SimCenter NHERI

Center for Computational Modeling and Simulation

Requirements Traceability Matrix (RTM)

NHERI SimCenter, UC Berkeley

Version 1.2

October 14, 2019

Contents

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1 Introduction

The Requirements Traceability Matrix (RTM) is presented as tables linking requirements with project deliverables. The requirements for the SimCenter have been obtained from a number of sources:

1. GC: Grand challenges in hazard engineering are the problems, barriers, and bottlenecks that hinder the ideal of a nation resilient from the effects of natural hazards. The vision documents referenced in the solicitation [2, 3, 5, 6] outline the grand challenges for wind and earthquake hazards. These documents all present a list of research and educational advances needed that can contribute knowledge and innovation to overcome the grand challenges. The advances summarized in the vision documents were identified through specially formed committees and workshops comprising researchers and practicing engineers. They identified both the grand challenges faced and also identified what was needed to address these challenges. The software needs identified in these reports that are applicable to research in natural hazards as permitted under the NSF NHERI program were identified in these reports. Those tasks that the NHERI SimCenter identified as pertaining to aiding NHERI researchers perform their research and those which would aid practicing engineers utilize this research in their work are identified here.

2. SP: From the senior personnel on the SimCenter project. The vision documents outline general needs without going into the specifics. From these general needs the senior personnel on the project identified specific requirements that would provided a foundation to allow research.

3. UF: SimCenter workshops, boot camps and direct user feedback. As the SimCenter develops and releases tools, feedback from researchers using these tools is obtained at the tool training workshops, programmer boot-camps, in one-on-one discussions, via direct email, and through online user feedback surveys.

2 Requirements

The software requirements are many. For ease of presentation they are broken into three groups:

1. Regional Scale - Activities to allow researchers to examine the resilience of a community to natural hazard events.
2. Building Scale - Activities to allow researchers to improve on methods related to response assessment and performance based design of individual buildings subject to the impact of a natural hazard.
3. Education - software development activities related to education of researchers and practicing engineers.

2.1 Regional Scale

Table 2.1: Requirements for Regional Simulations aiding Community Resilience

#	Description	SRC	WBS	PRI	VER
R1	Ability to perform regional simulation allowing communities to evaluate resilience and perform what-if types of analysis for natural hazard events	GC	1.3.10 rWhale	M	1.0
R1.1	Perform such simulations for ground shaking due to Earthquake	GC	1.3.10 rWhale	M	1.0
R1.2	Ability to perform such simulations for wave action due to Earthquake induced Tsunami	GC	1.3.10 rWhale	M	
R1.3	Ability to perform such simulations for wind action due to Hurricane	GC	1.3.10 rWhale	M	
R1.4	Ability to perform such simulations for wave action due to Hurricane Storm Surge	GC	R1.3.10 rWhale	M	
R1.5	Ability to perform such for multi-hazard simulations: wind + storm surge, rain, wind and water borne debris	GC	1.3.10 rWhale	M	
R1.6	Ability to incorporate damage to lifelines in determination of community resilience	GC	1.3.10 rWhale	M	

R2.1	Ability of stakeholders to perform simulations of different scenarios that aid in planning and response after damaging events	GC	1.3.10 rWhale	M	1.0
R2.2	Ability to utilize HPC resources in regional simulations that enables repeated simulation for stochastic modeling	GC	1.3.10 rWhale	M	1.0
R2.3	Provide open-source software for developers to test new data and algorithms	GC	1.3.10 rWhale	M	1.0
R2.4	Ability to use a tool created by linking heterogeneous array of simulation tools to provide a toolset for regional simulation	GC	1.3.10 rWhale	M	1.0
R2.5	Ability to utilize existing open-source software for faster deployment	GC	1.3.10 RDT	M	1.0
R2.6	Ability to utilize ensemble techniques	GC	1.3.10 rWhale	M	1.0
R2.7	Ability to include multi-scale nonlinear models	GC	1.3.10 rWhale	M	1.0
R2.8	Ability to include a formal treatment of uncertainty and randomness	GC	1.3.10 rWhale	M	1.0
R2.9	Ability to include latest information and algorithms (i.e. new attenuation models, building fragility curves, demographics, lifeline performance models, network interdependencies, indirect economic loss)	GC	rWhale 1.3.10	D	
R2.10	Ability to use GIS so communities can visualize hazard impacts	GC	1.3.10 rWhale	M	
R2.11	Ability to explore different strategies in community development, pre-event, early response, and post event, through long term recovery	GC	1.3.10 RDT	P	
R2.12	Ability to use system that creates and monitors real-time data, updats models, incorporates crowdsourcing technologies, and informs decision makers	GC	1.3.10 RDT	P	
R2.13	Ability to use sensor data to update models for simulation and incorporate sensor data into simulation	GC	1.3.10 RDT	P	

R3.1	Ability to use open-source version of Hazus	GC	1.3.6 pelicun	M	1.0
R3.2	Ability to incorporate improved damage and fragility models for buildings and lifelines	GC	1.3.6 pelicun	M	1.0

R3.3	Ability to incorporate improved indirect economic loss estimation models	GC	1.3.6 pelicun	M	
R3.4	Ability to include demand surge in determination of damage and loss estimation	GC	1.3.6 pelicun	M	
R3.5	Ability to include lifeline disruptions	GC	1.3.6 pelicun	M	
R4.1	Promote 'living' community risk models utilizing local inventory data from various scources	GC	1.3.0 rWhale	M	
R4.2	Ability to use cumulative knowledge bases rather than the piecemeal individual approaches	GC	1.3.3	M	
R4.3	Developing and sharing standardized definitions, measurement protocols and strategies for data collection	GC	1.3.3	M	
R4.3	Developing tools that utilize GIS information and online images, e.g. google maps, for data collection	GC	1.3.4 BRAILS	M	1.0
R4.3.1	Predicting if building is a soft-story building for earthquake simulations	UF	1.3.4 BRAILS	M	1.0
R4.3.2	Predicting roof shape of building for hurricane wind simulation	SP	1.3.4 BRAILS	M	1.0
R4.3.3	Predicting level first floor of occupancy for hurricane storm surge simulation	SP	1.3.4 BRAILS	M	
R4.4	Providing instruction on gathering information from WWW for purposes of these regional simulations	UF	1.2.3 Summer Bootcamp	M	V2.0
R4.5	Developing, sharing, and archiving datasets for analyzing and modeling resilience and vulnerability over time	GC	1.3.3	M	
R4.6	Ability to use GIS, high resolution elevation and soil data for wind and storm surge simulations	GC	1.3.10	D	
R4.7	Ability to use validated multi-scale models (materials, components, elements) of built environment	GC	1.3.3	D	
R4.8	Ability to use a national database of models for hazard, buildings, and lifelines created for multiple hazards	GC	P	1.3.3	

5.1	Ability to perform validation studies to calibrate accuracy of models	GC	1.3.10 rWhale	M	
5	Identify knowledge gaps and promote NSF generated knowledge through regional demonstration projects that help generate linkages to operational entities and decision makers	GC	1.4.2	M	
5.1	Provide Earthquake Testbeds	SP	1.4.2 Testbeds	M	1.0
5.1.1	Provide Bay Area Earthquake Testbed	SP	1.4.2 Testbeds	M	1.0
5.1.2	Provide Anchorage Earthquake Testbed	SP	1.4.2 Testbeds	M	1.1
5 .2	Provide Tsunami Testbed	SP	1.4.2 Testbeds	M	
5.3	Provide Atlantic City Hurricane Wind Testbed	SP	1.4.2 Testbeds	M	
5.4	Provide Atlantic City Hurricane Wind and Storm Surge Testbed	SP	1.4.2 Testbeds	M	
5.5	Provide Earthquake and Lifelines Testbed	SP	1.4.2 Testbeds	M	

KEY:
Source (SRC): GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Work Breakdown Structure (WBS): SimCenter WBS Number
Priority (PRI): M=Mandatory, D=Desirable, P=Possible Future
Version (VER): Version number the basic requirement was first met

2.2 Building Scale

For building scale simulations, the requirements are broken down by SimCenter application. There are a number of applications under development for each of the hazards. Many of the requirements related to UQ and nonlinear analysis are repeated amongst the different applications under the assumption that if they are beneficial to engineers dealing with one hazard, they will be beneficial to engineers dealing with other hazards.

2.2.1 Response of Building to Wind Hazard

The following are the requirements for response of single structure due to wind action. The requirements are being met by the WE-UQ application. All requirements in this section are related to work in WBS 1.3.7.

Table 2.2: Requirements for WE-UQ

#	Description	Source	Priority	Version
W1	**Ability to determine response of Building Subject to Wind Loading including formal treatment of randomness and uncertainty uncertainty**	GC	M	1.0
W1.1	Ability of Practicing Engineers to use multiple coupled resources (applications, databases, viz tools) in engineering practice	GC	M	1.0
W1.2	Ability to utilize resources beyond the desktop including HPC	GC	M	1.0
W1.3	Tool available for download from web	GC	M	1.0
W1.4	Ability to obtain training and education with respect to interaction of structure and wind to ensure research is appropriately applied	GC	M	
W2	**Ability to select from different Wind Loading Options**	SP	M	1.0
W2.1	Utilize Extensive wind tunnel datasets in industry and academia for wide range of building shapes	GC	M	2.0
W2.1.1	Accommodate Range of Low Rise building shapes	SP	M	
W2.1.1.1	Flat Shaped Roof - TPU dataset	SP	M	2.0
W2.1.1.2	Gable Shaped Roof - TPU dataset	SP	M	
W2.1.1.3	Hipped Shaped Roof - TPU dataset	SP	M	
W2.1.2	Accommodate Range of High Rise building	SP	M	1.0
W2.1.2.1	Interface with Vortex Winds DEDM-HRP Web service	SP	M	1.0
W2.1.3	Accommodate Data from Wind Tunnel Experiment	SP	M	2.0
W2.1.3.1	Cuboid - User Provided Wind Tunnel Experiment Data	SP	M	2.0

W2.2	Computational Fluid Dynamics tool for utilizing open source CFD software for practitioners	GC	M	1.1
W2.2.1	Simple CFD model generation and turbulence modeling	GC	M	2.0
W2.2.2	Uncoupled OpenFOAM CFD model with nonlinear FEM code for building response	SP	M	1.1
W2.2.3	Coupled OpenFOAM CFD model with nonlinear FEM code for building response	SP	M	
W2.3	Quantification of Effects of Wind Borne Debris	GC	D	
W2.4	Application to utilize GIS and online to account for wind speed given local terrain, topography and nearby buildings	GC	D	
W2.5	Ability to utilize synthetic wind loading algorithms	SP	M	1.0
W2.5.1	per Wittig and Sinha	SP	D	1.0
W3	**Ability to select different Building Model Generators**	GC	M	2.0
W3.1	Ability to quickly create a simple nonlinear building model	GC	D	1.0
W3.2	Ability to define building and use Expert System to generate FE mesh	SP		
3.2.1	Expert system for Concrete Shear Walls	SP	M	
3.2.2	Expert system for Moment Frames	SP	M	
3.2.3	Expert system for Braced Frames	SP	M	
W3.3	Ability to define building and use Machine Learning applications to generate FE	GC		
W3.3.1	Machine Learning for Concrete Shear Walls	SP	M	
W3.3.2	Machine Learning for Moment Frames	SP	M	
W3.3.3	Machine Learning for Braced Frames	SP	M	
W3.4	Ability to specify connection details for member ends	SP	M	2.2
W3.5	Ability to define a user-defined moment-rotation response representing the connection details	SP	D	2.2
W4	**Ability to Perform Nonlinear Structural Analysis**	GC	M	1.0
W4.1	Ability to use utilize existing nonlinear analysis software used in earthquake engineering	GC	M	1.0
W4.1.1	Utilize open source OpenSees software	SP	M	1.0
W4.2.1	Ability to provide own OpenSees Analysis script to OpenSees engine.	SP	D	1.0
W4.3.1	Ability to provide own Python script and use OpenSeesPy engine.	SP	O	1.2
W4.2	Ability to use alternative FEM engine	SP	M	2.0

U	**Ability to use various UQ Methods**	GC	M	
U1	**Forward Propogation Methods**	GC	M	1.0
U1.1	Ability to use basic Monte Carlo and LHS methods	SP	M	1.0
U1.2	Ability to use Importance Sampling	SP	M	2.0
U1.3	Ability to use Gaussian Process Regression	SP	M	2.0
U1.4	Ability to use Own External UQ Engine	SP	M	
U2	**Ability to use various Reliability Methods**	UF	M	1.0
U2.1	Ability to use First Order Reliability method	UF	M	
U2.2	Ability to use Second Order Reliability method	UF	M	
U2.2	Ability to use Surrogate Based Reliability	UF	M	
U2.3	Ability to use Own External Application to generate Results	UF	M	
U3	**Ability to user various Sensitivity Methods**	UF	M	1.0
U3.1	Ability to obtain Global Sensitivity Sobol's indices	UF	M	
U4	**Various Random Variable Probability Distributions**	SP	M	1.0
U4.1	Ability to Define Variables of different types:	SP	M	1.0
U4.1.1	Normal	SP	M	1.0
U4.1.2	Lognormal	SP	M	1.0
U4.1.3	Uniform	SP	M	1.0
U4.1.4	Beta	SP	M	1.0
U4.1.5	Weibull	SP	M	1.0
U4.1.6	Gumbel	SP	M	1.0
U4.2	User defined Distribution	SP	M	
U4.3	Define Correlation Matrix	SP	M	
U4.4	Random Fields	SP	M	
W8	**Ability to obtain Application Outputs**			
W8.1	Ability to see pressure distribution on building	GC	M	
W8.2	Ability to obtain basic building responses	SP	M	
W8.3	Ability to Process own Output Parameters	UF	M	1.1
WE	**Ability to obtain Educational Materials**			
WE1	Ability to obtain training to ensure the research is appropriately applied	GC	M	
WE2	Documentation exists on tool usage	SP	M	1.0
WE3	Video Exists demonstrating usage	SP	M	
WE4	Verification Examples Exist	SP	M	
WE4	Validation Examples Exist, validated against tests or other software	GC	M	
WM	**Misc.**			

WM1	Tool to allow user to load and save user inputs	SP	M	1.0
WM2	Installer which installs application and all needed software	UF	M	

KEY:
Source: GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Need: M=Mandatory, D=Desirable, P=Possible Future
Version: Version number the basic requirement was met

2.2.2 Response of Building to Hydrodynamic Effects Due to Tsunami or Coastal Inundation

The following are the requirements for response of single structure due to hydrodynamic effects of water caused earthquake induced tsunami or coastal inundation due to a Hurricane.. The requirements are being met by the Hydro-UQ application. All requirements in this section are related to work in WBS 1.3.7.

Table 2.3: Requirements for HydroUQ

#	Description	Source	Priority	Version
H1	**Ability to determine response of Building Subject to Wave Loading due to Tsunami and Coastal inundation including formal treatment of randomness and uncertainty uncertainty**	GC	M	
H1.1	Simulation of overland flow including waves, debris, flood velocity, erosion at building, and channeling effects	GC	M	
H1.2	Use CFD to model interface and impact between water loads and buildings	GC	M	
H1.3	Ability to quantify effect of flood borne debris	GC	M	
H1.4	Ability of Practicing Engineers to use multiple coupled resources (applications, databases, viz tools) in engineering practice	GC	M	
H1.5	Ability to utilize resources beyond the desktop including HPC	GC	M	
H1.6	Ability to obtain training and education with respect to interaction of structure and water to ensure research is appropriately applied	GC	M	

KEY:
Source: GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Need: M=Mandatory, D=Desirable, P=Possible Future
Version: Version number the basic requirement was met

2.2.3 Response of Building to Earthquake Hazard

The following are the requirements for response of single structure to earthquake hazards. The requirements are being met by the EE-UQ application. AAll requirements in this section are related to work in WBS 1.3.8.

Table 2.4: Requirements for EE-UQ

#	Description	Source	Priority	Version
E1	**Ability to determine response of Building Subject to Earthquake hazard including formal treatment of randomness and uncertainty uncertainty**	GC	M	1.0
E1.1	Ability of Practicing Engineers to use multiple coupled resources (applications, databases, viz tools) in engineering practice	GC	M 1.0	
E1.2	Ability to utilize resources beyond the desktop including HPC	GC	M	1.0
E1.3	Tool should incorporate data from www	GC	M	1.0
E1.4	Tool available for download from web	GC	M	1.0
E1.5	Ability to benefit from programs that move research results into practice and obtain training	GC	M	
E2	**Ability to select from different Input Motion Options**	SP	M	1.0
E2.1	Ability to select from Multiple input motions and view UQ due to all the discrete events	GC	M	1.0
E2.2	Ability to select from list of SimCenter motions	SP	M	1.0
E2.3	Ability to select from list of PEER motions	SP	D	1.0
E2.4	Ability to use OpenSHA and selection methods to generate motions	UF	D	1.0
E2.5	Ability to Utilize Own Application in Workflow	SP	M	1.0
E2.6	Ability to use Broadband	SP	D	
E2.7	Ability to include Soil Structure Interaction Effects	GC	M	1.1
E2.7.1	1D nonlinear site response with effective stress analysis	SP	M	1.1
E2.7.2	Nonlinear site response with bidirectional loading	SP	M	1.2
E2.7.3	Nonlinear site response with full stochastic characterization of soil layers	SP	M	
E2.7.4	Nonlinear site response, bidirectional different input motions	SP	M	
E2.7.5	Ability to couple models from point of rupture through rock and soil into structure, which represents future of professional design practice	GC	M	
E2.7.5.1	Interface using DRM method	SP	M	
E2.8	Utilize PEER NGA www ground motion selection tool	UF	D	2.0

E2.9	Ability to select from synthetic ground motions	SP	M	1.0
E2.9.1	per Vlachos, Papakonstantinou, Deodatis (2017)	SP	D	1.1
E2.9.2	per Dabaghi, Der Kiureghian (2017)	UF	D	2.0
E3	**Ability to select different Building Model Generators**	GC	M	1.0
E3.1	Ability to quickly create a simple nonlinear building model for simple methods of seismic evaluation	GC 2.T13	D	1.1
E3.2	Ability to use existing OpenSees model scripts	SP	M	1.0
E3.3	Ability to define building and use Expert System to generate FE mesh	SP		
E3.3.1	Expert system for Concrete Shear Walls	SP	M	
E3.3.2	Expert system for Moment Frames	SP	M	
E3.3.3	Expert system for Braced Frames	SP	M	
E3.4	Ability to define building and use Machine Learning applications to generate FE	GC		
E3.4.1	Machine Learning for Concrete Shear Walls	SP	M	
E3.4.2	Machine Learning for Moment Frames	SP	M	
E3.4.3	Machine Learning for Braced Frames	SP	M	
E3.5	Ability to specify connection details for member ends	UF	M	2.2
E3.6	Ability to define a user-defined moment-rotation response representing the connection details	UF	D	2.2
E4	**Ability to select from different Nonlinear Analysis options**	GC	M	1.0
E4.1	Ability to specify OpenSees as FEM engine and to specify different analysis options	SP	M	1.0
E4.2	Ability to provide own OpenSees Analysis script to OpenSees engine.	SP	D	1.0
E4.3	Ability to provide own Python script and use OpenSeesPy engine.	SP	O	1.2
E4.4	Ability to use alternative FEM engine.	SP	M	2.0
E5	**Engineering Demand Parameters**	SP	M	
E5.1	Ability to specify standardized set of outputs	SP	M	1.0
E5.2	Ability to Process own Output Parameters	UF	M	1.1
E5.3	Add to Standard Earthquake a variable indicating analysis failure	UF	D	
U	**Ability to use various UQ Methods**	GC	M	
U1	**Forward Propogation Methods**	GC	M	1.0
U1.1	Ability to use basic Monte Carlo and LHS methods	SP	M	1.0
U1.2	Ability to use Importance Sampling	SP	M	2.0

U1.3	Ability to use Gaussian Process Regression	SP	M	2.0
U1.4	Ability to use Own External UQ Engine	SP	M	
U2	**Ability to use various Reliability Methods**	UF	M	1.0
U2.1	Ability to use First Order Reliability method	UF	M	
U2.2	Ability to use Second Order Reliability method	UF	M	
U2.2	Ability to use Surrogate Based Reliability	UF	M	
U2.3	Ability to use Own External Application to generate Results	UF	M	
U3	**Ability to user various Sensitivity Methods**	UF	M	1.0
U3.1	Ability to obtain Global Sensitivity Sobol's indices	UF	M	
U4	**Various Random Variable Probability Distributions**	SP	M	1.0
U4.1	Ability to Define Variables of different types:	SP	M	1.0
U4.1.1	Normal	SP	M	1.0
U4.1.2	Lognormal	SP	M	1.0
U4.1.3	Uniform	SP	M	1.0
U4.1.4	Beta	SP	M	1.0
U4.1.5	Weibull	SP	M	1.0
U4.1.6	Gumbel	SP	M	1.0
U4.2	User defined Distribution	SP	M	
U4.3	Define Correlation Matrix	SP	M	
U4.4	Random Fields	SP	M	
EE	**Ability to obtain Educational material**			
EE1	Ability to use educational provisions to gain interdisciplinary education so as to gain expertise in earth sciences and physics, engineering mechanics, geotechnical engineering, and structural engineering in order to be qualified to perform these simulations	GC	D	
EE2	Documentation exists on tool usage	SP	M	1.1
EE3	Video Exists demonstrating usage	SP	M	1.1
EE4	Verification Examples Exist	SP	M	1.1
WE5	Validation Examples Exist, validated against tests or other software	GC	M	
EM	**Misc.**			
EM1	Tool to allow user to load and save user inputs	SP	M	1.0
EM2	Add to Standard Earthquake a variable indicating analysis failure	UF	D	
EM3	Installer which installs application and all needed software	UF	M	

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2.2.4 quoFEM

The following are the requirements are being for the quoFEM application. quoFEM is an application proving UQ and Optimization methods to existing FEM applications. uqFEM has a lower level interface to UQ and Optimization methods than the other applications (WE-UQ, EE-UQ, and PBE). It is thus a more powerful tool providing more capabilities for researchers. All requirements in this section are related to work in WBS 1.3.8.

Table 2.5: Reuirements for quoFEM

#	Description	Source	Priority	Version
Q1	A tool that facilitates civil engineers performing UQ methods and provides a platform for those in UQ to promote their research to a broader audience	SP	M	1.0
Q1.1	Ability to utilize existing open-source software for faster deployment	SP	M	1.0
Q1.2	Ability to extend to multiple UQ engines”	SP	M	
Q1.3	Ability to utilize resources beyond the desktop, e.g. HPC, for computations	SP	M	1.0
Q2	**Forward Uncertainty Propagation**	SP		
Q121	Input uncertainty characterization	SP	M	1.1
Q2.2	PDF Approximation	SP	M	1.1
Q2.3	Descriptive output statistics	SP	M	1.1
Q2.4	Basic Monte Carlo Sampling	SP	M	1.1
Q2.5	Importance Sampling for rare events	SP	M	2.0
Q2.6	Cross-Entropy sampling	SP	M	
Q2.7	Forward Propagation, GPR Surrogate	SP	M	2.0
Q2.8	Forward Propagation, PCE Surrogate	SP	M	2.0
Q2.9	Multi-fidelity sampling	SP	M	
Q2.10	Spatial/temporal stochastic models	SP	M	
Q3	**Sensitivity Analysis**			
Q3.1	Global sensitivity Sobol’s indices	SP	M	2.0
Q4	**System Identification and Bayesian Inference**			
Q4.1	Parameter estimation	SP	M	
Q4.2	Basic Bayesian parameter updating	SP	M	
Q4.3	Advanced MCMC-based Bayesian updating	SP	M	
Q4.4	Advanced Surrogate-based Bayesian updating	SP	M	
Q4.5	Model class selection	SP	M	
Q4.6	Sequential Bayesian updating	SP	M	
Q5	**Optimization under Uncertainty**			
Q5.1	Reliability-Based Design Optimization	SP	M	

Q5.2	Single-objective optimization under uncertainty	SP	M	
Q5.3	Multi-objective optimization under uncertainty	SP	M	
Q6	**Reliability Analysis**			
Q6.1	First/Second Order Reliability Methods	SP	M	2.0
Q6.2	Surrogate-based reliability	SP	M	2.0
QE	**Ability to obtain Educational material**	SP	M	1.0
QE1	Documentation exists on tool usage	SP	M	1.0
QE2	Video Exists demonstrating usage	SP	M	1.0
QE3	Verification Examples Exist	SP	M	

KEY:
Source: GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Need: M=Mandatory, D=Desirable, P=Possible Future
Version: Version number the basic requirement was met

2.2.5 Performance Based Engineering

The following are the requirements for application(s) related to performance based engineering of a single structure related to natural hazards such as earthquake and hurricane . The requirements are being met by the PBE application. All requirements in this section are related to work in WBS 1.3.9.

Table 2.6: Requirements for PBE

#	Description	Source	Priority	Version
P1	**Ability to determine damage and loss calculations for a building subjected to a natural hazard including formal treatment of randomness and uncertainty uncertainty**	GC	M	1.0
P1.1	Ability to determine damage and loss for multiple different hazards	GC	M	
P1.1.1	Damage and Loss for ground shaking due to Earthquake	GC	M	1.0
P1.1.2	Damage and Loss due to Wind Loading	GC	M	
P1.1.3	Damage and Loss due to water damage due to Tsunami or Coastal Inundation	GC	M	
P1.1	Ability of Practicing Engineers to use multiple coupled resources (applications, databases, viz tools) in engineering practice	GC	1.0	
P1.2	Ability to utilize resources beyond the desktop including HPC	GC	M	1.0
P1.3	Tool should incorporate data from WWW	GC	M	1.0
P1.4	Tool available for download from web	GC	M	1.0
P1.5	Ability to use new viz tools for viewing large datasets generated by PBE	GC	M	1.0
P2	**Various Motion Selection Options for Hazard Event**	SP	M	1.0
P2.1	Various Earthquake Events	SP	M	1.0
P2.1	Ability to select from all EE-UQ Event Options listed in EE-UQ E2	SP	M	1.0
P2.2	Various Wind Loading Options	SP	M	
P2.1	Ability to select from all WE-UQ Event Options listed in WE-UQ W2	SP	M	1.0
P2.3	Various Water Loading Options	SP	M	
P2.3.1	Ability to select from all HydroUQ Event Options	SP	M	1.0
P3	**Building Model Generation**	GC	M	
P3.1	Ability to Select All Building Model Generators in EE-UQ	SP	M	1.0
3.2	Ability to Select All Building Model Generators in WE-UQ	SP	M	
3.3	Ability to Select All Building Model Generators in HydroUQ	SP	M	

P4	**Perform Nonlinear Analysis**	GC	M	1.0
P4.1	Ability to specify OpenSees as FEM engine and to specify different analysis options	SP	M	1.0
P4.2	Ability to provide own OpenSees Analysis script to OpenSees engine.	SP	D	1.0
P4.3	Ability to provide own Python script and use OpenSeesPy engine.	UF	O	
P4.4	Ability to use alternative FEM engine.	SP	M	2.0
P5	**Uncertainty Quantification Methods**	GC	M	1.0
P5.1	Ability to use all forward propogation methods available in EE-UQ and WE-UQ section U1	SP	M	1.0
P6	**Random Variables for Uncertainty Quantification**	GC	M	1.0
P6.1	Ability to use all random variable distributions in EE-UQ and WE-UQ section U4	SP	M	1.0
P8	**Engineering Demand Parameters**			
P8.1	Ability to Process own Output Parameters	UF	M	
P8.2	Add to Standard Earthquake a variable indicating analysis failure	UF	D	
P8.3	Allow users to provide their own set of EDPs for the analysis.	UF	D	2.0
P9	**Damage and Loss Assessment**	GC	M	1.0
P9.1	Different Assessment Methods	GC	M	2.0
P9.1.1	Ability to perform component-based (FEMA P58) loss assessment for an earthquake hazard.	SP	M	1.0
P9.1.2	Ability to perform component-assembly-based (HAZUS MH) loss assessment for an earthquake hazard.	SP	D	1.1
P9.1.3	Ability to perform downtime estimation using the REDi methodology.	UF	D	
P9.1.4	Ability to describe building performance with additional decision variables from HAZUS (e.g., business interruption, debris)	SP	D	
P9.1.5	Ability to perform time-based assessment	GC	M	
P9.1.6	Ability to perform damage and loss assessment for hurricane wind	GC	M	
P9.1.7	Ability to perform damage and loss assessment for storm surge	GC	M	
P9.2	Control	SP	M	1.0
P9.2.1	Allow users to set the number of realizations	SP	M	1.0
P9.2.2	Allow users to specify the added uncertainty to EDPs	SP	M	1.0
P9.2.3	Allow users to decide which decision variables to calculate	SP	D	1.0

P9.2.4	Allow users to set the number of inhabitants on each floor and customize their temporal distribution.	SP	D	1.0
P9.2.5	Allow users to specify the boundary conditions of repairability.	SP	D	1.0
P9.2.6	Allow users to control collapse through EDP limits.	SP	D	1.0
P9.2.7	Allow users to specify the replacement cost and time for the building.	SP	M	1.0
P9.2.8	Allow users to specify EDP boundaries that correspond to reliable simulation results.	SP	D	1.0
P9.2.9	Allow users to specify collapse modes and characterize the corresponding likelihood of injuries.	SP	D	1.0
P9.2.10	Allow users to specify the collapse probability of the structure.	UF	M	1.2
P9.2.11	Allow users to use empirical EDP data to estimate the collapse probability of the structure.	UF	M	1.2
P9.2.12	Allow users to choose the type of distribution they want to estimate the EDPs with.	UF	D	1.2
P9.2.13	Allow users to perform the EDP fitting only for non-collapsed cases.	UF	M	1.2
P9.2.14	Allow users to couple response estimation with loss assessment.	UF	M	
P9.3	Component damage and loss information	SP	M	1.0
P9.3.1	Make the component damage and loss data from FEMA P58 available.	SP	M	1.0
P9.3.2	Ability to use custom components for loss assessment.	SP	D	1.0
P9.3.3	Allow users to set different component quantities for each floor in each direction.	SP	D	1.0
P9.3.4	Allow users to set the number of identical component groups and their quantities within each performance group.	UF	D	1.0
P9.3.5	Use a generic JSON data format for building components that can be shared by component-based and component-assembly-based assessments.	SP	D	1.1
P9.3.6	Convert FEMA P58 and HAZUS component damage and loss data to the new JSON format and make it available with the tool.	SP	D	1.1
P9.3.7	Make component definition easier by providing a list of available components in the given framework (e.g. FEMA P58 or HAZUS) and not requesting inputs that are already available in the data files.	UF	D	1.2

P9.3.8	Make the component damage and loss data from FEMA P58 2nd edition available.	UF	M	2.0
P9.3.9	Improve component definition by providing complete control over every characteristic on every floor and in every direction	UF	D	2.0
P9.3.10	Allow users to view fragility and consequence functions in the application	UF	D	
P9.3.11	Allow users to edit fragility and consequence functions in the application	UF	D	
P9.4	Stochastic loss model	SP	M	1.0
P9.4.1	Allow the user to specify basic dependencies (i.e. independence or perfect correlation) between logically similar parts of the stochastic model (i.e. within component quantities or one type of decision variable, but not between quantities and fragilities)	SP	D	1.0
P9.4.2	Allow the user to specify basic dependencies between reconstruction cost and reconstruction time.	SP	D	1.0
P9.4.3	Allow the user to specify basic dependencies between different levels of injuries.	SP	D	1.0
P9.4.4	Allow the user to specify intermediate levels of correlation (i.e. not limited to 0 or 1) and provide a convenient interface that makes sure the specified correlation structure is valid.	SP	D	
P9.4.5	Allow the user to specify the correlation for EDPs.	SP	D	
PM	**Misc.**	UF	M	1.2
PM.1	Tool to allow user to load and save user inputs	SP	M	1.0
PM.2	Simplify run local and run remote by removing workdir locations. Move to preferences	UF	D	1.2
P M.3	Add to EDP a variable indicating analysis failure	UF	D	
PM.4	Installer which installs application and all needed software	UF	M	
PE	**Ability to gain educational materials that will help and encourage PBE**	GC	M	1.0
PE.1	Documentation exists on tool usage	SP	M	1.1
PE.2	Video Exists demonstrating usage	SP	M	1.1
PE.3	Verification Examples Exist	SP	M	1.1
PE.4	Validation Examples Exist, validated against tests or other software	GC	D	

KEY:
Source: GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Need: M=Mandatory, D=Desirable, P=Possible Future
Version: Version number the basic requirement was met

2.3 Education

The following are educational activities obtained that are related to software development.

Table 2.7: Requirements for Educational Software Components

#	Description	SRC	WBS	PRI	VER
ED1	Ability to obtain education w.r.t. interaction of structure and wind and water	GC		D	
ED2	Ability to use reference datasets from experimental tests for analysis comparisons to increase confidence in numerical simulations; ability to gain understanding of nonlinear response of materials, components, and framing systems using integrated laboratory research and numerical simulation	GC	1.3.11	M	1.0
ED2.1	Ability for Braced Frames	SP	1.3.11 BFM	D	1.0
ED2.2	Ability to gain such for Concrete Shear Walls	SP	1.3.11 SWIM	D	1.0
ED2.3	Ability for Columns utilizing PEER database	SP	1.3.11	D	
ED2.4	Ability for moment frames using Japanese test data	SP	1.3.11	D	

KEY:
Source (SRC): GC=Needed for Grand Challenges, SP=Senior Personnel, UF=User Feedback
Work Breakdown Structure (WBS): SimCenter WBS Number
Priority (PRI): M=Mandatory, D=Desirable, P=Possible Future
Version (VER): Version number the basic requirement was first met