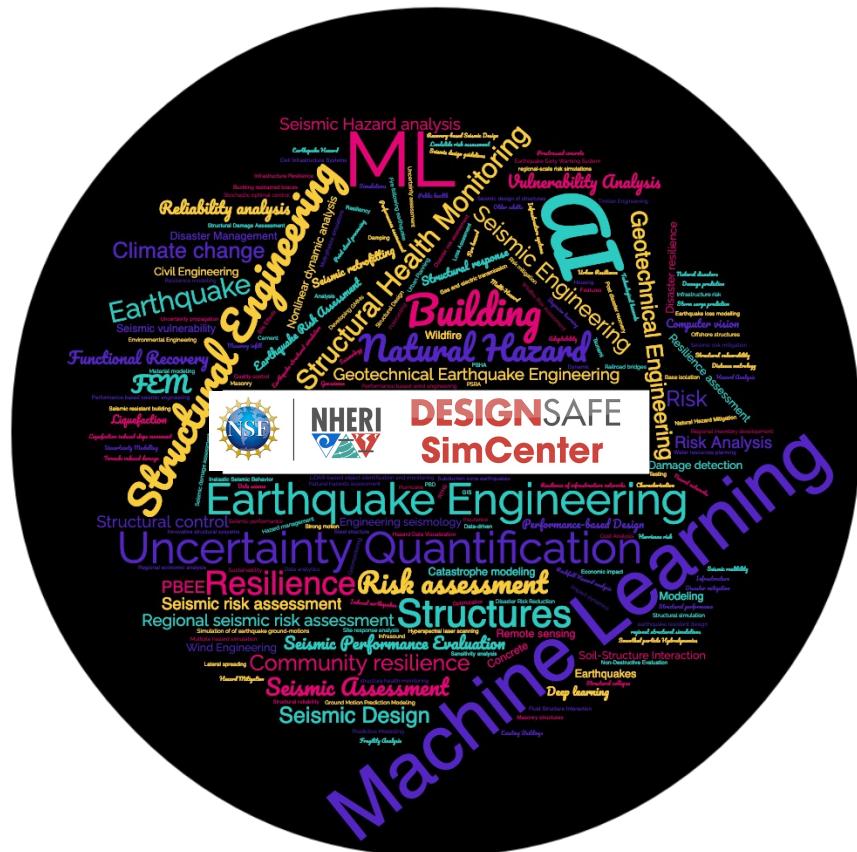
<https://nheri-simcenter.github.io/SimCenterBootcamp2022/>

Who is in the room?

20% report having used SimCenter tools

How many have used DesignSafe resources?

Undergraduate student	3%
Masters student	15%
PhD student	39%
Postdoc or Researcher	12%
Faculty	15%
Federal, state, or local government agency	1%
Practitioner	9%
Other	6%



Outline

- Welcome
- Introduction to NHERI
 - Introduction to DesignSafe (slides by Prof. Ellen M. Rathje, PI DesignSafe)
 - Introduction to SimCenter (slides by Prof. Sanjay Govindjee, PI SimCenter)
- ML in Earthquake Engineering: Opportunities and Challenges



Natural Hazards
Engineering
Research
Infrastructure

NSF's Facilities/Programs



For more information, visit the
NHERI DesignSafe website: DesignSafe-ci.org

What is DESIGNSAFE-CI ?



A NATURAL HAZARDS
ENGINEERING COMMUNITY



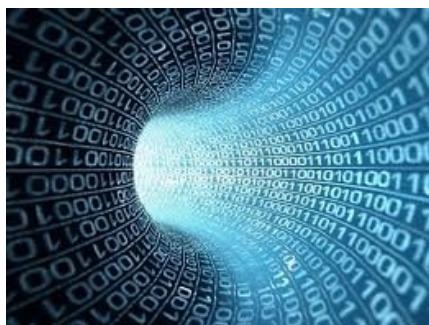
- A web-based research platform that enables transformative research to protect human life/reduce damage during natural hazard events

DesignSafe Vision

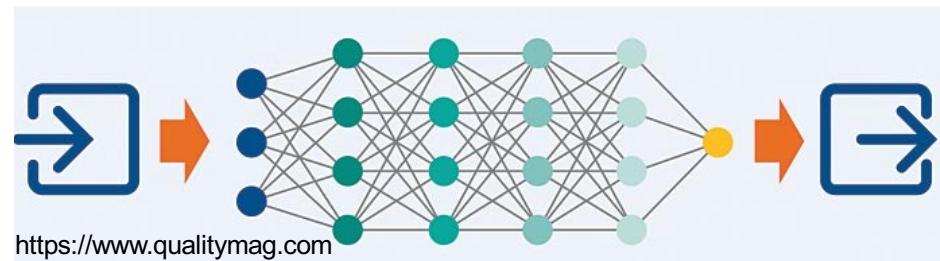
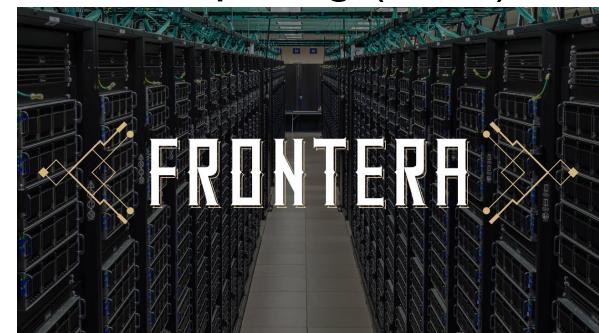
- Foster a cultural shift in natural hazards research towards the **pervasive use of cyberinfrastructure** and the **ubiquitous publishing/reuse of data**
 - Provide a platform for data sharing/publishing
 - Enable research workflows and access to high performance computing (HPC)
 - Deliver cloud-based tools that support the analysis, visualization, and integration of diverse data types

Research Ecosystem

Data



High Performance Computing (HPC)



Scripts/Codes/Algorithms

DesignSafe Components



A screenshot of the Data Depot interface. It shows a search bar at the top with the placeholder "Find in Published Projects". Below it is a sidebar with links for "My Data", "My Projects", "Shared with Me", "Box.com", and "Dropbox.com". The main area displays a project titled "Collaborative Research: Development, experimental validation and case studies for the next generation of landslide tsunami models for coastal hazard mitigation (Simulation)".

A screenshot of the Workspace interface. It features a sidebar with "Data Depot", "Tools & Applications", "Recon Portal", "SimCenter Research Tools", "User Guides", and "Use Cases". A "Learning Center" button is located in the top right corner of the workspace area.

A screenshot of the Tools & Applications interface. It shows categories for "Simulation [7]", "Visualization [8]", "Data Processing [2]", and "Partner Data Apps [5]". Specific tools listed include ADCIRC, clawpack, Dakota, and LS-DYNA.

A screenshot of the Recon Portal interface. It shows a map of the Americas with several blue location pins. A sidebar on the left lists "2019 Hurricane Dorian" and "2019 Hurricane Barry".

www.designsafe-ci.org

Visit NHERI DesignSafe's YouTube Channel for the Full Archive

Featured Playlists

- DesignSafe Webinars
- SimCenter Series: Studying Coastal Hazards with HydroUQ
- 2021 Joint NSF NHERI WOW and Lehigh RTMD EF User Workshop
- SimCenter Series: Advances in Computational Modeling and Simulation

DesignSafe Data Depot

Private

Public

DATA DEPOT

+ Add

- My Data
- My Projects**
- Shared with Me
- Box.com
- Dropbox.com
- Google Drive
- Published**
- Published (NEES)
- Community Data

Help ▾

Find in My Projects

Rename Move Copy Preview Preview Images Download Move to Trash

Project ID	Project Title	Project PI	Last Modified
PRJ-3127	Seismic Landslide Inventories	Ellen Rathje	5/13/21 10:19 AM
PRJ-2998	Machine Learning Models for the Evaluation of the Lateral Spreading Hazard in the Avon River Area Following the 2011 Christchurch Earthquake	Maria Giovanna Durante	5/12/21 12:48 PM
PRJ-1844	Liquefaction Evaluations of Finely Interlayered Sands, Silts and Clays	Ross Boulanger	3/16/21 1:11 PM
PRJ-3031	DesignSafe Ground Motion Database	Albert Kottke	2/4/21 12:47 PM
PRJ-3028	Simulations of Earthquake-Induced Permanent Slope Displacements of Simple, Generalized Earth Slopes using LS-Dyna	Ellen Rathje	2/1/21 6:05 PM
PRJ-1823	Landslide inventory for the Mw7.8 14 November 2016, Kaikōura Earthquake	Chris Massey	1/26/21 1:13 PM
PRJ-2824	Numerical modeling of lateral spread displacements at free-face sites using OpenSees	Ellen Rathje	12/16/20 2:58 PM
PRJ-2951	Zalachoris and Rathje GMM for Earthquakes in Texas, Oklahoma, and Kansas	Ellen Rathje	11/5/20 12:10 PM
PRJ-2662	Displacement and subsurface characteristics of select lateral spread locations from the 2011 Christchurch, New Zealand earthquake	Ellen Rathje	10/28/20 5:31 PM

Published Datasets

Make ★your★ data count!

*Make your research re-producible and
your data re-usable*



- **Formally publish** data sets in stable data repositories
 - DesignSafe, Zenodo, Dataverse, figshare, Dryad, others
- Data needs a permanent, **digital location (DOI)** not just a URL
 - List curated data sets on your CV, just like papers
- Cite data publication **in your reference list** of your paper using DOI, citation language

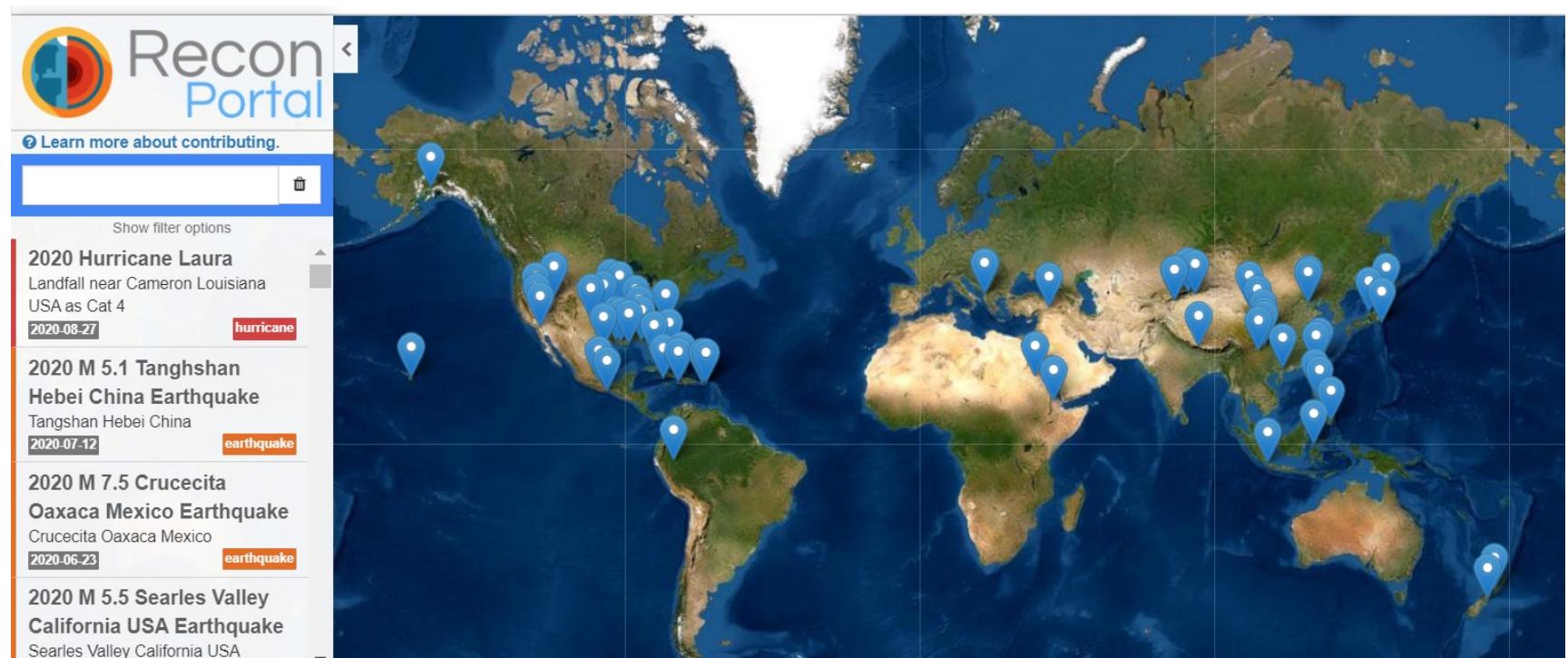
provided here. Additionally, the probabilistic approaches described in this paper are implemented as executable Jupyter notebooks (Saygili 2018a, b). These notebooks can be accessed in the Data

References

Saygili, G., Rathje, E., and Wang, Y. (2018a). “Probabilistic seismic hazard analysis for the sliding displacement of rigid sliding masses [Data set].” Designsafe-CI (<https://doi.org/10.17603/ds22d6k>)

Reconnaissance Portal

Identifying Archived Datasets from Recon Events



Recon Portal → Data Depot

The image shows a screenshot of the Recon Portal website. On the left, there's a sidebar with a logo and a list of available datasets. A yellow box highlights the list of datasets, and a yellow arrow points from this box to a specific location on a map of Florida. The map shows the coastline and a small blue dot indicating the location of Hurricane Michael's landfall near Panama City. To the right of the map is a detailed project page for 'PRJ-2113 | StEER - Hurricane Michael'. The page includes fields for PI (Kijewski-Correa, Tracy), CoPIs (Prevatt, David; Roueche, David; Robertson, Ian; Berman, Jeffrey; Mosalam, Khalid; Grilliot, Michael), Project Type (Field Research), Event (Hurricane Michael | Panama City, FL | 10-10-2018 | Lat 30.0800° N Long 85.6075° W), Event Type (Hurricane), DOI(s) in Dataset (10.17603/ds2-5aej-e227, 10.17603/ds2-vmqv-j36), Related Work (Preliminary Virtual Reconnaissance Report (PVRR), Early Access Reconnaissance Report (EARR)), and Keywords (StEER, Reconnaissance, Hurricane, Hurricane Michael, Damage Assessment, UAS, Laser Scan, Streetview). Below this is a descriptive text about the project, mentioning the FAST team's work in Florida after the hurricane. At the bottom, there are sections for 'View Data Diagram' and two mission boxes: 'Mission | StEER Field Assessment Structural Team (FAST)' and 'Mission | RAPID EF Team', each with a checkbox.

Available datasets:

- Hurricane Michael - StEER P-VAT Report
- Hurricane Michael Field Reconnaissance: Contrasting Performance of Structures at Design Wind Speeds
- ARA Windfield Data Day
- Hurricane Michael - StEER FAT Early Access Report
- NHERI REU: Assessing Structural Damage During Hurricane Michael of Low-Rise Large-Volume Steel Structure using Structure-from-Motion and LiDAR
- NHERI REU: Survey and Investigation of Residential Buildings Damaged by Hurricane Michael
- Assessing the Performance of Elevated Wood Buildings Including Manufactured Housing
- Finalized StEER FAST and RAPID EF teams reports

PRJ-2113 | StEER - Hurricane Michael

PI: Kijewski-Correa, Tracy
CoPIs: Prevatt, David; Roueche, David; Robertson, Ian; Berman, Jeffrey; Mosalam, Khalid; Grilliot, Michael
Project Type: Field Research
Event: Hurricane Michael | Panama City, FL | 10-10-2018 | Lat 30.0800° N Long 85.6075° W
Event Type: Hurricane
DOI(s) in Dataset: 10.17603/ds2-5aej-e227, 10.17603/ds2-vmqv-j36
Related Work: Preliminary Virtual Reconnaissance Report (PVRR), Early Access Reconnaissance Report (EARR)
Keywords: StEER, Reconnaissance, Hurricane, Hurricane Michael, Damage Assessment, UAS, Laser Scan, Streetview

On October, 10 2018, Hurricane Michael made landfall just south of Panama City, FL with the National Hurricane Center reporting a minimum pressure 919 MB and maximum sustained winds of 150 mph. Regardless of its place in history, Hurricane Michael caused catastrophic damage from high winds over a wide swath that stretched across much of the FL panhandle and inland into southeastern GA and beyond. natural hazards engineering community to swiftly deploy a Field Assessment Structural Team (FAST). This FAST broadly assessed the performance of a representative subset of structural typologies in coastal and inland areas. Its teams conducted assessments between October 13-15, 2018. FAST collected data in Florida from Panama City Beach east and south to Indian Pass and north to Marianna. The communities assessed included: Panama City Beach, Panama City (and surrounding communities), Mexico Beach, Port St. Joe, Apalachicola, a few routes out to barrier islands in the region, and the inland communities of Blountstown and Marianna. As part of an independent yet complementary effort, the RAPID EF continued data collection on November 7-8, 2018 in and around Panama City and Mexico Beach, using a variety of technologies including unmanned aerial vehicles, laser scanners and applied streetview technologies. This self-funded initiative generated an additional dataset that complements the data collected by StEER and is thus curated jointly in this project. This project encompasses the final product of StEER's response to this event: Curated Dataset, linking to previously published products: Preliminary Virtual Reconnaissance Report (PVRR) and Early Access Reconnaissance Report (EARR).

View Data Diagram

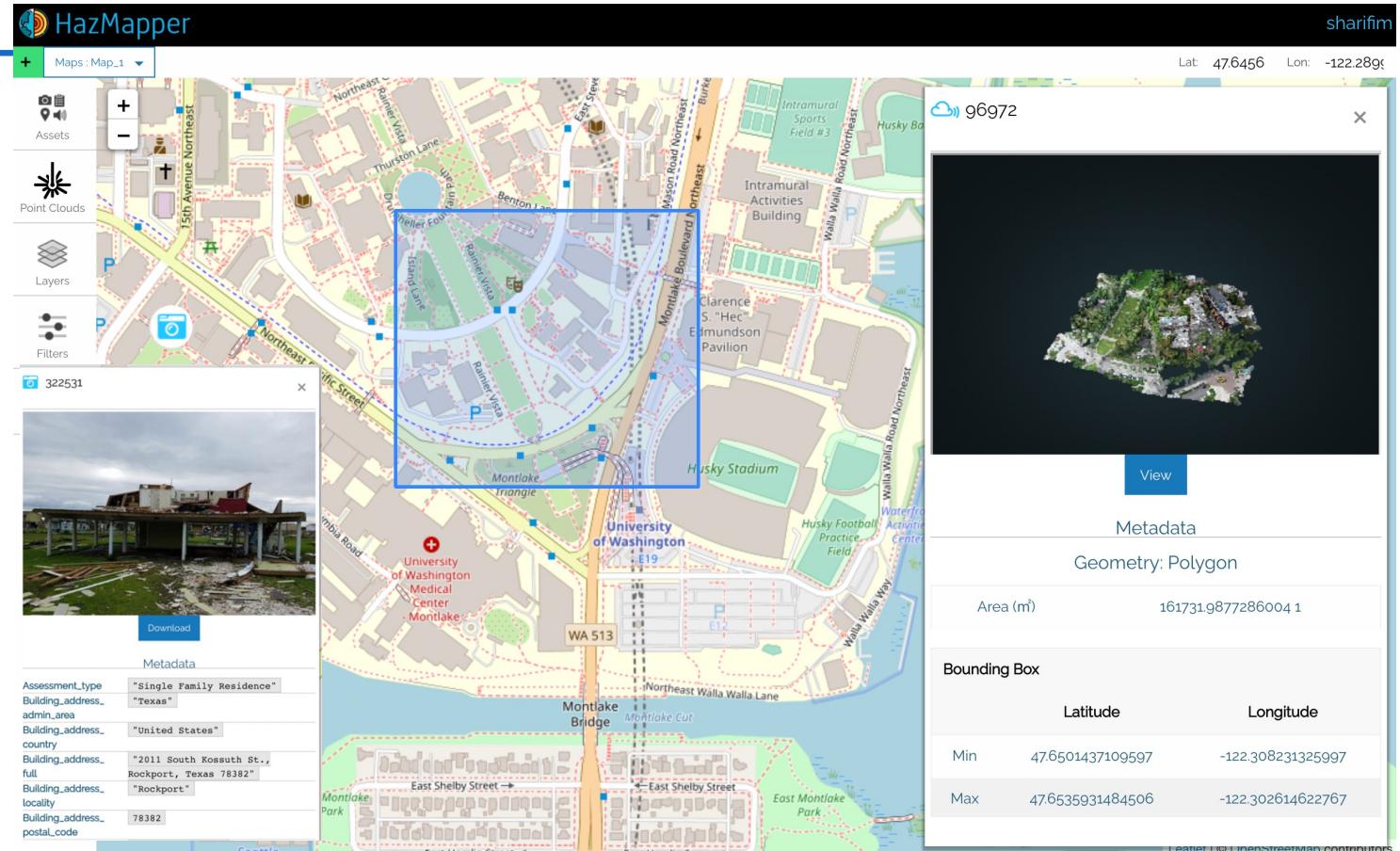
Mission | StEER Field Assessment Structural Team (FAST)

Mission | RAPID EF Team

NHERI SimCenter
Center for Computational Modeling & Simulation



- Easy access to images and point cloud data
- Location and preview exposed
- Link to Potree point cloud viewer
- Links to Street View imagery (Mapillary)



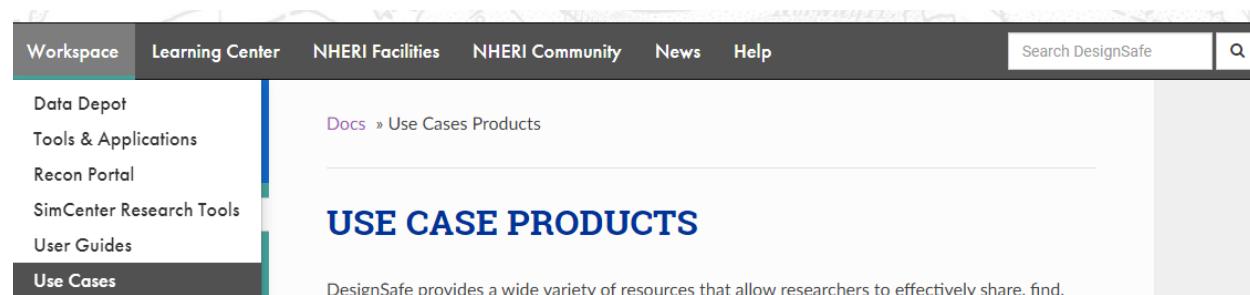
Tools and Applications

Simulation	SimCenter Tools	Visualization	Analysis	Hazard Apps	Utilities	My Apps
ADCIRC 	ANSYS 	clawpack 	Dakota 	LS-DYNA 	LS-Pre/Post (DCV) 	
MPM 	OpenFOAM 	OpenSees 	OpenSees-STKO 	jupyterhub 		

- HPC-enabled simulation codes (run on portal or Command Line, easy access to HPC allocation (CPUs, GPUs) through DesignSafe
- Cloud-based tools for data analysis and visualization

DesignSafe Use Cases

- Expanding the use of DesignSafe is facilitated by demonstrated use cases in Natural Hazards Eng
 - Use cases include project descriptions, scripts, documented Jupyter notebooks, etc.
- Twelve use cases documented within DesignSafe



DesignSafe Use Cases

DS Use Case Products

Search docs

≡ Use Cases Products

- General Use Cases
- Geohazard Use Cases
- Hurricane and Windstorm Use Cases
- Seismic Use Cases

Taggit

ML and AI

NGL Database

MPM Landslide

Large-Scale Storm Surge

Visualizing Storm Surge

Wind Flow

Field Sensing Wind Events

USE CASE PRODUCTS

DesignSafe provides a wide variety of resources that allow researchers to effectively share, find, analyze, and publish data; perform numerical simulations and utilize high performance computing (HPC); and integrate diverse datasets.

General Use Cases

- [Damage Tagging of Field Images \(Taggit, HazMapper\)](#)
- [Machine Learning and AI Resources \(Jupyter, Interactive Data Analytics, HPC\)](#)

Geohazard Use Cases

- [Data Analysis using Next Generation Liquefaction \(NGL\) Database \(NGL, Jupyter, SQL, Interactive Data Analytics\)](#)
- [Landslide Runout Simulations \(MPM, Jupyter, Paraview, HPC\)](#)

Hurricane and Windstorm Use Cases

- [Large-Scale Ensemble Simulations of Storm Surge \(ADCIRC, pylauncher, Jupyter, HPC\)](#)
- [Visualization of Storm Surge Impacts \(ADCIRC, Jupyter, QGIS\)](#)
- [Simulation of Wind Flow around Buildings \(OpenFOAM, Jupyter, Paraview, HPC\)](#)
- [Analysis of Field Sensor Data from Wind Events \(Jupyter, Interactive Data Analysis\)](#)

Seismic Use Cases

- [Site Response Analysis and Model Calibration \(OpenSees, SimCenter quoFEM, ...\)](#)
- [Simulating the Seismic Performance of Reinforced Concrete Walls \(OpenSees, ...\)](#)
- [Soil-Structure-Interaction Simulations \(OpenSees, STKO, Jupyter, HPC\)](#)
- [Experimental Visualization of Shaking Table Data \(Jupyter, Interactive Data Analysis at NHERI Facility\)](#)

DS Use Case Products

Search docs

Use Cases Products

Taggit - Image Tagging

ML and AI

NGL Database

≡ MPM Landslide

- Background
- Input generation
- Running the MPM Code
- Post Processing

Large-Scale Storm Surge

Visualizing Surge for Regional Risks

CFD Analysis of Winds on Structures

Field Sensing Wind Events

OpenSees Model Calibration

Seismic Response of Concrete Walls

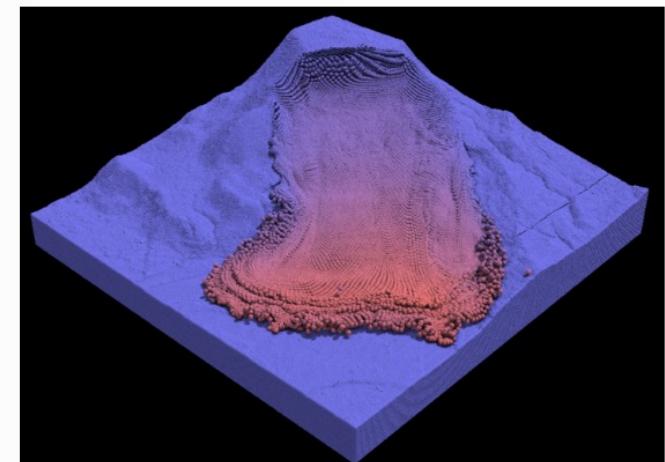
Soil Structure Interaction

Experimental Shake Table Testing

Oso landslide with in situ visualization

In situ visualization is a broad approach to processing simulation data in real-time - that is, wall-clock time, as the simulation is running. Generally, the approach is to provide data extracts, which are condensed representations of the data chosen for the explicit purpose of visualization and computed without writing data to external storage. Since these extracts (often images) are vastly smaller than the raw simulation itself, it becomes possible to save them at a far higher temporal frequency than is practical for the raw data, resulting in substantial gains in both efficiency and accuracy. In situ visualization allows simulations to export complete datasets only at the temporal frequency necessary for economic check-point/restart.

We leverage in situ viz with MPM using [TACC Galaxy](#).



Learning Center



Webinars and Workshops

TRAINING

Upcoming Training

Tutorial and workshop opportunities from across the NHERI DesignSafe community of sites and facilities.

SEPT 30
What's New in DesignSafe
Online Register

OCT 21-22
NHERI@UTexas Large Mobile Shaker Workshop
Online Register

DEC 16-17
NHERI@UCSD Users Training Workshop
Online

Training Archive

The thumbnail shows a video player interface for a YouTube video. At the top, it says 'DESIGN SAFE CI' and 'ESTIMATING PERSONAL HEAT EXPOSURE WITH WEARABLE TEMPERATURE SENSORS HUMAN-BUILT-NATURAL SYSTEMS'. Below the title, there is a description: 'This webinar will introduce viewers to the current scientific understanding of exposure to extreme heat and highlight the importance of accounting for this exposure in our assessments of vulnerability to extreme heat. I will also briefly introduce viewers to the National Science Foundation (NSF) funded Three City Heat and Electrical Failure Adaptation (3CEFA) study, which was the project that the personal heat exposure data was collected for. Finally, I will present the dataset that we published through DesignSafe titled, "Personal Heat Exposure". I will connect this dataset to broader concepts of vulnerability in addition to presenting preliminary results associated with the dataset. The dataset includes both quantitative data in the form of temperature and humidity measurements made with wearable sensors provided to each human participant; as well as qualitative data in the form of participant-completed time-activity diaries that document their daily experiences with extreme heat.' A 'Watch on YouTube' button is at the bottom left, and a play button icon is in the center.

NEW [Watch on YouTube](#)

2022 Dataset Award Winner: Estimating Personal Heat Exposure with Wearable Temperature Sensors
June 15, 2022

Visit [NHERI DesignSafe's YouTube Channel](#) for the Full Archive

Featured Playlists

- DesignSafe Webinars
- SimCenter Series: Studying Coastal Hazards with HydroUQ
- 2021 Joint NSF NHERI WOW and Lehigh RTMD EF User Workshop
- SimCenter Series: Advances in Computational Modeling and Simulation

Learning Center: NHERI YouTube Channel

The image shows a screenshot of a YouTube channel page. On the left, there's a thumbnail for a 'DesignSafe Tutorials' playlist with 42 videos and 1,322 views, updated 6 days ago. Below it are icons for sharing and a 'SUBSCRIBE' button. On the right, there's a list of five video thumbnails, each with a title, duration, and a 'More' options menu:

- 1 Hurricane Matthew Storm Surge and Wave Simulations with Data Assimilation | September 15, 2021 (58:38) NHERI DesignSafe-CI Media
- 2 CPT-Based Liquefaction Case Histories Compiled from 3 Earthquakes in New Zealand | July 21, 2021 (1:10:15) NHERI DesignSafe-CI Media
- 3 Dataset of Lightly Reinforced Concrete Wall Test: Researchers Publishing on DesignSafe, May 11, 2021 (54:01) NHERI DesignSafe-CI Media
- 4 SciANN: TensorFlow API for scientific computations with neural networks | April 28, 2021 (WORKSHOP) (55:21) NHERI DesignSafe-CI Media
- 5 SciANN: TensorFlow API for scientific computations with neural networks | April 28, 2021 (WEBINAR) (1:05:24) NHERI DesignSafe-CI Media

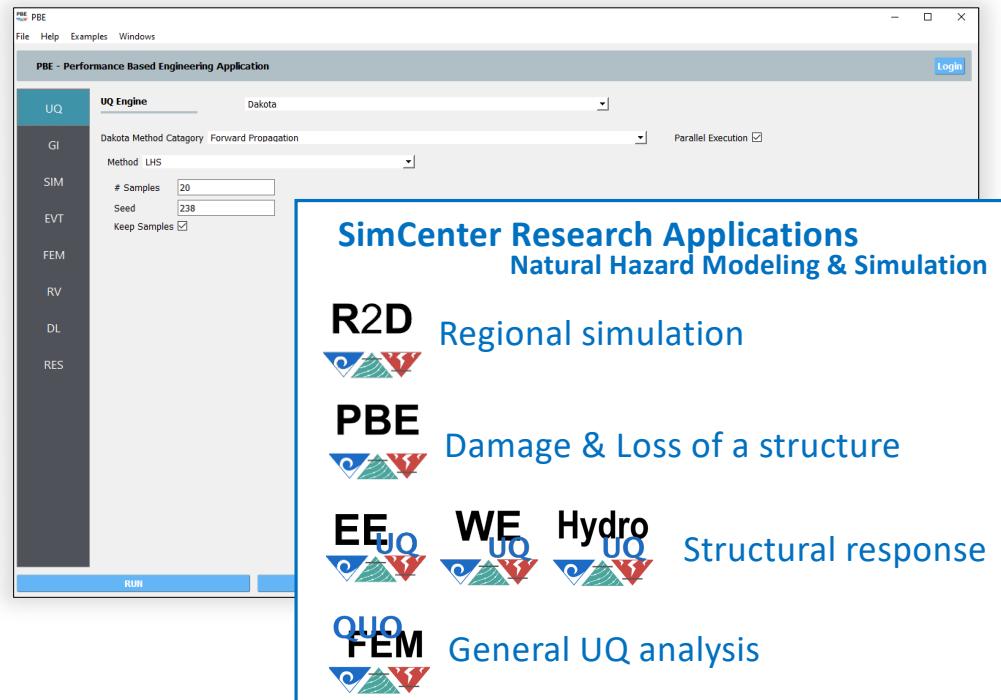
What is NHERI SimCenter?

Center for Computational Modeling & Simulation

Center that provides **software applications** for researchers in **Natural hazard engineering**



Researchers
Industry
Government Agencies



SimCenter Research Applications
Natural Hazard Modeling & Simulation

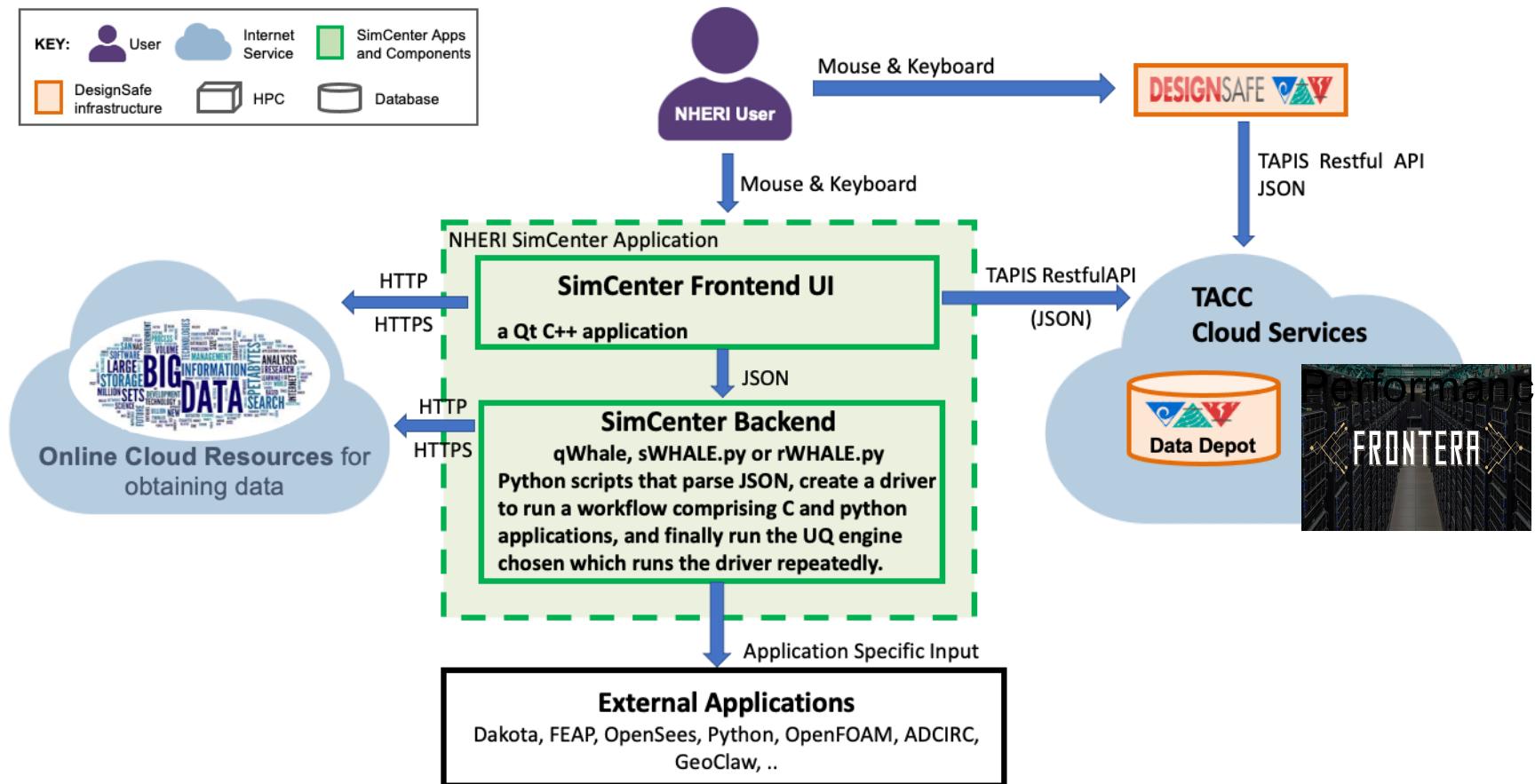
R2D Regional simulation

PBE Damage & Loss of a structure

EE **WE** **Hydro** Structural response

QUA **FEM** General UQ analysis

UI Launches Scientific Workflows

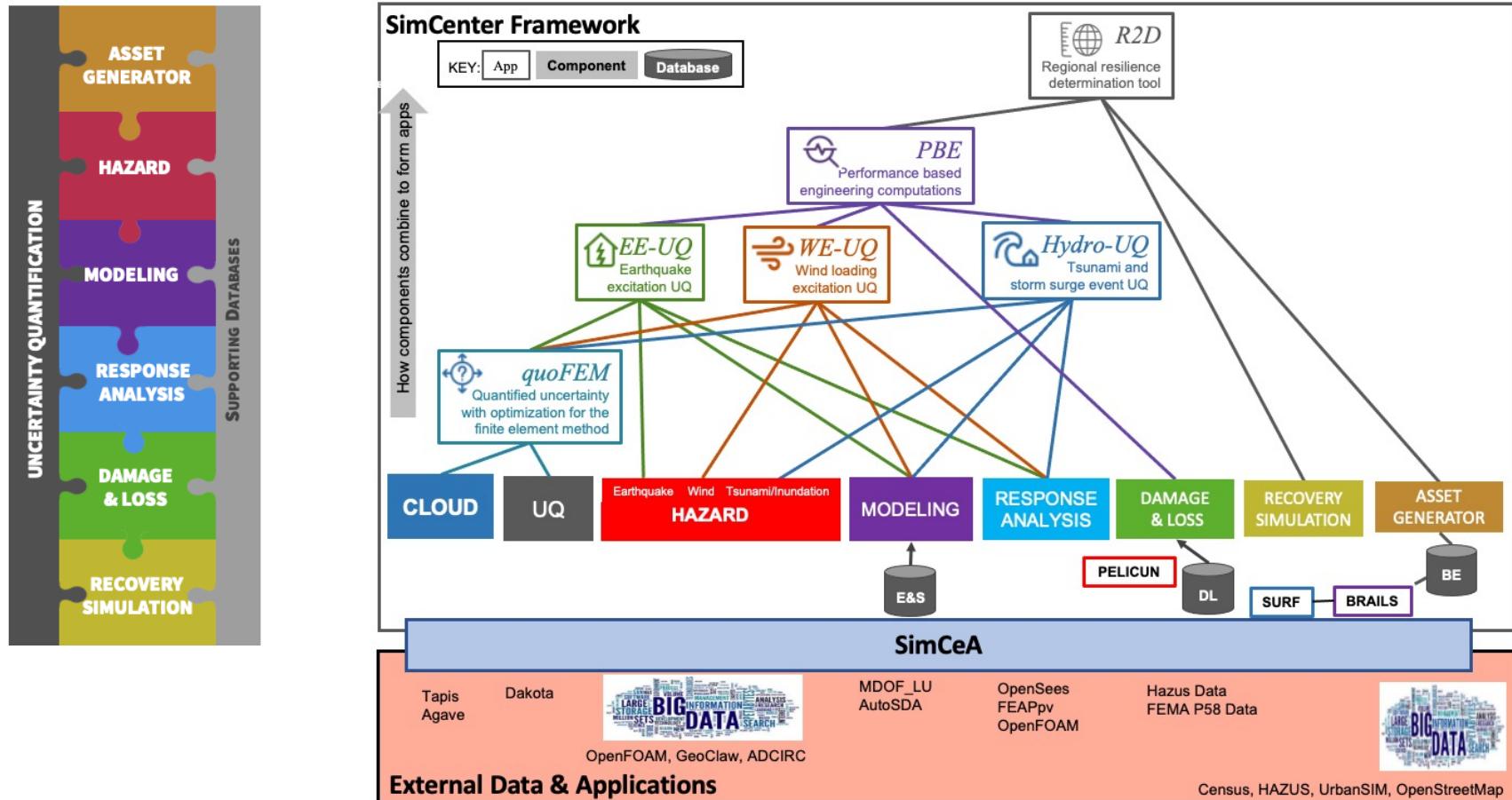


Computational Framework for Building Workflows



OpenSource :: Multi-Fidelity :: Multi-Hazard

SimCenter Applications Built with Framework





Workflow Application

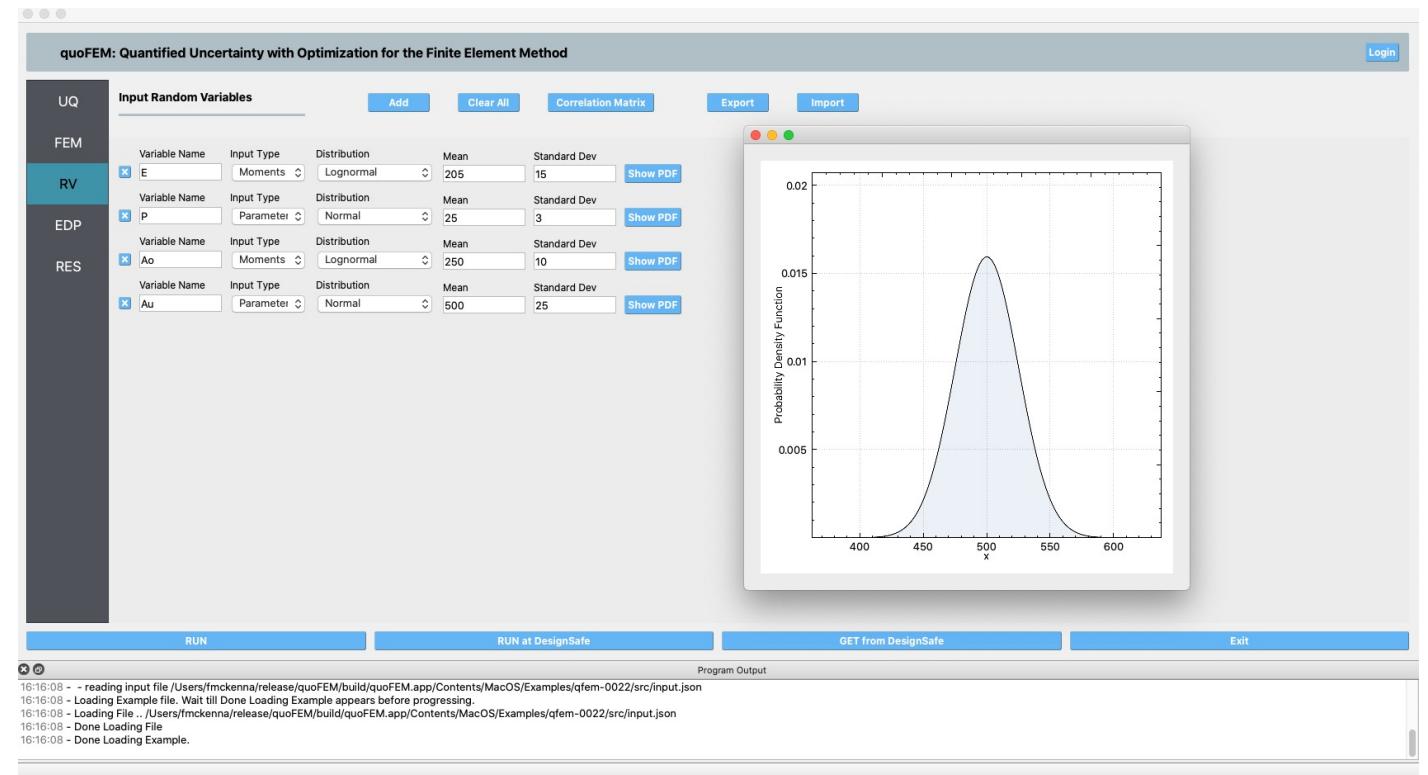


quoFEM (v3.0)

Integrates Simulation Applications with UQ Applications

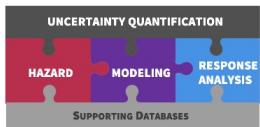
UQ Problem Types:

- Sampling
- Sensitivity
- Reliability
- Calibration
- Bayesian Calibration
- Surrogate Modeling





EE-UQ Workflow Application



EE-UQ V3.0

Integrates UQ applications of quoFEM , Earthquake Loading Applications, Building Model Generators with analysis application to determining response of building to earthquake loading

Hazard (Earthquake):

Stochastic Motions

PEER NGA Search with target spectrum

Site Response with Random Fields

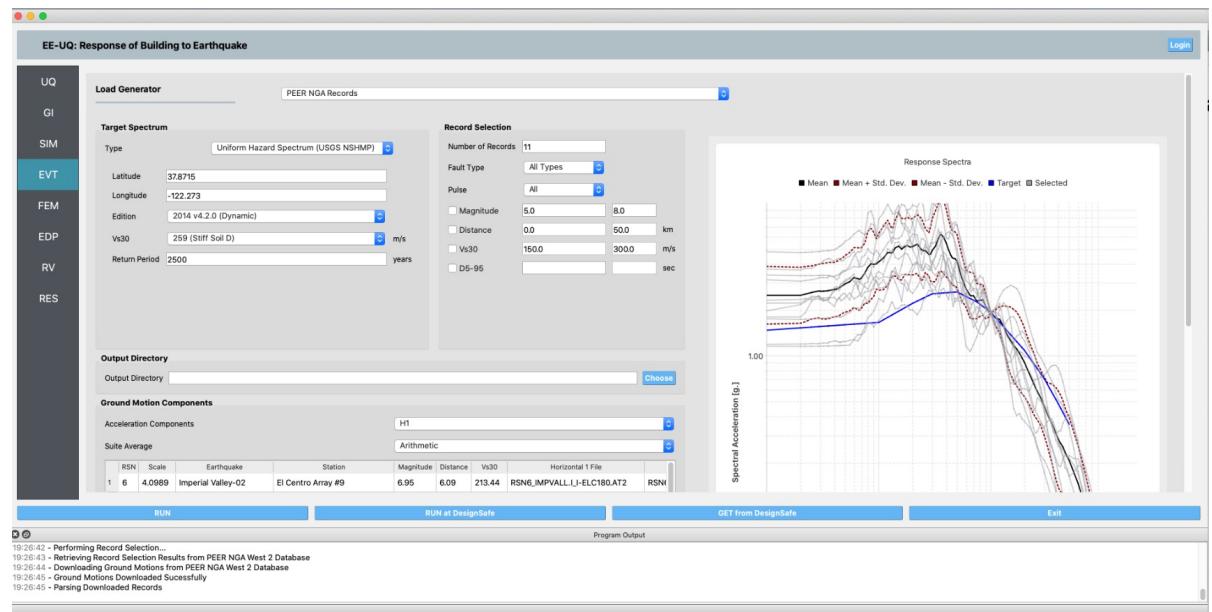
Modeling (Building):

OpenSees

Nonlinear Shear Spring (MDOF)

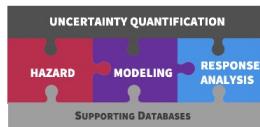
Steel Building Design & Build (AutoSDA)

Concrete Building Design & Build





Workflow Application



WE-UQ V2.2.0

Integrates quoFEM UQ applications, Wind Loading Applications and Building Model Generators with analysis engine to determine response of building subjected to wind loading.

Hazard (Wind):

Stochastic Wind

Database-enabled utilizing Vortex-Winds TPU's low-rise wind tunnel datasets

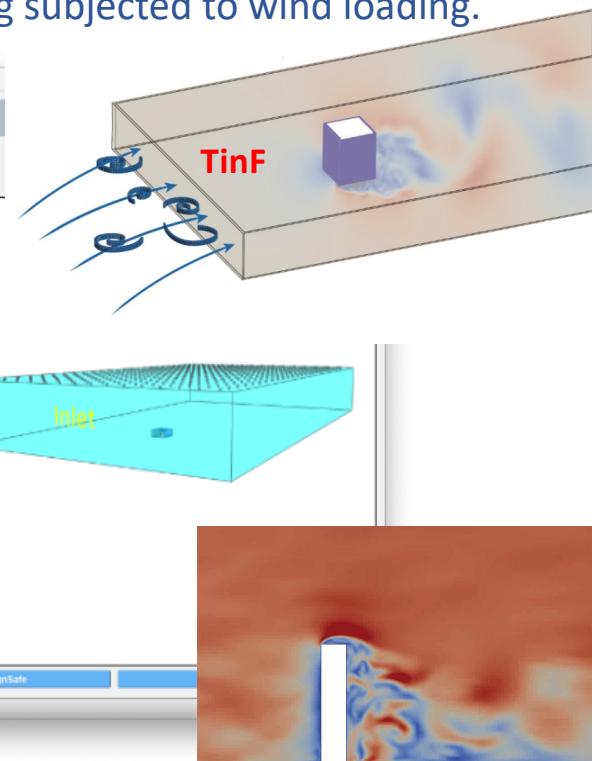
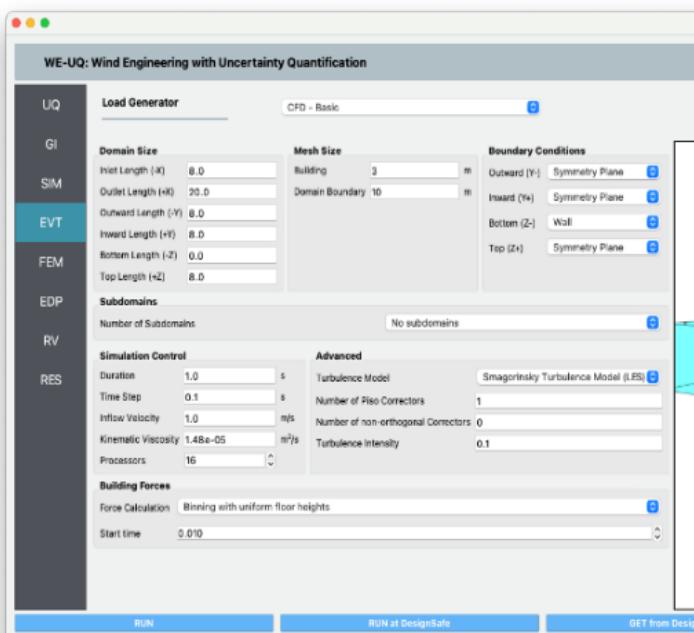
User-provided wind tunnel test data

Uncoupled or **coupled** CFD simulations using OpenFOAM & incorporating TinF options for expert users

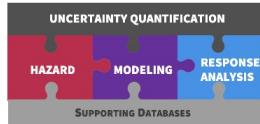
Modeling (Building)

OpenSees

Nonlinear Shear Spring (MDOF)



Hydro UQ Workflow Application

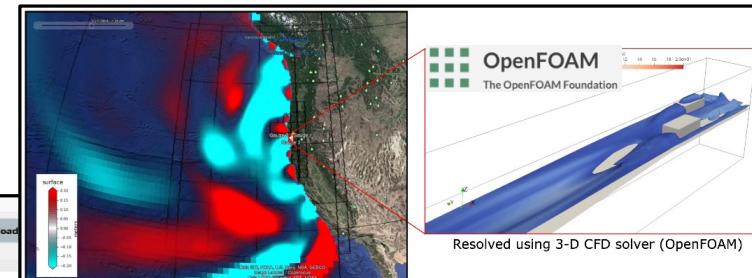


Hydro-UQ V1.0.0 –

Integrates UQ applications, Tsunami & Storm Surge Loading Applications and Building Model Generators with Analysis engine to determine response of structure.

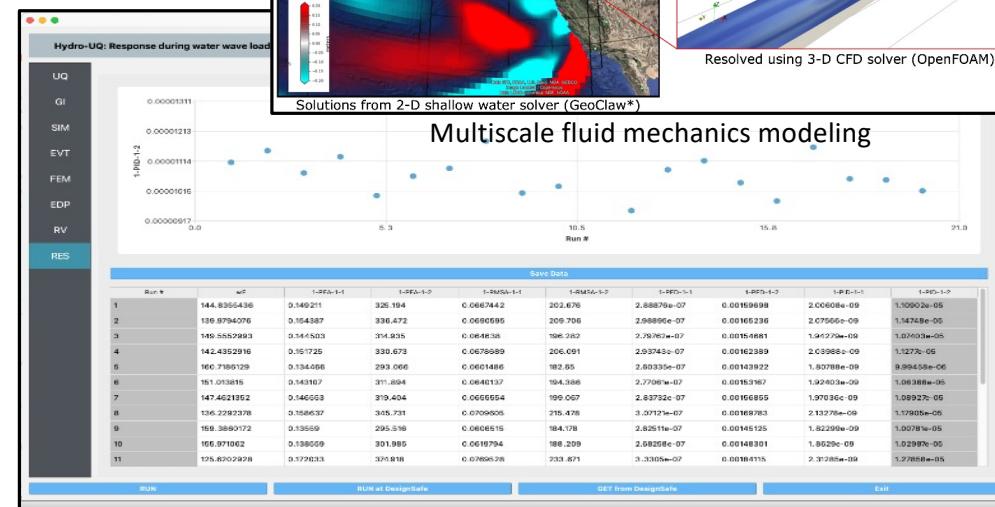
Hazard (Tsunami and storm surge):

2D Shallow-water → 3D CFD
OSU wave flume digital twin
Easy to use turbulence models for studying broken & unbroken wave behavior



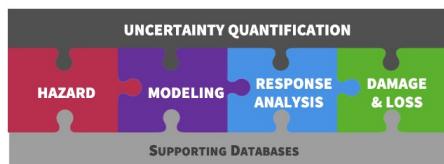
Modeling (Building)

OpenSees
Nonlinear Shear Spring (MDOF)



Probabilistic structural response

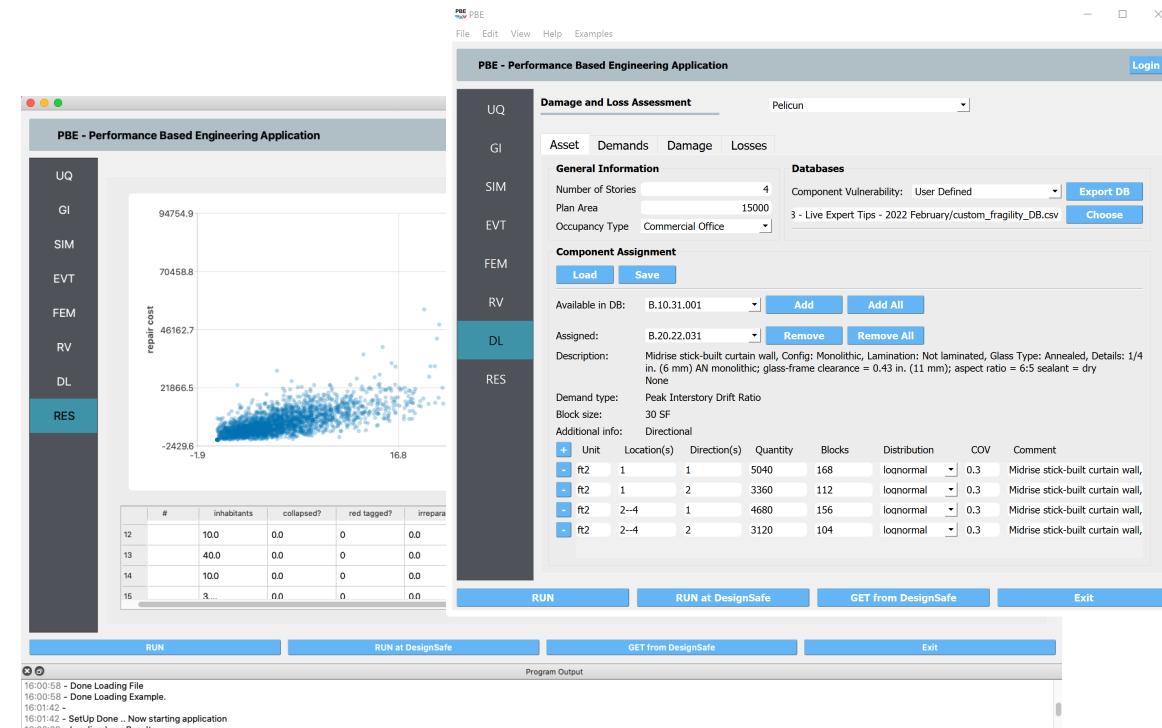
PBE Workflow Application



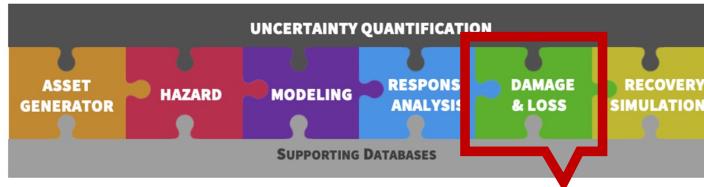
PBE v2.0 (3.0 coming this month!)-
Integrates UQ applications of quoFEM, Building Model Generators, Earthquake Loading, analysis engine and our PELICUN tool for damage and loss assessment.

Damage & Loss (using PELICUN):

- Building-level assessment (e.g., HAZUS)
- Component-level assessment (e.g., FEMA P58)
- Supports external response estimation
- Customizable fragility & consequence functions

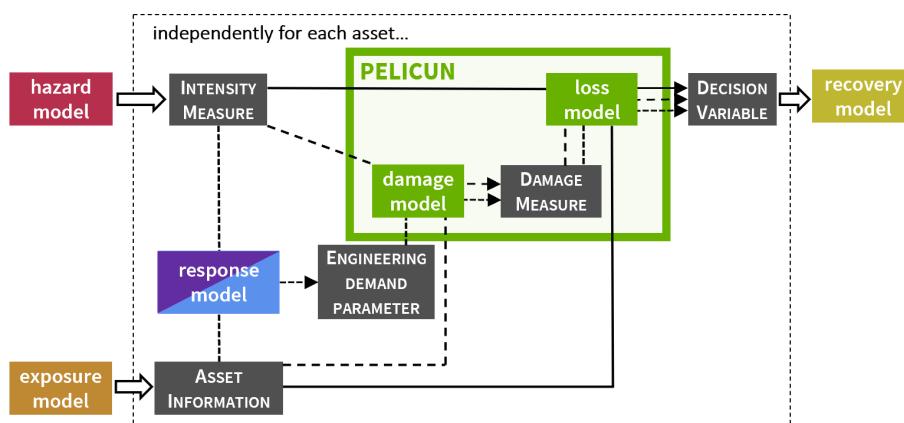


Pelicun: Performance Assessment

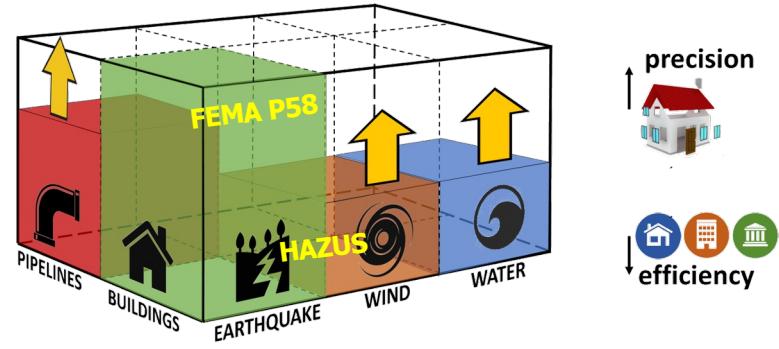


Newest Pelicun features:

- Standardized data schema that unifies performance model data across hazards, assets, and resolutions
- Cascading damages and damage processes
- Customizable damage – consequence mapping
- Portfolio and regional assessment
- Uncertainty in component assignments



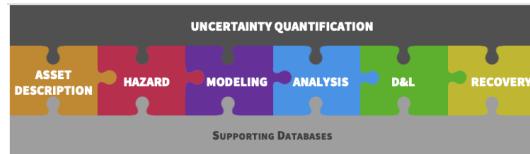
Multi-Fidelity Approach



Community-Driven Development
of New Models & Data



Workflow Application



Asset definition

csv files
GIS files

Hazard definition

Regional Site Response
User-supplied earthquake and hurricane grids
Raster-defined earthquake, hurricane, and tsunami intensity fields
Earthquake scenario simulation
Hurricane wind field simulation

Damage and loss

HAZUS
User-provided fragility functions

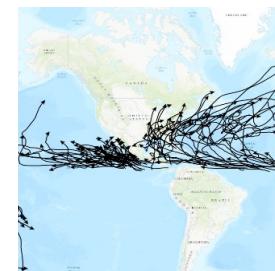
R2D V2.1 –

Create **complex workflows** for regional hazard simulation to facilitate research in disaster risk management and recovery.

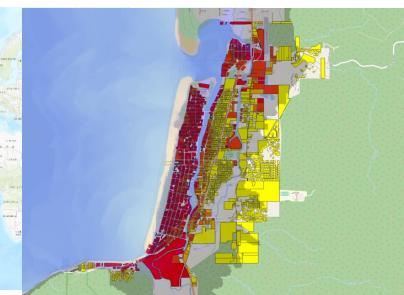
Multiple Hazards



Earthquakes

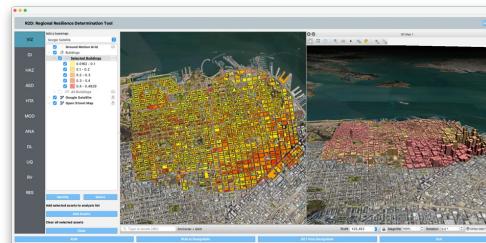


Hurricanes

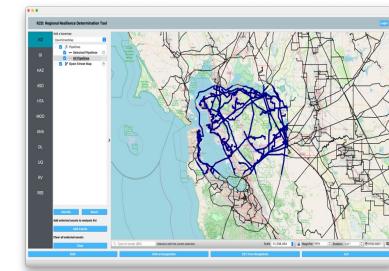


Tsunamis

Multiple Assets



Buildings



Lifelines

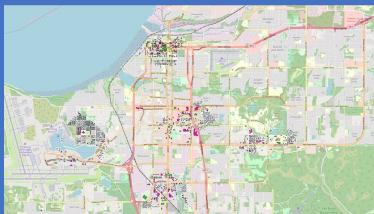
R2D  **Regional Testbeds & Examples Available**

Earthquake

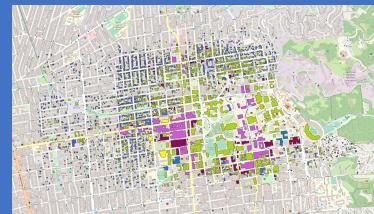
IM PGA



Recorded GMs



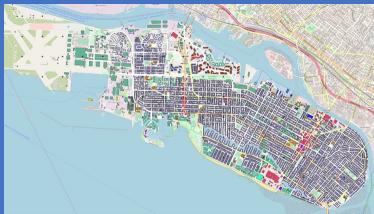
Physics-based GMs



NGAWII GMs



Liquefaction



USGS ShakeMap



Site-response



Wind



Wind/Water



Hurricane:

Usage of AI/ML in SimCenter Workflows

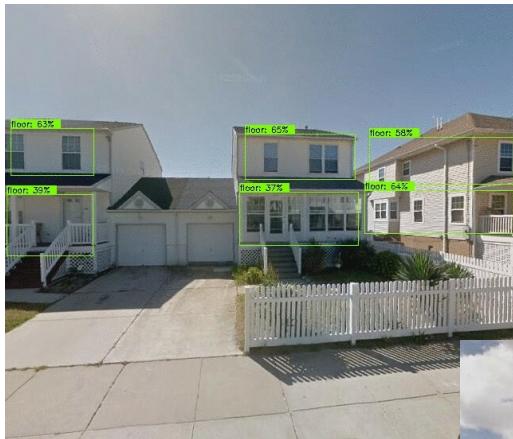
1.Inventory Collection

2.Reduction of Simulation Time

1. Inventory Generation

3 Categories of ML Methods Used:

1. **Image Classification:** to assign to an input image a single label from a fixed set of labels
2. **Image Segmentation:** to locate (detect) objects and object boundaries in an input image
3. **Image Processing:** using image segmentation combine object location with mathematics of pinhole cameras to determine information



BRAILS creates regional-scale building inventories at building-level granularity using deep learning and computer vision techniques. BRAILS is capable of predicting:

- Roof shape
- Roof cover type
- Occupancy type
- Era of construction

Classification

- Number of floors
- Existence of chimneys
- Existence of garages

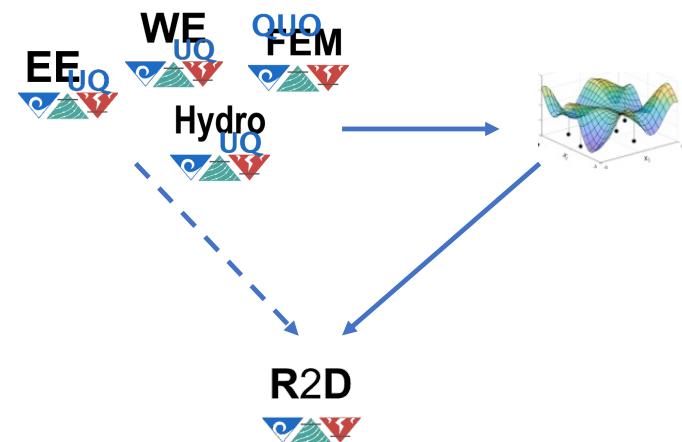
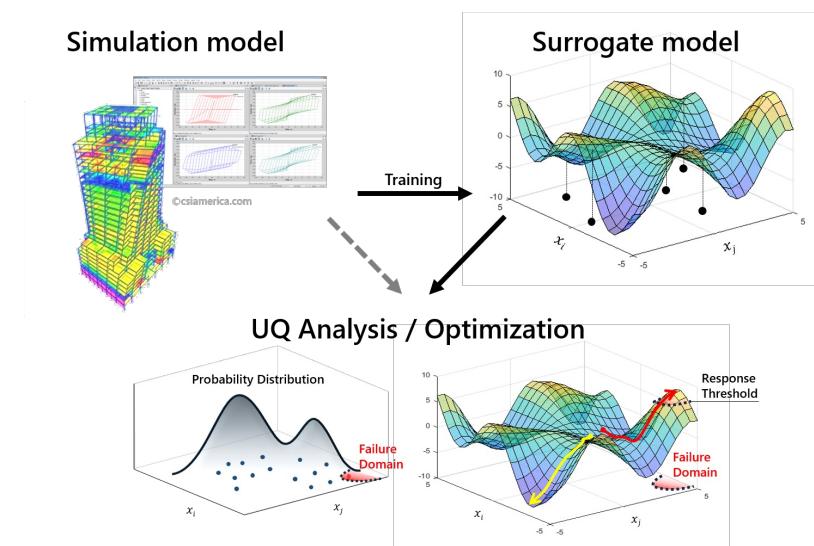
Object
Detection

- Building height
- Roof eave height
- Roof pitch angle
- Window area
- First floor height

Image
Processing

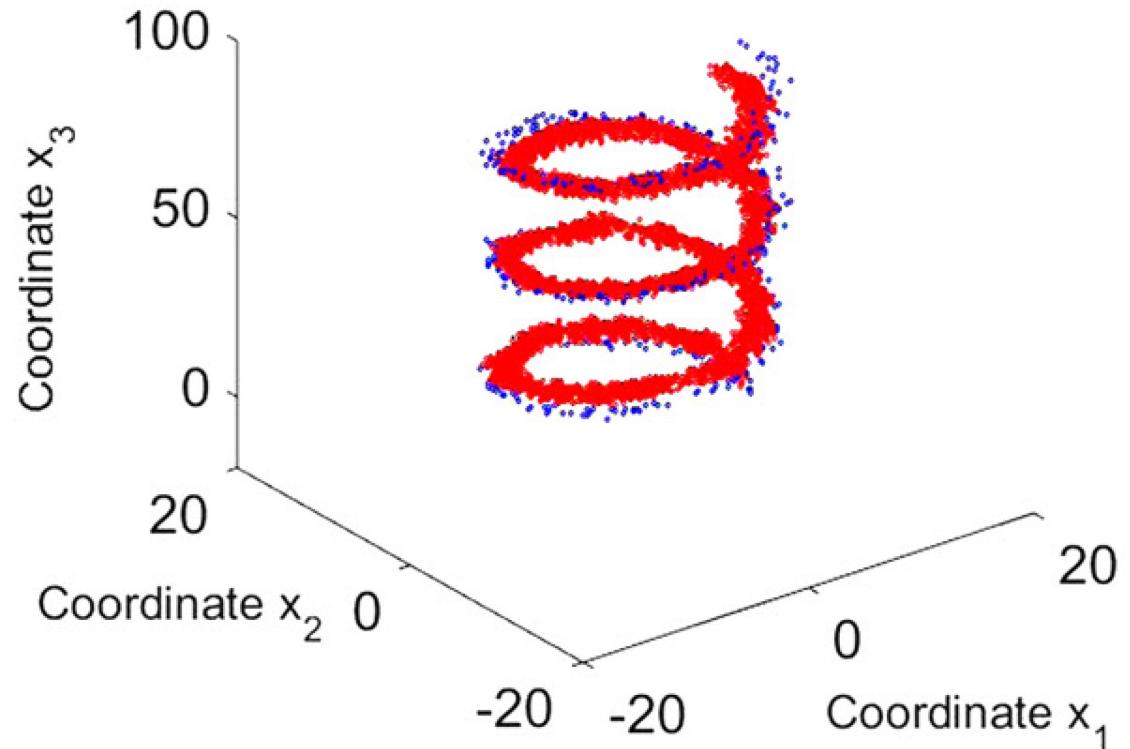
2. Reduction of Simulation Time

Use ML to generate Surrogates to replace Numerical Simulations in Workflow

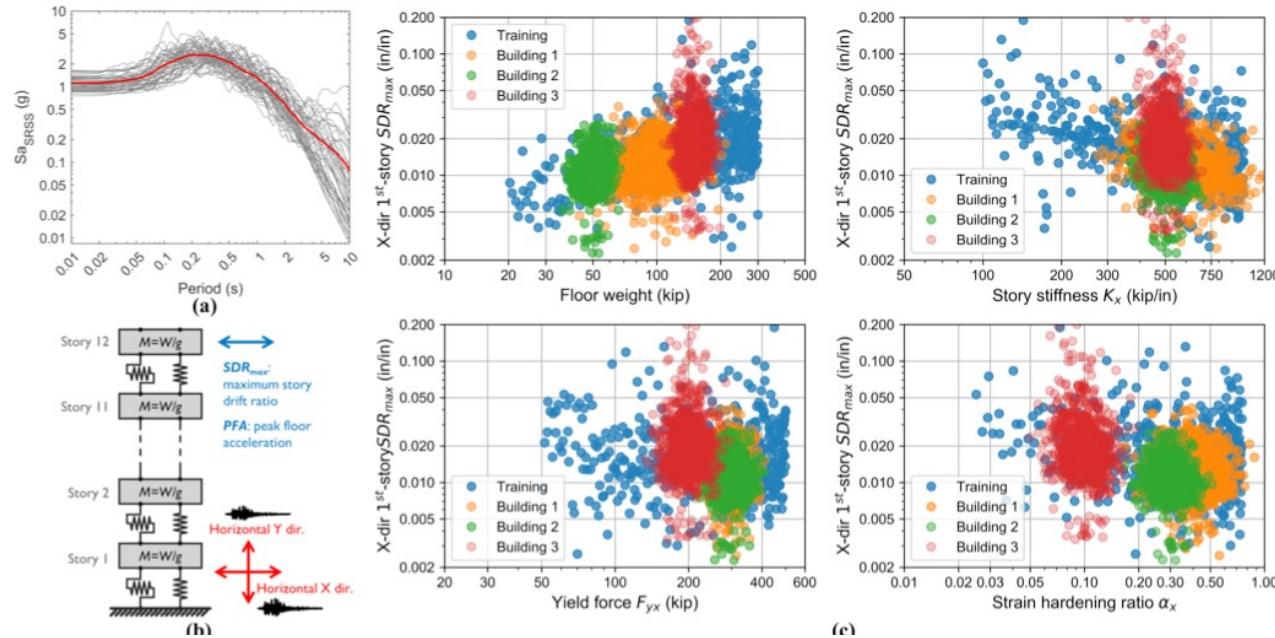


Advanced Manifold Learning Methods

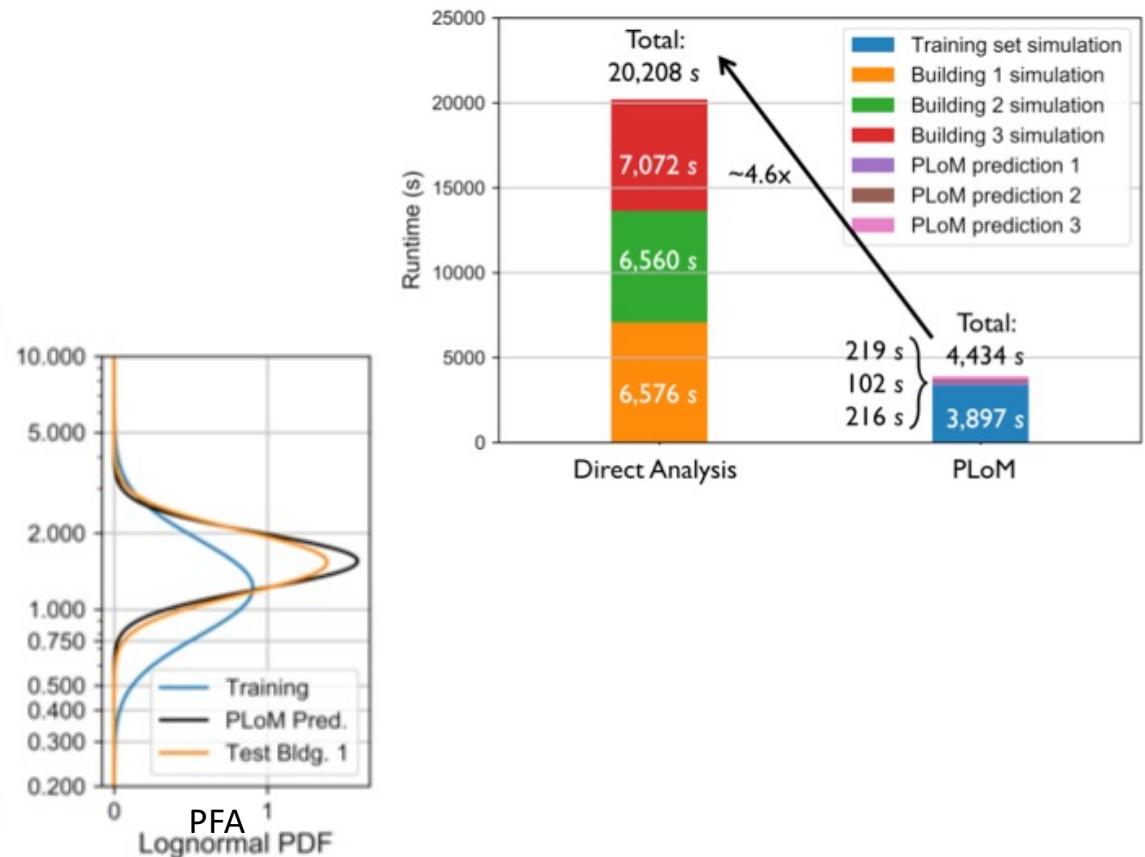
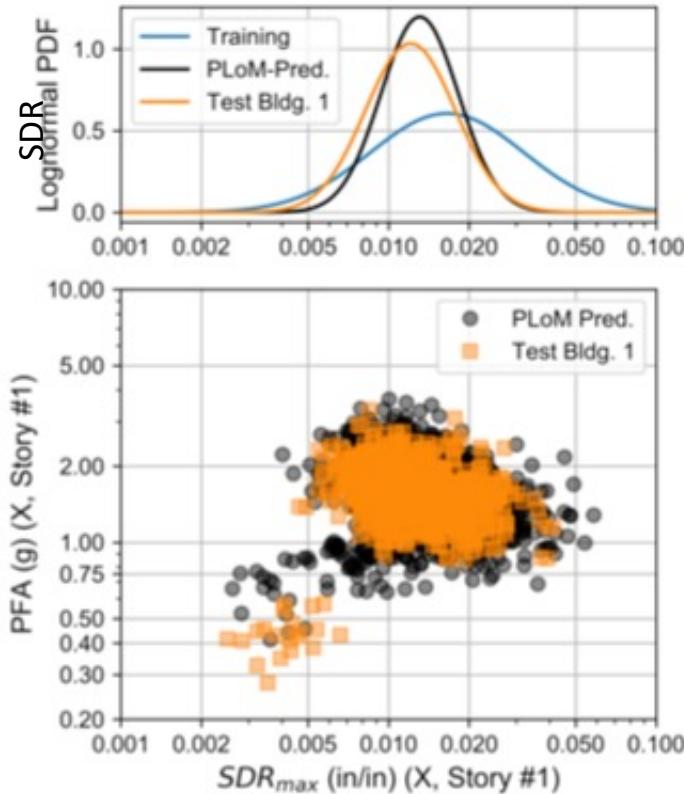
- Identification of non-linear response manifolds via **PLoM** method of Soize and Ghanem (2016,2020)
- Limited data
- High-dimensional stochastic problems



PLoM Example



PLoM Example



Outline

- Welcome
- Introduction to NHERI
- ML in Earthquake Engineering: Opportunities and Challenges