FIU | Wall of Wind

NHERI Experimental Facility

SimCenter NHERI

Center for Computational Modeling and Simulation

Overview of Computational Workflow for Regional and Building-Level Simulations

Speaker: Tracy Kijewski-Correa
University of Notre Dame

August 10, 2020
11:40 am – 12:00 pm PDT
2:40 pm -3:00 pm EDT

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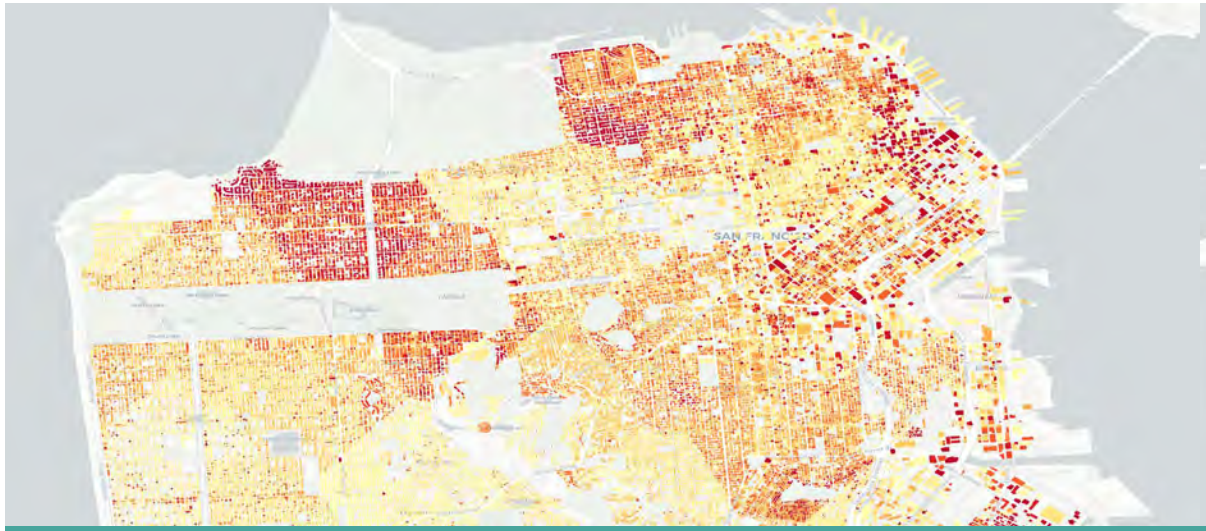
Why Testbeds?

- **Creates computational scaffolding** upon which community developers can contribute to increase workflow fidelity
- **Demonstrates integration** of SimCenter tools and best-of-breed software
- End-to-end simulation creates need for **diverse expertise/contributions** from research community
- **Broaden impacts** of isolated research contributions
- Illuminates deficits in data, models and simulation capabilities for **next-generation research**
- Demonstrates **societal impacts**, encouraging uptake by decision makers
- **Spurs collaboration** around grand challenge of advancing state-of-the-art in risk assessment

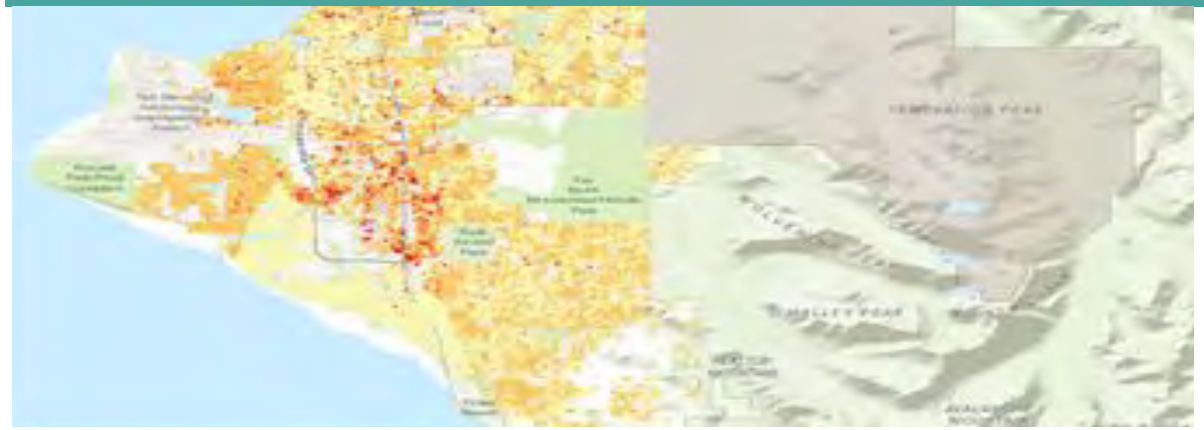
Current Testbeds

San Francisco



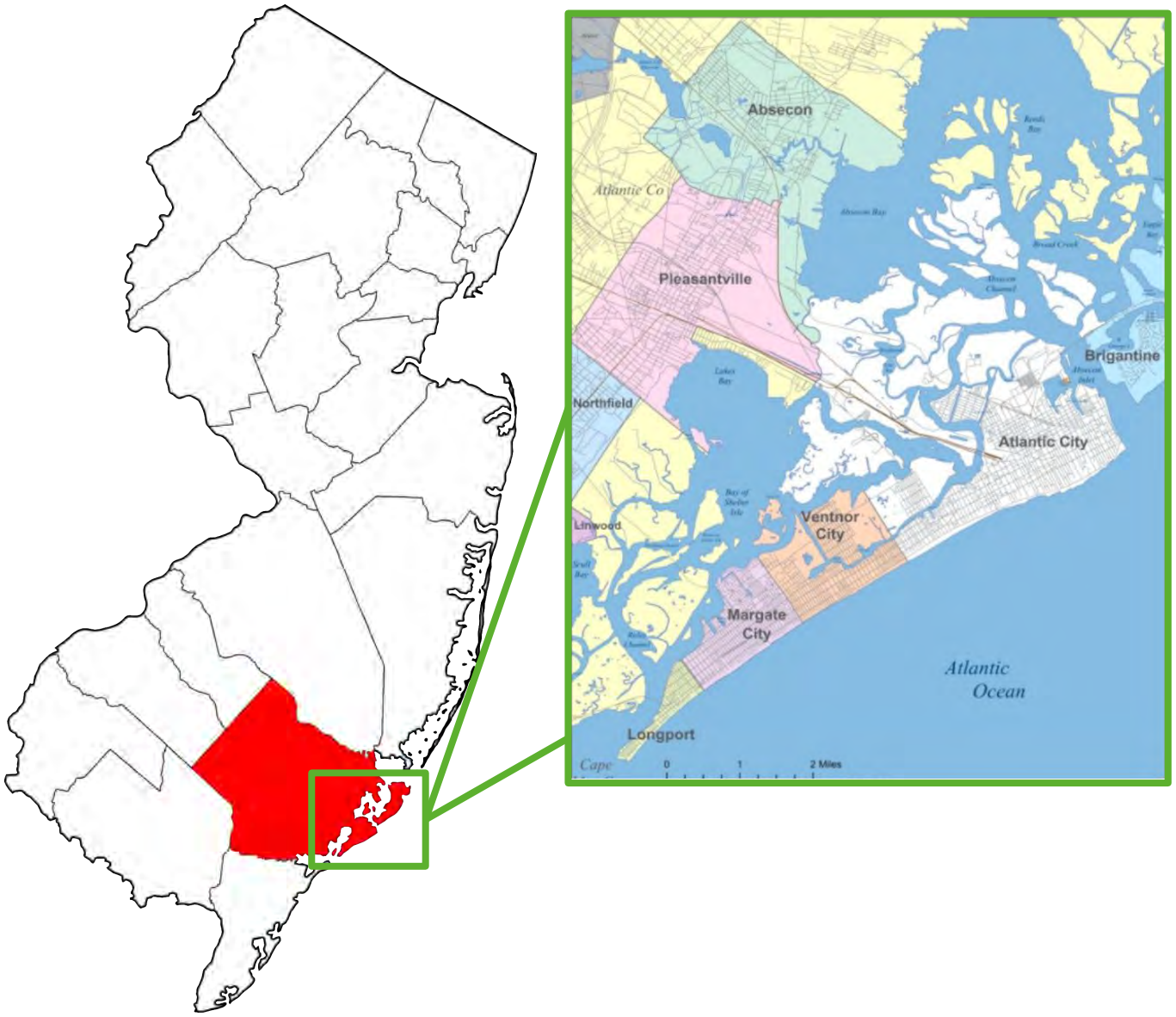
Oakland-Alameda

Anchorage

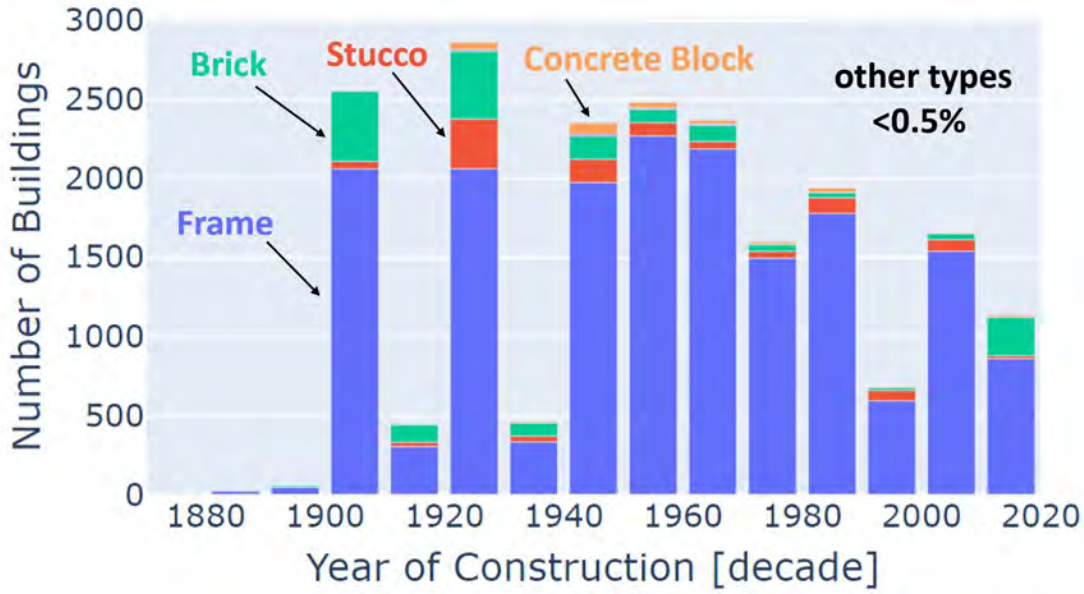


Advancement: increased granularity of risk assessments (from census blocks to parcel-scale) for specific building performance, eventually to the component-level

Why Atlantic City?



- **NJcoast:** Existing relationships and surrogate models, opportunities for uptake
- Statewide open data initiatives
- Full spectrum of relevant typologies, low- and high-rise



Supported Hazards

Opportunity to examine a number of intersecting and cascading hazards

Emphasis on hazards creating demands/response along primary load path:

- Wind
- Storm surge
- Wave action

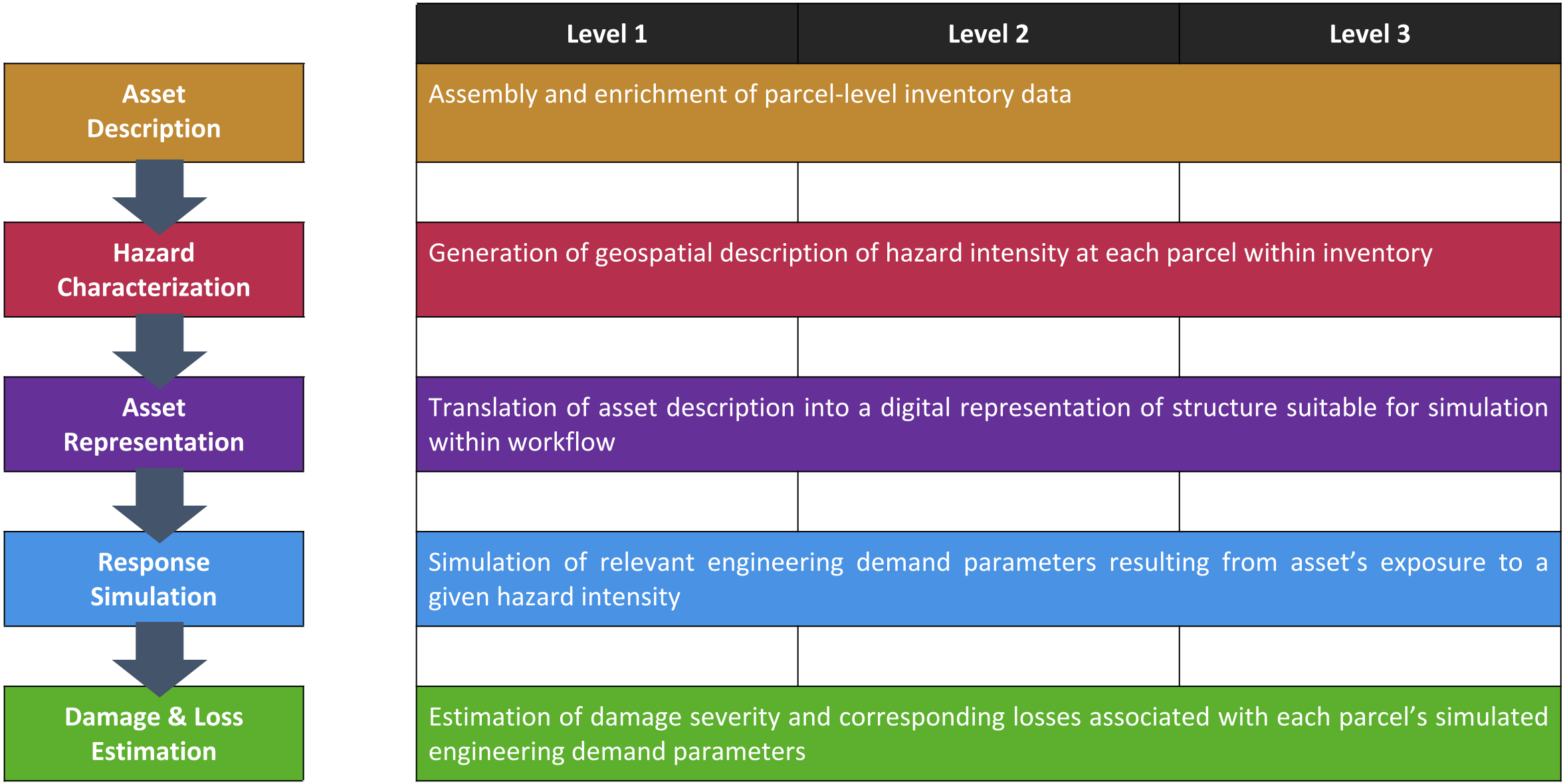
Unsupported hazards:

- Inland flooding

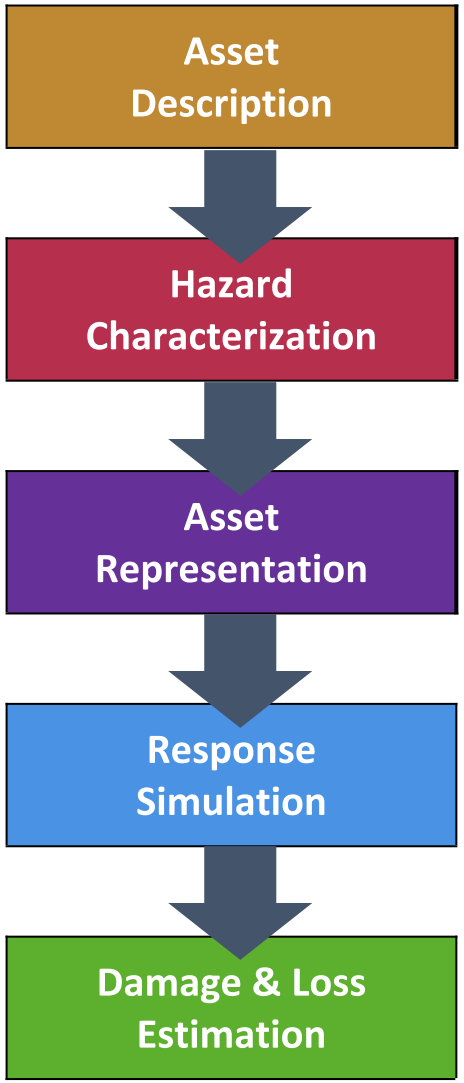
Other considerations captured through descriptions of exposure and vulnerability:

- Water penetration
- Effect of wind-driven debris

Modular Approach

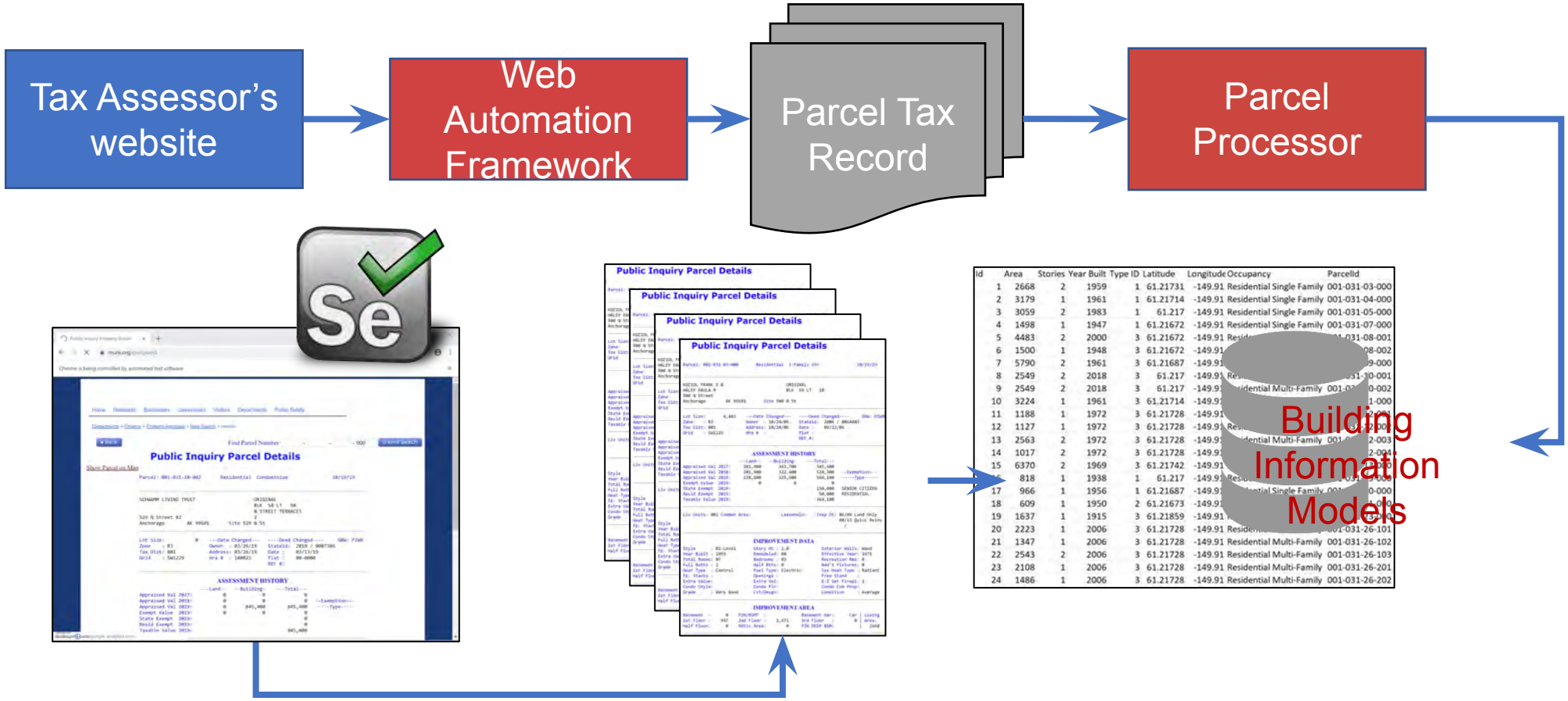


Asset Description



Level 1	Level 2
OBJECTIVE: Assembly and enrichment of parcel-level inventory data	
Augmented Parcel Approach: Large-scale building inventory derived from tax assessor data with: 1. Automated roof classification from imagery (BRAILS) 2. Identification of foundation elevation 3. Data gaps addressed using machine learning (SURF) **SUPPORTING DATABASES** ● Tax Assessor Data ● Imagery data (satellite and streetview) ● Microsoft building footprints	**3D Geometric Description:** Augmented Parcel Approach further enhanced to include additional geometric information: 1. Identification of building surfaces, extraction of dimensions (e.g., roof pitch, eave length) 2. Approximation by equivalent simplified geometry **SUPPORTING DATABASES** ● Tax Assessor Data ● Imagery data (satellite and streetview) ● Microsoft building footprints

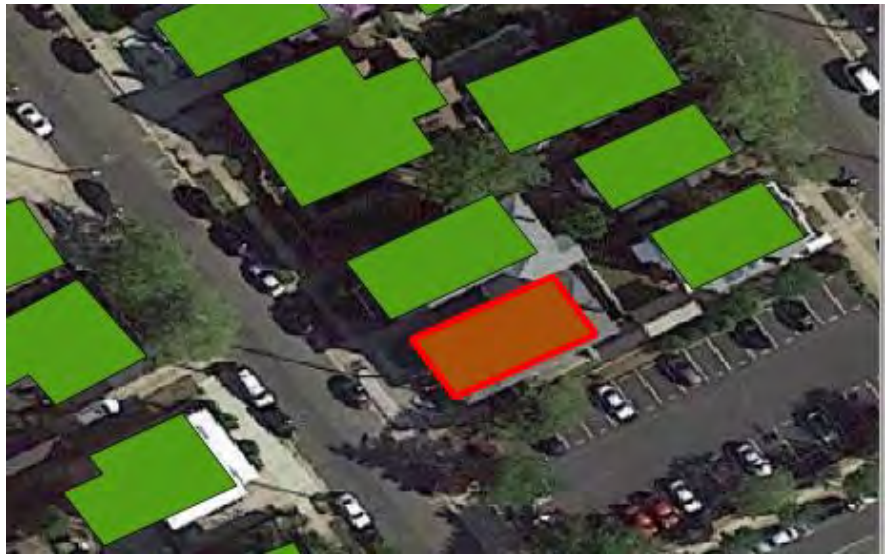
Web Automation: Buildings Inventory



BRAILS (v1.0)

Building Recognition using AI at Large Scale (BRAILS)

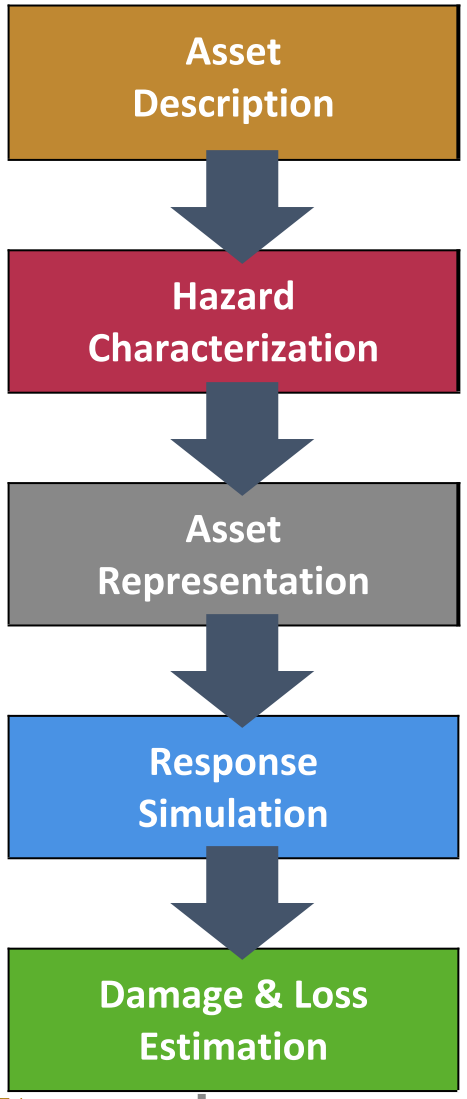
PURPOSE: new AI-enabled tool using machine learning (ML) and deep learning (DL) to create enhanced building inventory databases of cities to assist regional-scale simulations



CAPABILITIES

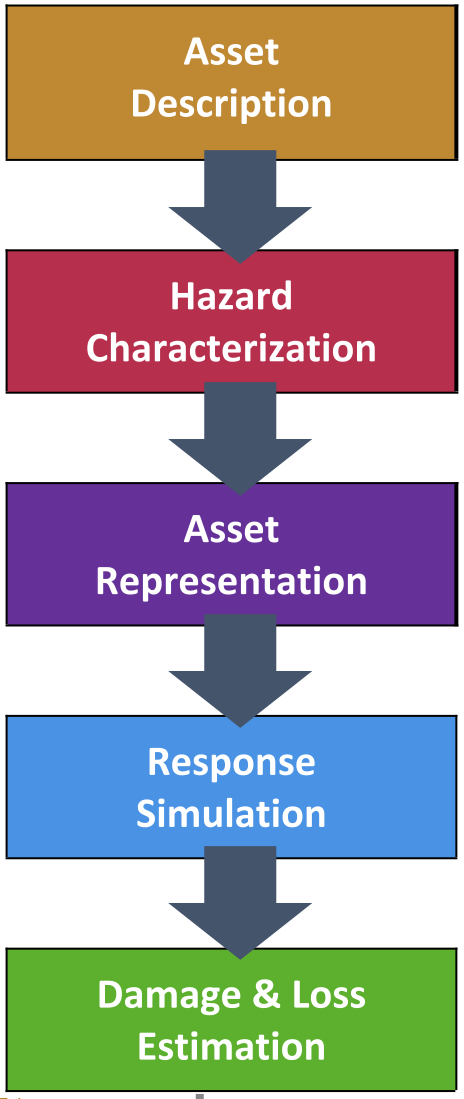
- Identification of roof shapes to improve the damage and loss calculations in hurricane workflows, using data from Open Street Maps and images from Google Maps
- Identification of elevation of lowest structural element to define foundation elevation/type
- Identification of surfaces and openings to extract geometric details

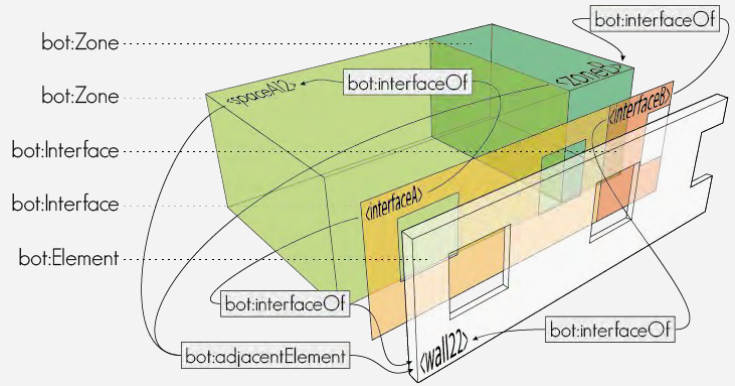
Hazard Characterization



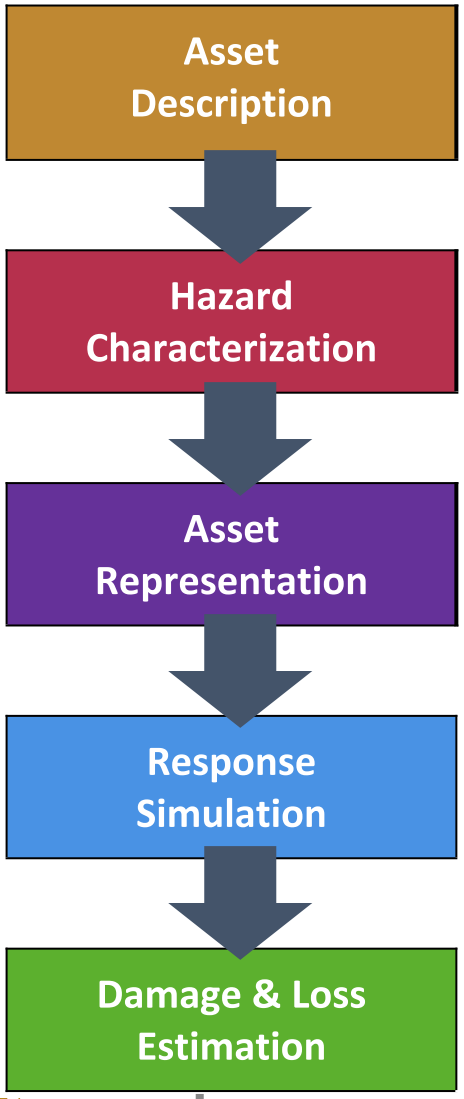
Level 1	Level 2
OBJECTIVE: Generation of geospatial description of hazard intensity at each parcel within inventory	
Pre-Defined Scenarios: Geospatial description of hazard intensity (wind speed, surge depth, LiMWA) mapped to each parcel location: 1. Library of high-fidelity historical and synthetic storm scenarios (Cat 5 AC Scenario, Superstorm Sandy) 2. Design values from prescriptive code and regulatory products **SUPPORTING DATABASES** 1. Land Use/Land Cover, Topobathy DEM 2. Basic wind speeds (ASCE 7-16 via ATC) and Flood Insurance Rate Maps	**User-Defined Simulations:** Access to fast-to-compute models with modifications for site effects 1. Linear analytical wind field model accounting for site-specific exposure 2. Variety of options including XBEACH **SUPPORTING DATABASES** ● Land Use/Land Cover ● Topobathy DEM

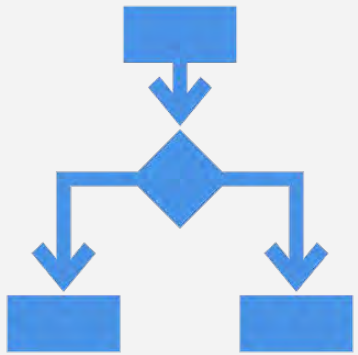
Asset Representation



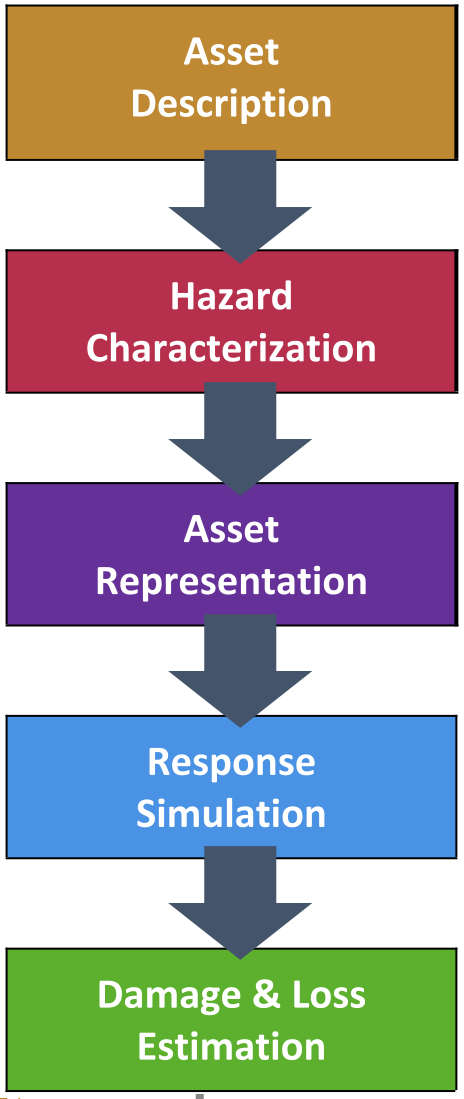
Level 1	Level 2
OBJECTIVE: Translation of asset description into a digital representation of structure suitable for simulation within workflow	
Attribute Assignment: Description of each parcel by HAZUS-specified attributes: 1. Translation of asset description into HAZUS-consistent building classifications 2. For each classification, assignment of HAZUS-required attributes using time-evolving rulesets derived from: a. Augmented parcel data b. Building codes/standards c. Industry trends/norms d. Site-specific hazards, exposure e. Attitudinal/Behavioral data	**Spatial Description:** 3D representation of building envelope & assumed load path using: 1. Standard archetypes (typical geometries) with dimensions 2. Accompanying data model for storing spatial information for surfaces, interfaces (load path) 

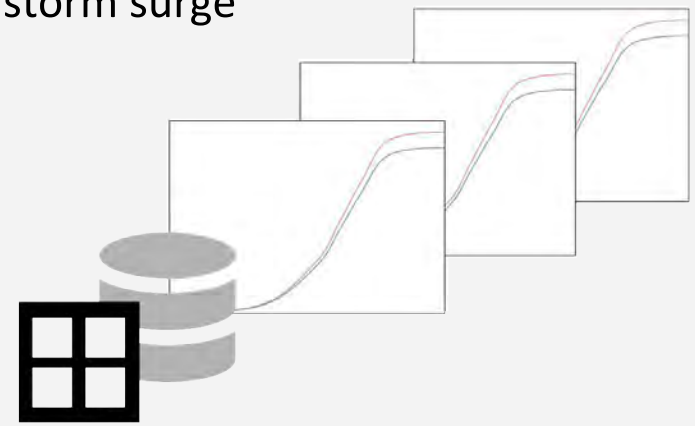
Response Simulation



Level 1	Level 2
OBJECTIVE: Simulation of relevant engineering demand parameters resulting from asset's exposure to a given hazard intensity	
Not applicable. *Hazard Intensity Measures (Hazard Characterization) directly related to Damage/Loss by HAZUS-MH Vulnerability Functions*	**Fault Tree Analysis:** Propagation of failure through load path based on surface pressures/loads derived from Hazard Characterization using: 1. Tokyo Polytechnic University (TPU) Pressure databases [WE UQ] 2. Parametric model for hydrodynamic loads 

Damage & Loss Modeling



Level 1	Level 2
OBJECTIVE: Estimation of damage severity and corresponding losses associated with each parcel's simulated engineering demand parameters	
Vulnerability Description: Direct adoption of HAZUS-MH vulnerability functions, supplemented by other vulnerability descriptions for special cases ▶ Fit normal or lognormal CDFs to HAZUS damage data (more efficient storage, simulation) ▶ Couple loss assessment with damages, find expected loss ratio for each damage state	**Fragility Description:** Component fragility library for placeholder Generic Building Models (GBMs) with cascading damage and accounting for losses driven by wind vs. storm surge 
SUPPORTING DATABASES 1. HAZUS-MH Hurricane Damage and Loss Model (wind and flood)	**SUPPORTING DATABASES** 1. Damage and Loss functions for GBM components (compiled)

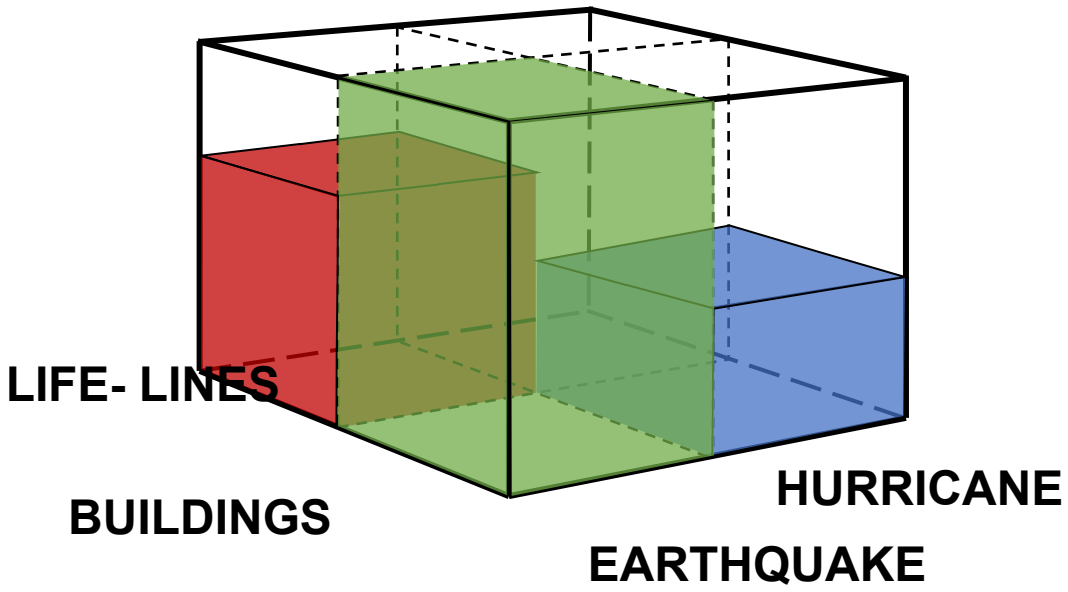
PELICUN (v2.0)

Probabilistic Estimation of Losses, Injuries, and Community resilience Under Natural disasters

PURPOSE: provide multi-hazard, multi-fidelity capabilities to estimate impact of natural hazards on the built environment

CAPABILITIES

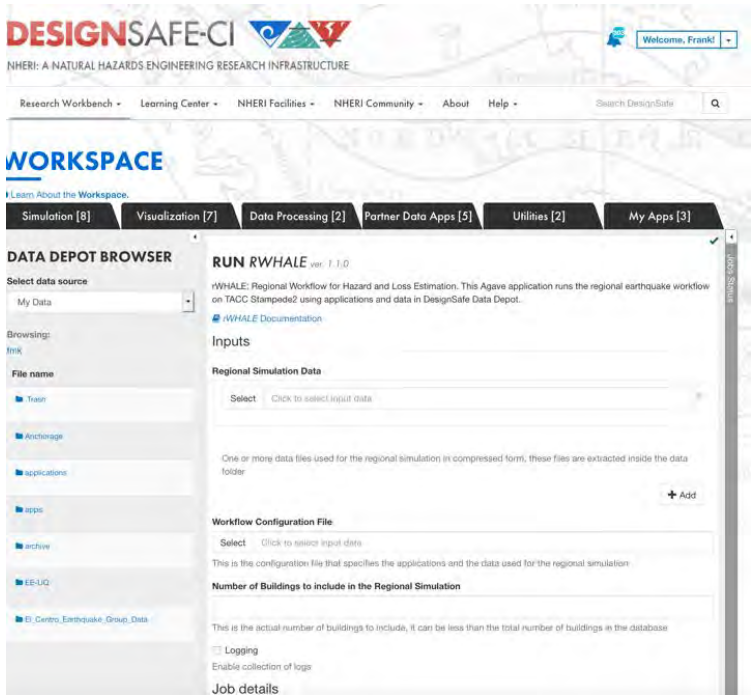
- Damage and loss models for earthquake and wind hazards: HAZUS and FEMA P58
- Database of 8500 building/component configuration files
- Approaches to describe uncertainty in structural response
- Auto-population feature for regional simulations
- Integrated into rWHALE



rWHALE (v2.0)

Regional Workflow for Hazard and Loss Estimation

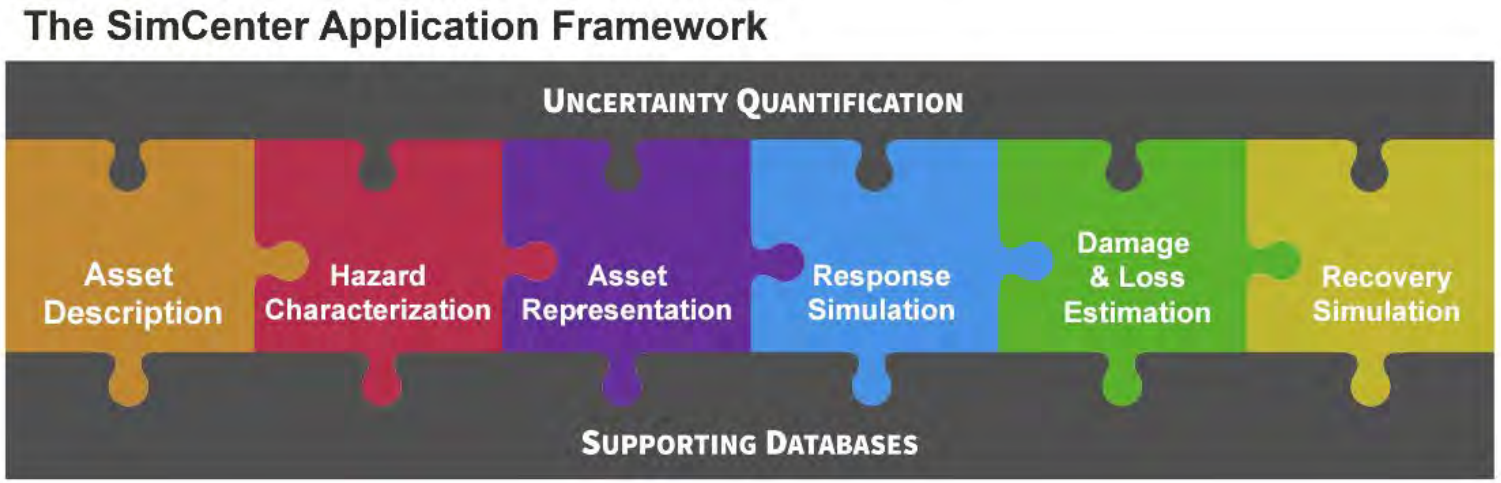
PURPOSE: backend application for simulating regional effects of natural hazards on buildings and infrastructure

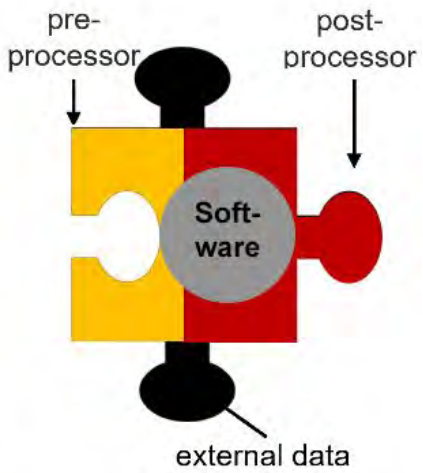


FEATURES

- Currently executes earthquake and hurricane wind simulations
- Pre-packaged version for small-scale simulations on a local computer
- Cloud-based version for large-scale regional simulations on HPC accessible through DesignSafe-CI workspace
- Uses building inventory and hazard data directly from DesignSafe-CI Data Depot

Software Application Framework

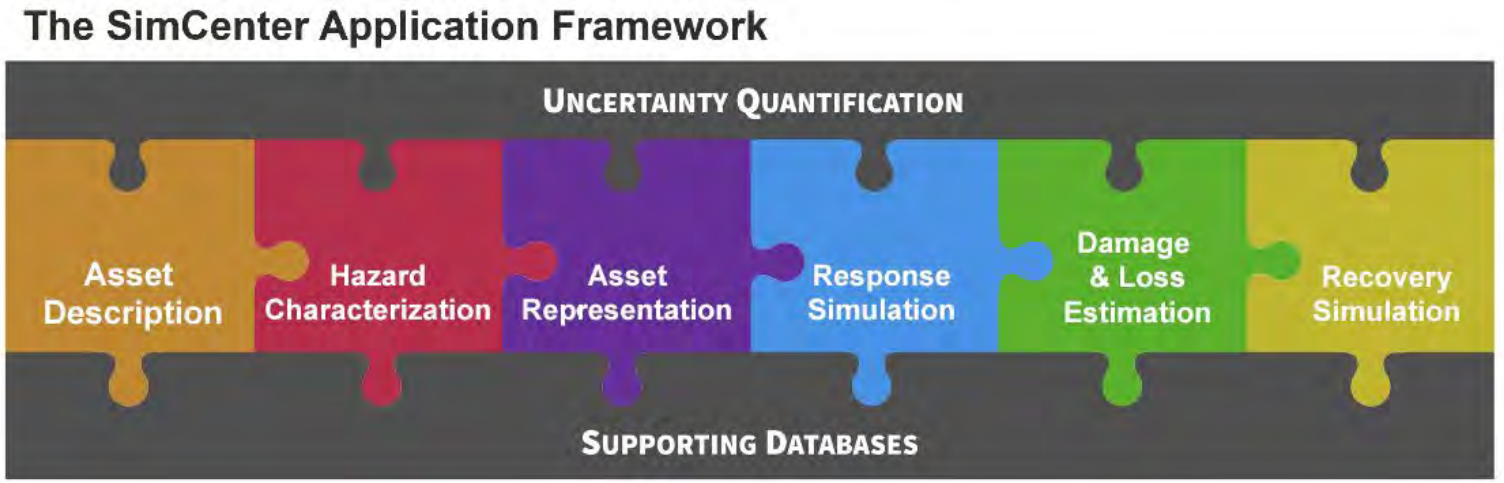


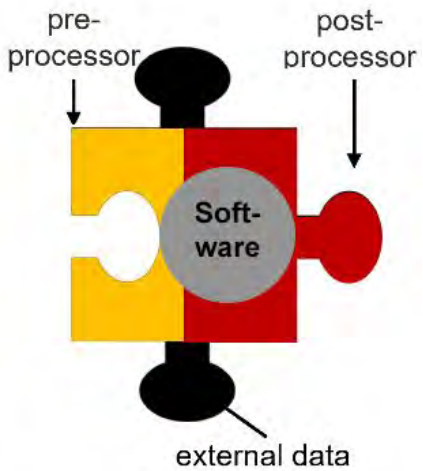


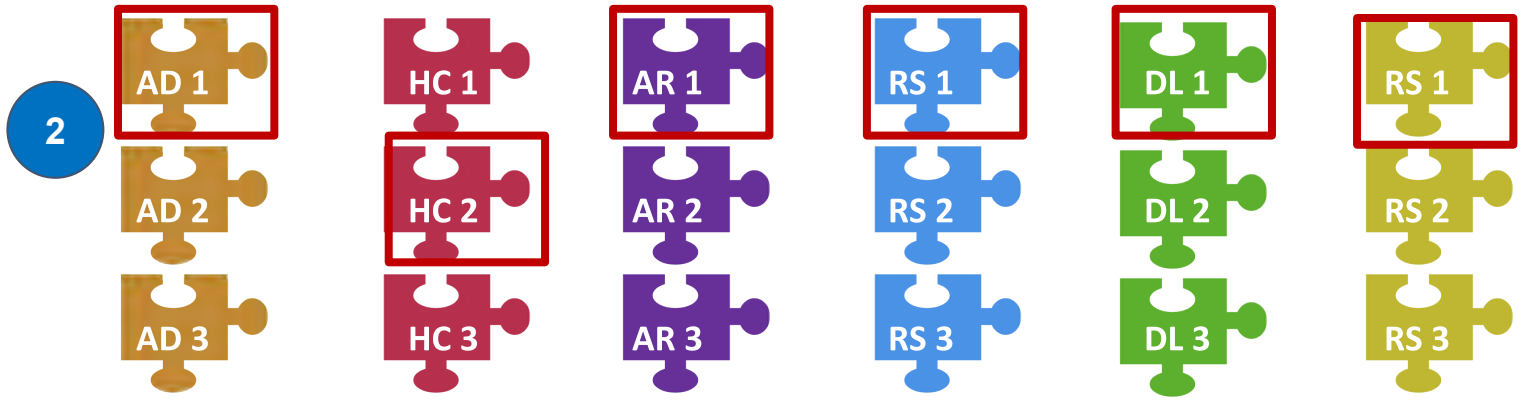
Scientific Workflow Systems: Applications that enable users to build, launch and monitor scientific workflows

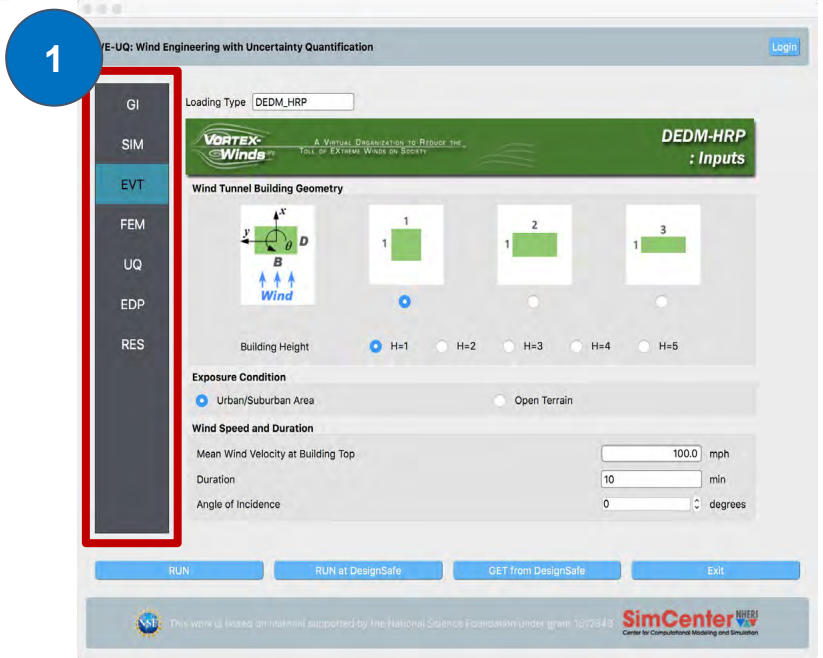
- **automation of process** in which information is passed from one application to the next using **standard interfaces** that also connect **supporting databases** and **UQ modules**
- applications are **modular, extensible** (users introduce preferred applications for each module, leverage existing and newly developed software)
- **scalable:** workflow for single building can be integrated into regional workflows for inventories of buildings

Software Application Framework: Frontend

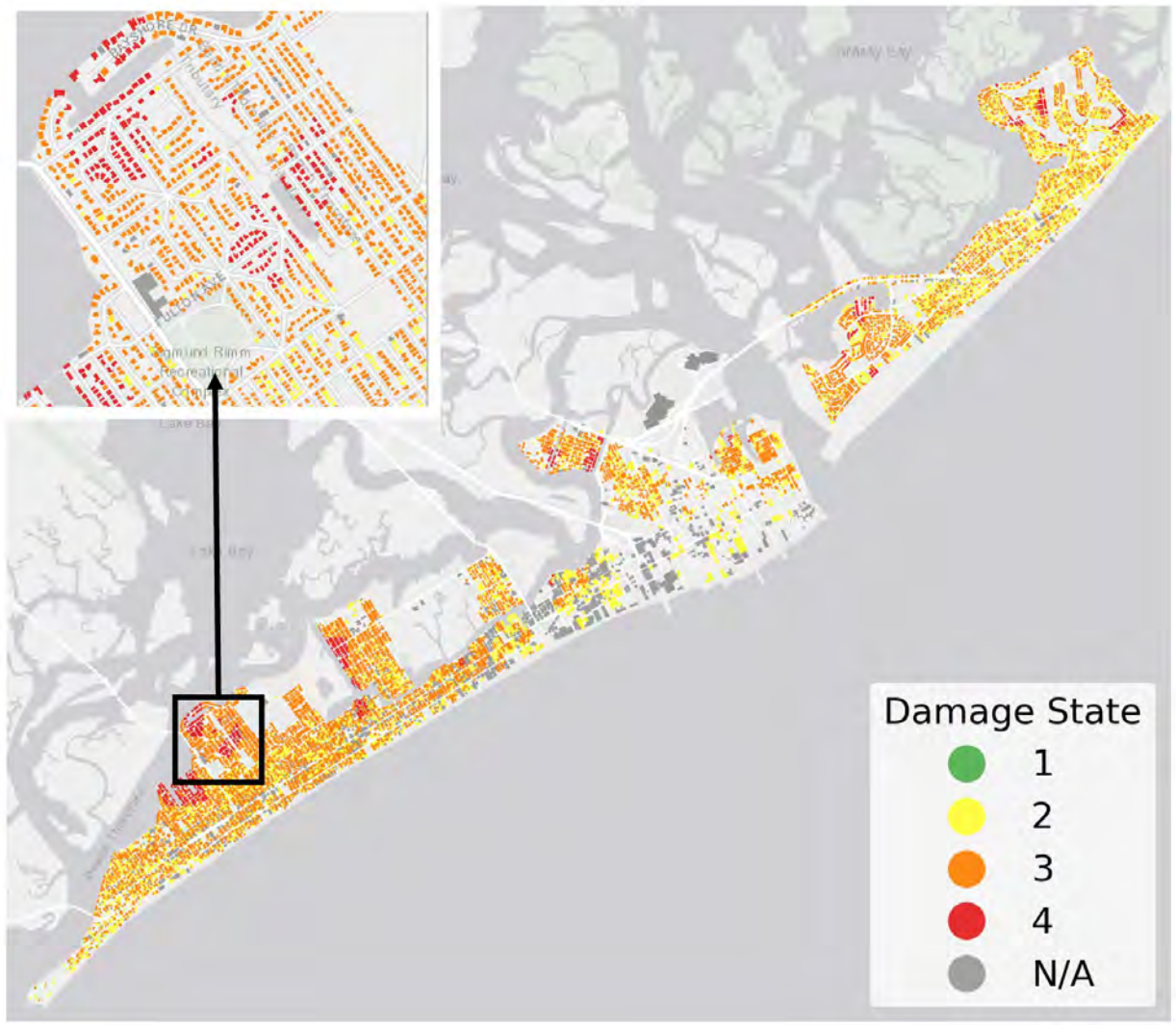


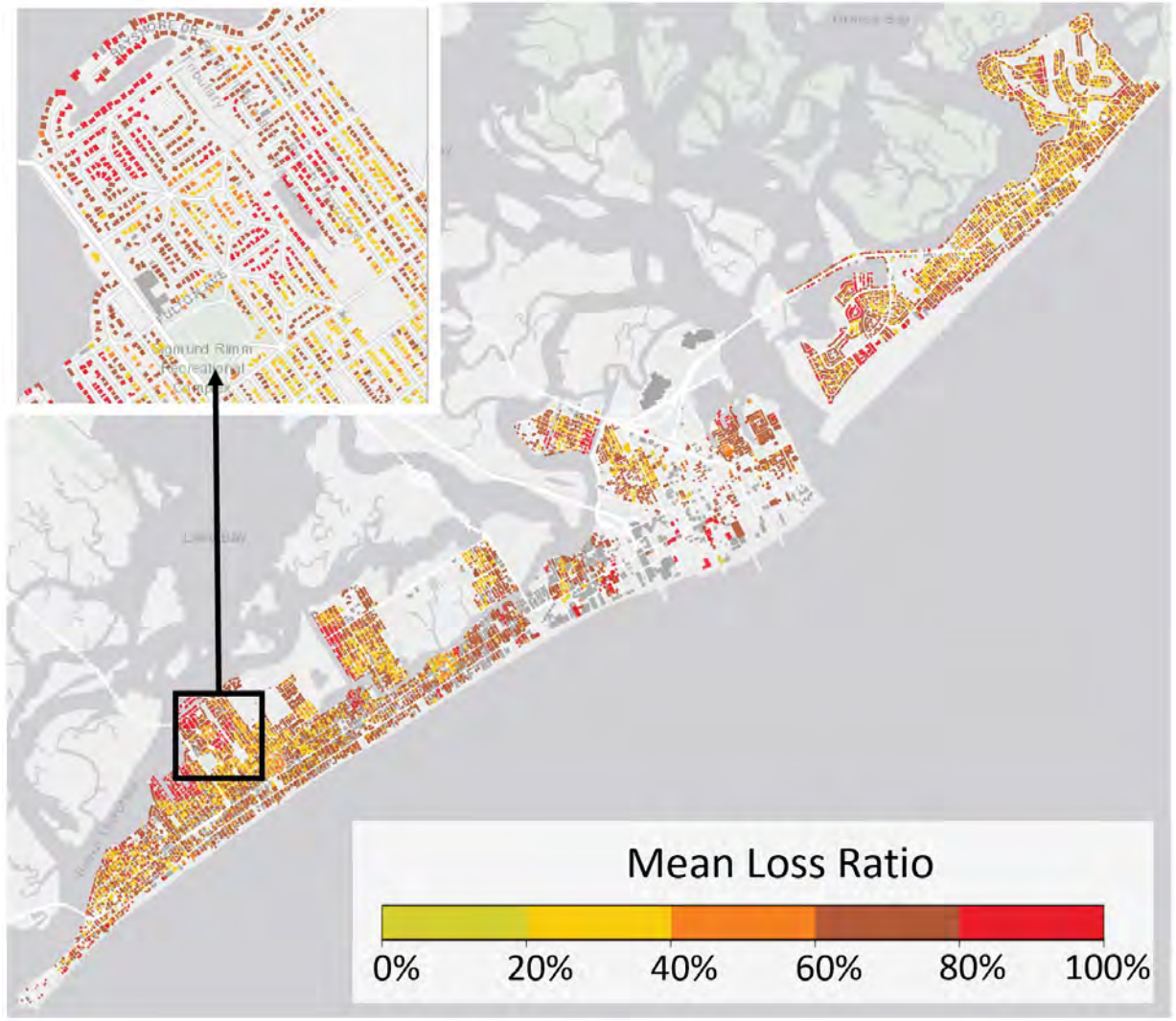






Visualization





Closing

- Democratize access to computational simulation tools
- Products are open and available to everyone
  - http://SimCenter.DesignSafe-CI.org
  - http://github.com/NHERI-SimCenter
- Community-driven software development:
  - Input on workflows, tools needed
  - Contribute products and data