



SimCenter tools for simulated ground motion utilization

Matt DeJong

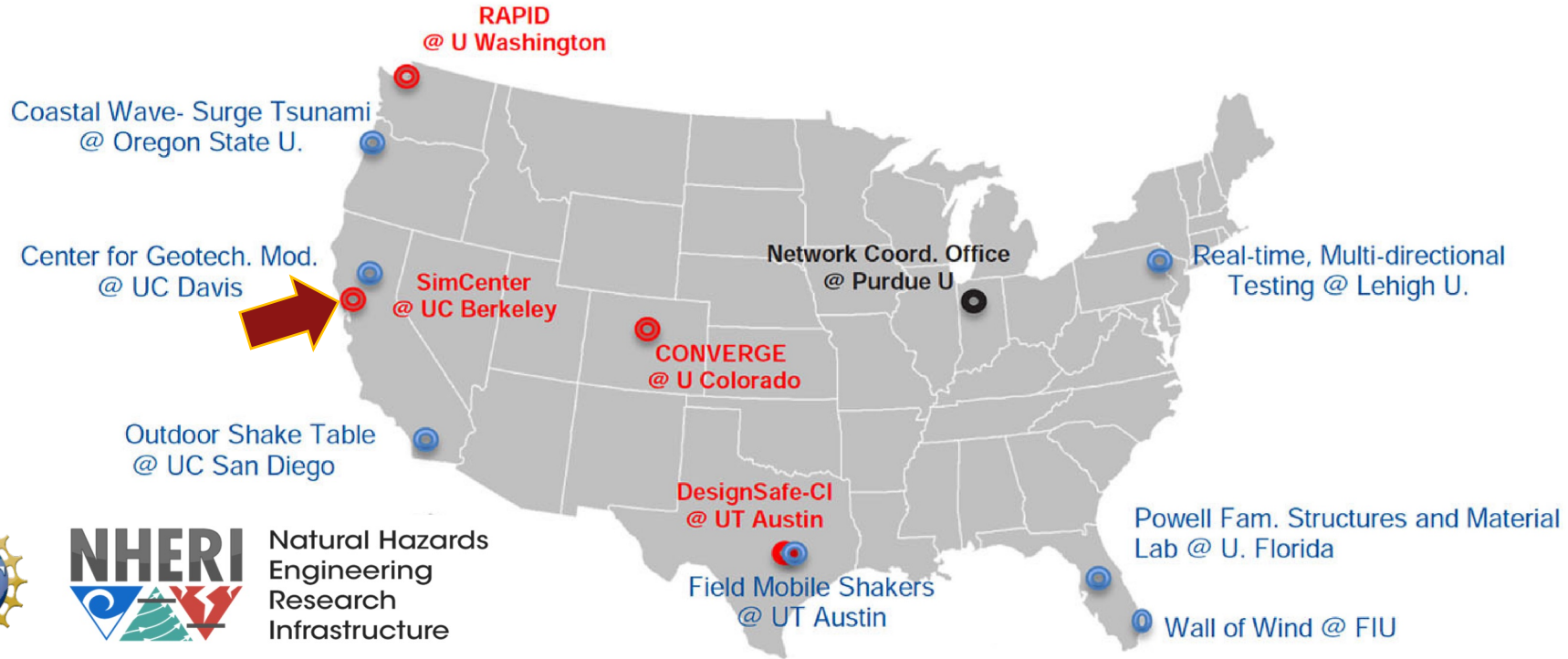
PI & Co-Director of SimCenter

Co-Director of CSI

University of California, Berkeley

NSF NHERI – Large-scale Collaboration

- ❖ Experimental facilities (7), Cyber-infrastructure, Field Reconnaissance, and Simulation Software
- ❖ Current project period: 2014-2025; future initiative (2026-2035) under development



Natural Hazards
Engineering
Research
Infrastructure

Computational Modeling and Simulation Center



Advance the Nation's capability to **simulate the impact** of natural hazard events on structures, lifelines, and communities.



Create an open-source and extensible application framework, integrate existing tools and data, and develop new software to provide the **next-generation of regional disaster simulation tools**



Support researchers and practitioners with **education and training**, and connect them with high-performance computing resources.

The SimCenter Team

Directors

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Gregory G. Deierlein

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Matthew Schoettler
Adam Zsarnoczay

Co-PIs

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Laura Lowes
Satish Rao

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Sina Naeimi Dafchahi
Jinyan Zhao

Faculty Domain Experts

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John Bray
Henry Burton
Joel Conte
Rachel Davidson
Ann-Margaret Esnard

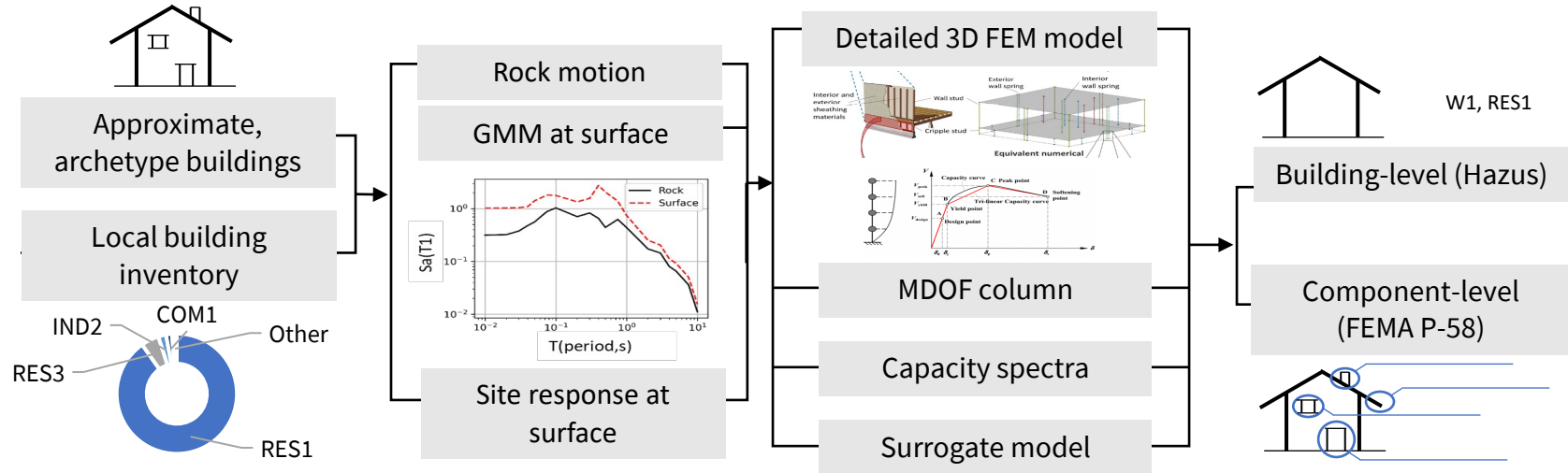
Faculty Domain Experts cont.

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Cathernie Gorle
Sanjay Govindjee
Andrew Kennedy
Tracy Kijewski-Correa
Patrick Lynett
Peter Mackenzie-Helnwein
Michael Motley
Kenichi Soga
Michael Shields
Seymour Spence
Alexandros Taflanidis
Ertugrul Taciroglu
Stella Yu

Unifying Simulation Platform

Foster large-scale collaboration in the Disaster Science community

Facilitate transition from local to regional scale, multi-hazard studies



ASSET INVENTORY



EVENT INTENSITY



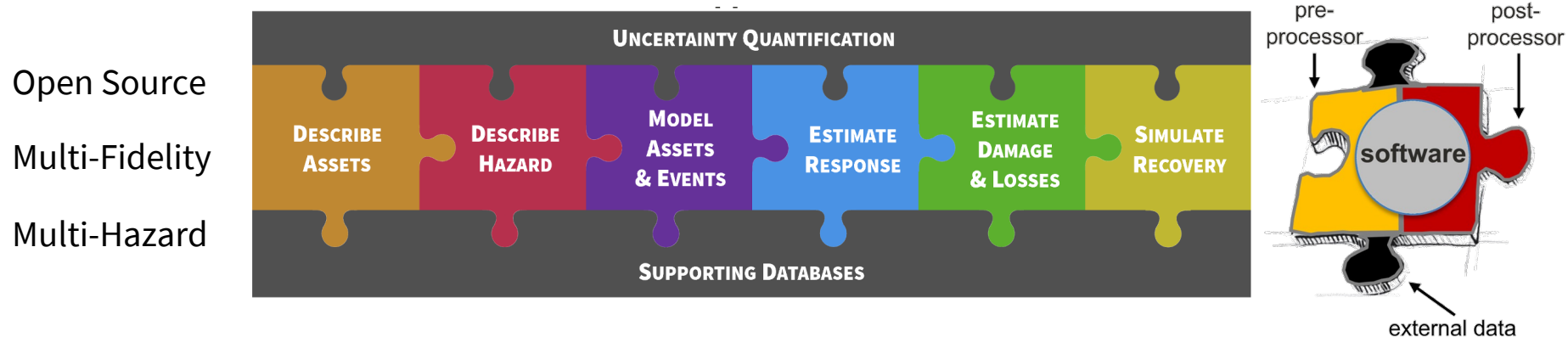
STRUCTURAL BEHAVIOR



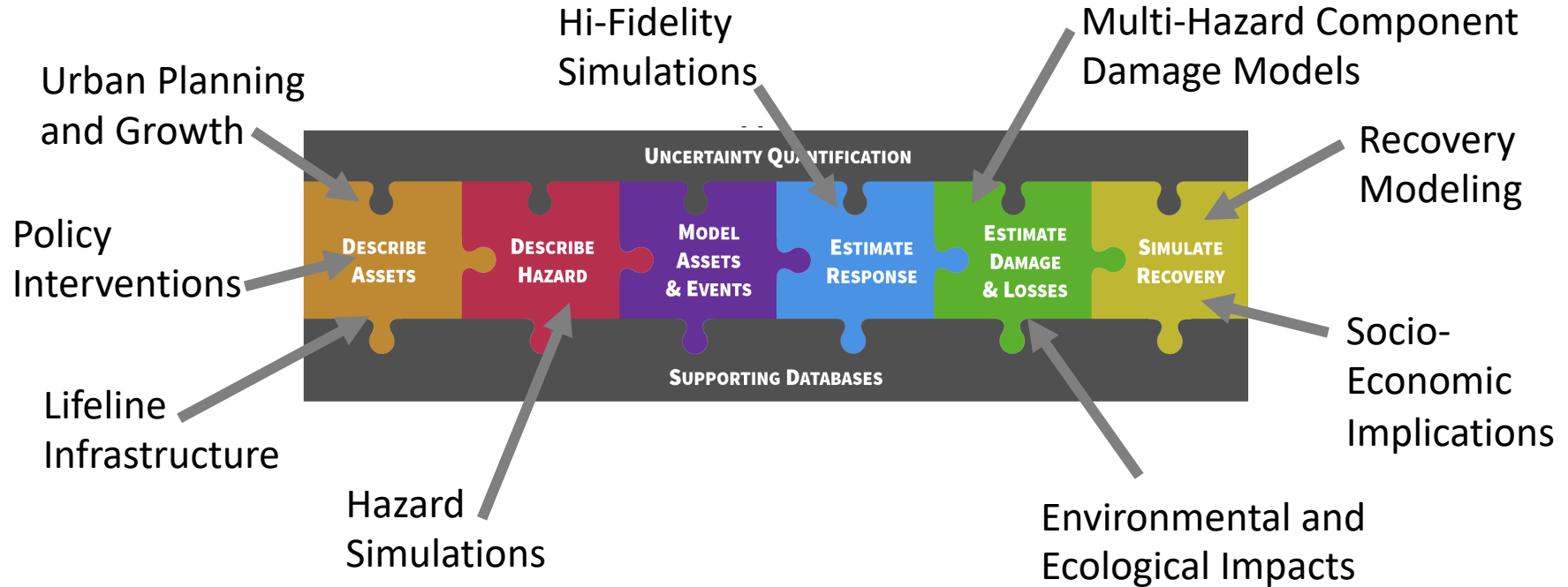
DAMAGE & LOSSES

SimCenter Application Framework

Foster large-scale collaboration in the Disaster Science community
Facilitate transition from local to regional scale, multi-hazard studies

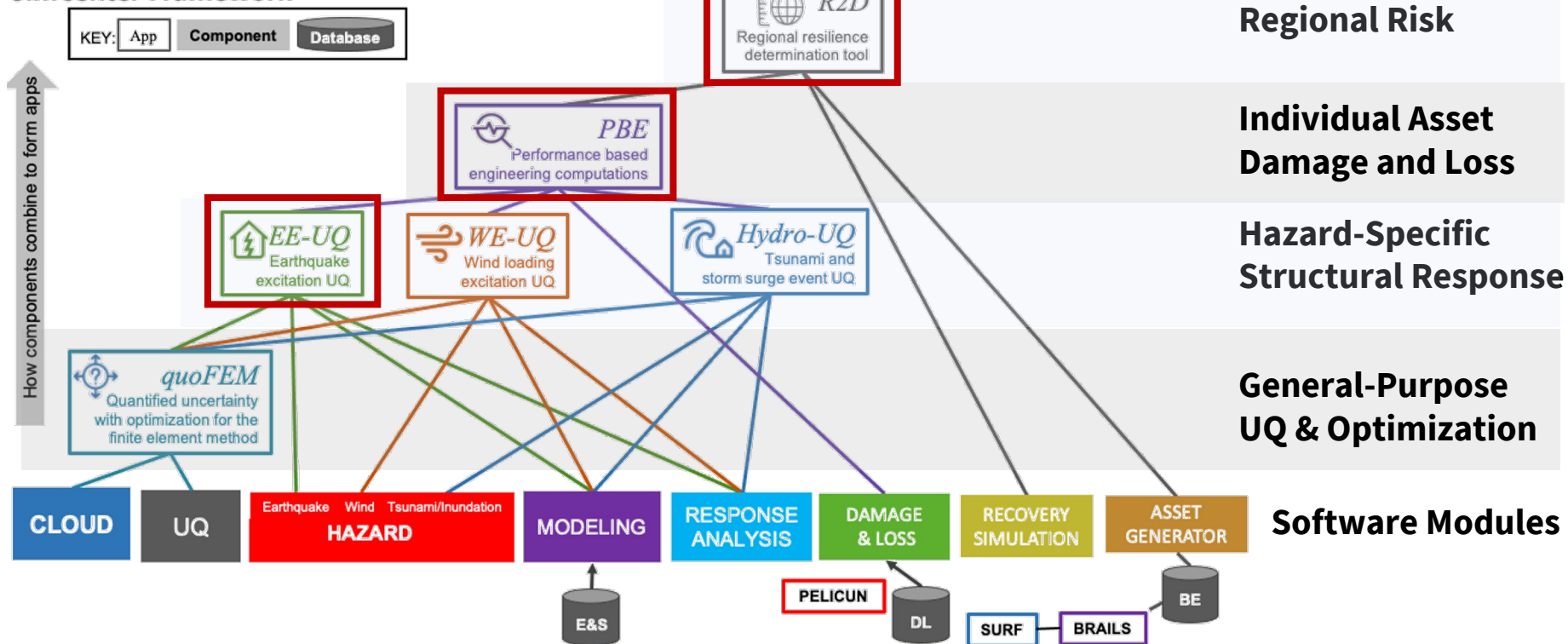


Framework for Multi-Disciplinary Collaboration

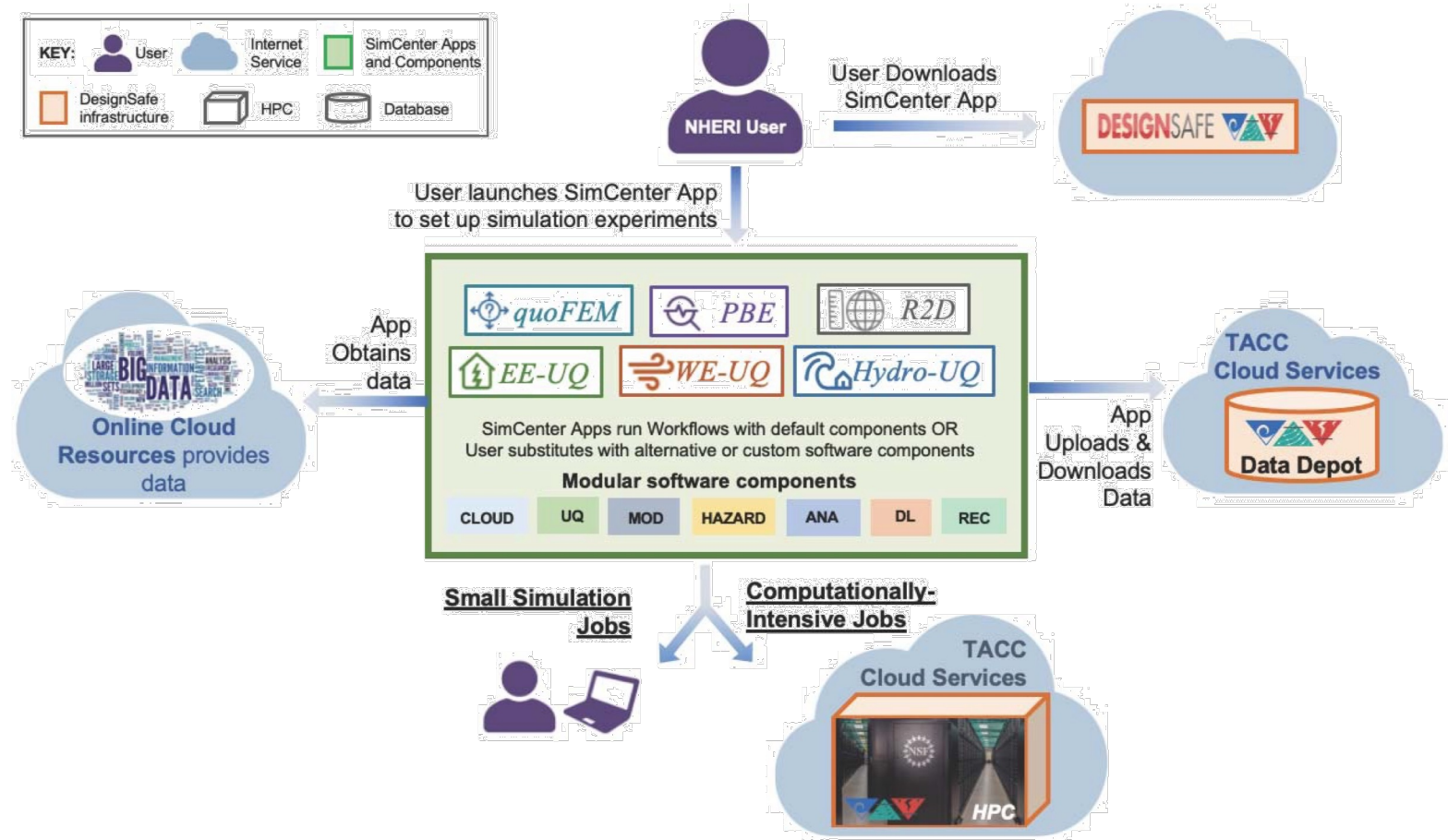


SimCenter – Desktop Applications

SimCenter Framework

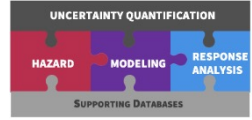


Integration with Online Resources





Desktop Application for Earthquake Engineering (EE-UQ)



EE-UQ V3.2

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

UQ Problem Types:~

- Sampling
- Sensitivity
- Reliability
- Surrogate Modeling (new features)

Hazard (Earthquake):

- Stochastic Motions
- PEER NGA Search with target spectrum
- Site Response with Random Fields

Modeling (Building):

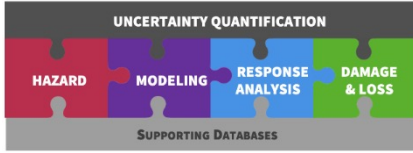
- OpenSees
- Nonlinear Shear Spring (MDOF)
- Steel Building Design & Build (AutoSDA)
- Concrete Building Design & Build
- Multi-Model Surrogate

Response:

- OpenSees
- Multi-Model

| ID | Scale | Earthquake | Station | Magnitude | Distance | V30 | Horizontal File |
|----|-------|---------------------------|--------------------|-----------|----------|--------|--------------------------|
| 1 | 6 | 4.0989 Imperial Valley-02 | E1 Centro Array #9 | 6.95 | 6.09 | 213.44 | RSNG_MPVALL_L-ELC190.AT2 |

PBE Desktop Application for Performance Assessment

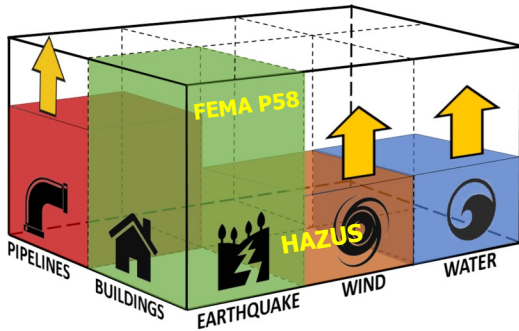


PBE v3.0

Performance-Assessment of Buildings and Infrastructure Components
Multi-Hazard and Multi-Fidelity (PELICUN library of damage and loss models)

Damage & Loss (using PELICUN):

- Building-level assessment (e.g., HAZUS)
- Component-level assessment (e.g., FEMA P58)
- Supports external response estimation
- Customizable damage & loss models



Damage and Loss Assessment Pelicun

General Information

- Number of Stories: 4
- Plan Area: 15000
- Occupancy Type: Commercial Office

Databases

- Component Vulnerability: User Defined
- 3 - Live Expert Tips - 2022 February/custom_fragility_DB.csv

Component Assignment

Available in DB: B.10.31.001

Assigned: B.20.22.031

Description: Midrise stick-built curtain wall, Config: Monolithic, Lamination: Not laminated, Glass Type: Annealed, Details: 1/4 in. (6 mm) AN monolithic; glass-frame clearance = 0.43 in. (11 mm); aspect ratio = 6:5 sealant = dry None

Demand type: Peak Interstory Drift Ratio
Block size: 30 SF
Additional info: Directional

| Unit | Location(s) | Direction(s) | Quantity | Blocks | Distribution | COV | Comment |
|-------|-------------|--------------|----------|--------|--------------|-----|-----------------------------------|
| - ft2 | 1 | 1 | 5040 | 168 | lonormal | 0.3 | Midrise stick-built curtain wall, |
| - ft2 | 1 | 2 | 3360 | 112 | lonormal | 0.3 | Midrise stick-built curtain wall, |
| - ft2 | 2-4 | 1 | 4680 | 156 | lonormal | 0.3 | Midrise stick-built curtain wall, |
| - ft2 | 2-4 | 2 | 3120 | 104 | lonormal | 0.3 | Midrise stick-built curtain wall, |

Table from bottom plot:

| # | inhabitants | collapsed? | red tagged? |
|----|-------------|------------|-------------|
| 12 | 10.0 | 0.0 | 0 |
| 13 | 40.0 | 0.0 | 0 |
| 14 | 10.0 | 0.0 | 0 |
| 15 | 3 | 0.0 | 0 |

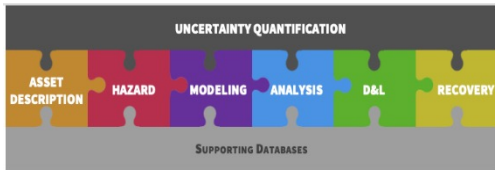
Program Output

```

16:00:58 - Done Loading File
16:00:59 - Done Loading Example.
16:01:42 -
16:01:42 - SetUp_Done - Now starting application
16:01:50 -
    
```




Desktop Application for Regional Simulation



R2D V2.1

Create and run **complex workflows for regional simulation** of natural hazards to facilitate research in disaster risk management and recovery.

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

Response, Damage and loss

FEM simulations of response
HAZUS and other fragility models
User-provided fragility functions

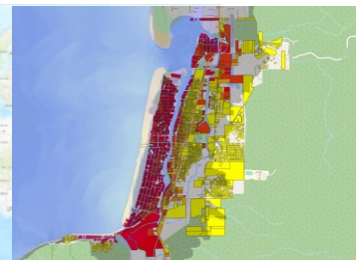
Multiple Hazards



Earthquakes

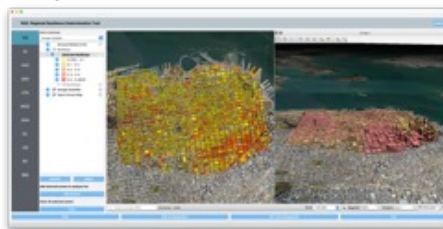


Hurricanes

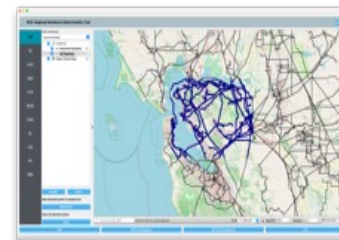


Tsunamis

Multiple Assets



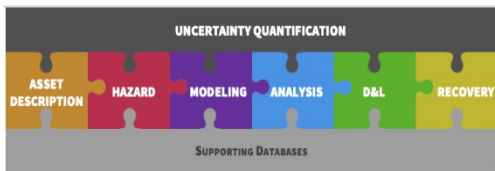
Buildings



Lifelines



Desktop Application for Regional Simulation



R2D V2.1

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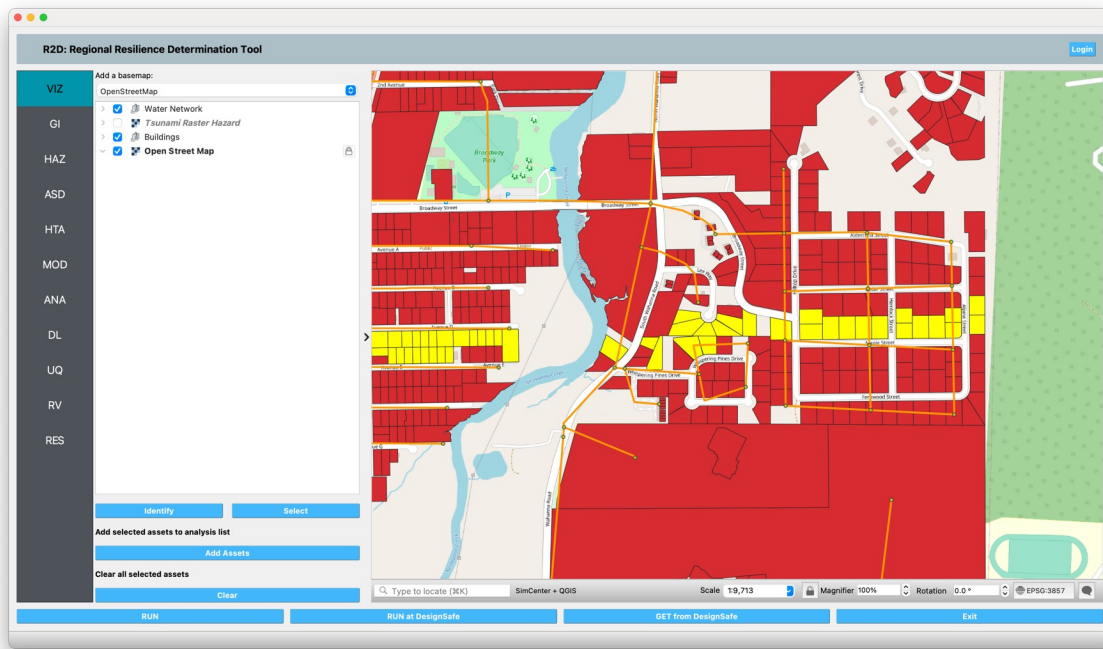
csv files
GIS files

Hazard definition

Regional Site Response
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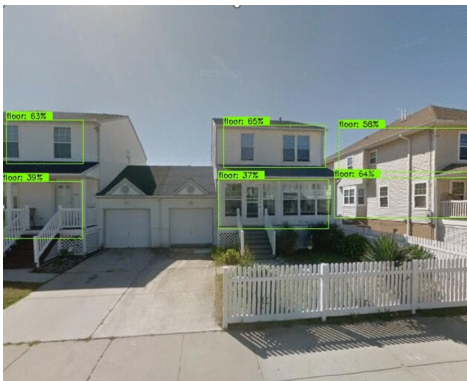
FEM simulations of response
HAZUS and other fragility models
User-provided fragility functions



High-Res Inventories – Computer Vision – BRAILS



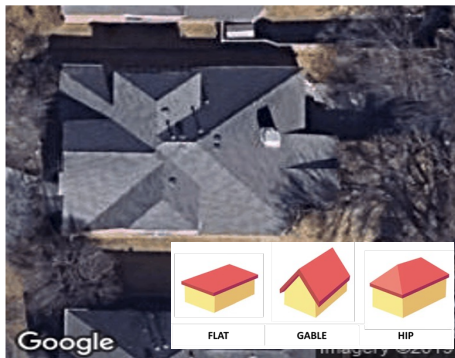
Elevations & Window Area



Number of Floors



Occupancy Class



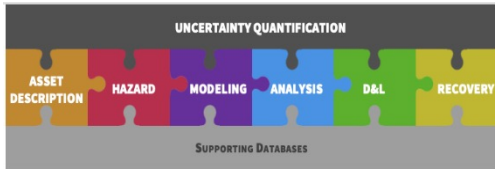
Roof Shape

BRAILS: Building Recognition using AI at Large Scale

- Detect building features
- Library of AI models and approaches
 - *semantic segmentation*
 - *classification (multi-class transformer)*
 - *object detection*
- Seeded with trained models for several common building features.
- Validated with field reconnaissance and ZTRAX



Desktop Application for Regional Simulation



R2D V2.1

Create and run **complex workflows** for regional simulation of natural hazards to facilitate research in disaster risk management and recovery.

Asset definition

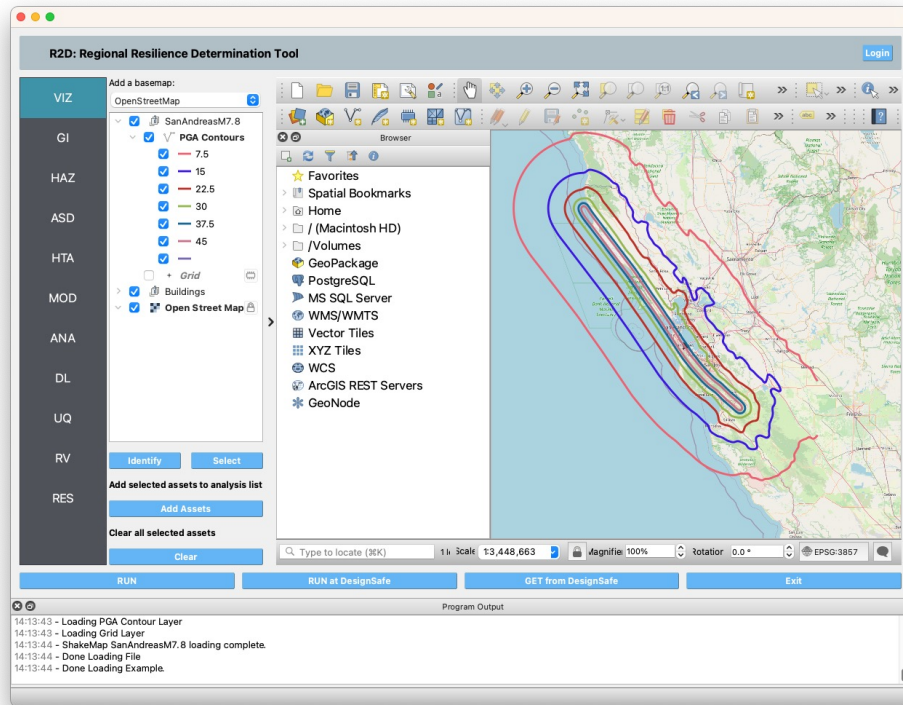
- csv files
- GIS files

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

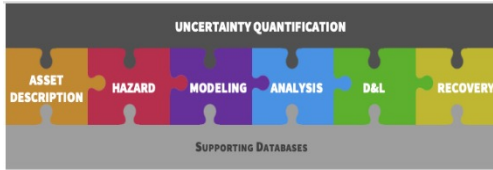
Response, Damage and loss

- FEM simulations of response
- HAZUS and other fragility models
- User-provided fragility functions





Desktop Application for Regional Simulation



R2D V2.1

Create and run **complex workflows for regional simulation** of natural hazards to facilitate research in disaster risk management and recovery.

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
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Response, Damage and loss

- FEM simulations of response
- HAZUS and other fragility models
- User-provided fragility functions

R2D: Regional Resilience Determination Tool Login

Regional Results Summary

Disclaimer: The presented simulation results are not representative of any individual building's response. To understand the response of any individual building, please consult with a professional structural engineer. The presented tool does not assert the known condition of the building. Just as it cannot be used to predict the negative outcome of an individual building, prediction of safety or an undamaged state is not assured for an individual building. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Regional Map Estimated Regional Totals

Casualties: 2.23 Fatalities: 0.06
 Losses: 3.16e+06 Repair Time [days]: 3.09e+03
 Structural Losses: 3.13e+06 Non-structural Losses: 0

Casualties

Casualties Economic Losses Relative Prop. Losses

Detailed Results

Sorting Filter: Asset ID

| Asset ID | Repair Cost | Repair Time | Replacement Probability | Fatalities | Loss Ratio |
|----------|-------------|-------------|-------------------------|------------|------------|
| 1 | 3.35e+03 | 26.8 | 0 | 0.0005 | 0.0864 |
| 2 | 5.04e+04 | 29.7 | 0 | 0.0005 | 0.0973 |
| 3 | 3.02e+03 | 31.2 | 0 | 0.0005 | 0.105 |
| 4 | 5.12e+03 | 33.9 | 0 | 0.0005 | 0.116 |
| 5 | 2.74e+04 | 29.7 | 0 | 0.0005 | 0.1 |

Select a subset of buildings to display the results: e.g., 1, 3, 5-10, 12 Select

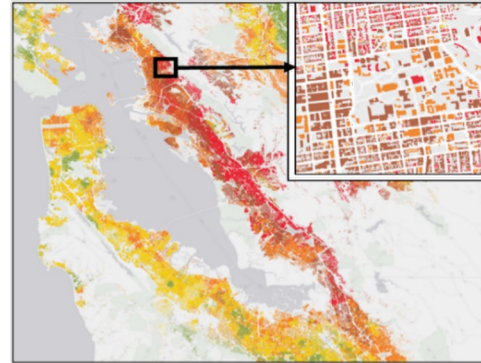
Export folder: C:/Users/zsarn/Desktop/Results.pdf Browse

Export to PDF

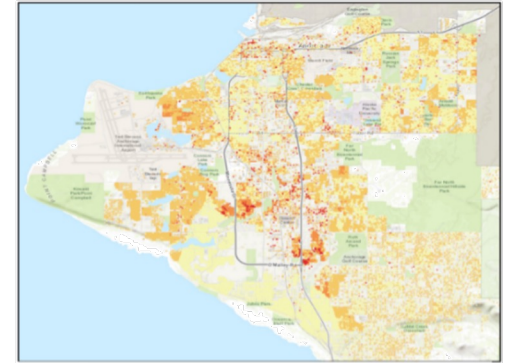
RUN RUN at DesignSafe GET from DesignSafe Exit

SimCenter – Regional Testbeds

- Proof of concept
- Benchmark & verify methods
- Engage researchers and users
- Identify gaps & opportunities
- Establish data standards



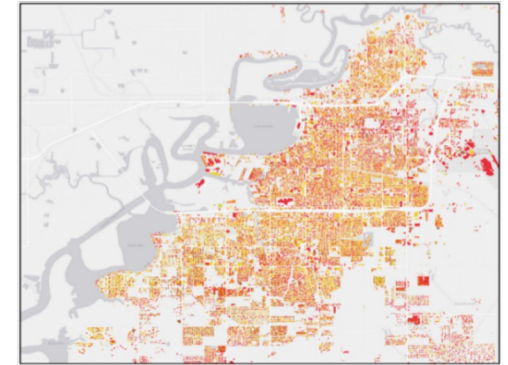
SF Bay Area – EQ Scenario



Anchorage – EQ Hindcast



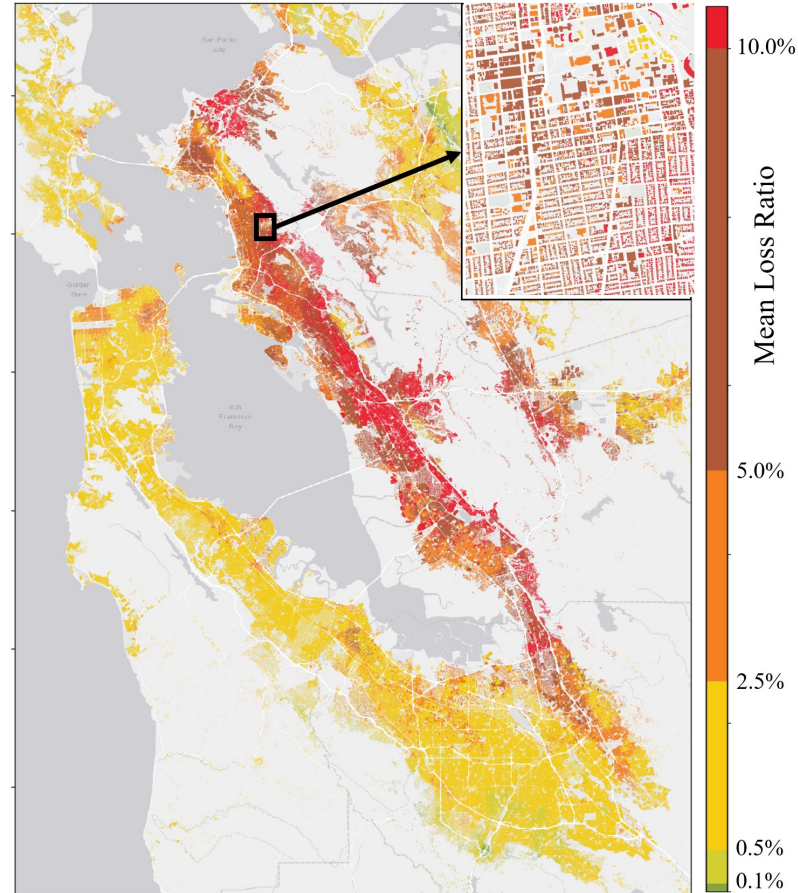
Atlantic City – Hurricane Scenario



Lake Charles – Hurricane Hindcast

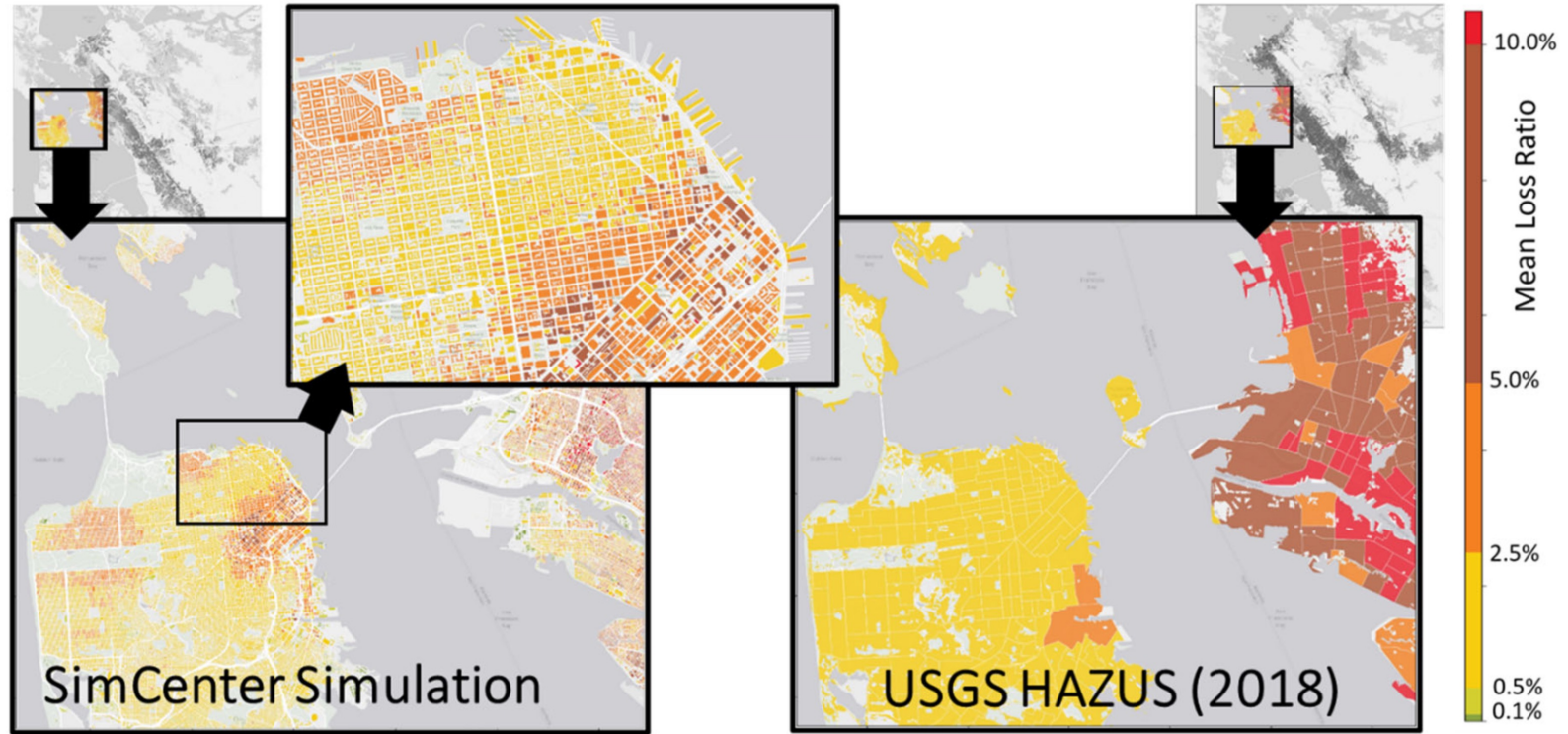
San Francisco Bay Area M7.0 Earthquake Testbed

- **M7.0 earthquake in the SF Bay Area**
Hayward fault – physics-based simulation (LLNL-SW4)
- **High-resolution building inventory**
1.84 million buildings with footprint & main features
- **Building-specific structural analyses**
OpenSees idealized MDOF response models
HazuS earthquake damage and loss models
- **Uncertainty Quantification**
uncertainty in buildings, damage, and losses
25 realizations capture possible outcomes
- **High-Performance Computing**
DesignSafe HPC (Stampede2 at TACC)
embarrassingly parallel: 2 hr runtime using 10K cores



San Francisco Bay Area M7.0 Earthquake Testbed

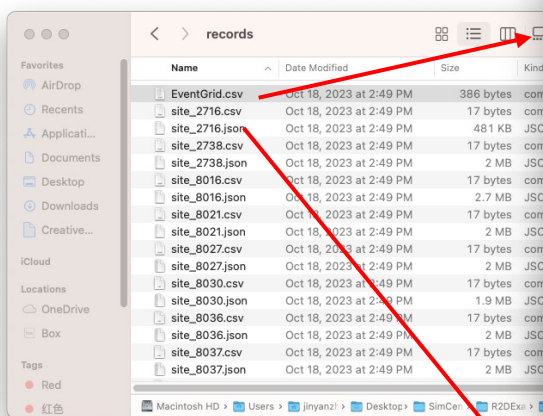
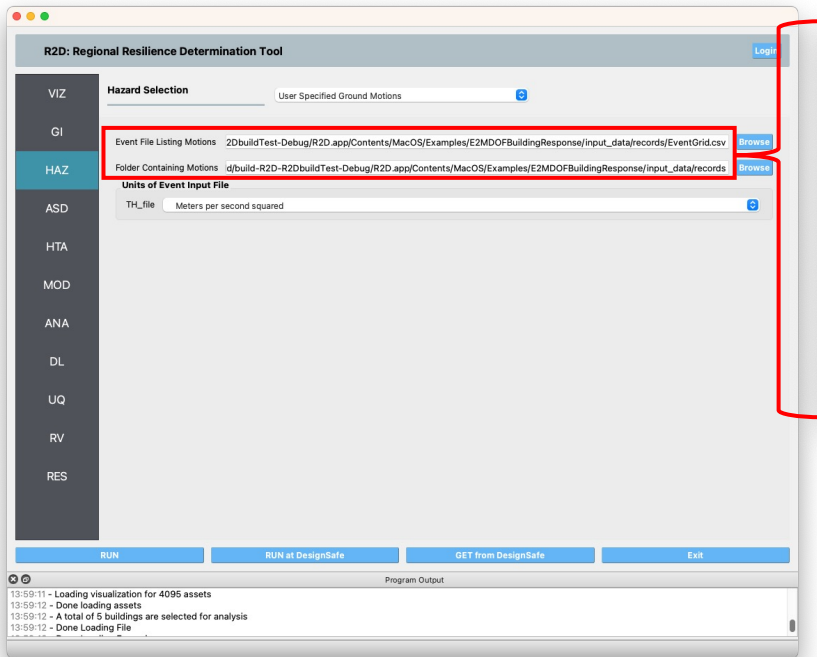
High Resolution Modeling: Parcel-level resolution enables unprecedented quantification of *engineered interventions for policy level decisions*



R2D Earthquake hazard definition options in R2D

Option 1: User-specified ground motions

Users prepare an **Event Grid** file to define site locations and a group of **Site Record** files, which contains the **Intensity Measures** or **Time History** record at the sites.



| GP_file | Longitude | Latitude |
|---------------|-----------|----------|
| site_2716.csv | -149.892 | 61.219 |
| site_2738.csv | -148.885 | 63.389 |
| site_8016.csv | -149.864 | 61.192 |
| site_8021.csv | -149.91 | 61.113 |
| site_8027.csv | -149.889 | 61.161 |
| site_8030.csv | -149.806 | 61.179 |
| site_8036.csv | -149.966 | 61.178 |
| site_8037.csv | -149.985 | 61.156 |
| site_8038.csv | -149.883 | 61.218 |

Event Grid file

```
{
  "name": "2716",
  "dT": 0.005,
  "data_x": [
    0.00062005,
    0.00030842,
    0.00067245,
    -0.0034336,
    -0.012782,
    -0.018999,
    -0.024339,
    -0.019844999999999998,
    -0.0066695,
    0.0071368,
    0.022449,
    0.027128,
    0.019879,
    0.0070247,
    -0.013061,
    -0.037041,
    -0.058727,
    -0.074888000000000001,
    -0.076453,
    -0.062114,
    -0.055663,
    -0.064996,
    -0.068393,
    0.060774
  ]
}
```

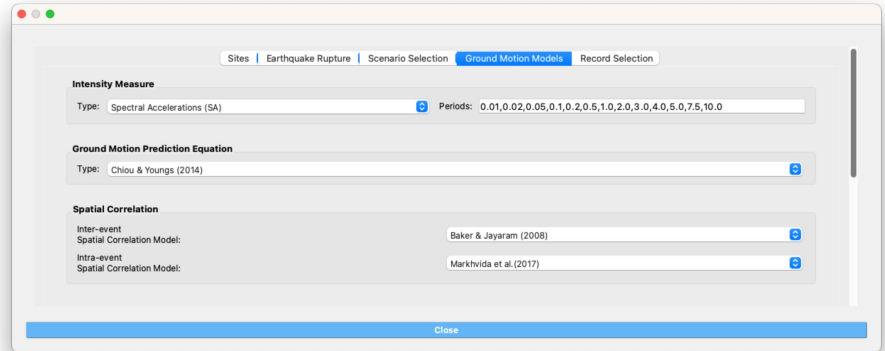
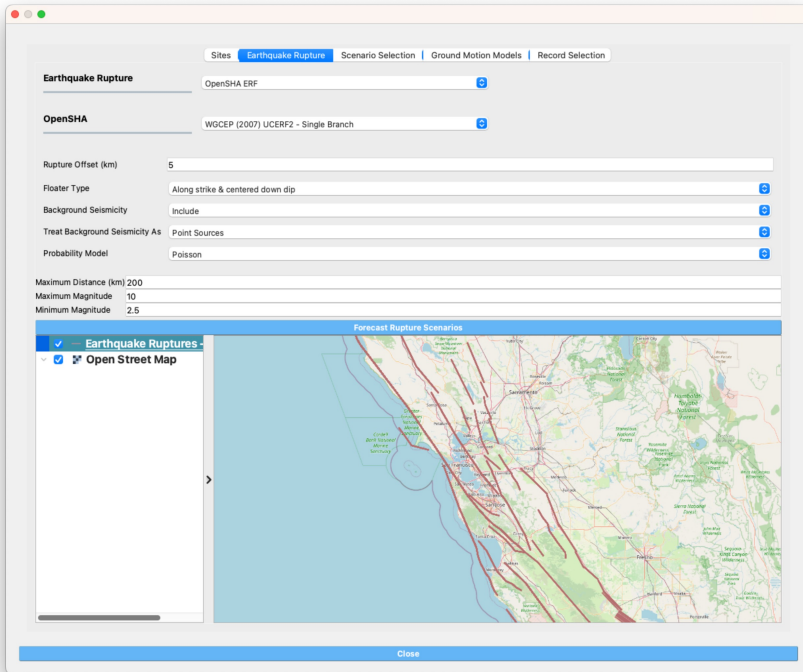
Site Record file



Earthquake hazard definition options in R2D

Option 1: User-specified ground motions (cont'd)

R2D has a regional ground motion simulation tool to predict ground motion maps from **earthquake rupture forecasts, ground motion prediction equations, and spatial correlation models.**



R2D Earthquake hazard definition options in R2D

Option 2: Import from ShakeMap Scenario

Users prepare a **ShakeMap Grid (.xml)** file that defines a grid and the intensity measures at each grid point.

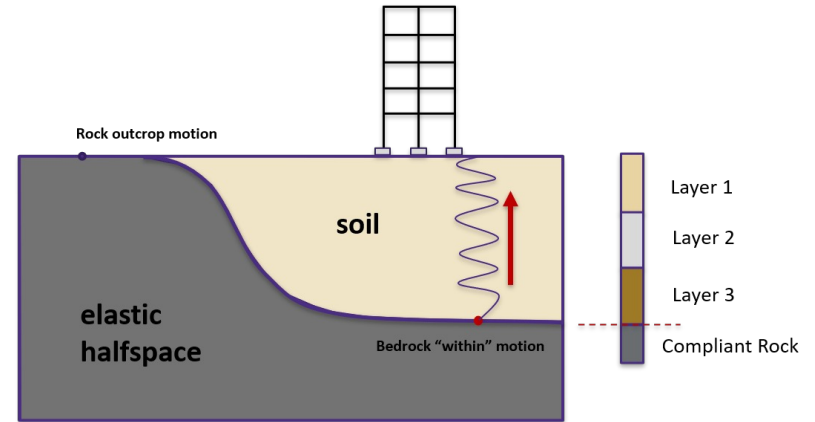
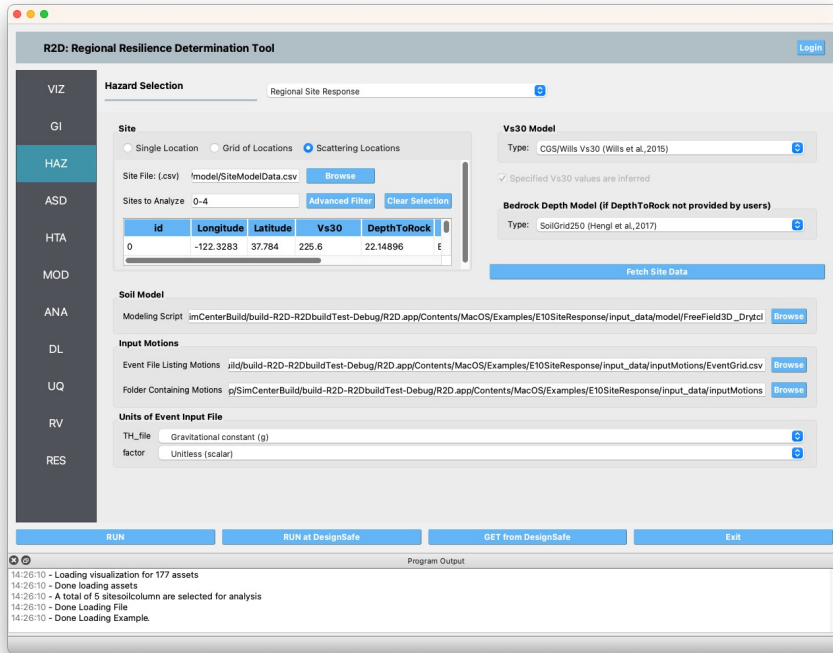
The image displays the R2D: Regional Resilience Determination Tool interface. On the left, the 'HAZ' (Hazard) tab is active, showing the 'Hazard Selection' section. A 'List of Imported ShakeMaps' window is open, listing 'SanAndreasM7.8'. Below this, a 'grid.xml' file is open in a text editor, showing XML code for a ShakeMap Grid. The XML includes event information (magnitude 7.8, depth 9.8) and grid specifications (lat_min, lon_max, etc.). The main interface shows a map with a grid overlay and various intensity measure contours (PGA, PGV, MI, PSA03, PSA10, PSA30). The 'HAZ' tab is selected, and the 'Add a basemap' section shows 'Open Street Map' selected. The 'Program Output' window at the bottom shows the loading progress of the grid and ShakeMap files.

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<shakemap_grid xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://
earthquake.usgs.gov/earthquake.usgs.gov/eqcenter/shakemap" xsi:schemaLocation="http://earthquake.
usgs.gov http://earthquake.usgs.gov/eqcenter/shakemap/xml/schemas/shakemap.xsd"
event_id="npsanandreasassapsasm7p8_se" shakemap_id="npsanandreasassapsasm7p8_s
e" shakemap_version="2" code_version="3.5.1543" process_timestamp="2016-06-22T15:
00:30:15Z" shakemap_originator="us" map_status="RELEASED" shakemap_event_type="SCE
<NAR10">
<event event_id="npsanandreasassapsasm7p8_se" magnitude="7.8" depth="9.8" lat="
39.156800" lon="-123.830000" event_timestamp="2013-10-10T12:00:00UTC" event_netw
ork="nc" event_description="N. San Andreas; North Coast + Peninsula + Santa Cruz
<Mountain" />
<grid_specification lon_min="-127.330000" lat_min="35.823465" lon_max="-120.3300
00" lat_max="40.490132" nominal_lon_spacing="0.016667" nominal_lat_spacing="0.01
6667" nlon="421" nlat="281" />
<event_specific_uncertainty name="pga" value="0.000000" numsta="" />
<event_specific_uncertainty name="pgv" value="0.000000" numsta="" />
<event_specific_uncertainty name="mi" value="1.000000" numsta="0" />
<event_specific_uncertainty name="psa03" value="0.000000" numsta="" />
<event_specific_uncertainty name="psa10" value="0.000000" numsta="" />
<event_specific_uncertainty name="psa30" value="0.000000" numsta="" />
<grid_field index="1" name="LON" units="dd" />
<grid_field index="2" name="LAT" units="dd" />
<grid_field index="3" name="PGA" units="pctg" />
<grid_field index="4" name="PGV" units="cms" />
<grid_field index="5" name="MI" units="intensity" />
<grid_field index="6" name="PSA03" units="pctg" />
<grid_field index="7" name="PSA10" units="pctg" />
<grid_field index="8" name="PSA30" units="pctg" />
<grid_data>
-127.3300 40.4901 0.33 1.99 2.08 0.97 1.67 0.95
-127.3133 40.4901 0.33 2.05 0.98 1.68 0.96
-127.2967 40.4901 0.34 2.01 2.13 0.99 1.69 0.96
-127.2800 40.4901 0.34 2.03 2.14 1.1 0.97
-127.2633 40.4901 0.35 2.04 2.17 1.02 1.72 0.97
-127.2467 40.4901 0.35 2.05 2.18 1.03 1.73 0.98
-127.2300 40.4901 0.36 2.06 2.2 1.04 1.74 0.98
-127.2133 40.4901 0.37 2.08 2.21 1.05 1.75 0.98
U= grid.xml Top L2 Git-master (nXML Valid)
</nil -mouse-> is undefined
```

R2D Earthquake hazard definition options in R2D

Option 3: Regional Site Response

Users provide ground motion records at the bedrock level and compute the ground surface response with one-dimensional response analyses using OpenSees.

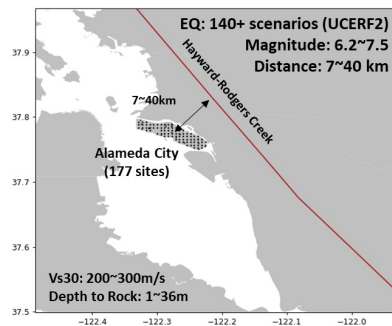


Current R2D Workflow to include Site Response effects

- Coupling GMS, building inventory and damage and loss assessment
- Modular approach with flexible soil and structural model definition
- Conducting Risk Assessment in Research Area

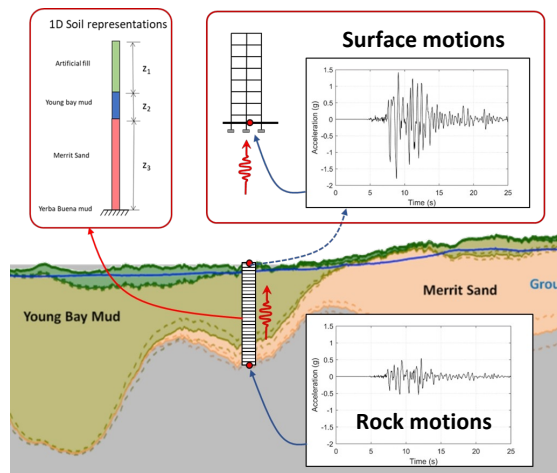
Workflow using 1D SiteResponse

Earthquake ground motions



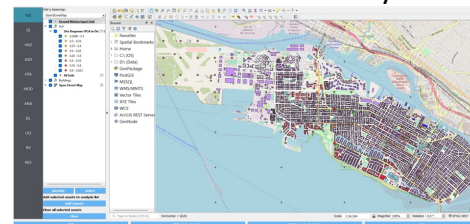
- **Rock motions:**
 1. **GMPE w/ rock Vs30 + record selection**
 2. **Physics-based earthquake records**

1D Soil layer simplification and building analysis

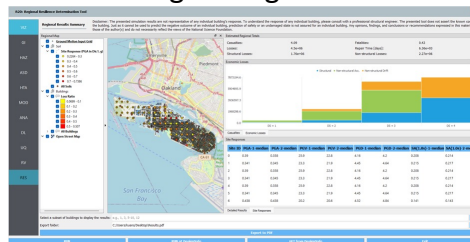


Risk Assessment(R2D)

Surface motion intensity



Building damage and loss

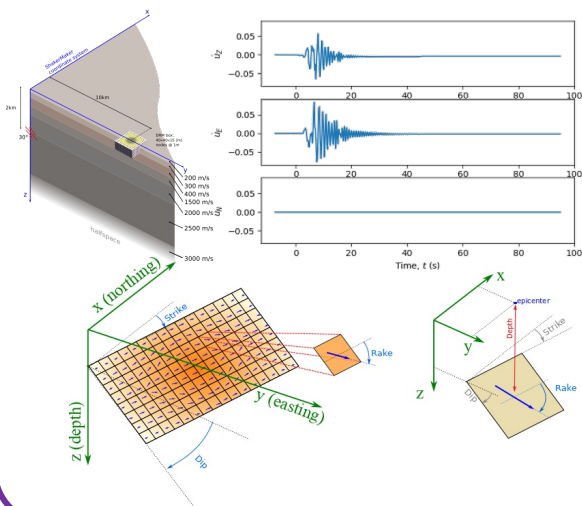


Proposed R2D Workflow to include SiteResponse effects

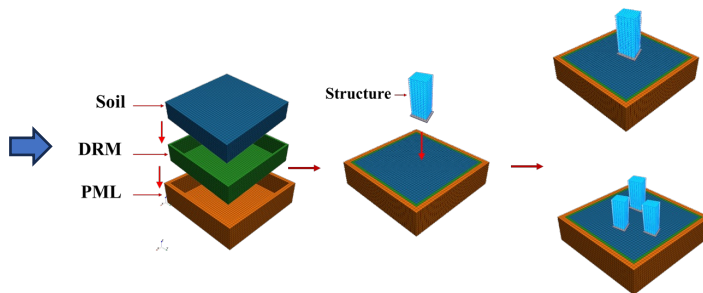
- Transition to Cutting-Edge Simulations that includes DRM and PML
- Exploring Source Rupture Modeling and Uncertainty
- Conducting Risk Assessment in Research Area

Workflow using DRM and PML

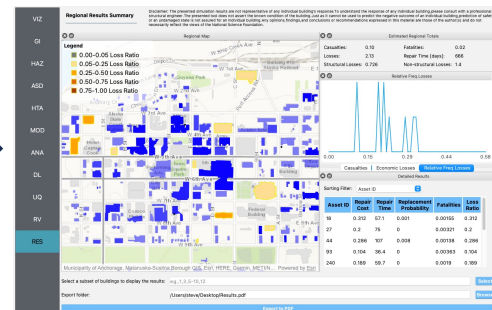
Source Modeling



State-of-the-Art Finite Element Model



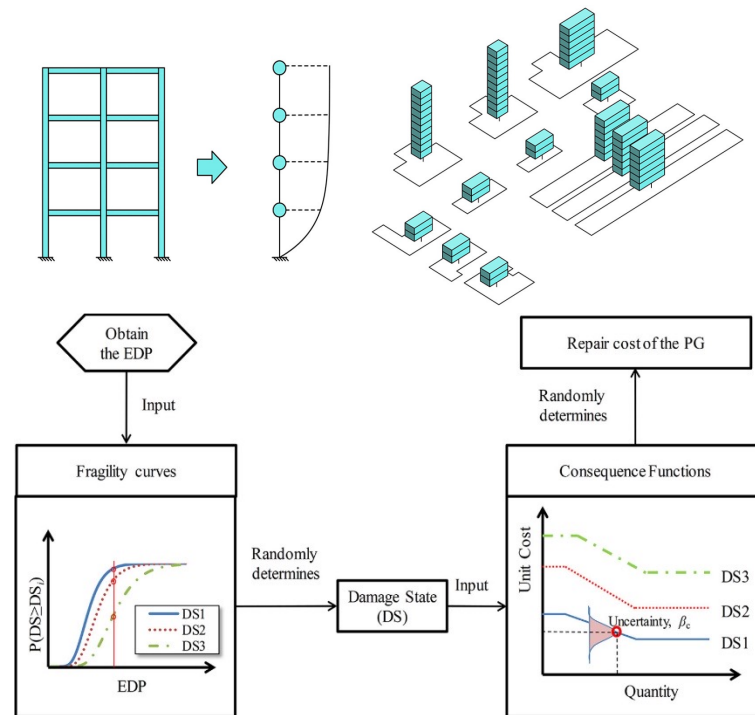
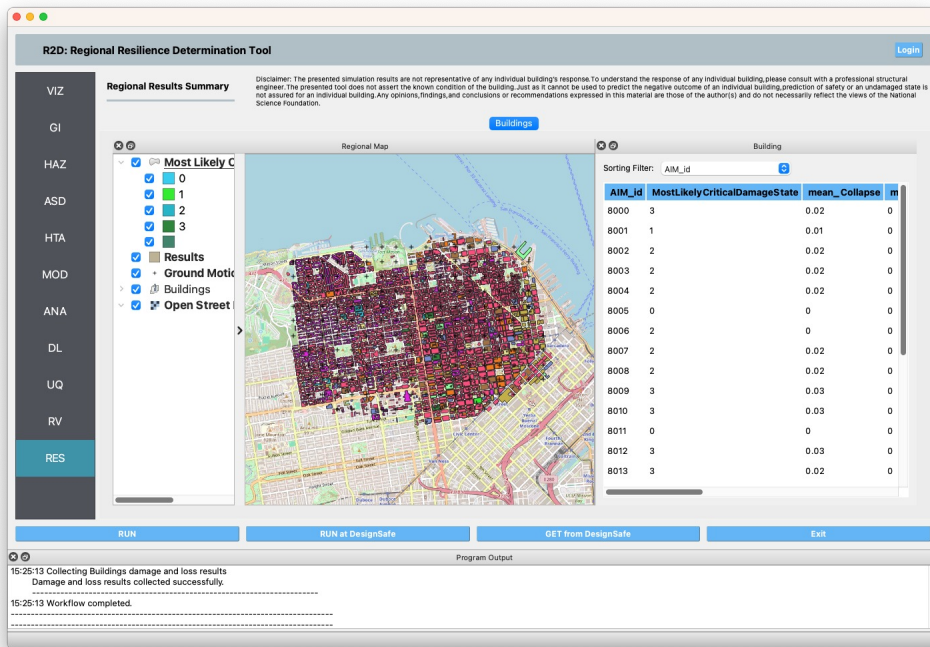
Risk Assessment(R2D)



R2D Application of the ground motions

Application 1: Building safety assessment

Building level performance assessment using **Intensity Measures** or story level performance assessment using multi-degree of freedom OpenSees models and ground motion **Time History** records.



R2D Application of the ground motions

Application 2: Transportation infrastructure safety assessment

High-level performance assessment using ground motion **Intensity Measures** and FEMA's Hazus fragility curves for highway bridges, tunnels, and roadways.

R2D: Regional Resilience Determination Tool

Regional Results Summary

Disclaimer: The presented simulation results are not representative of any individual building's response. To understand the response of any individual building, please consult with a professional structural engineer. The presented tool does not assert the known condition of the building. Just as it cannot be used to predict the negative outcome of an individual building, prediction of safety or an undamaged state is not assured for an individual building. Any opinions, findings, and conclusions expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Buildings Transportation Network

Most Likely Critical Damage State

Results

- Ground Motion Grid
- Tunnel
 - Selected Tunnel
 - Tunnel.geojson
- Roadway
 - Selected Roadway
 - Roadway.geojson
- Bridge
 - Selected Bridge
 - Bridge.geojson
- Buildings
- Open Street Map

Regional Map

Roadway

Sorting Filter: AIM_id

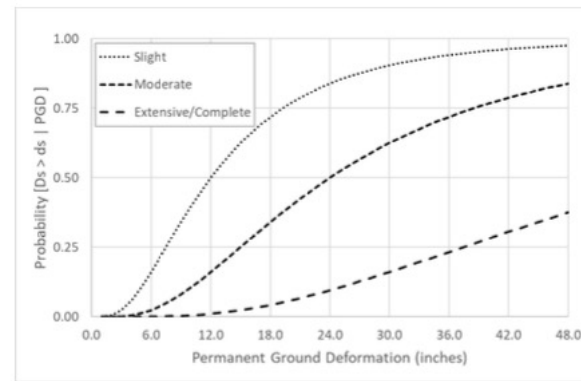
| AIM_id | MostLikelyCriticalDamageState | mean_Collapse | |
|--------|-------------------------------|---------------|---|
| 30215 | 0 | 0 | 0 |
| 30216 | 3 | 0 | 0 |
| 30217 | 3 | 0 | 0 |
| 30220 | 0 | 0 | 0 |
| 30221 | 0 | 0 | 0 |
| 30222 | 0 | 0 | 0 |
| 30223 | 0 | 0 | 0 |
| 30224 | 0 | 0 | 0 |
| 30225 | 0 | 0 | 0 |

Bridge Roadway Tunnel

RUN RUN at DesignSafe GET from DesignSafe Exit

Program Output

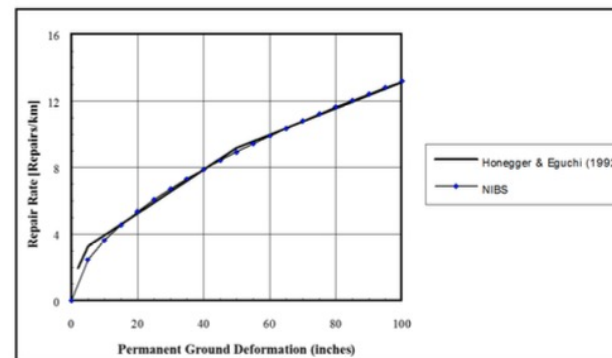
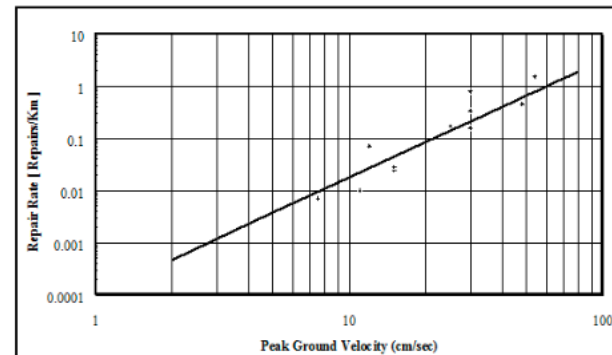
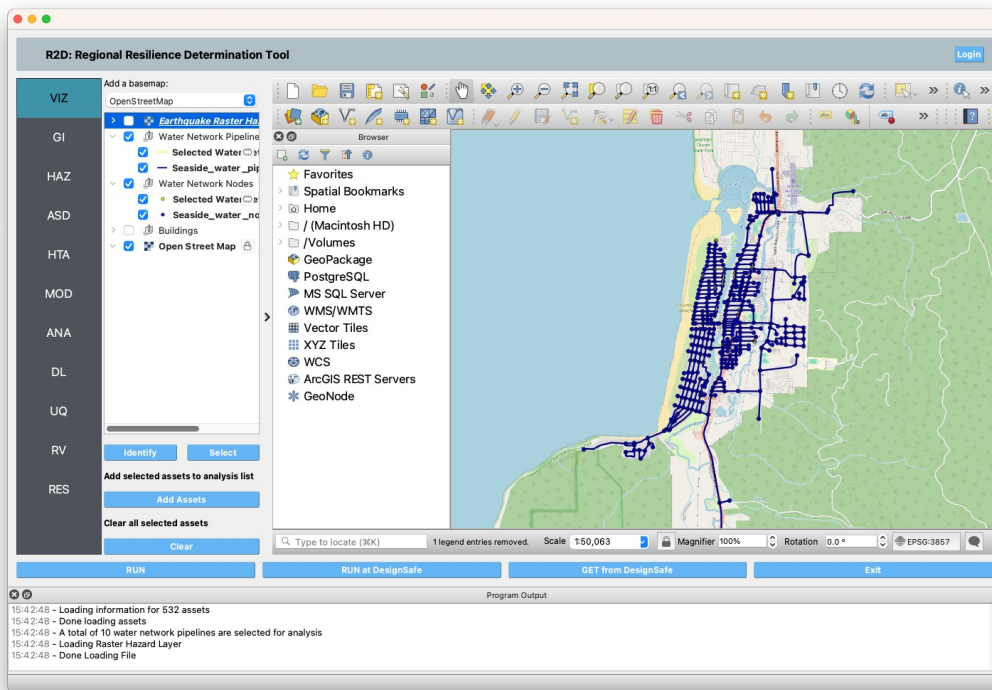
15:38:03 - Importing results
15:38:04 - Analysis complete



R2D Application of the ground motions

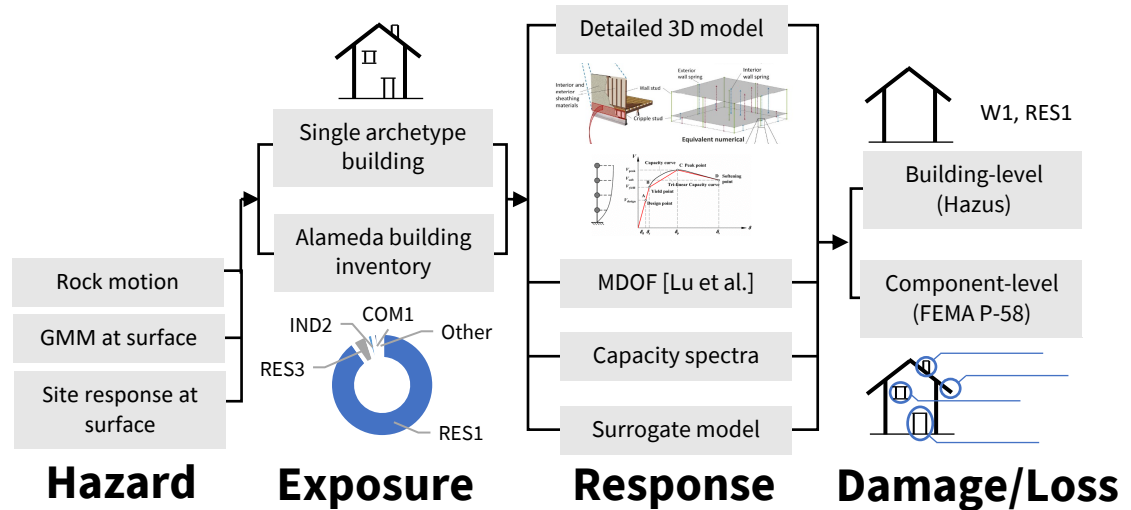
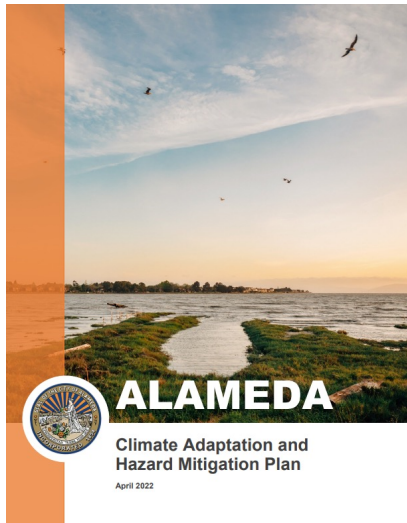
Application 3: Water pipeline infrastructure safety assessment

High-level performance assessment using ground motion **Intensity Measures** and FEMA's Hazus fragility curves for water pipeline, pumps and tanks.



Alameda Case Study

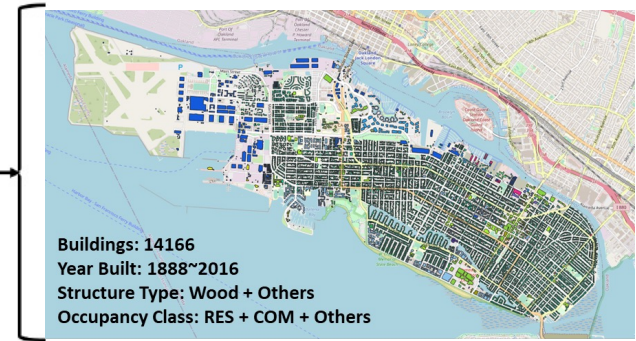
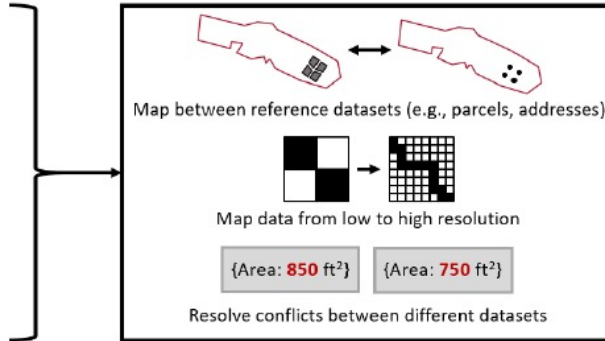
- Inform the Local Hazard Mitigation Plan
- Support research in geotechnical engineering and recovery modeling
- Initiate assessment of multiple subsystems (building, bridge/transportation, pipelines)



Alameda Case Study – Buildings, Transportation & Water

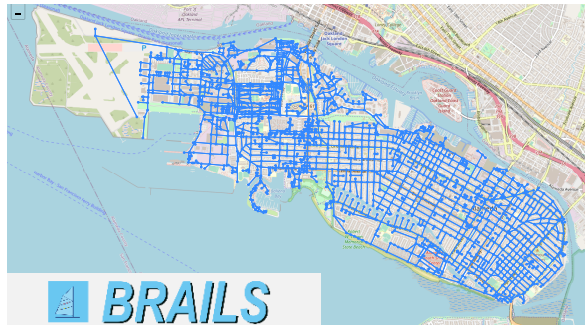
High-Fidelity Building Inventory

Publicly available datasets

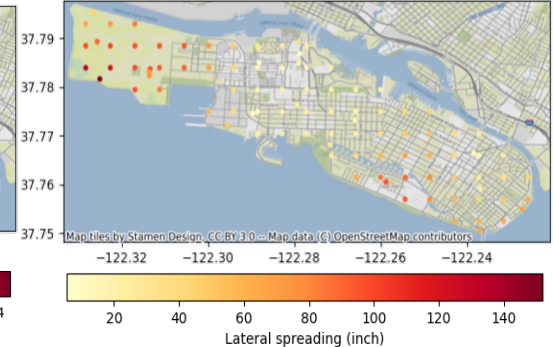
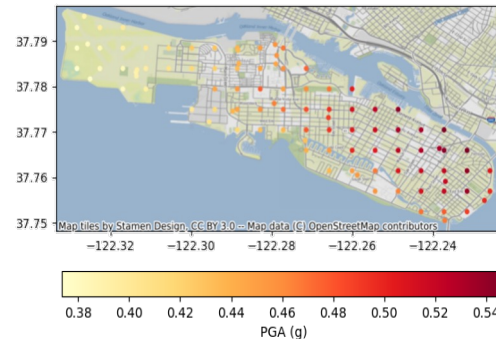


Transportation & Water Infrastructure

Bassman T.J., Zarnóczy A., Saw J., Wang S., Deierlein G.G., "High-Fidelity Testbed Development for Regional Risk Assessment in Alameda, California", 12th NCEE, 2022

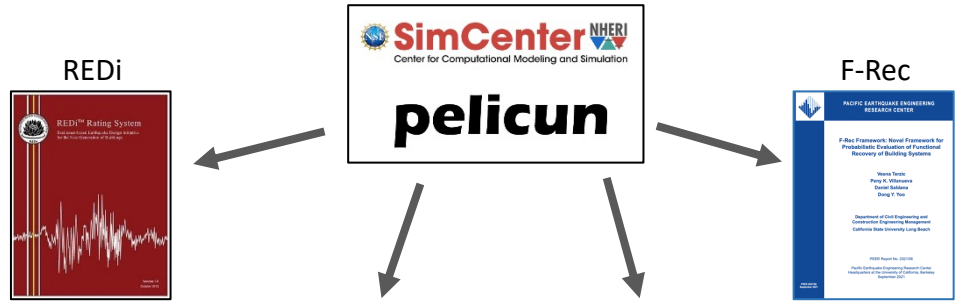
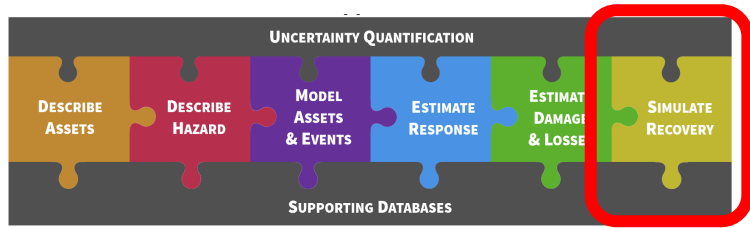


Inventory Generation Tools



Ground Shaking and Permanent Deformation

Modeling Functional Recovery



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a nonprofit corporation

Functional Recovery: A Conceptual Framework with Policy Options
A white paper of the Earthquake Engineering Research Institute
December 6, 2019

Executive Summary
Earthquake-resistant design, especially as required by building codes, has always been primarily about safety. Over the last few years, policymakers and advocates have begun calling for “better than code” seismic design (Federal Register, 2016; San Francisco, 2016; NIST, 2017).

A productive way to think about this goal is to envision codes and standards written to achieve not only safety, but also acceptable recovery times. The recent NHERF masterplans, which REDI supported and helped to draft, does this. It calls for FEMA and NIST to convene experts to recommend “options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake reoccupancy and functional recovery time” (42 U.S.C. 7705b); Senate Bill 1766, 2018).

The NHERF masterplans state two objectives for the post-earthquake timeline: reoccupancy and functional recovery. For a building, the first objective, reoccupancy, is the ability to re-occupy, like shelter, and begin the recovery phase early (NHERF, 2017). Functional recovery is the second objective: it marks the resumption of building services as needed to support a significant measure of the building’s intended purpose(s) (see Barbour, 2011). Similarly, for infrastructure systems functional recovery marks the resumption of the system’s services as needed to allow users to resume most of their pre-earthquake activities (Davis, 2019c; 2019a).

A working definition, suitable for both buildings and lifeline infrastructure, is presented in the paper, as follows: *Functional recovery is a post-earthquake state in which capacity is sufficiently maintained or restored to support pre-earthquake functionality.*

Thus, design for functional recovery means considering both safety and recovery time in design. Where current reoccupancy or recovery times are unacceptable, higher performance goals might be set, resulting in changes to what and how we build. But in many cases, reoccupancy or recovery times might already be adequate, in which case “better than code” performance would mean only that the recovery goals and expectations are better understood and more clearly recognized.

We recognize that a design shift for functional recovery will need to consider interdependencies between at least five physical systems that comprise the built environment and will involve five sets of linked but largely independent issues.

The systems are:

- Buildings, core and existing, serving all occupancies and uses
- Water and wastewater systems
- Energy systems
- Communication systems

Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time
FEMA P-2090 / NIST SP-1254 / January 2021

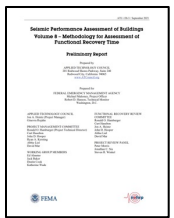
ARUP

TREADS



Molina Hutt et al.

ATC-138



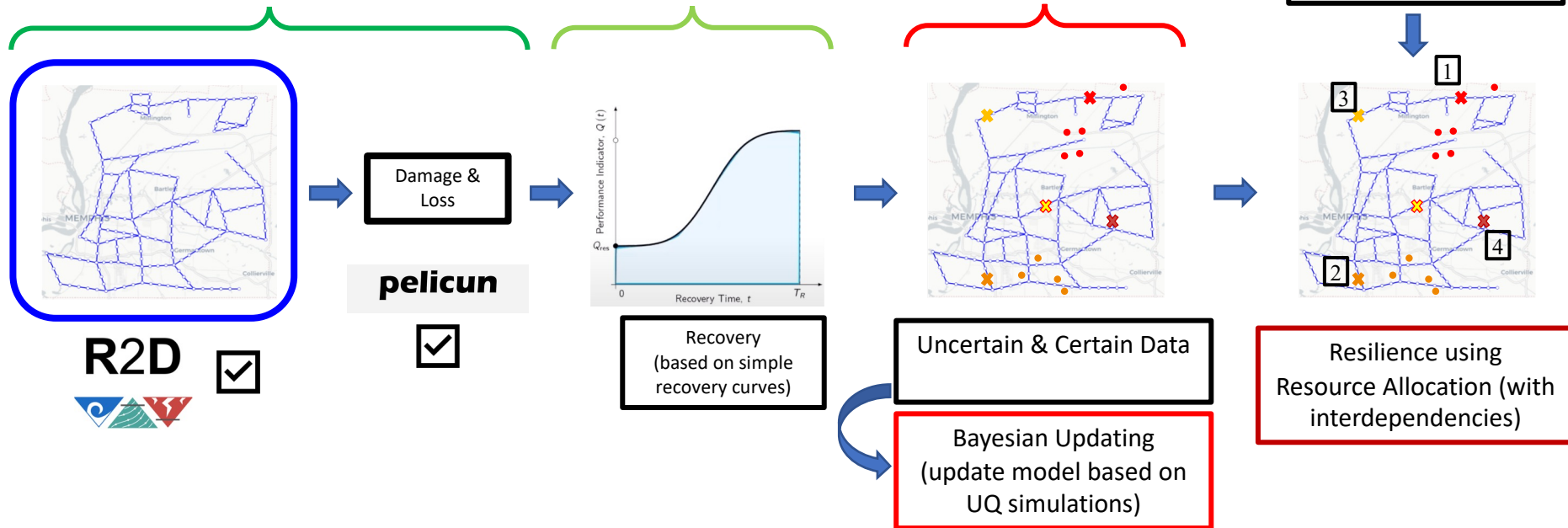
FEMA, ATC

Terzic et al.

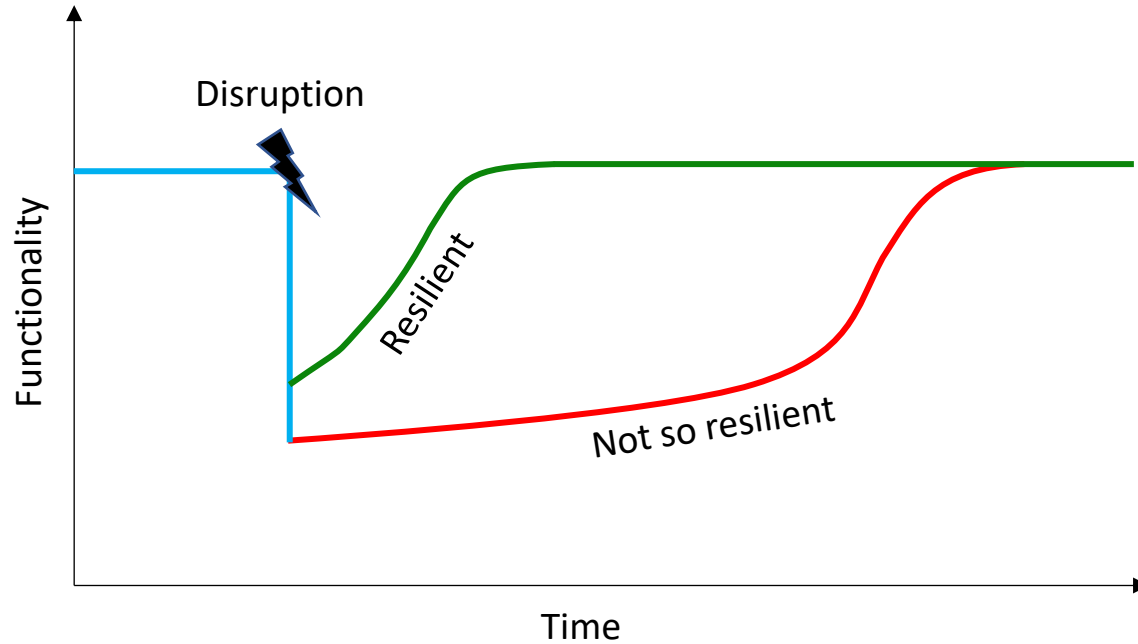
- Opportunities for comparisons and benchmarking
- Recognize and leverage synergies in future development
- Open-source code supports both research and practice

GOAL: D/L+R+UQ+Interdependencies

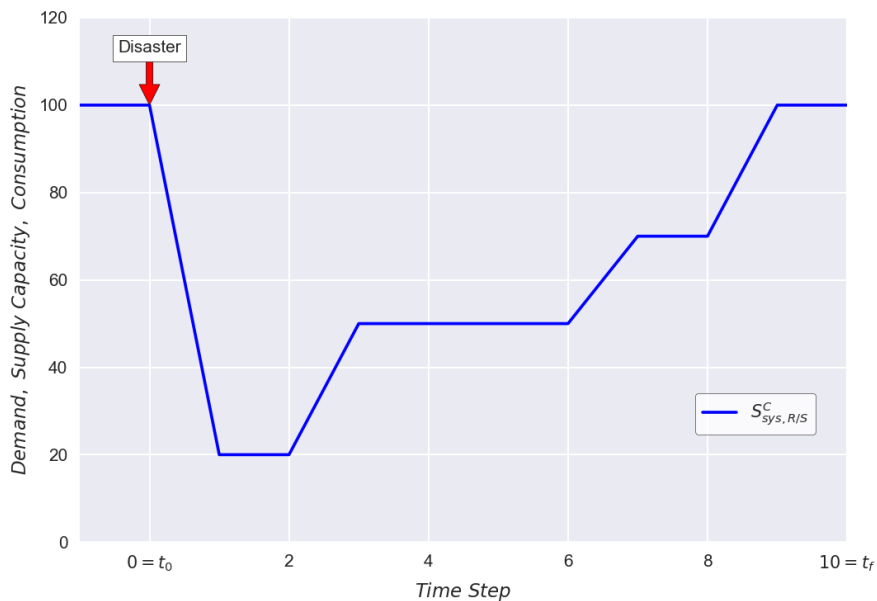
- Tool to allocate resources post-event based on both certain and uncertain data and uncertainty in other parameters (i.e. known pipe/valve break) + **OTHER INFRASTRUCTURE DAMAGE DATA**



What is resilience?



Resilience assessment using supply/demand/consumption

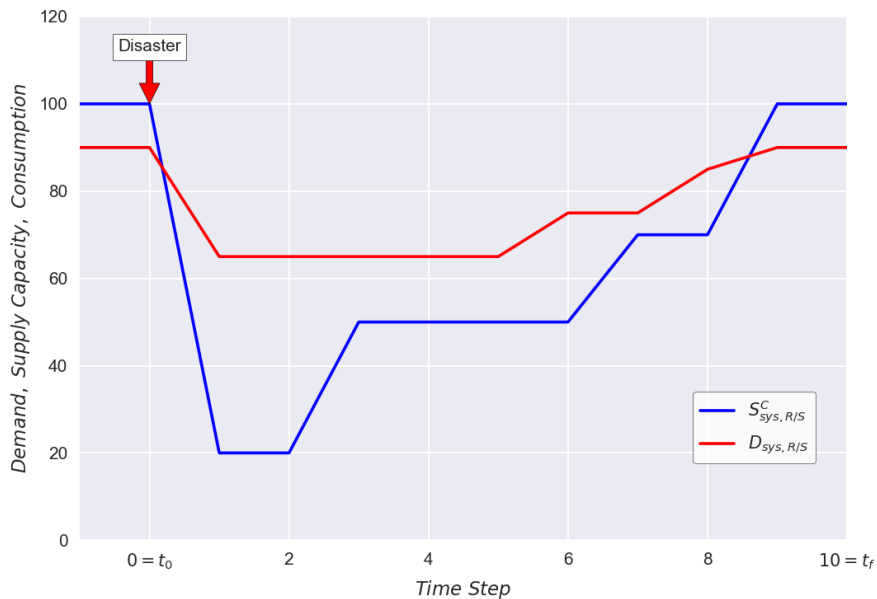


Post-disaster demand, supply and consumption of a system during recovery.

Disaster Resilience Quantification:

- System Supply: $S_{sys,R/S}^C(t) = \sum_{i \in \{1, \dots, I\}} S_{i,R/S}^C(t)$

Resilience assessment using supply/demand/consumption

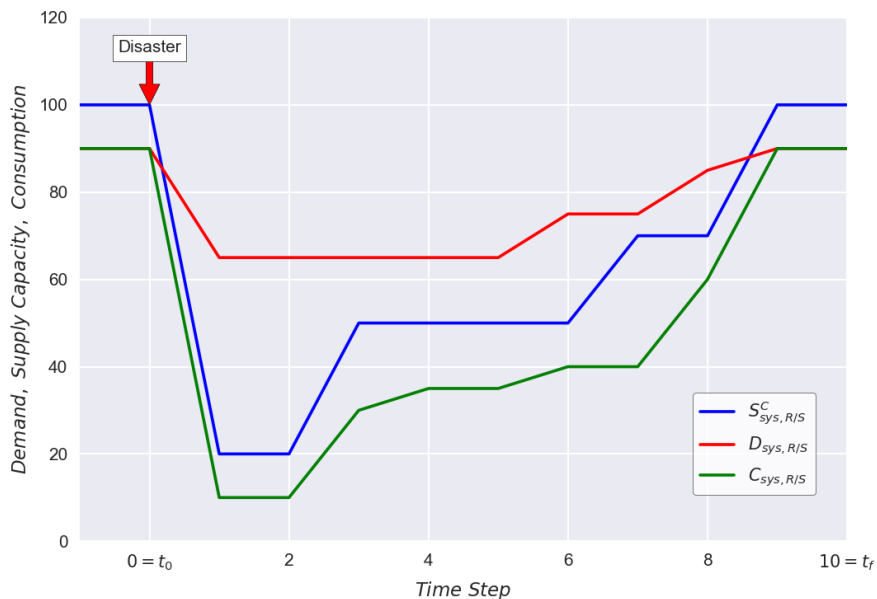


Post-disaster demand, supply and consumption of a system during recovery.

Disaster Resilience Quantification:

- **System Supply:** $S^C_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} S^C_{i,R/S}(t)$
- **System Demand:** $D_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} D_{i,R/S}(t)$

Resilience assessment using supply/demand/consumption

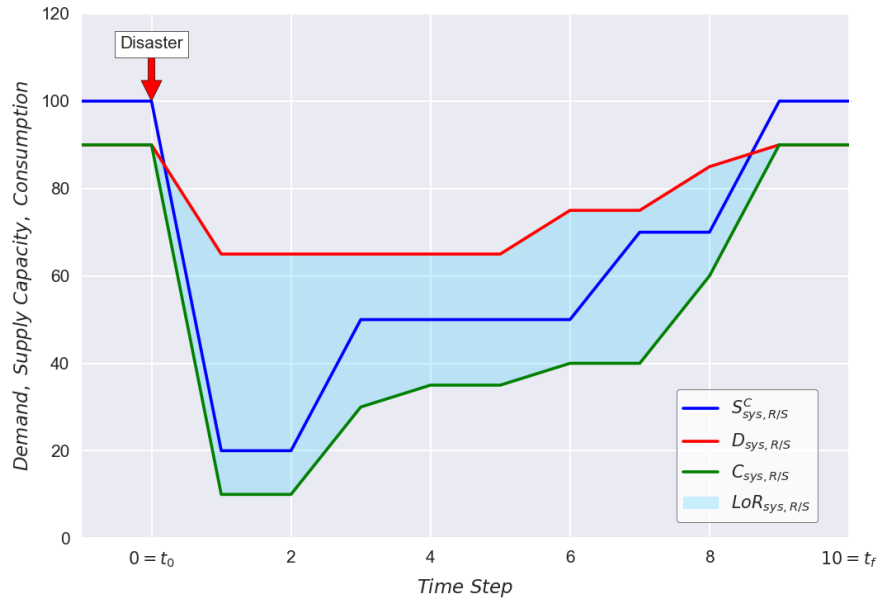


Post-disaster demand, supply and consumption of a system during recovery.

Disaster Resilience Quantification:

- **System Supply:** $S_{sys,R/S}^C(t) = \sum_{i \in \{1, \dots, I\}} S_{i,R/S}^C(t)$
- **System Demand:** $D_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} D_{i,R/S}(t)$
- **System Consumption:** $C_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} C_{i,R/S}(t)$

Resilience assessment using supply/demand/consumption



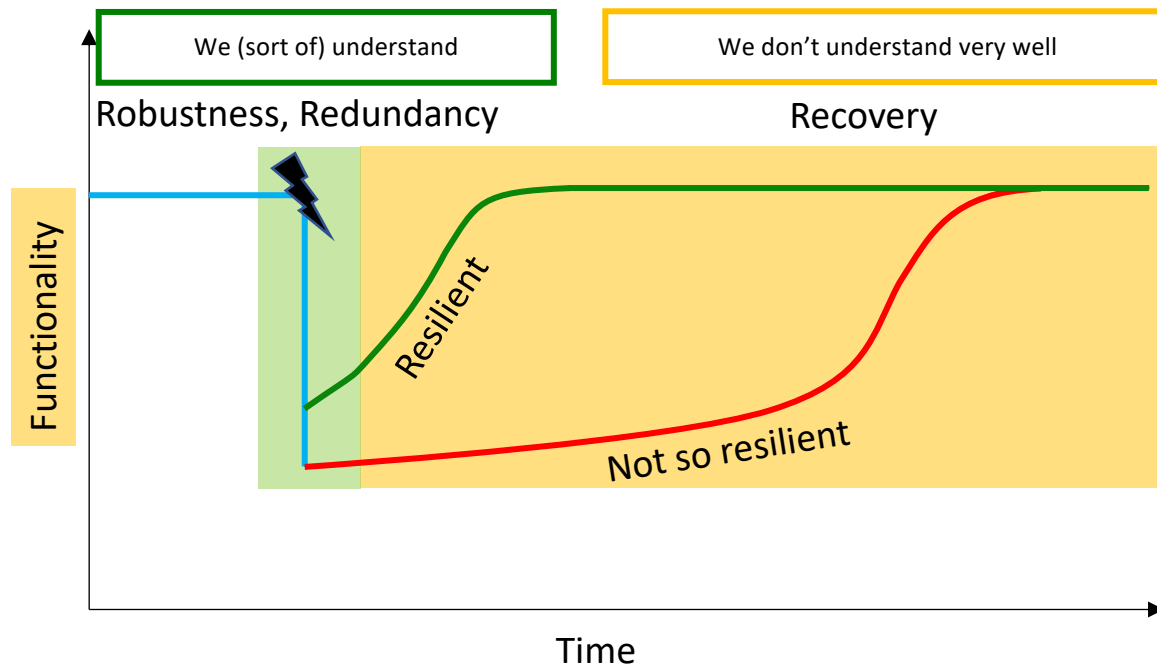
Post-disaster demand, supply and consumption of a system during recovery.

Disaster Resilience Quantification:

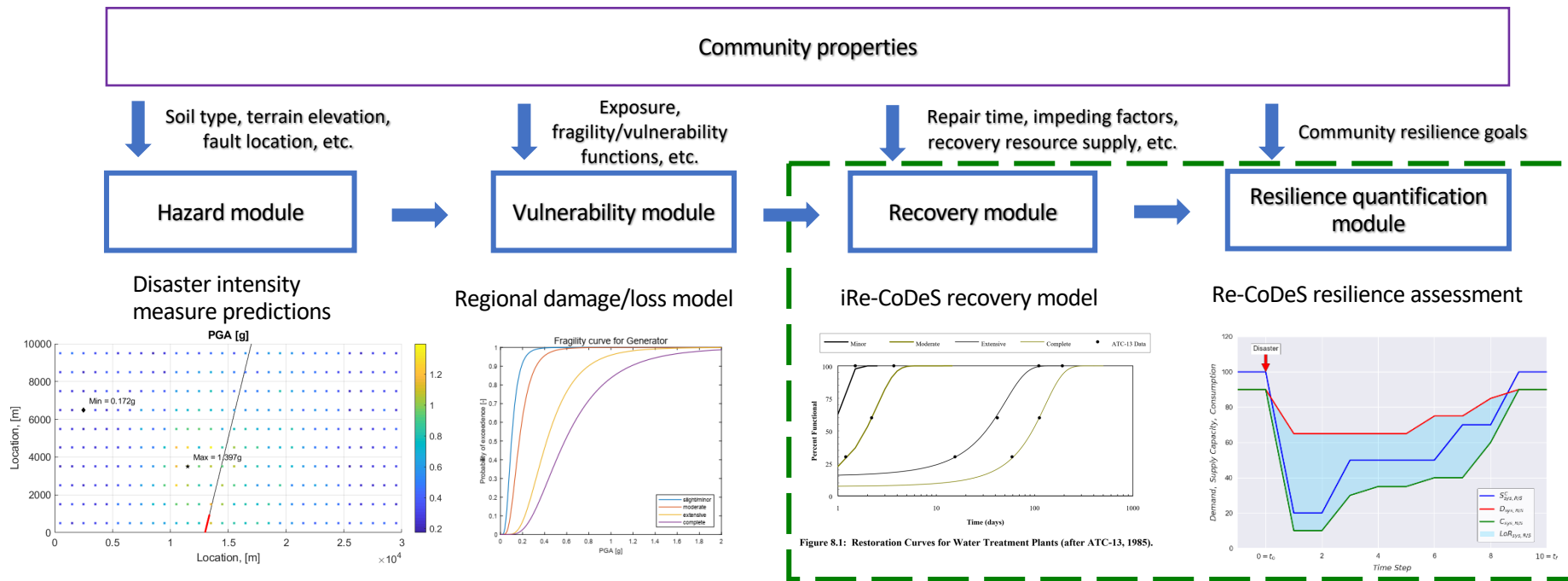
- **System Supply:** $S_{sys,R/S}^C(t) = \sum_{i \in \{1, \dots, I\}} S_{i,R/S}^C(t)$
- **System Demand:** $D_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} D_{i,R/S}(t)$
- **System Consumption:** $C_{sys,R/S}(t) = \sum_{i \in \{1, \dots, I\}} C_{i,R/S}(t)$
- **Resilience Metric:**

$$LoR_{sys,R/S} = \int_{t_0}^{t_f} (D_{sys,R/S}(t) - C_{sys,R/S}(t)) dt$$

How well do we understand our built environment?



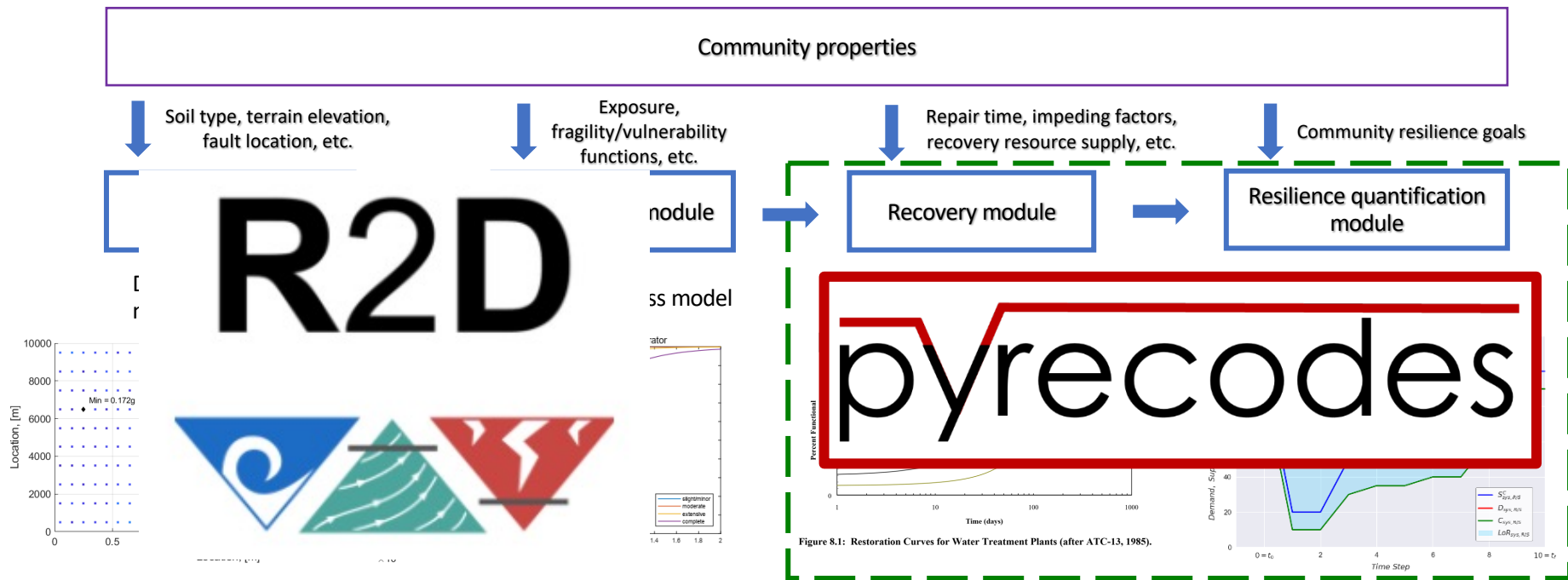
iRe-CoDeS computational workflow: physics-based and modular



Blagojević, Kipfer, Didier, Stojadinović (2020) *Probability-based Resilience Assessment of Communities with Interdependent Civil Infrastructure Systems*. Proceeding of the 17th World Conference on Earthquake Engineering, Sendai, Japan.

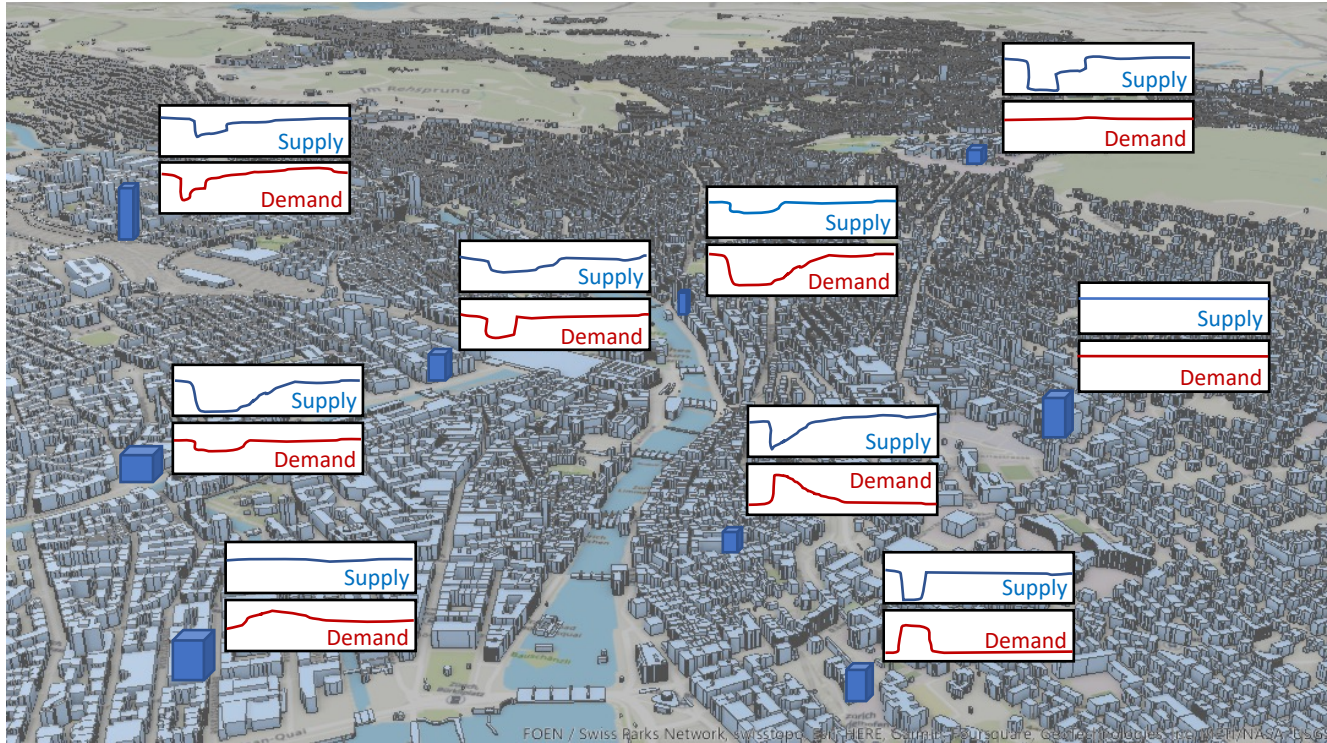
Blagojević, Kipfer, Didier, Stojadinović (2020) *Scenario-based Resilience Assessment of Communities with Interdependent Civil Infrastructure Systems*. Proceeding of the 17th World Conference on Earthquake Engineering, Sendai, Japan.

iRe-CoDeS computational workflow: physics-based and modular



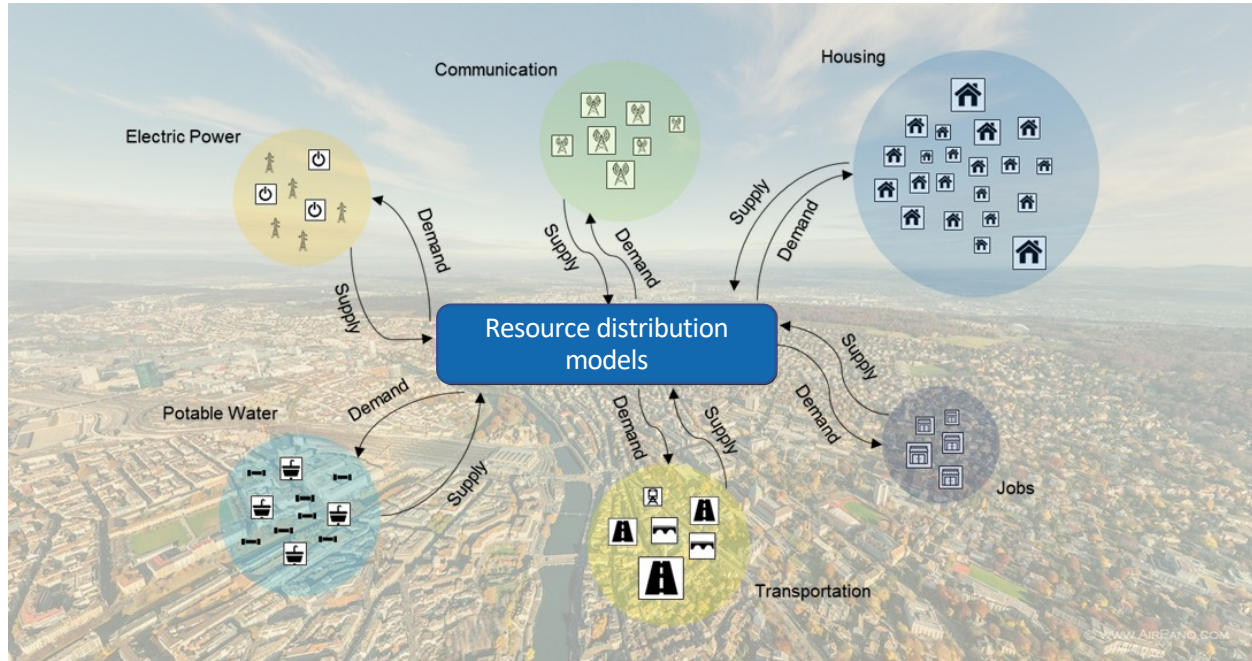
pyrecodes is an open-source framework for regional disaster recovery simulation and disaster resilience assessment of interdependent systems.

Monitor/simulate components' resource supply and demand during recovery



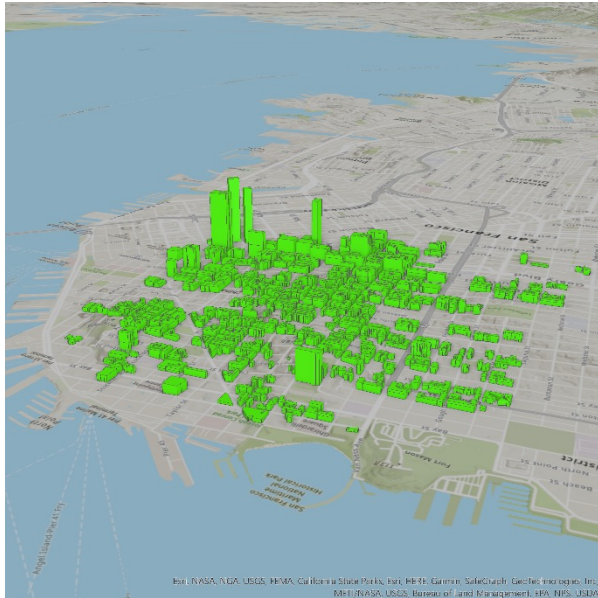
Blagojević, Hefti, Henken, Didier, Stojadinović (2022) *Quantifying Disaster Resilience of a Community with Interdependent Civil Infrastructure Systems*. Structure and Infrastructure Engineering.

Component interdependencies simulated as a flow of resources and services

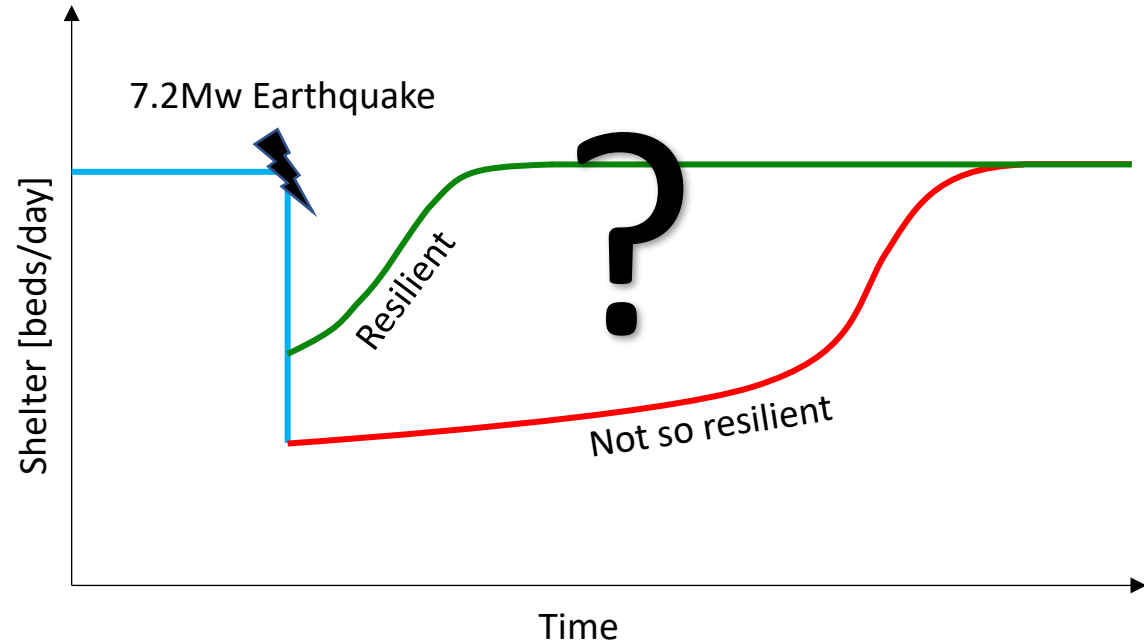


Blagojević, Hefti, Henken, Didier, Stojadinović (2022) *Quantifying Disaster Resilience of a Community with Interdependent Civil Infrastructure Systems*. Structure and Infrastructure Engineering.

Case Study: Housing Resilience of North-East San Francisco



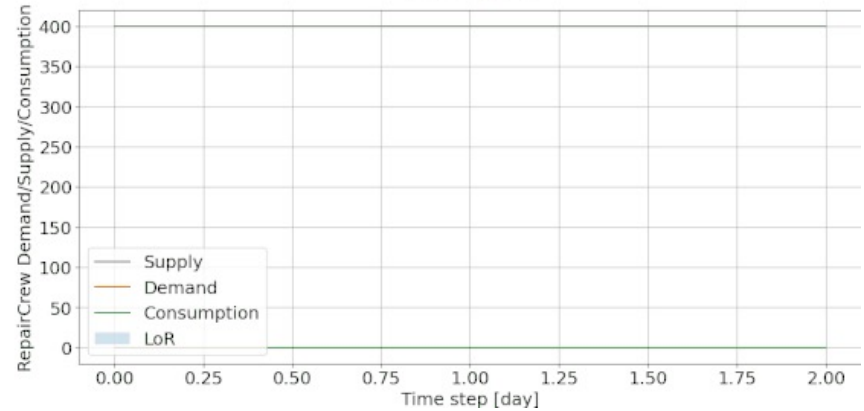
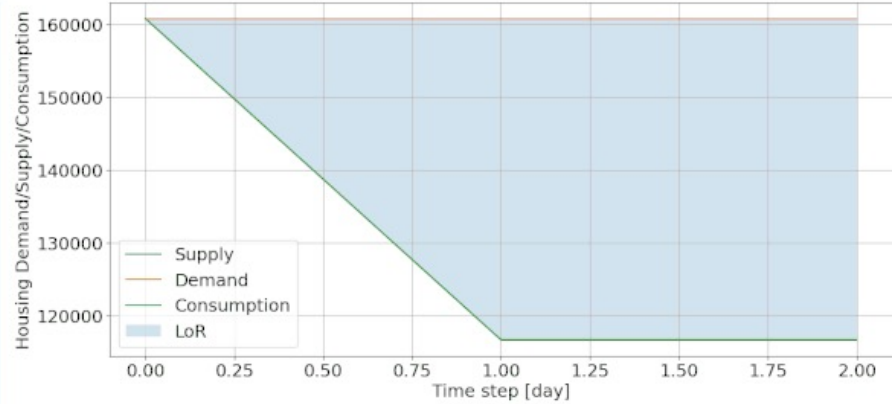
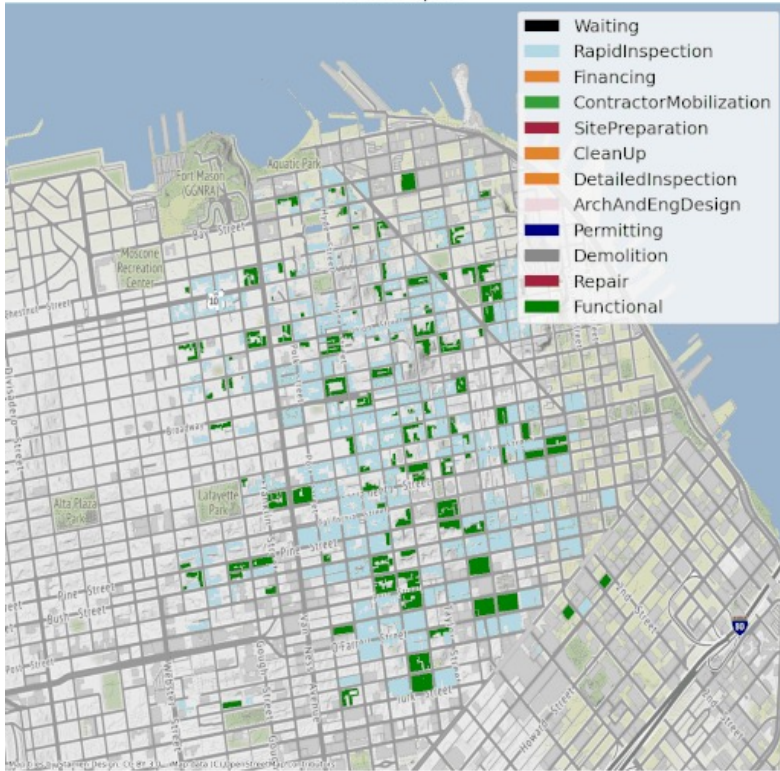
Residential buildings considered in the Case Study.



Blagojević and Stojadinović (2022) *A Demand-Supply Framework for Evaluating the Effect of Resource and Service Constraints on Community Disaster Resilience*. Resilient Cities and Structures.

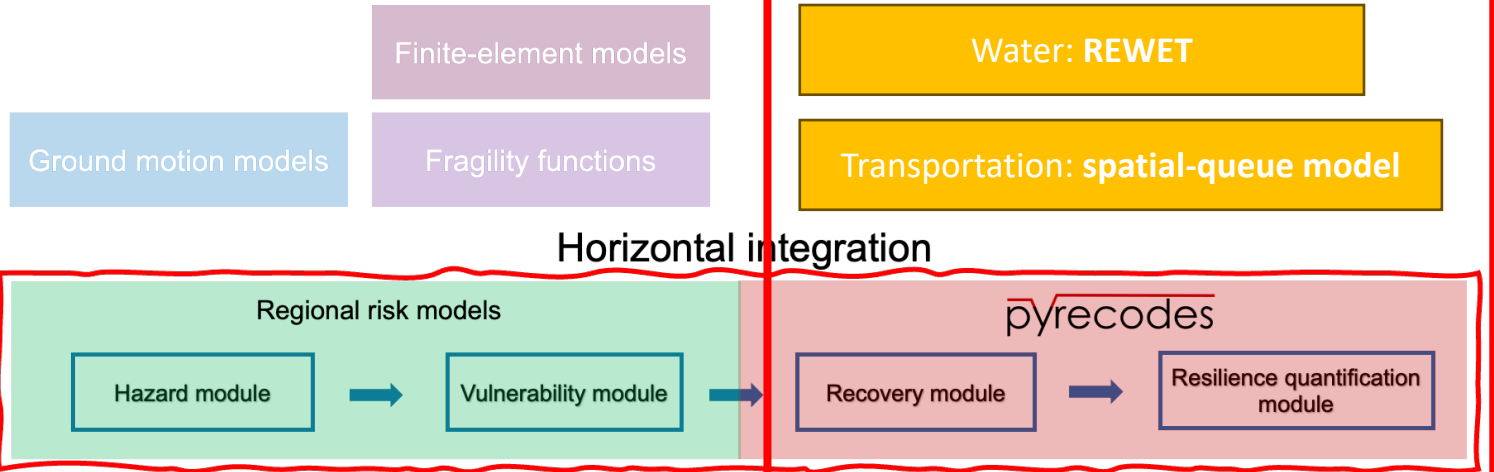
Housing recovery of North-East San Francisco

Time Step: 2

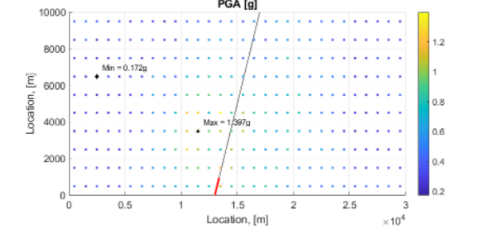


Blagojević and Stojadinović (2022) *A Demand-Supply Framework for Evaluating the Effect of Resource and Service Constraints on Community Disaster Resilience*. Resilient Cities and Structures.

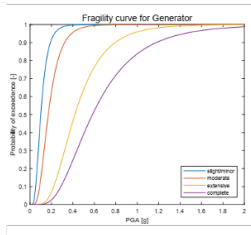
pyrecodes: integration and future development



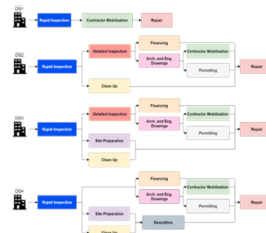
Disaster intensity measure assessment



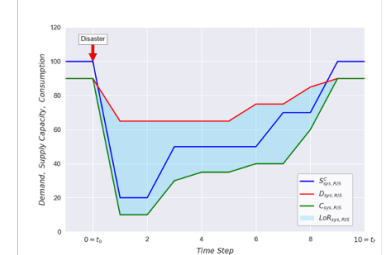
Regional damage/loss model



iRe-CoDeS regional recovery model



Re-CoDeS resilience assessment



SimCenter Portal

SIMCENTER
COMPUTATIONAL MODELING
AND SIMULATION CENTER

Navigation: About, Research Tools, Learning Tools, Backend Components, Knowledge Hub, Join the Community, Collaborate

What is the SimCenter?
Join the Community
Get answers SimCenter FAQs

Upcoming Events

- SimCenter Training for Regional Simulations - Registration Open - May 21, 2021, 10:00 AM - 12:00 PM (Pacific)
- SimCenter Development Team Office Hours - May 21, 2021, 12:00 PM - 1:00 PM (Pacific)

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AND SIMULATION CENTER

Navigation: About, Research Tools, Learning Tools, Backend Components, Knowledge Hub, Join the Community, Collaborate

REGIONAL RESILIENCE DETERMINATION (R2D) TOOL (LATEST VERSION 1.0)

The Regional Resilience Determination Tool (R2D) is a graphical user interface for the SimCenter application framework designed to simulate the regional impact of natural hazards. R2D advances the capabilities of the natural hazards engineering community by facilitating the high-resolution assessment of disaster impact and risk on a regional scale. Researchers can investigate disaster scenarios or perform a probabilistic assessment by considering a diverse set of plausible events and propagate the uncertainty in the hazard and the characteristics of the built environment through simulations. The user interface of the R2D Tool facilitates importing and querying input data that describes the regional hazard and the built environment and helps researchers with setting up and running the simulations either on their computer or at the HPC clusters available at DesignSafe. Once the simulations are completed, the main results are visualized in the tool and detailed results are also available for post processing.

Several examples are provided to demonstrate the application's versatility when it comes to assembling simulation workflows of various levels of complexity:

- E1 - Basic HAZUS
- E2 - MDOF Building Response
- E3 - Physics-based Ground Motions
- E4 - OpenSpacePy FEM
- E5 - Ground Shaking + Liquefaction

See the Tool's Documentation for details on these examples.

The current version allows users to investigate the performance of the buildings in the region when subjected to earthquake events. The application is being expanded to allow researchers to investigate the effects of a hurricane event, and future versions will incorporate lifelines and respond to users' feature requests. Interested beta testers should contact NHERI-SimCenter@berkeley.edu.

SimCenter
Regional Resilience Determination Tool

2. User Guide

The R2D app, as will be discussed in Software Architecture, is a scientific workflow application that creates workflows and runs them in the background. These workflows can involve multiple different backend applications. Once the R2D app is started, the user is presented with the user interface shown in Fig. 2.5. It is in this UI where the user selects the applications to run in a workflow, inputs the necessary parameters for each of these applications, starts the workflow either locally or remotely, and finally views the simulation results. The main window of the UI is divided into several separate areas:

Message Area
Login Button
Input Panel
Panel Selection Ribbon
Push Buttons

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- 1. About
- 1.1. Acknowledgments
- 2. Copyright and License
- 3. Abbreviations
- USER MANUAL
 - 1. Installation
 - 2. User Guide
 - 2.1. VIZ: Visualization
 - 2.2. GI: General Information
 - 2.3. HAZ: Hazards
 - 2.4. ASD: Asset Definition
 - 2.5. HTA: Hazard to Asset
 - 2.6. MOD: Asset Modeling
 - 2.7. ANA: Asset Analysis
 - 2.8. DL: Damage and Loss
 - 2.9. UQ: Uncertainty Quantification

- Software & Documentation
- Education and Training Webinars
- Forum & Other Communication

<https://simcenter.designsafe-ci.org/>



