SimCenter NHERI

Center for Computational Modeling and Simulation

2021 AI Bootcamp

Introduction to SimCenter

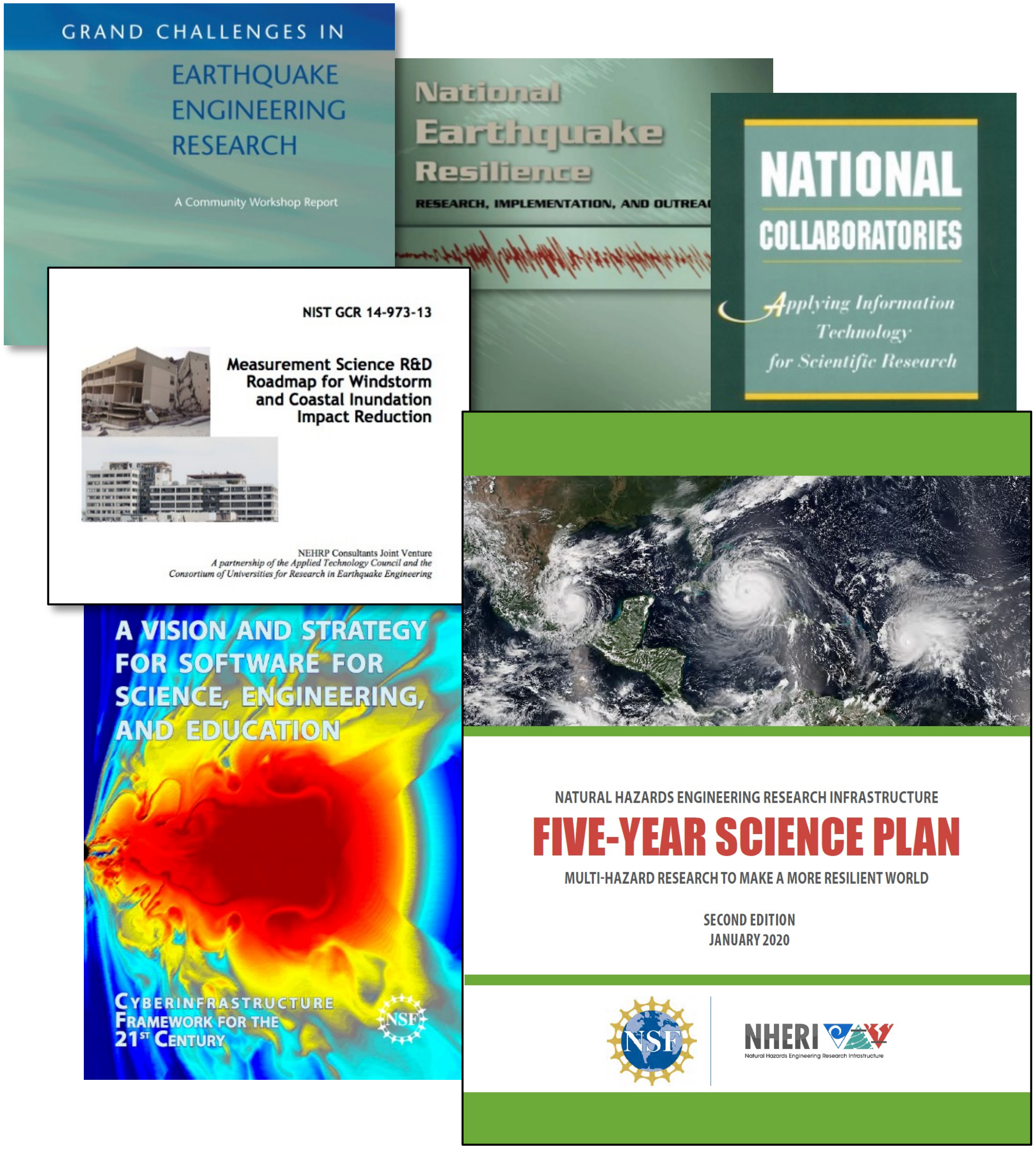
Frank McKenna

University of California, Berkeley

NSF award: CMMI 1612843

NSF's Facilities/Programs

NSF NHERI Science Plan

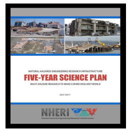


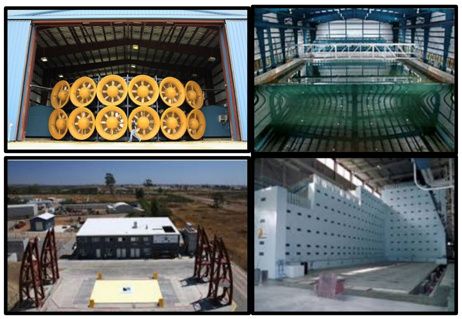
Grand Challenges:

1. Quantify the damaging characteristics of earthquakes, windstorms, and associated hazards—tsunamis, storm surge, and waves
2. Assess the physical vulnerability of civil infrastructure and the social vulnerability of communities
3. Develop technologies and engineering tools to design, construct, retrofit, and operate resilient and sustainable infrastructure

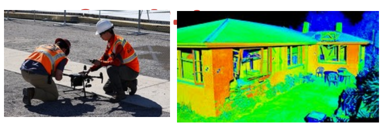
SimCenter Within NHERI

NCO





Experimental



Rapid facility

DESIGNSAFE-CI
A NATURAL HAZARDS ENGINEERING COMMUNITY

Data Storage

HPC

Agave Platform TACC web API

SimCenter NHERI
Center for Computational Modeling and Simulation

Cloud-enabled research applications
Scalable to run on HPC with emphasis on UQ

Front-end

SimCenter Research Applications

uQ FEM PBE EE-UQ CWE-UQ

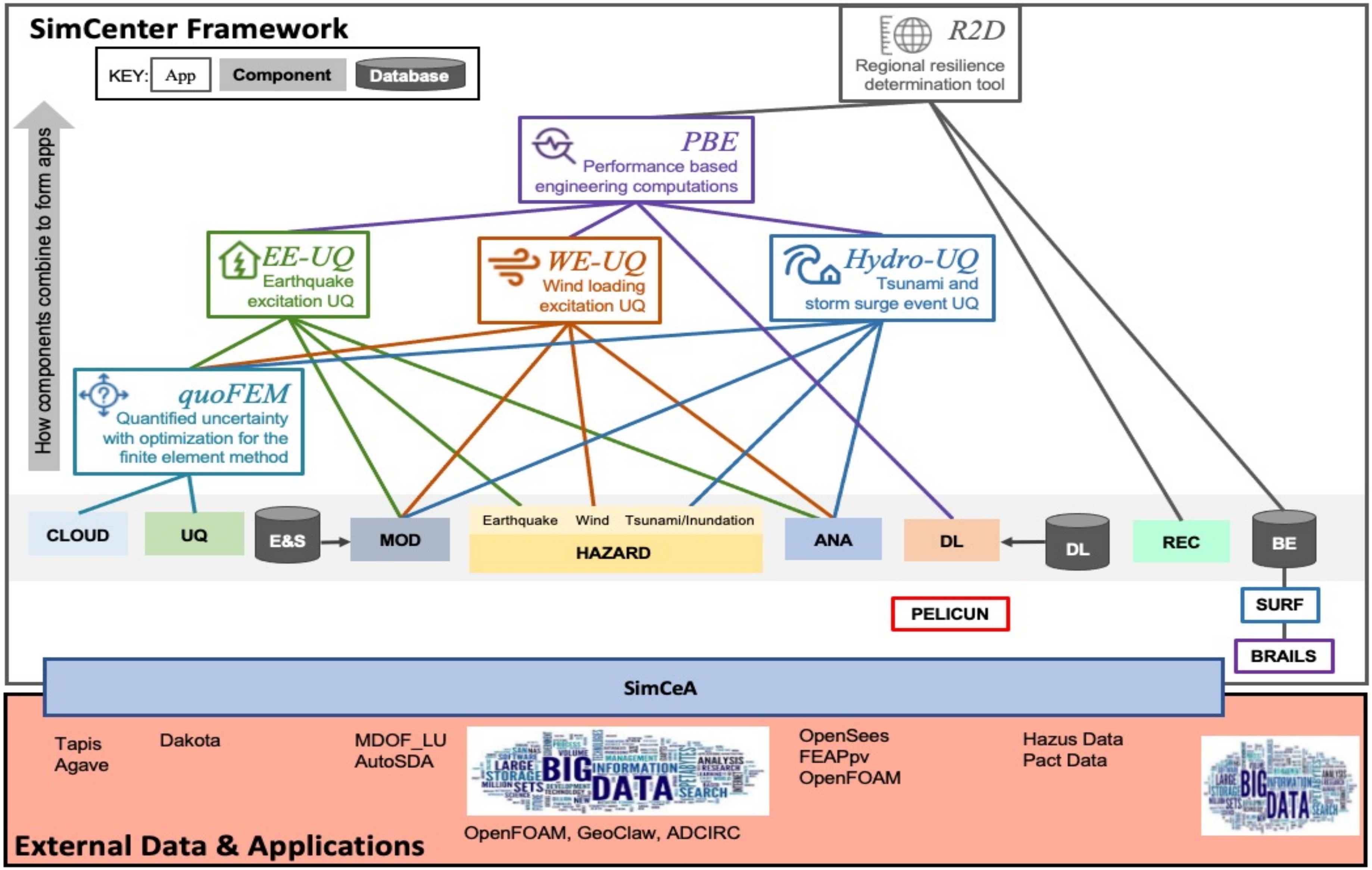
We are a Virtual EF

SimCenter Software Goals

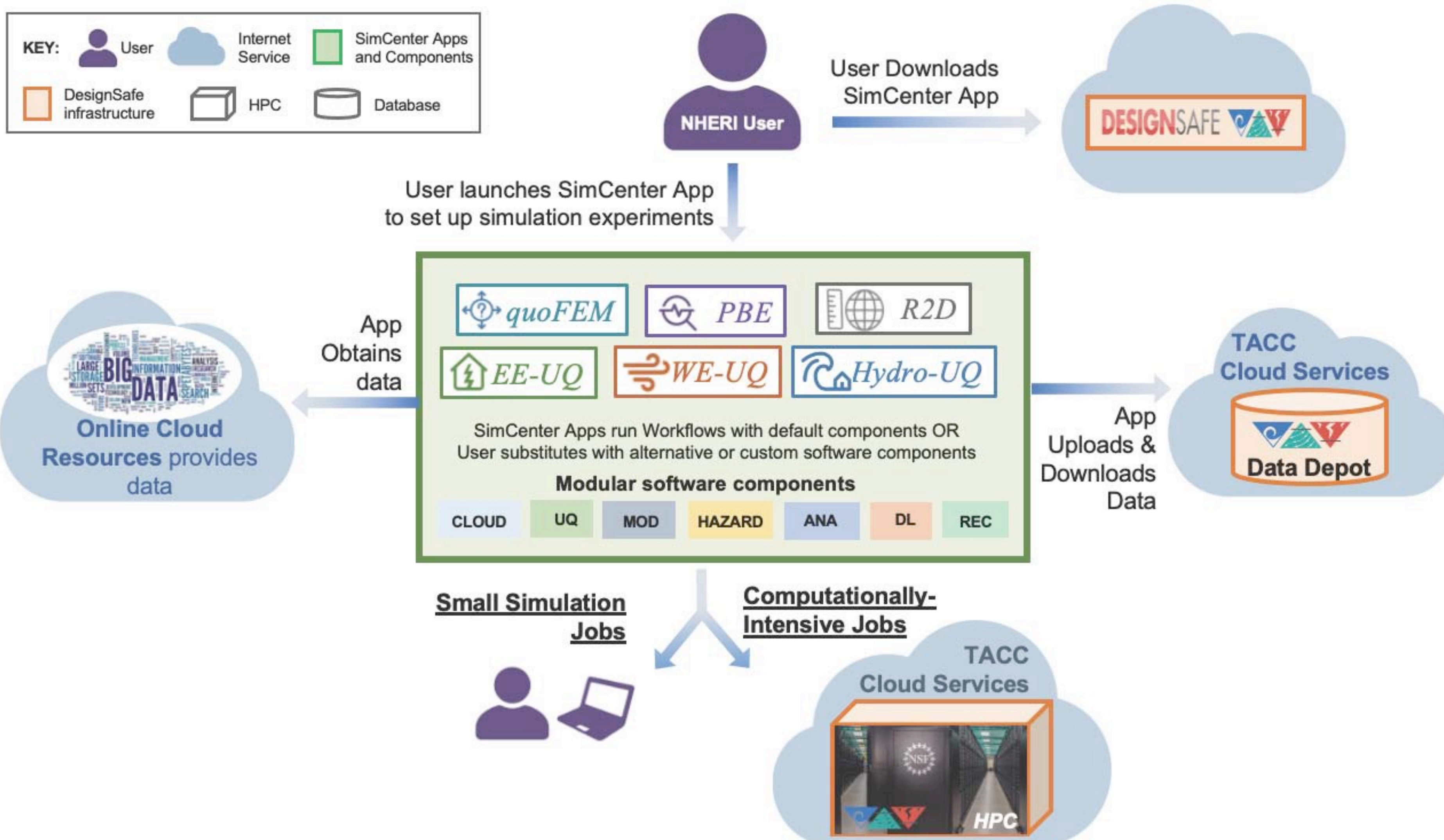
To produce Extensible Software Researchers in NHE can use in their research

- Develop an **open-source computational framework** to support decision-making to enhance community resilience to natural hazards **in the face of uncertainty**;
- **Design a framework** that is sufficiently **flexible, extensible, and scalable** so that any component of it can be enhanced to improve the analysis and thereby better meet the needs of the community;
- **Seed the framework** with enough **data** and **interfaces to existing simulation tools** so that it can be employed in the near-term;
- **Release tools/applications built using this framework** that meets the computational needs of researchers in natural hazards engineering;
- **Provide an ecosystem** that fosters collaboration between scientists, engineers, urban planners, public officials, and others who seek to improve community resilience to natural hazards.

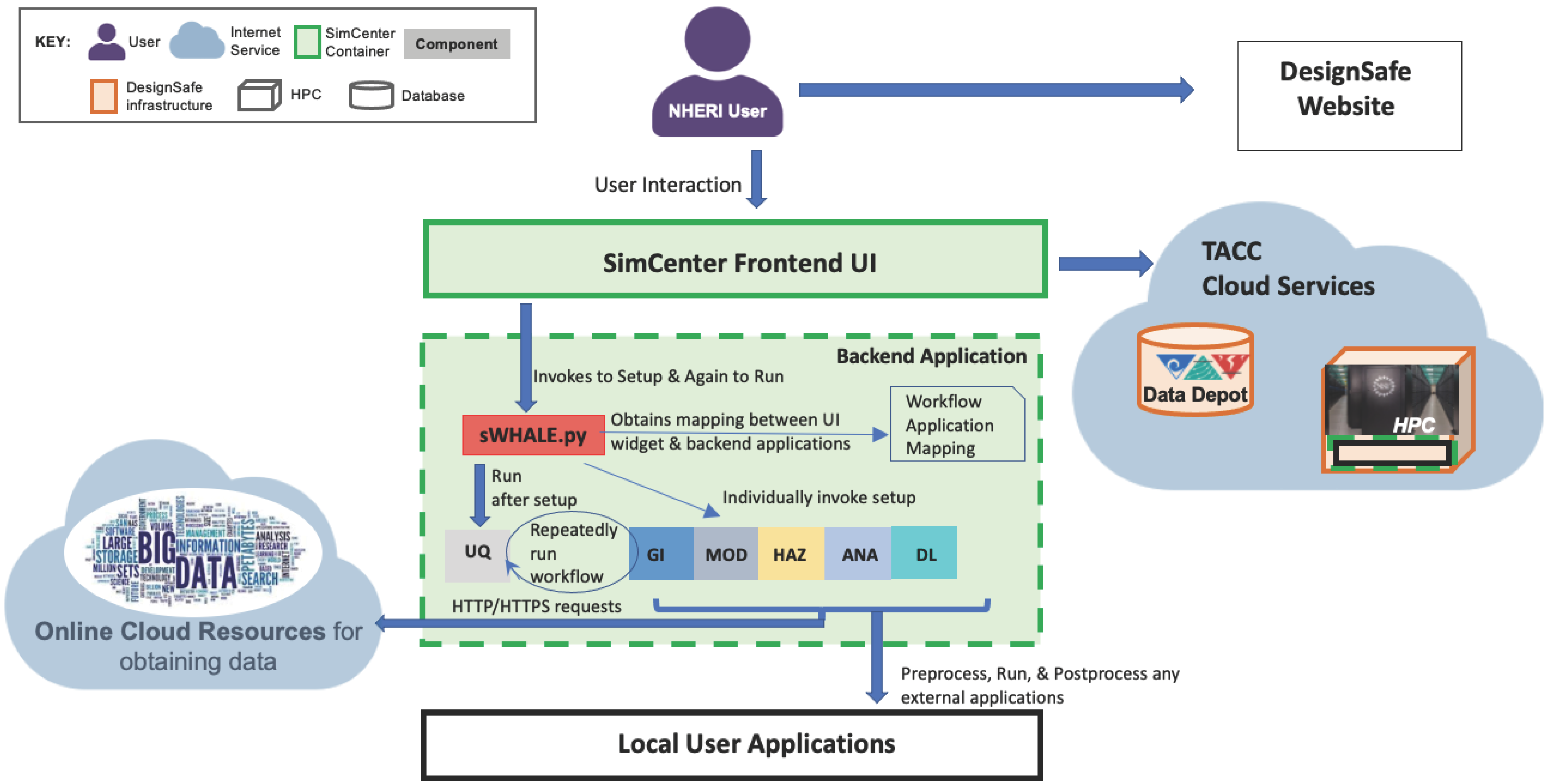
Computational Framework



Computational Framework



Computational Framework



Workflow Applications

QUOFEM

Coupling: Quantification of Uncertainties & Optimization with FEM

EE UQ   WE UQ   Hydro UQ

Response of structure to natural hazard effects: ground shaking, wind effects, and surge/tsunami flows

PBE

Performance-based computations of individual facilities to natural hazards

R2D

Regional assessment of facilities and systems to natural hazards to support resilience decision making

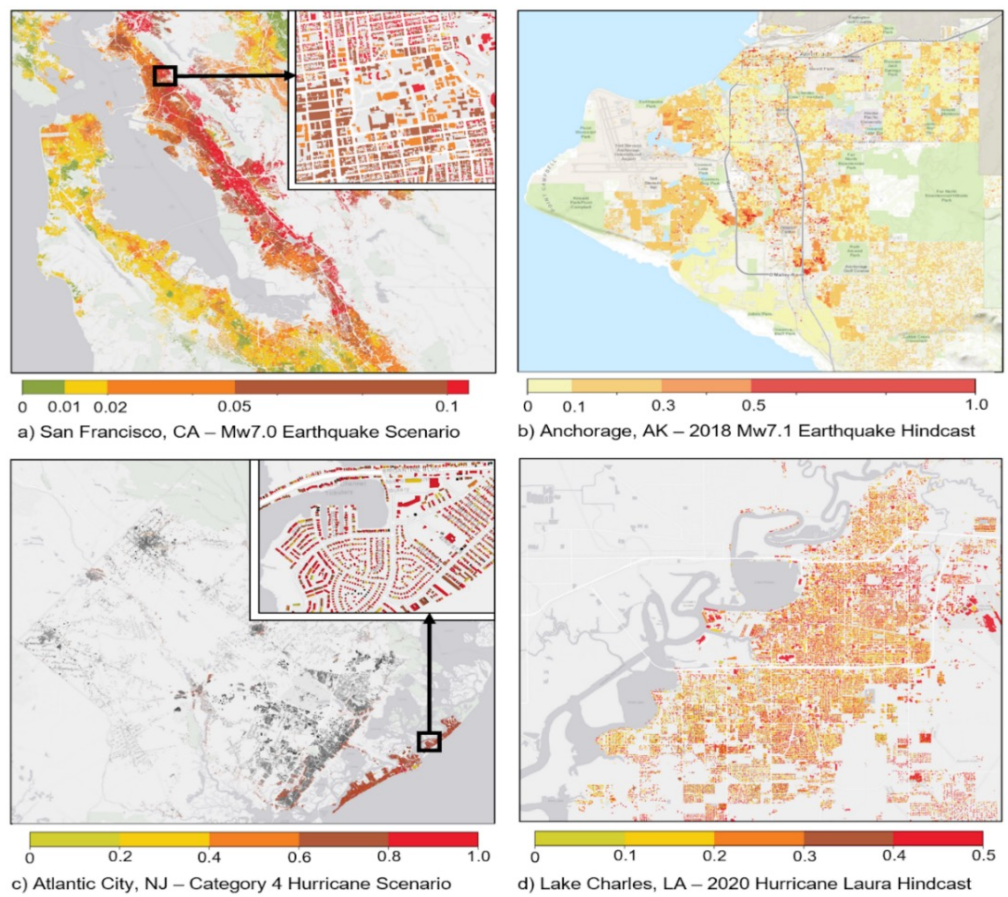
Regional Testbed Applications

https://simcenter.designsafe-ci.org/testbeds/

Motivation & Objectives

- proof of concept
- test and verify workflows
- engage research developers and users
- identify research opportunities, e.g.,validation through post-event simulations
- identify gaps in research & development
- help establish data standards and formats

Regional earthquake and hurricane scenarios, each with a unique focus



a) San Francisco, CA – Mw7.0 Earthquake Scenario

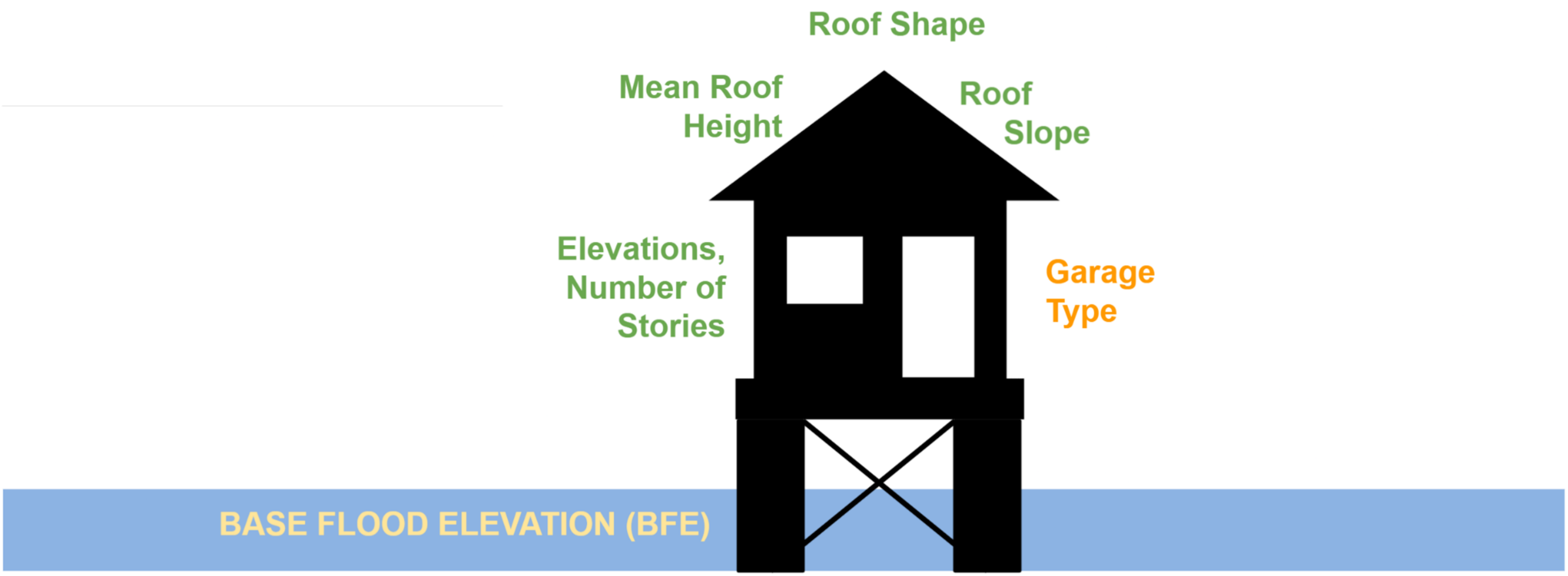
b) Anchorage, AK – 2018 Mw7.1 Earthquake Hindcast

c) Atlantic City, NJ – Category 4 Hurricane Scenario

d) Lake Charles, LA – 2020 Hurricane Laura Hindcast

SimCenter Uses AI for Developing building inventories

Developing building inventories



Developing building inventories

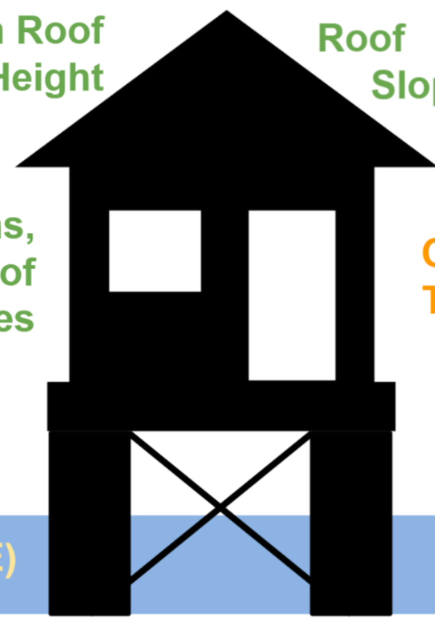
Augmented Parcel Approach: Fusion data from multiple sources

PARCEL GEOMETRY DATA	THIRD-PARTY DATA	AI/ML	STATISTICAL INFERENCE
• State, Parish, or Municipal DB • MS Footprint DB • OpenStreetMaps	• Tax Assessor Data • Building Permit Data • Open GIS Data • ATC Hazards by Location • Land Use/Land Cover DB • US Census, ACS, AHS • Real Estate DB (e.g., Zillow ZTRAX)	• Foundation Features • First Floor and Roof Elevations • Roof Geometry and Dimensions • Openings	• Year of Construction • Structural Design Details e.g., roof cover type, sec. water resistance, shutters, garage type

Developing building inventories

BASIC INFORMATION
Latitude, Longitude
Occupancy Class (Residential)
Building Type (Material = Wood)
Year Built

HAZARD INFORMATION
Design Wind Speed (ATC)
Avg. Temperature (NOAA)
LU/LC (Parish Data)
Special Flood Hazard Area (FEMA)

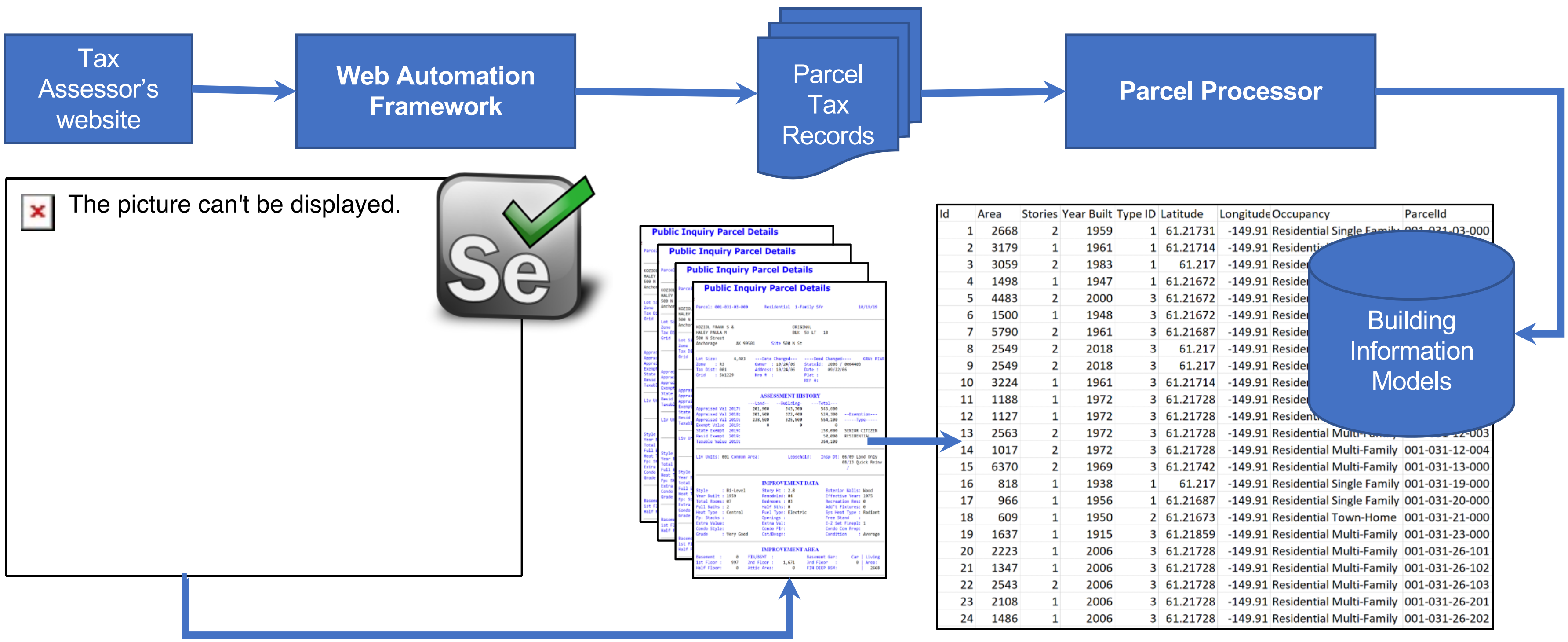


METHODOLOGY
Third Party Data
Spatial Inference (ML)
Computer Vision Methods
Statistically Assigned/Inferred

Third-party Datasets

Ideal case: Data publicly available in a repository or through an API

Web Automation: Facilitates data collection from public websites



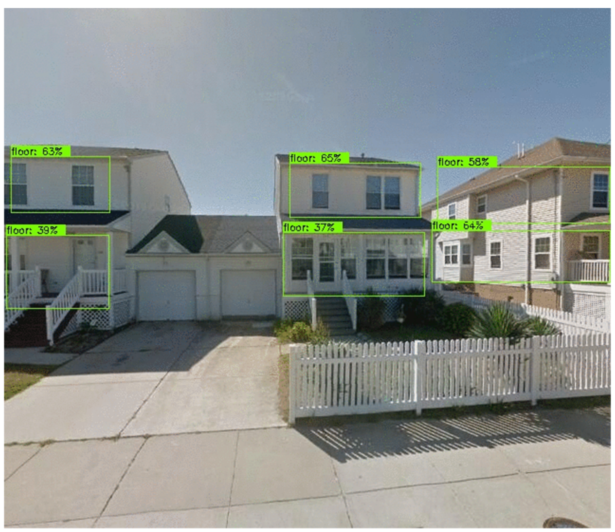
Id	Area	Stories	Year Built	Type ID	Latitude	Longitude	Occupancy	ParcelId
1	2668	2	1959	1	61.21731	-149.91	Residential Single Famil	001-031-03-000
2	3179	1	1961	1	61.21714	-149.91	Residenti	
3	3059	2	1983	1	61.217	-149.91	Reside	
4	1498	1	1947	1	61.21672	-149.91	Reside	
5	4483	2	2000	3	61.21672	-149.91	Reside	
6	1500	1	1948	3	61.21672	-149.91	Reside	
7	5790	2	1961	3	61.21687	-149.91	Reside	
8	2549	2	2018	3	61.217	-149.91	Reside	
9	2549	2	2018	3	61.217	-149.91	Reside	
10	3224	1	1961	3	61.21714	-149.91	Reside	
11	1188	1	1972	3	61.21728	-149.91	Reside	
12	1127	1	1972	3	61.21728	-149.91	Residenti	
13	2563	2	1972	3	61.21728	-149.91	Residential Multi	12-003
14	1017	2	1972	3	61.21728	-149.91	Residential Multi-Family	001-031-12-004
15	6370	2	1969	3	61.21742	-149.91	Residential Multi-Family	001-031-13-000
16	818	1	1938	1	61.217	-149.91	Residential Single Family	001-031-19-000
17	966	1	1956	1	61.21687	-149.91	Residential Single Family	001-031-20-000
18	609	1	1950	2	61.21673	-149.91	Residential Town-Home	001-031-21-000
19	1637	1	1915	3	61.21859	-149.91	Residential Multi-Family	001-031-23-000
20	2223	1	2006	3	61.21728	-149.91	Residential Multi-Family	001-031-26-101
21	1347	1	2006	3	61.21728	-149.91	Residential Multi-Family	001-031-26-102
22	2543	2	2006	3	61.21728	-149.91	Residential Multi-Family	001-031-26-103
23	2108	1	2006	3	61.21728	-149.91	Residential Multi-Family	001-031-26-201
24	1486	1	2006	3	61.21728	-149.91	Residential Multi-Family	001-031-26-202

Machine Learning

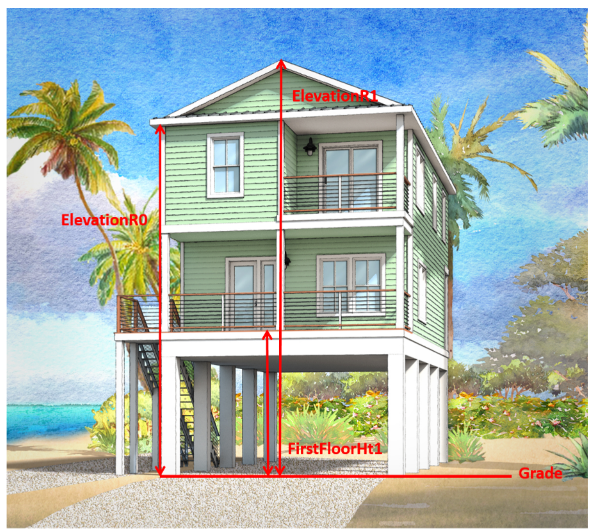
[BRAILS](#): Collection of calibrated machine learning models

- Supports both direct use and location-specific training on additional data
- Good experience with crowdsourced image labeling through [Zooniverse](#)

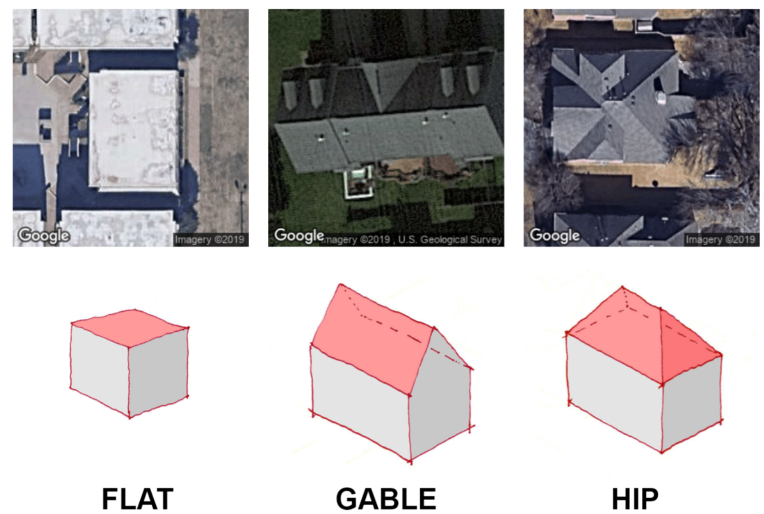
Number of Stories



Elevation & Geometry



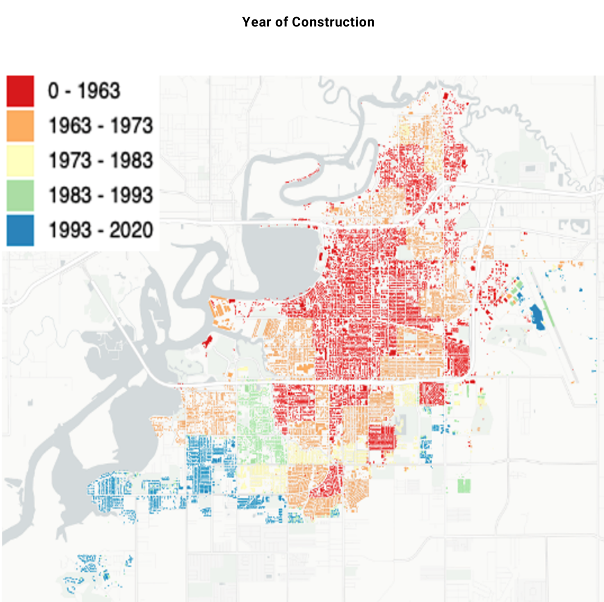
Roof Classification

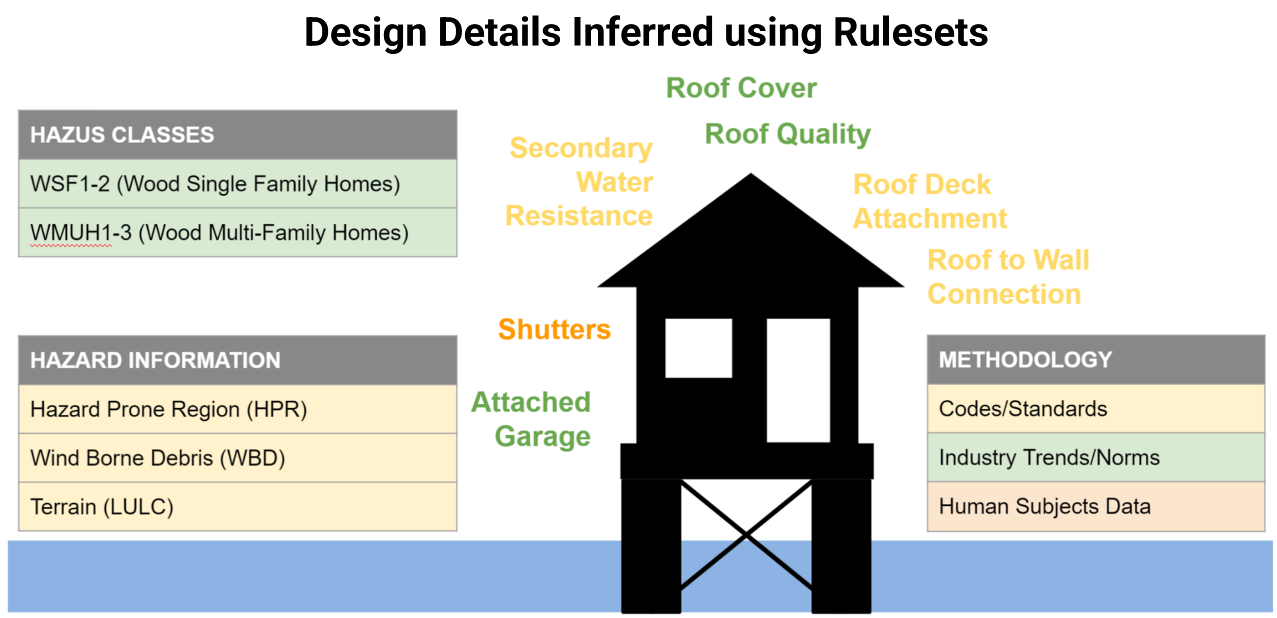


Statistical Inference

SURF: Infers building attributes based on known data nearby -> fills the gaps

Rulesets: Time-evolving logic to infer building attributes based on codes and industry norms at each design era & behavioral data





Statistical Inference

Ruleset Example

HAZUS Building Attribute Rulesets - Wind - WSF1-2		
Note: Defaults should be assigned to all WSF1-2 Buildings as defined below; then rulesets should be applied to override those defaults as informed by available data.		
SWR		
Valid Entries	yes, no	**Input Variable**
Default	no	**Input Variable Source**
Years Ruleset Applies	**Ruleset**	**Notes**
YearBuiltNJDEP > 2000	Assign as a Random Variable (RV) IF RoofShape = Gable OR Hip, SWR = yes (RV = 60%) IF RoofShape = Gable OR Hip, SWR = no (RV = 40%)	Minimum drainage recommendations are in place in NJ (See belo data from NC Coastal Homeowner Survey (2017) to capture poter Requirements: R903.4 Roof Drainage. Unless roofs are sloped to R903.4.1 Secondary (Emergency Overflow) Drains or Scuppers: V scuppers shall be provided where the roof perimeter construction drains allow buildup for any reason.
1983 < YearBuiltNJDEP ≤ 2000	IF RoofShape=Flat, SWR=yes ELSEIF RoofShape=(Gable or Hip) & RoofSlope <= 0.17, SWR=yes ELSEIF RoofShape=(Gable or Hip) & RoofSlope (> 0.17 & < 0.33) & AvgJanTemp=Below, SWR=yes ELSEIF RoofShape=(Gable or Hip) & RoofSlope (> 0.17 & < 0.33) & AvgJanTemp=Above, SWR=no ELSEIF RoofShape=(Gable or Hip) & RoofSlope >= 0.33, SWR=no	**This rule applies until 1984, for anything from 1983 or earlier,** According to 903.2 in the 1995 CABO, for roofs with slopes betwe applied. In severe climates (less than or equal to 25 degrees avera the 1995 CABO, roofs with slopes greater than or equal to 4:12 sh cemented together is considered to be secondary water resistance underlayment of some sort, but the ruleset is based on asphalt shi According to table No. R-803.4 in 1992 CABO, for roofs with slope

Statistical Inference

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```python
# Secondary Water Resistance (SWR)
# Minimum drainage recommendations are in place in NJ (See below).
# However, SWR indicates a code-plus practice.
SWR = False # Default in Reorganzied Rulesets - WIND
if year > 2000:
    # For buildings built after 2000, SWR is based on homeowner compliance
    # data from NC Coastal Homeowner Survey (2017) to capture potential
    # human behavior (% of sealed roofs in NC dataset).
    SWR = random.random() < 0.6
elif year > 1983:
    # CABO 1995:
    # According to 903.2 in the 1995 CABO, for roofs with slopes between
    # 2:12 and 4:12, an underlayment consisting of two layers of No. 15
    # felt must be applied. In severe climates (less than or equal to 25
    # degrees Fahrenheit average in January), these two layers must be
    # cemented together.
    # According to 903.3 in the 1995 CABO, roofs with slopes greater than
    # or equal to 4:12 shall have an underlayment of not less than one ply
    # of No. 15 felt.
    #
    # Similar rules are prescribed in CABO 1992, 1989, 1986, 1983
    #
    # Since low-slope roofs require two layers of felt, this is taken to
    # be secondary water resistance. This ruleset is for asphalt shingles.
    # Almost all other roof types require underlayment of some sort, but
    # the ruleset is based on asphalt shingles because it is most
    # conservative.
    if BIM['roof_shape'] == 'flt': # note there is actually no 'flt'
        SWR = True
    elif BIM['roof_shape'] in ['gab','hip']:
        if BIM['roof_slope'] <= 0.17:
            SWR = True
        elif BIM['roof_slope'] < 0.33:
            SWR = (BIM['avg_jan_temp'] == 'below')
```

excerpt from ruleset script for WSF1-2 buildings