



# NHERI Computational Modeling and Simulation Center

## User Workshop

May 18, 2018

### Research Tools: Plan, Current Tools & Release Dates

 NHERI 

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## Software Experts Say We Need to Solve Grand Challenges related to Natural Hazards

- 1) Applications that generate UQ in Response Quantities:
- 2) Applications to perform Performance Based Engineering
- 3) Applications for Community Resiliency
- 4) Educational Applications

**THESE ARE THE APPLICATIONS WE PROPOSED  
TO DEVELOP IN A MANNER THAT WOULD ALLOW  
RESEARCHERS TO BOTH USE THEM AND BUILD UPON THEM**

## RESEARCH TOOLS WE HAVE PROMISED

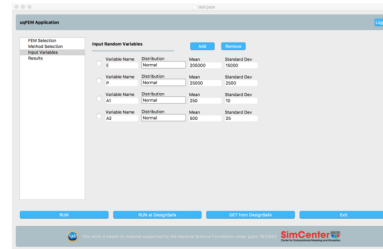
- uqFEM: enhance FEM applications with UQ & Optimization capabilities
- EE-UQ: response of buildings to earthquake events
- CWE-UQ: response of buildings to wind events
- PBE: downtime & loss estimator for building subject to hazard
- RDT: regional resiliency determination

WBS No.	Tool	Y1	Year 2												Y3	Y4	Y5
			Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept			
1.2.7	User Needs Workshop									+1							
1.3.2	Experimental Datasets	10			+1						+6			+2	+10	+10	+10
1.3.2	Simulation Models	802*									+25			+25	+50	+50	+50
1.3.3	Existing Building Data			+1.8M										+0.7M			
1.3.5	AI-M-1	IP													V1.0		
1.3.5	AI-M-2					V0.1		V1.0									
1.3.5	AI-M-3	V0.2			V1.0		V1.0							V1.1			
1.3.6	AI-DL-1	V0.1			V0.2		V1.0							V1.1			
1.3.6	AI-DL-2																
1.3.7	CWE-UQ		V0.1		V0.2		V1.0			V1.0				V2.0	V2.X	V3.X	
1.3.8	EE-UQ					V0.1		V0.2	V0.2	V1.0				V2.0	V2.X		
1.3.8	uqFEM				V0.1	V1.0				V1.0					V2.X		
1.3.9	PBE Tool			IP					V0.1			V0.2		V1.0	V1.X	V2.X	V3.X
1.3.10	RDT Tool														V1.X	V2.X	V3.X
1.3.11	Educational App (MDOF)	V1.0			V1.1												
1.3.11	Educational App (Pile Group)	V1.0					V2.0		V2.0								
1.3.11	Educational App (Base Isolation)				IP			V0.1			V0.2			V1.0			
1.3.11	Educational App (Wind vs. Earthquake)				IP				V0.1			V0.2		V1.0			
1.3.11	Additional Education App														+2	+2	+2
1.4.2	Large Testbed – Regional Earthquake Event			W1.0	W1.1						W1.2				W1.3	W1.4	W1.5
1.4.2	Large Testbed – Regional Wind, Storm surge, or Tsunami Event		IP											W2.1	W2.2	W2.3	W2.4
1.4.2	Large Testbed – TBD														W3.1	W3.2	W3.3



## Tool to add UQ & Optimization Capabilities to Existing FE code.

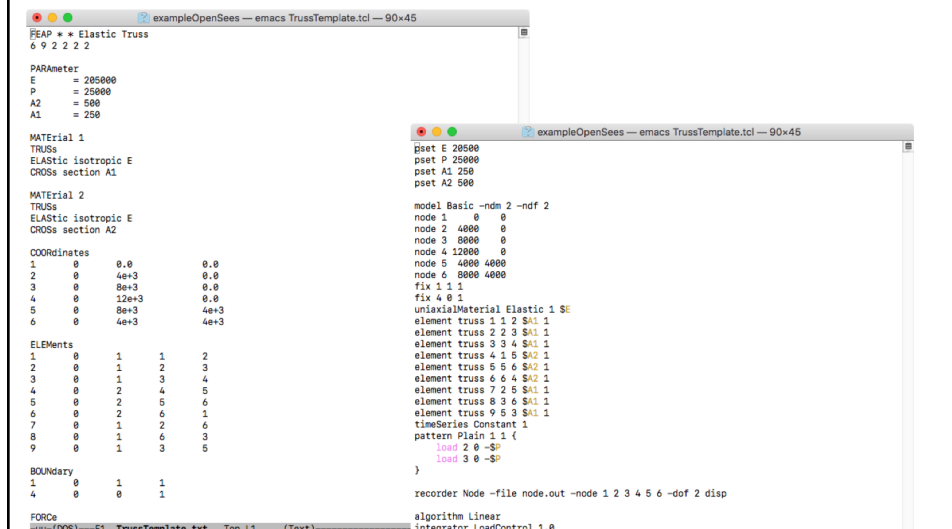
- User provide input file & script for an existing FE application
- Application reads & creates random variables for parameters specified in input
- User defines the UQ or Optimization Method (Sampling, Parameter Estimation, Bayesian Calibration)
- User specifies the distributions on the Random Variables
- User submits to local machine or remotely to DesignSafe-ci



### Release Dates:

- V1.0 (June 2018)
- V2.0 (2019)
- V3.0 (2020)

## Takes as Input Standard FE input file



## User Selects FE Application and Input File

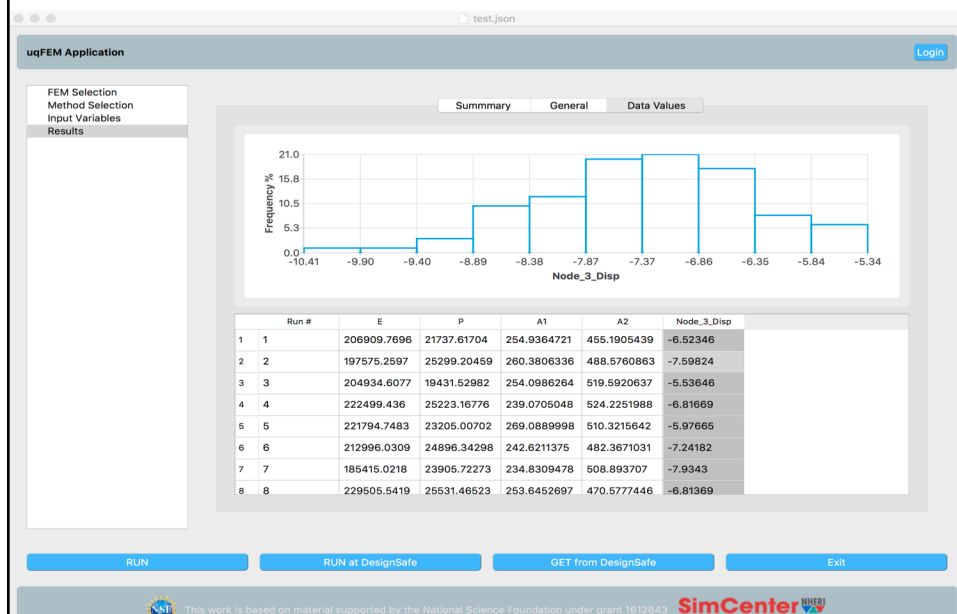
The screenshot shows the 'uqFEM Application' web interface. The 'Finite Element Application' section is active, displaying a dropdown menu with 'OpenSees' selected. Below this, the 'Input Script' field shows the path '/Users/fmckenna/NHERI/uqFEM/exampleOpenSees/TrussTemplate.tcl' with a 'Choose' button. The 'Postprocess Script' field shows the path '/Users/fmckenna/NHERI/uqFEM/exampleOpenSees/postprocess.py' with a 'Choose' button. The left sidebar contains links for 'FEM Selection', 'Method Selection', 'Input Variables', and 'Results'. At the bottom, there are four buttons: 'RUN', 'RUN at DesignSafe', 'GET from DesignSafe', and 'Exit'. The footer includes the NSF logo, a statement about National Science Foundation support, and the SimCenter logo.

## User Specifies UQ Method & EDP

The screenshot shows the 'uqFEM Application' web interface with the 'UQ Method' section active. The 'UQ Method' dropdown is set to 'Sampling'. Below it, the 'Method' field is 'LHS', '# Samples' is '100', and 'Seed' is '10'. The 'Response Parameters' section has an 'Add' button and a 'Remove' button. A radio button is selected for 'Variable Name' with the value 'Node\_3\_Displacement'. The left sidebar contains links for 'FEM Selection', 'Method Selection', 'Input Variables', and 'Results'. At the bottom, there are four buttons: 'RUN', 'RUN at DesignSafe', 'GET from DesignSafe', and 'Exit'. The footer includes the NSF logo, a statement about National Science Foundation support, and the SimCenter logo.

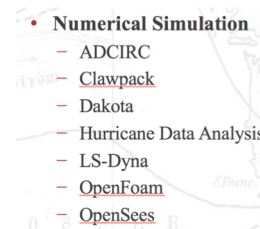


## User Runs & Looks at Results



## Questions for Breakouts

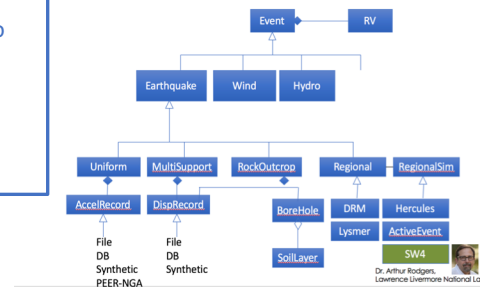
- Additional Features
  - Other Sim Applications (on DesignSafe)
  - RV types
  - Methods, e.g. Structural Reliability
  - Other Applications for UQ
- Other *Examples Needed for Testing*
  - *SSI (Pedro soil column)*
  - *Experimental Test Data*





## Tool to Predict the Response of a Building to an Earthquake Event

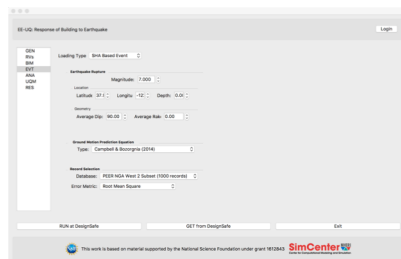
- Moment Frames, Braced Frames, and Concrete Shear Wall Buildings
- User to specify random variables and to **obtain measure of uncertainty in computed responses**
- To include **SSI**
- Jobs to run locally or **remotely at DesignSafe**.



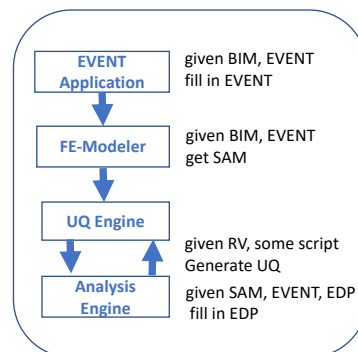
### Release Dates:

- V1.0 (June 2018) Uniform Excitation + Moment Frame
- V2.0 (Sept 2018) Rock Outcrop motion
- V3.0 (?????) Soil Box around Building

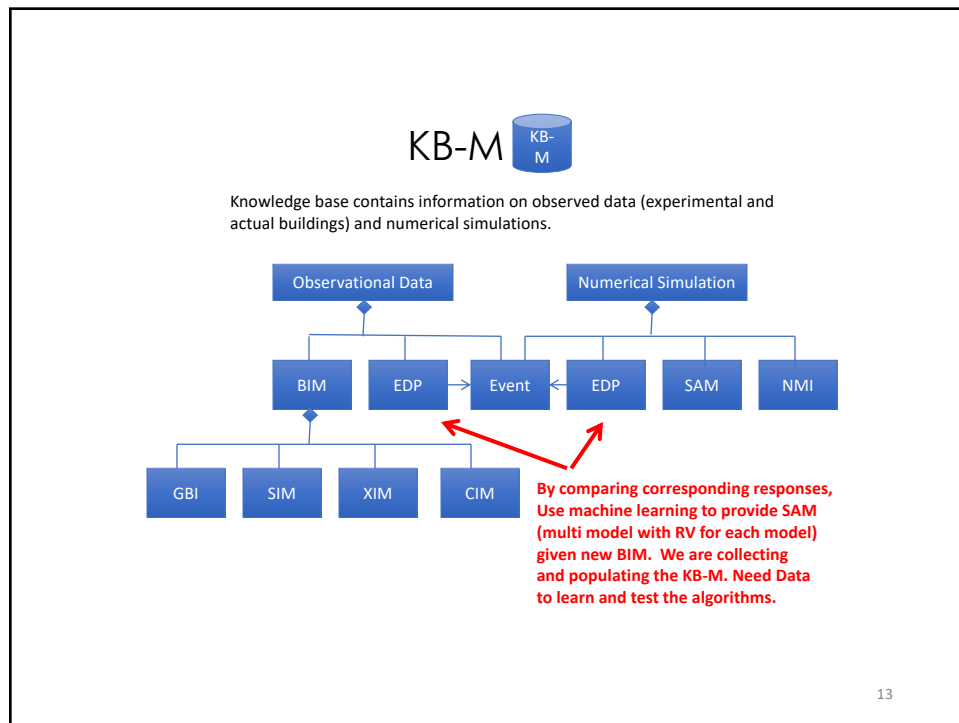
## Tool Architecture



**Front End UI** in which user defines (RV, BIM, EVENT, EDP)

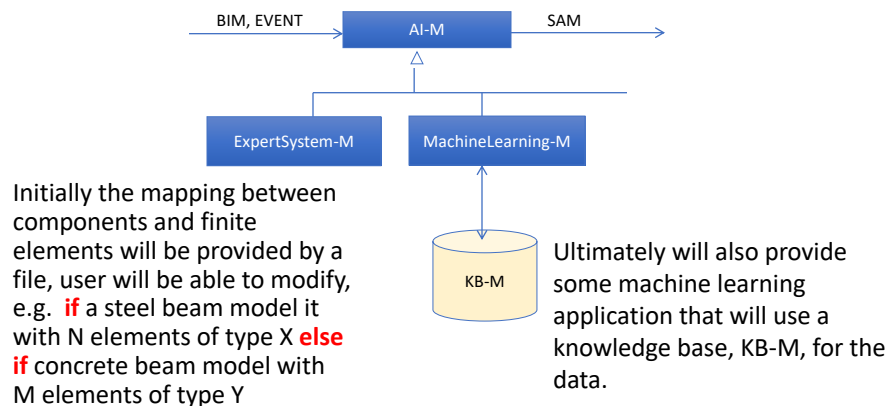


**Back End Workflow**  
running locally or on XSEDE through DesignSafe



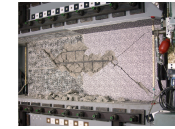
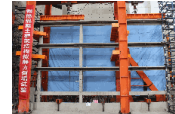
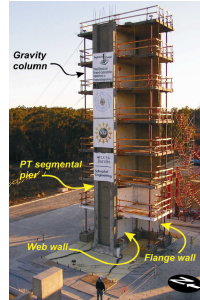
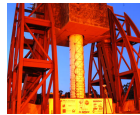
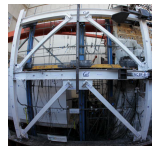
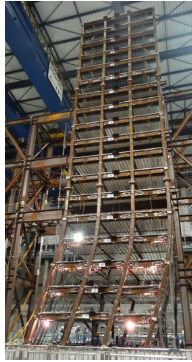
## Some AI Code To Make it Work

AI produces the SAM (structural analysis) models.

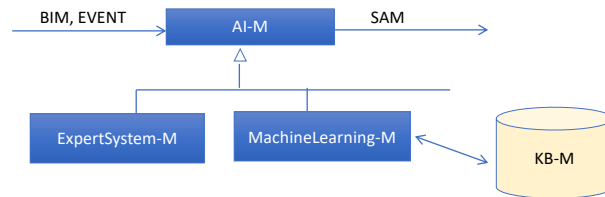


Collected 9 experimental datasets:

Dataset Name	Hazard	ndm	Material	Structural Type	Year	Laboratory	FE Models	# Models	# Random Models
18-Story Steel Hi-Rise at E-Defense	Seismic	3D	Steel	Moment Frame	2013	E-Defense	OpenSees	4	200
2-Story NCBF at UCB	Seismic	2D	Steel	Braced Frame	2012	UC Berkeley	OpenSees	3	0
7-Story RC Building at UCSD	Seismic	3D	RC	Shear Wall	2006	UC San Diego	Various	0	0
Collapse of 4-Story Steel Building at E-Defense	Seismic	3D	Steel	Moment Frame	2007	E-Defense	OpenSees	1	0
Collapse of RC Frame at Tsinghua University	Seismic	2D	RC	Moment Frame	2011	Tsinghua University	OpenSees, MSC Marc	4	200
RC Columns at Tsinghua University	Seismic	2D	RC	Moment Frame Comp.	2011	Tsinghua University	OpenSees, MSC Marc	6	200
RC Joint at Tsinghua University	Seismic	2D	RC	Moment Frame Comp.	2011	Tsinghua University	OpenSees, MSC Marc	4	0
Large-Scale Bridge Column at UCSD	Seismic	3D	RC	Inverted Pendulum	2010	UC San Diego	Various	3	200
Squat RC Shear Wall at ELSA	Seismic	2D	RC	Shear Wall Comp.	2012	ELSA, JRC Ispra	OpenSees	1	0



### AI-M-1: Machine Learning application that will use related Experimental and Simulation Data to Generate SAM files



Stella Yu

**Challenge:** Is to turn BIM and SAM files into a numerical representation on which machine learning algorithms can be turned loose.

**Current Working Approach:** based on component level approach to modeling:

1. From paired (BIM,SAM) files identify and model corresponding components.
2. Knowing how each component is modeled, create a model representation given BIM
3. Generate possible SAM models for each component in the BIM



## User Specifies General Building Properties

EE-UQ: Response of Building to Earthquake
Login

GEN

RVs

BIM

EVT

ANA

UQM

RES

Name

Revision

Type

Year

Stories

Height

**Location**

Name

Latitude

Longitude

**Units**

Force

Length

Temperature

Time

RUN at DesignSafe
GET from DesignSafe
Exit

## User Specifies RV

EE-UQ: Response of Building to Earthquake
Login

GEN  
 RVs  
 BIM  
 EVT  
 ANA  
 UQM  
 RES

Input Random Variables
Add Remove

<input type="radio"/> Variable Name	<input type="radio"/> Distribution	Mean	Standard Dev
<input type="radio"/> E	<input type="text" value="Normal"/>	<input type="text" value="29000"/>	<input type="text" value="310"/>
<input type="radio"/> Grade50Fy	<input type="text" value="Normal"/>	<input type="text" value="60"/>	<input type="text" value="10"/>

RUN at DesignSafe
GET from DesignSafe
Exit

## User Specifies Building Components

EE-UQ: Response of Building to Earthquake

Login

- GEN
- RVs
- BIM**
- EVT
- ANA
- UQM
- RES

GeneralInformation

- Layout
  - Floors
  - Clines
- Geometry
  - Beams**
  - Columns
  - Braces
  - Walls
- Properties
  - Materials
    - Concrete
    - Steel
  - Framesections
    - Concrete Rectangular Colu...
    - Concrete Box Column
    - Concrete Circular Column
    - Concrete Pipe Column
    - Concrete Rectangular Beam
    - Concrete Tee Beam
    - Concrete L Beam
    - Concrete Cross Beam
    - Steel Wide Flange
    - Steel Channel
    - Steel Double Channel

	Name	Floor	CLine1	CLine2	section	ratio_start	ratio_end
1	1	1	1	2	W30X191		
2	2	1	2	3	W30X191		
3	3	1	3	4	W30X191		
4	4	2	1	2	W30X211		
5	5	2	2	3	W30X211		
6	6	2	3	4	W30X211		
7							
8							
9							
10							
11							
12							
13							
14							

RUN at DesignSafe GET from DesignSafe Exit

This work is based on material supported by the National Science Foundation under grant 1612843

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

## User Specifies Earthquake Inputs

EE-UQ: Response of Building to Earthquake
Login

GEN  
RVs  
BIM  
**EVT**  
ANA  
UQM  
RES

Loading Type   SHA Based Event ▾

<b>Earthquake Rupture</b>	
Magnitude:	7.000 ▾
Location	
Latitude: 37.f ▾	Longitude: -12.f ▾   Depth: 0.0f ▾
Geometry	
Average Dip: 90.00 ▾	Average Rake: 0.00 ▾
Ground Motion Prediction Equation	
Type:	Campbell & Bozorgnia (2014) ▾
Record Selection	
Database:	PEER NGA West 2 Subset (1000 records) ▾
Error Metric:	Root Mean Square ▾

RUN at DesignSafe

GET from DesignSafe

Exit

### Other Loading (SSI):

```

graph TD
    Event --> RV
    Event --> Earthquake
    Event --> Wind
    Event --> Hydro
    Earthquake --> Uniform
    Earthquake --> MultiSupport
    Earthquake --> RockOutcrop
    Earthquake --> Regional
    Earthquake --> RegionalSim
    Uniform --> AccelRecord
    MultiSupport --> DisoRecord
    RockOutcrop --> Borehole
    Regional --> DRM
    Regional --> Hercules
    RegionalSim --> Hercules
    AccelRecord --> File
    AccelRecord --> SHA-PEER
    AccelRecord --> Synthetic
    AccelRecord --> PEER-NGA
    DisoRecord --> File
    DisoRecord --> DB
    DisoRecord --> Synthetic
    Borehole --> SoilLayer
    DRM --> Lysmer
    Hercules --> ActiveEvent
    Hercules --> SW4
  
```

Dr. Arthur Rodgers  
University of California, Berkeley

This work is based on material supported by the National Science Foundation under grant 1612843

## User Specifies Analysis Options

EE-UQ: Response of Building to Earthquake

Login

GEN

RVs

BIM

EVT

ANA

UQM

RES

Analysis Options:


1. Integration Schemes?
2. Convergence Test?
3. Damping (need to put somewhere)

Solver, Constraint enforcement


RUN at DesignSafe

GET from DesignSafe

Exit



This work is based on material supported by the National Science Foundation under grant 1612843



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## User Specifies UQ Method Options

EE-UQ: Response of Building to Earthquake

Login

GEN

RVs

BIM

EVT

ANA

UQM


RES

Method	# Samples	Seed
LHS	1000	536

RUN at DesignSafe

GET from DesignSafe

Exit

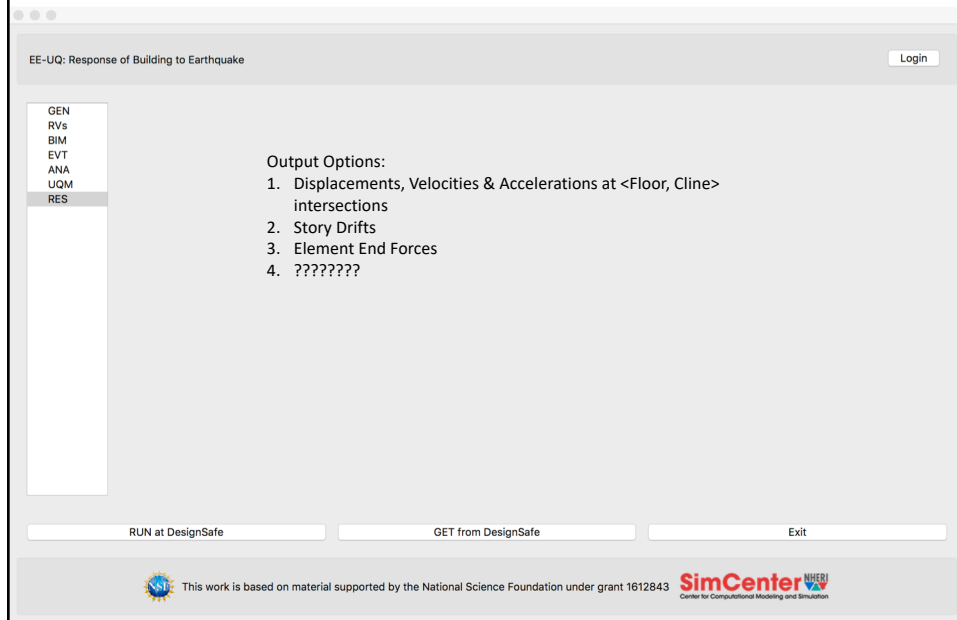


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## User Specifies Output Quantities



## PBE Tool to Predict the Damage & Loss to a Building given some Hazard Event



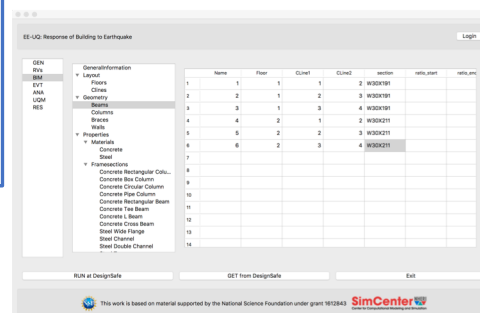
- User Inputs Building Information
  - Structural & Contents
- User Selects from different loading options & Inputs Parameters
- User Specifies RV distributions
- The tool when run will auto generate the analysis model, run a set of deterministic simulations and use Pact or equivalent to generate D&L all on DesignSafe
- User selects run & views different output results.

### Release Dates:

- V1.0 (Sept 2018) Earthquake
- V2.0 (2020) Wind
- V3.0 (2021) Water

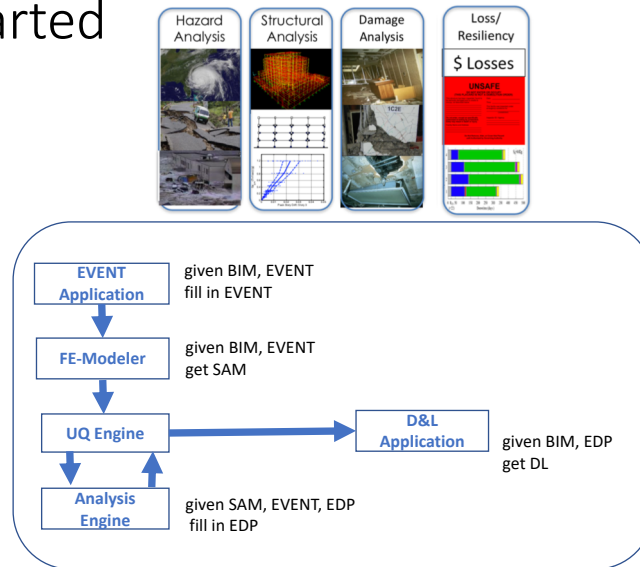
### Research Opportunities:

- In addition to modeling & hazards, different applications for calculating damage & loss
- Validated data for different fragility and loss curves.





## Development Has Not Officially Started



## Questions for Breakouts

- Uncertainty:
  - Include pre-defined built in RV, e.g. SteelE, Steel50Fy
  - Ensembles (AI to produce or could put in the mapping file and build multiple with expert system)
  - How to account for Model Bias
  - Incorporation of Reduced Order Models
- Modeling
  - AI – data, data, data
  - Initial Mapping (Filip)
  - For continuum Modeling of walls, any good open-source quad mesher
  - For SSI Group (John, Pedro, ET, Peter) + Michael Gardner
    - Soil Layers
    - Built in Soil Properties, e.g. Clay
    - Use existing components from PileGroupTool application
- Interface (the spreadsheet is envisioned as the underlying model in MVC)
  - Existing 3d Graphical anybody like?
  - Interpreter languages
- Damage & Loss
  - Applications, i.e. OpenSLAT, your own
  - Fragility & Cost Functions