Resilient Design for Functional Recovery

Emergence Over the Past Decade, Codification of Prescriptive Requirements, and Pre-Qualification of Structural Systems

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Professor @ California State University, Chico

Acknowledgement of Many Collaborators on Resilient Design:

SP3 Team (specifically Ed Almeter, Jared DeBock, and Dave Welch), many visionary Structural Engineers in our profession, ATC-138 Project Team (FEMA-funded), NIST project by Liel/Cook, National Code groups, and many more….!

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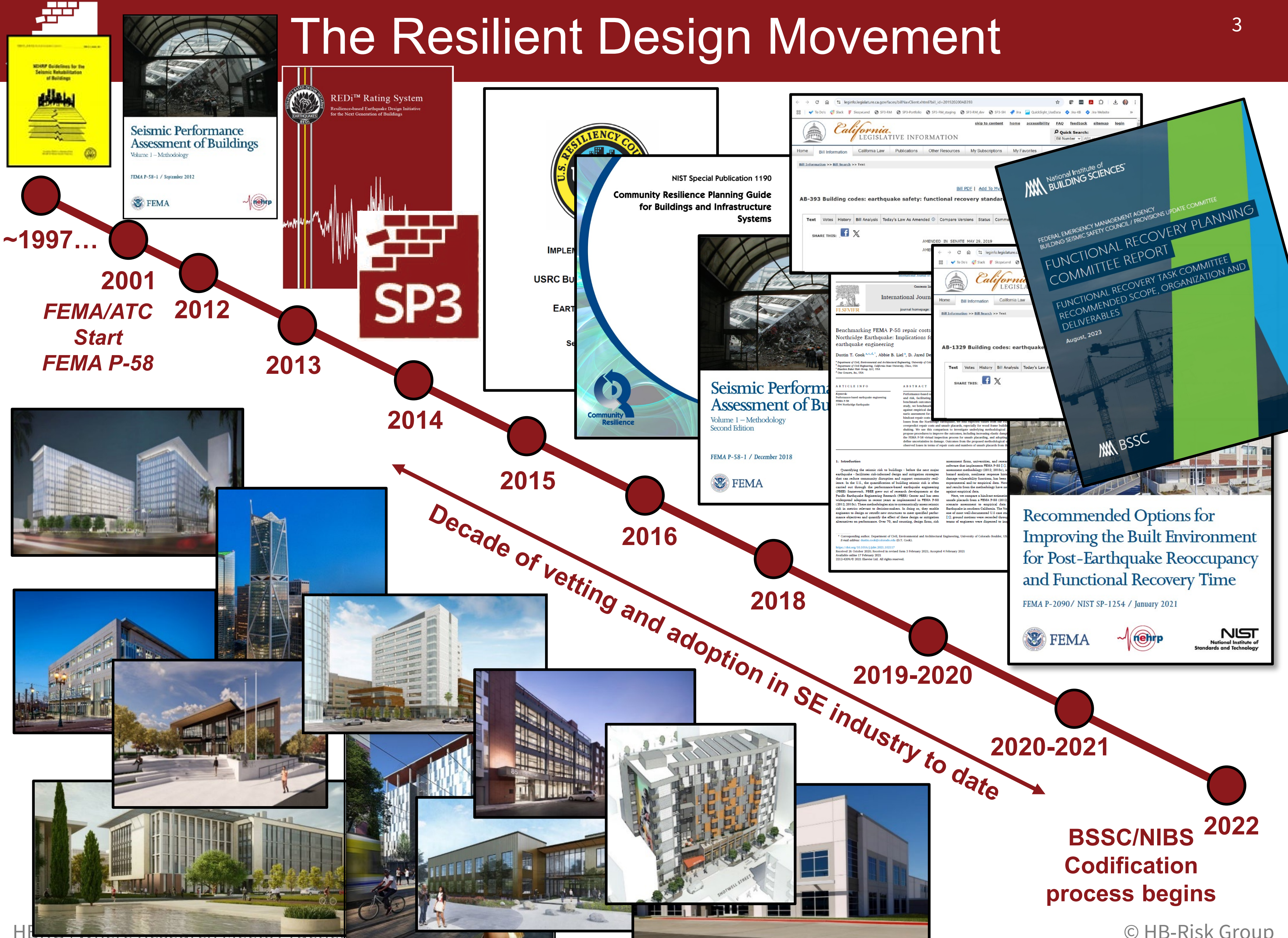
SEAONC Seminar, San Francisco, California; April 8, 2025

Quick Upfront Comments

- Building code development process details will not be fully provided (but concepts will be provided).
- Much of this work merges my academic work and SP3 software support work. I will mention the software when appropriate (when it is needed to enable something), but will focus more on the technical and academic developments.

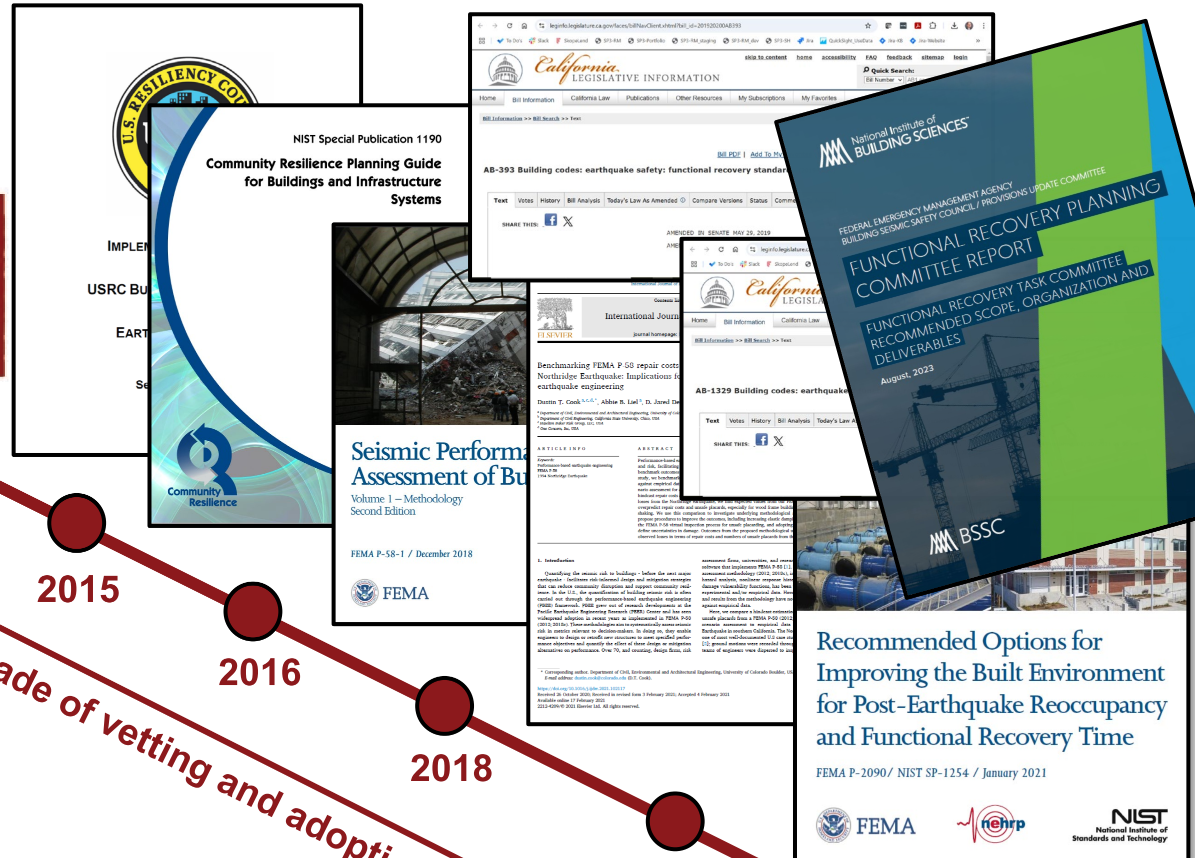
The Resilient Design Movement



The Resilient Design Movement

- Over the past decade, FEMA P-58 resilient design and risk assessment methods have been used and vetted by many early-adopter seismic-focused structural engineering companies. This has been instrumental in providing confidence for current resilient design codification efforts.

The Resilient Design Movement



- ~1997…
- 2001 — *FEMA/ATC Start FEMA P-58*
- 2012
- 2013
- 2014
- 2015
- 2016
- 2018
- 2019-2020
- 2020-2021
- 2022 — BSSC/NIBS Codification process begins

Decade of vetting and adoption in SE industry to date

- 2022 — BSSC/NIBS Codification process begins
- 50% draft — ~Q3 2023
- 75% draft — ~June 2024
- 100% draft — Feb. 5th 2025
- Complete draft sent to ASCE 7 TC10 — March 2025
- Further edits, and qualify more structural systems — Q1 2025 to ~Q1 2026

The Resilient Design Movement (25 years)

- This stuff often feels new, but it is really not! This has been developed and vetted extensively over the past 25 years.

Last 25 Years:

- **Decade #1 (2001-2012):** Creation of FEMA P-58 seismic risk assessment method.
- **Decade #2 (~2012-2023):**
  - ✓ Broad early-adopter use, vetting, building confidence, and many refinements.
  - ✓ Development of FEMA P-58-based Functional Recovery (FR) methods.
  - ✓ Development of FEMA P-58 automations to make building-specific analysis possible even with limited building information (preliminary design, portfolios of buildings, etc.).
- **Decade #3 (2022-Present):**
  - ✓ Development of building code requirements for Resilient Design for FR.
  - ✓ Further adoption and mainstream use for Resilient Design for FR.
  - ✓ Other broad uses not specifically focused on today (individual building seismic risk assessment, individual building retrofit, retrofit prioritization, assessment of large portfolios of buildings, etc.).

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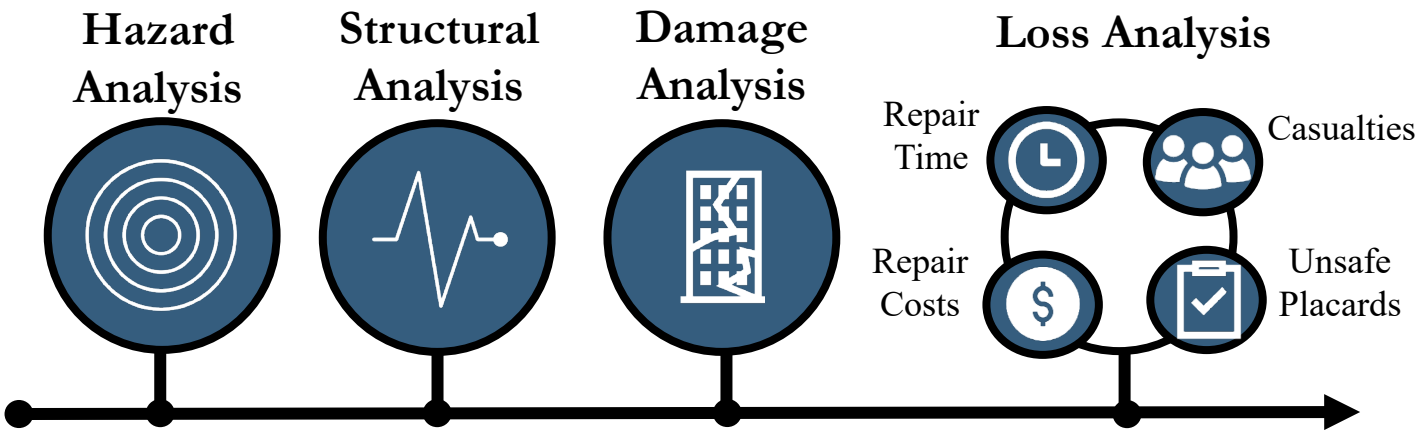
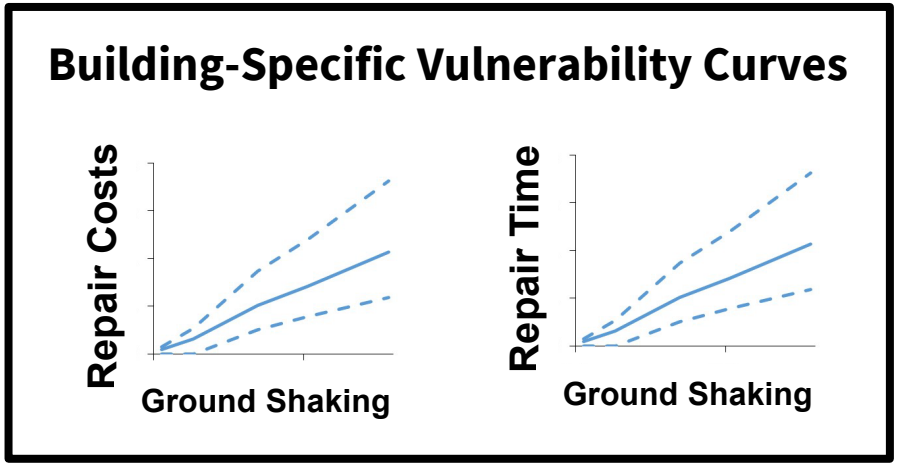
FEMA P-58 Seismic Risk Assessment Method





SP3 Software Compliments FEMA P-58

FEMA P-58 (with Function Module) provides the **comprehensive** and **standardized** approach to evaluate functional recovery times (with ~$20M to develop).

SP3 provides a user-friendly software to integrate all steps of FEMA P-58 (with Functional Recovery Module), with ~$10M to develop.

The initial assessment should take a couple **hours** and **not weeks** (with <u>huge focus</u> on automations).

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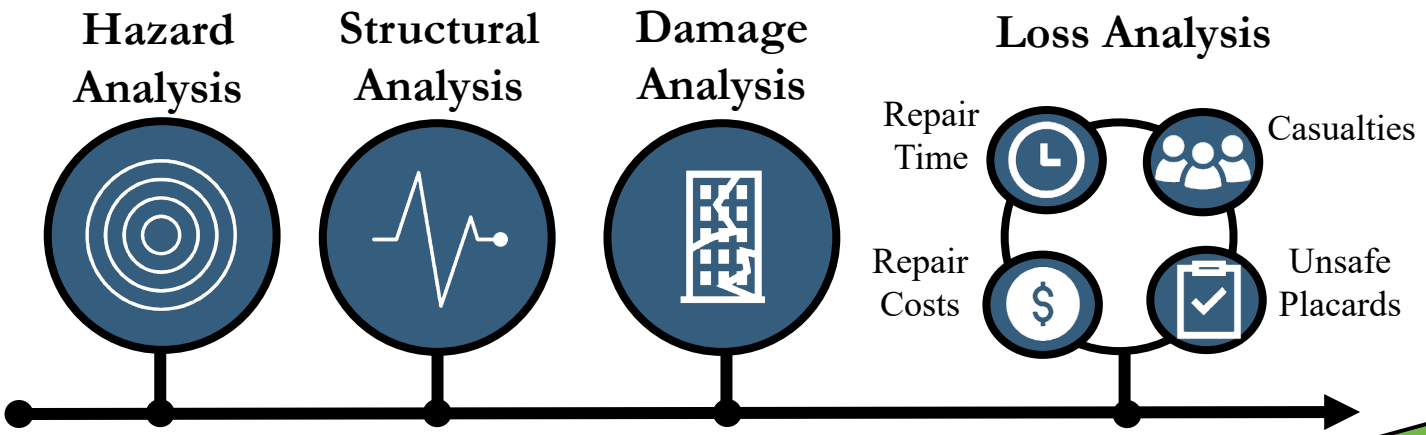
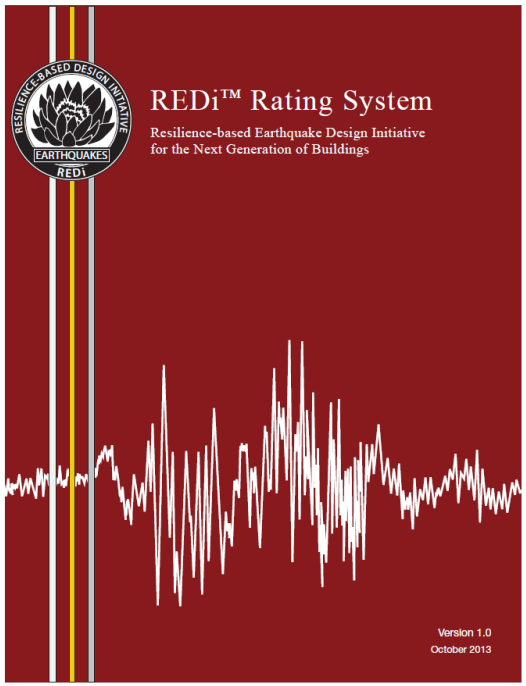
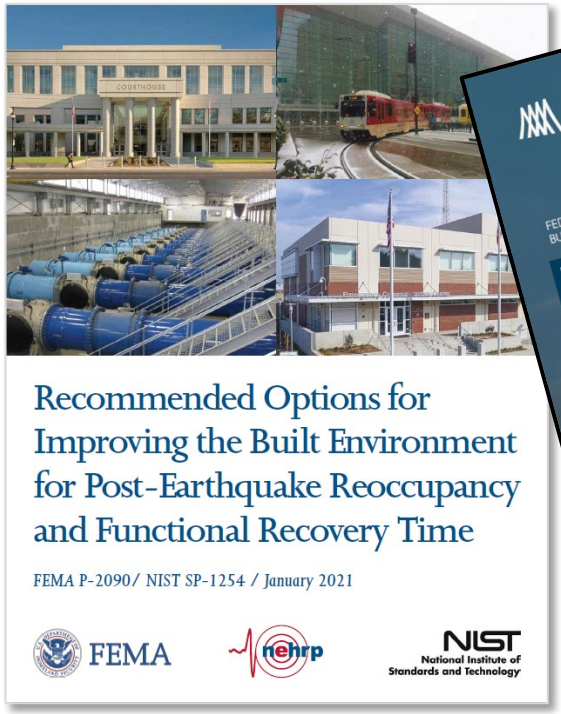
FEMA P-58 with Functional Recovery Module







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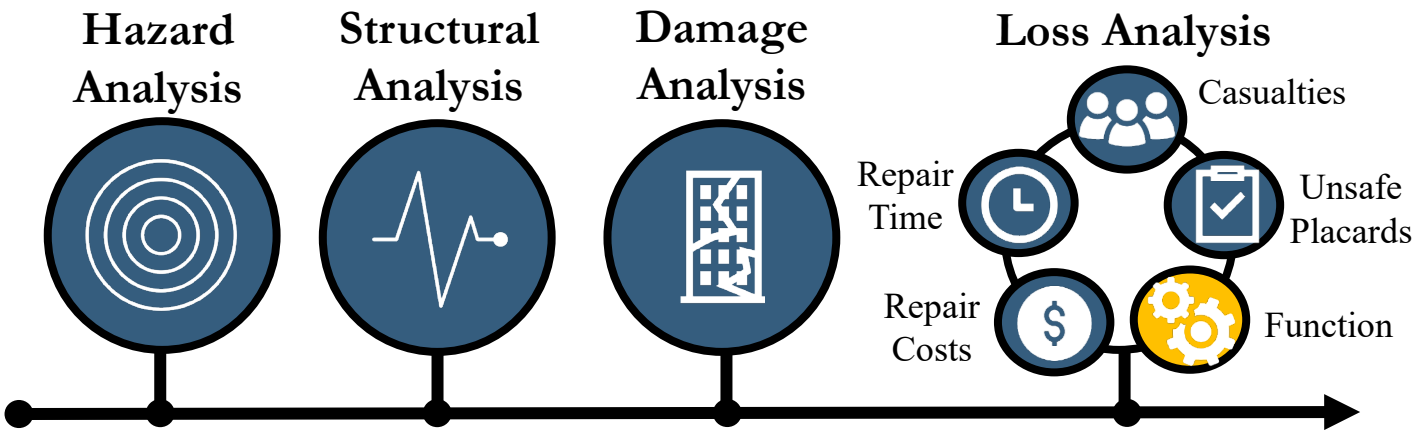
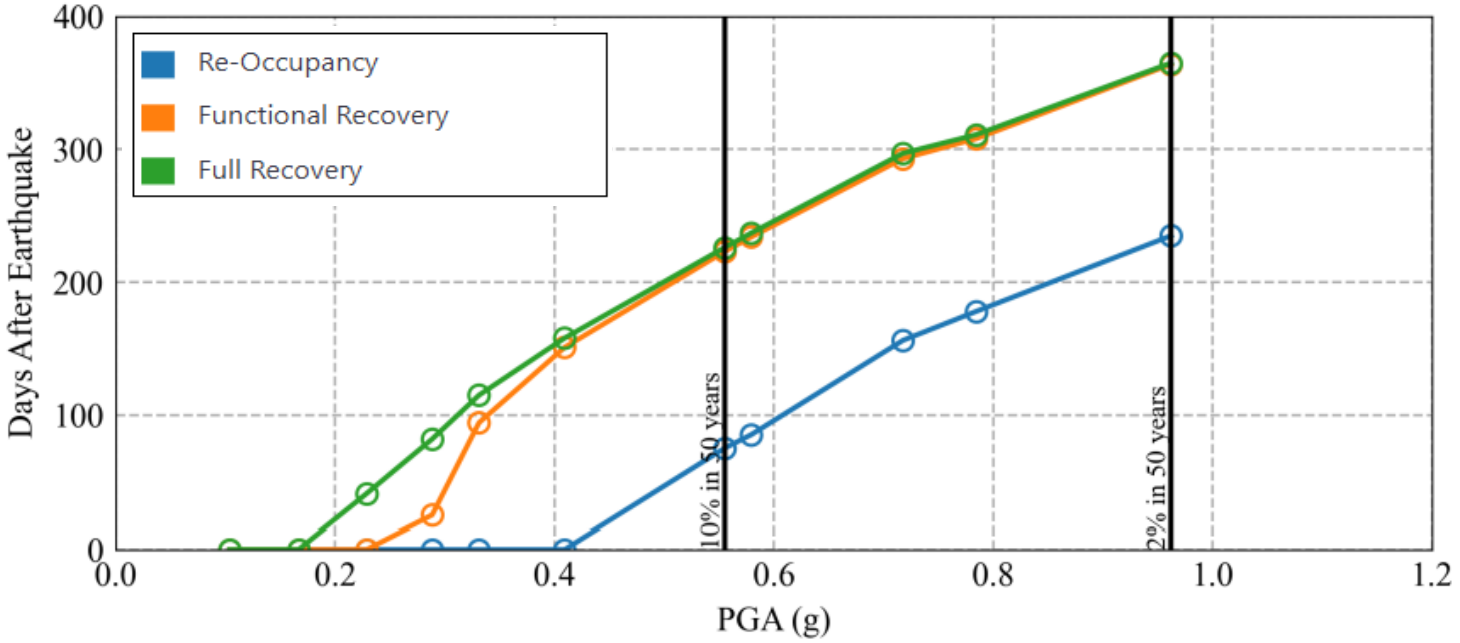
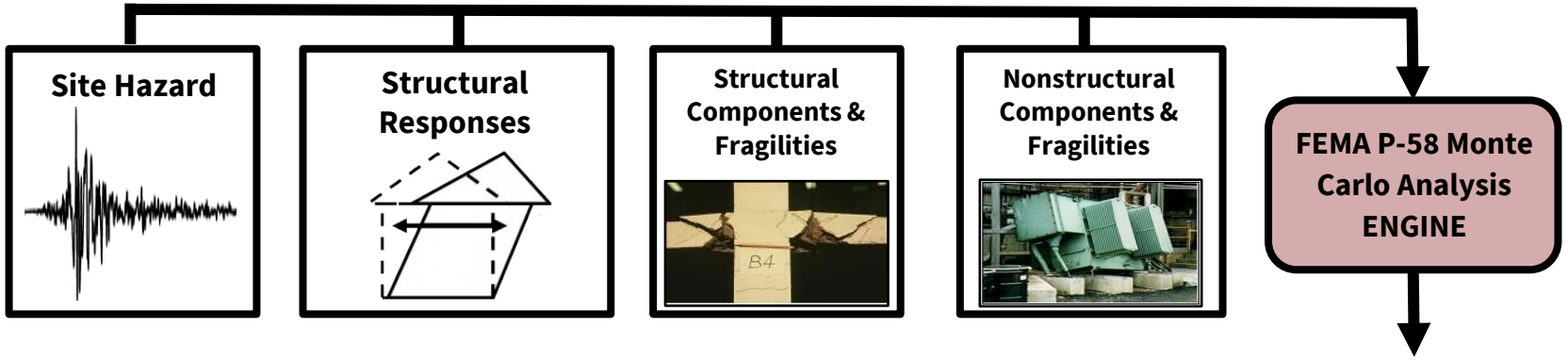


The **FEMA P-58 Functional Recovery Module** now provides **reoccupancy** and **functional recovery** times.



FEMA P-58 Analysis Automation

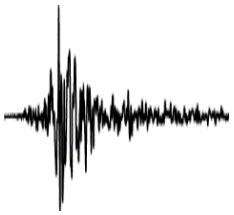


Much Learning from Early-Adopter Use:

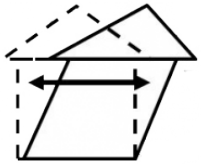
- This is a complex method and it takes a lot of work to do it!
- We need more automations to approximate the steps, so we can get building-specific risk assessments without full NL RHA.
- Automations would support things like preliminary design (no model yet), assessments of large groups of buildings (no budget for modeling each building), etc.

FEMA P-58 Analysis Automation

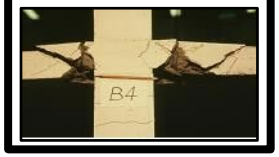
Site Hazard



Structural Responses



Structural Components & Fragilities



Nonstructural Components & Fragilities

FEMA P-58 Monte Carlo Analysis ENGINE

Basic Building and Site Information

(e.g. location, construction year, structural system, occupancy, etc.)

Additional Secondary Modifiers

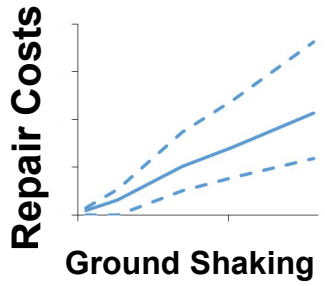
(irregularities, building geometric layout and square footage, etc.)

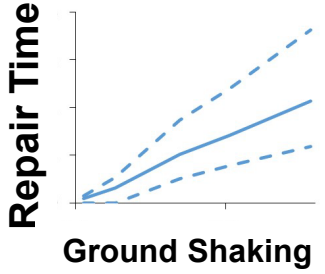
SP3-RiskModel ENGINE (automation of FEMA P-58)

SP3-RiskModel ENGINE

Based on FEMA P-58, but with extensive automation, to enable building/site-specific risk modeling with any level of input information.

Building-Specific Vulnerability Curves





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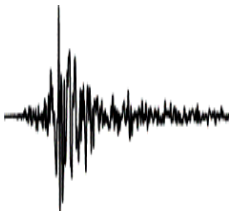

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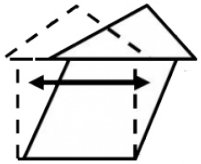

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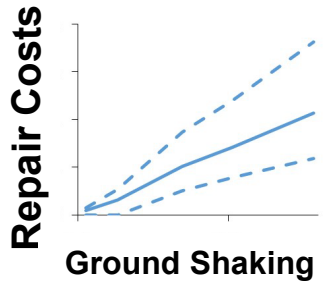

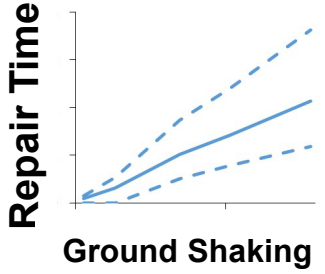

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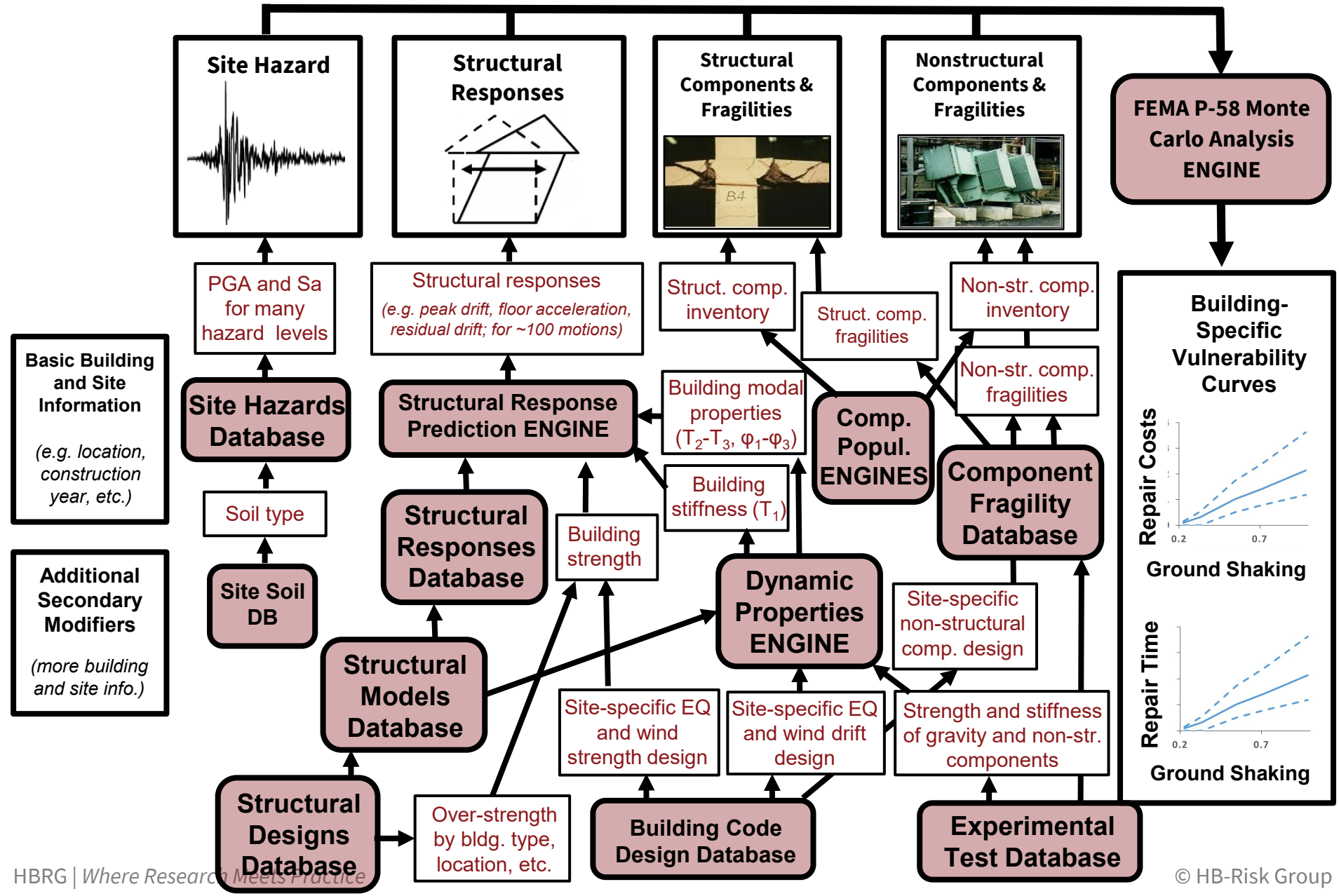

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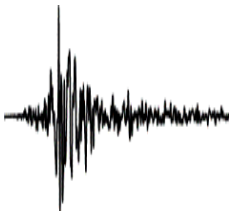

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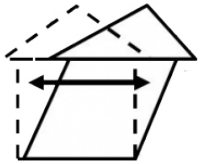

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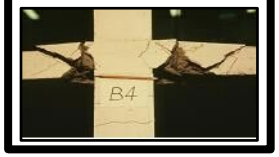

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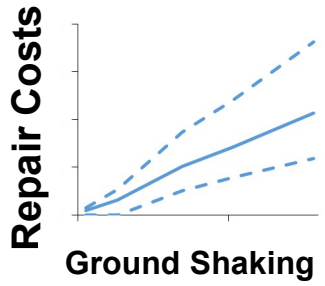
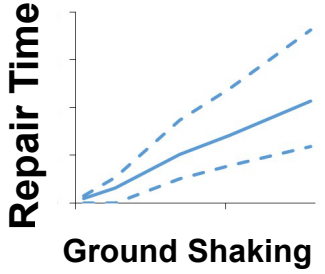
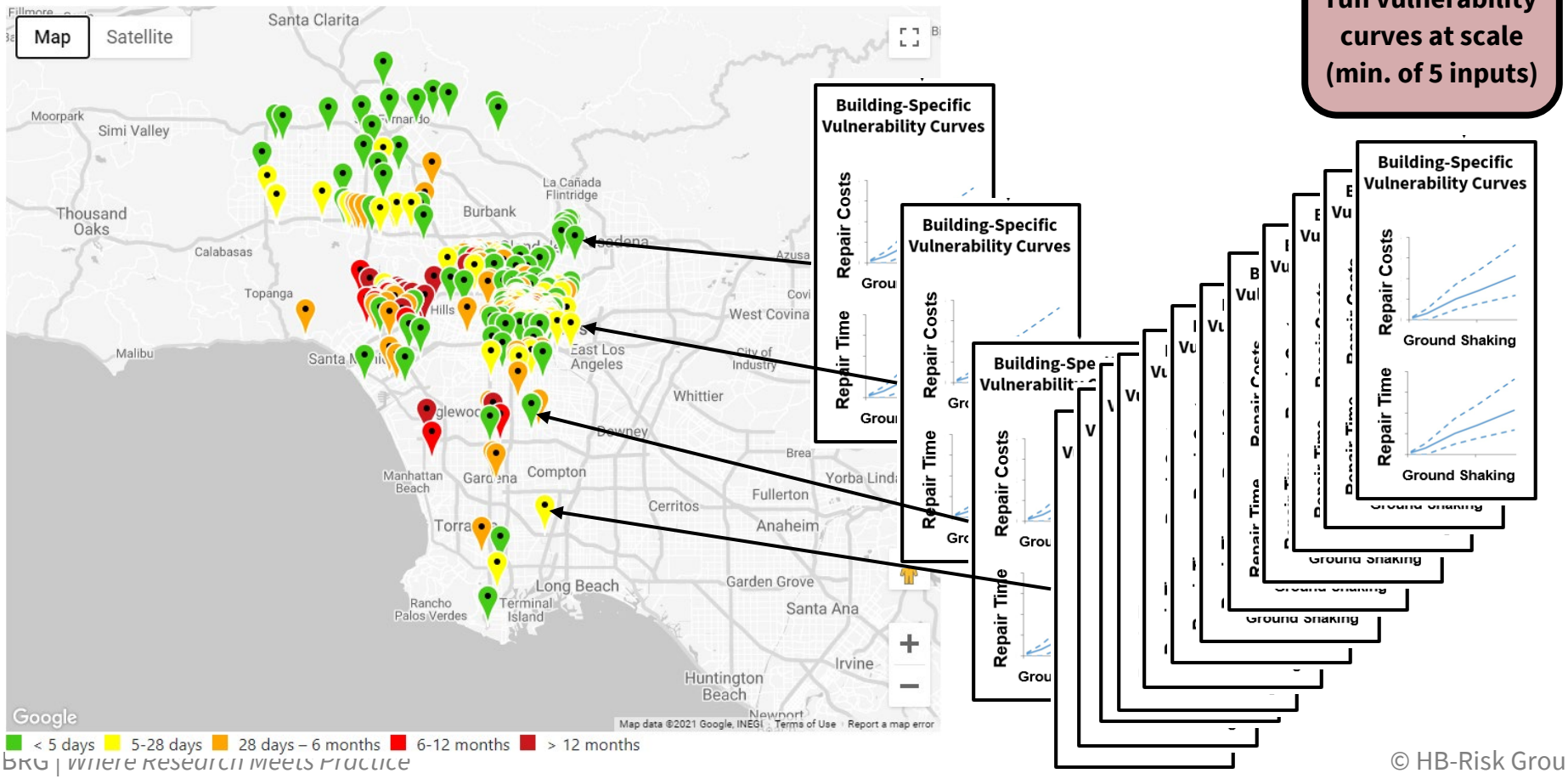


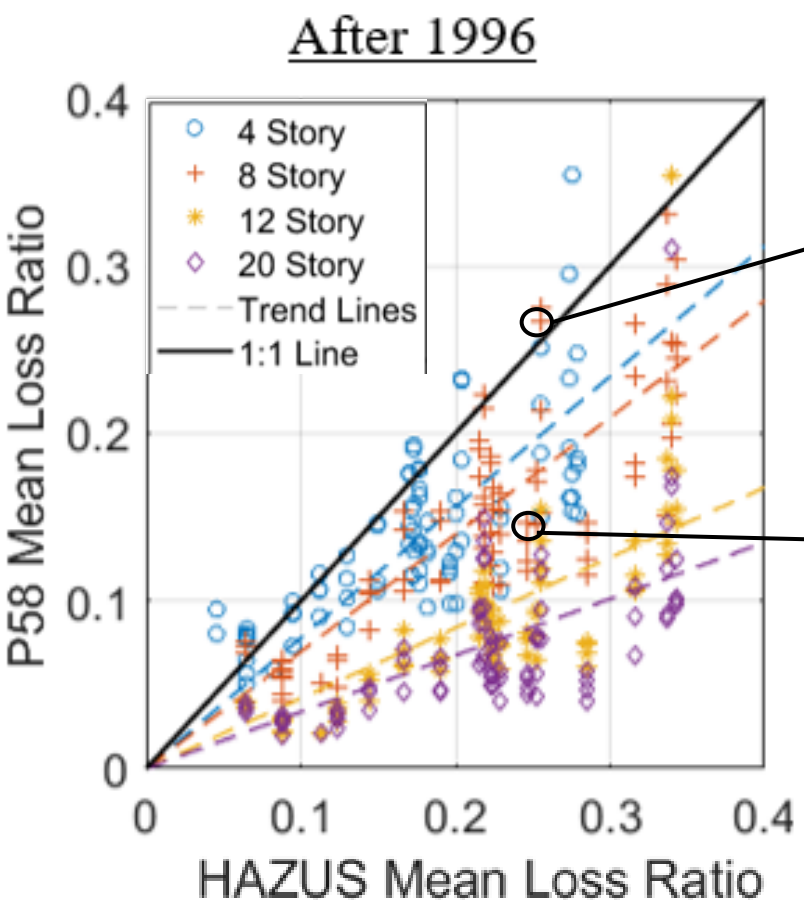


FEMA P-58 Analysis Automation

- We now can also do FEMA P-58 modeling of large inventories of buildings.
- This gives building-specific vulnerability curves, even with minimal building info.
- This also can include portfolio aggregation (e.g. loss exceedance curves).



Why Building-Specific Attributes Matter



FEMA P-58 mean losses compared to HAZUS mean losses for reinforced concrete moment frames, at a 10% in 50 hazard.

Model A:
2016 - 8 Story RCMF Office in San Jose

Model B:
2016 - 8 Story RCMF Office in Los Angeles

	Model A	Model B
PGA (g)	0.53	0.53
S_{d1} (g)	0.60	0.84
Strength (g)	0.11	0.15
Period (s)	1.64	1.36
P-58 Loss	**0.27**	**0.15**
Hazus Loss	**0.25**	**0.25**

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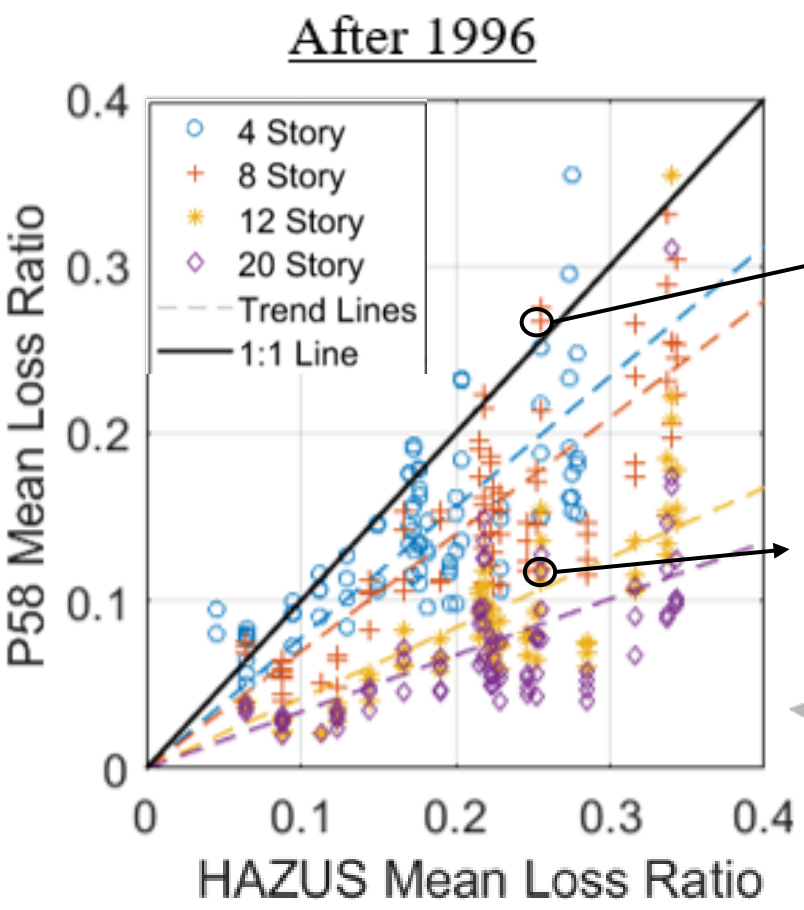
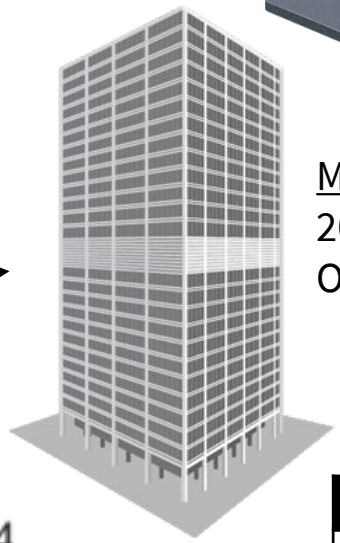


Model A:
2016 - 8 Story RCMF Office in San Jose



Model C:
2016 – 20 Story RCMF Office in San Jose

	Model A	Model C
PGA (g)	0.53	0.53
S_{d1} (g)	0.60	0.60
Strength (g)	0.11	0.082
Period (s)	1.64	2.56
P-58 Loss	**0.27**	**0.12**
Hazus Loss	**0.25**	**0.25**

FEMA P-58 provides loss estimates based on the specifics of the structure (e.g. strength, height, period).

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Process for Qualifying a Structural System

Use of FEMA P-58 for Functional Recovery Provisions:

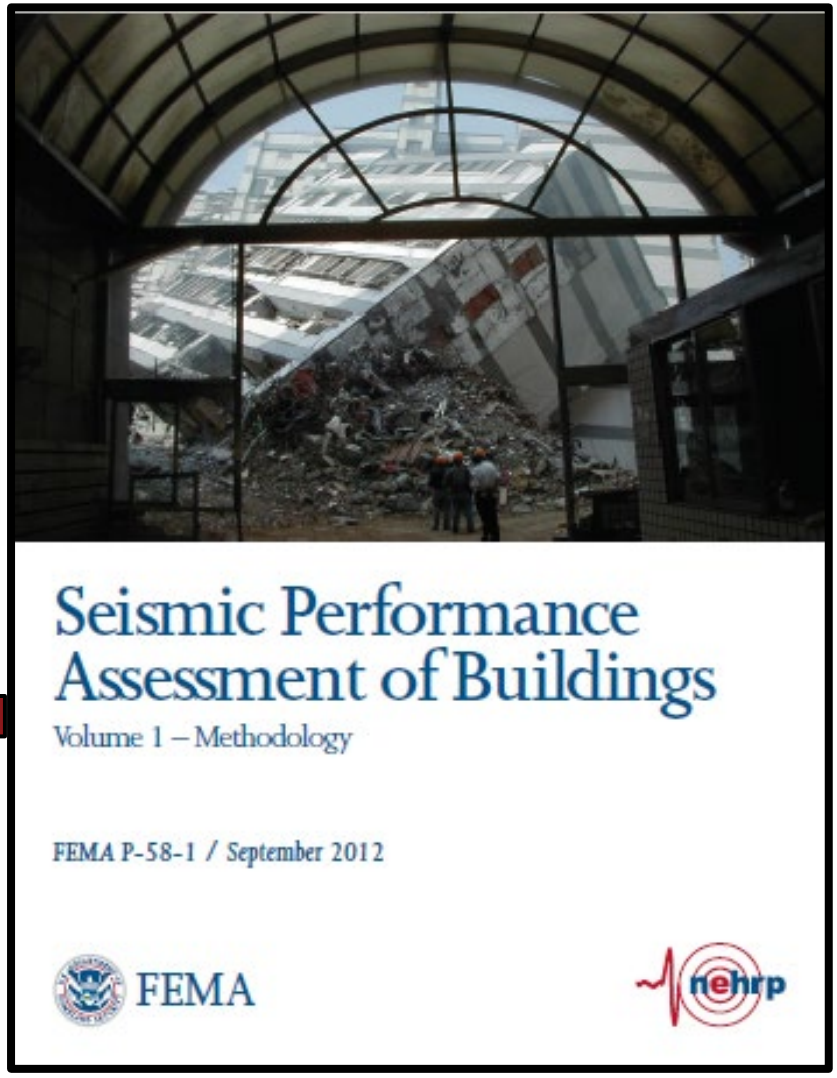
Table 24.1-1. Target Functional Recovery Time

Functional Recovery Category	Target Functional Recovery Time	
	General Expectation	Acceptance Criteria
A	Immediate	0 hours
B	Within a few days	72 hours
C	Within a couple of months	2 months
D	Within half a year	6 months

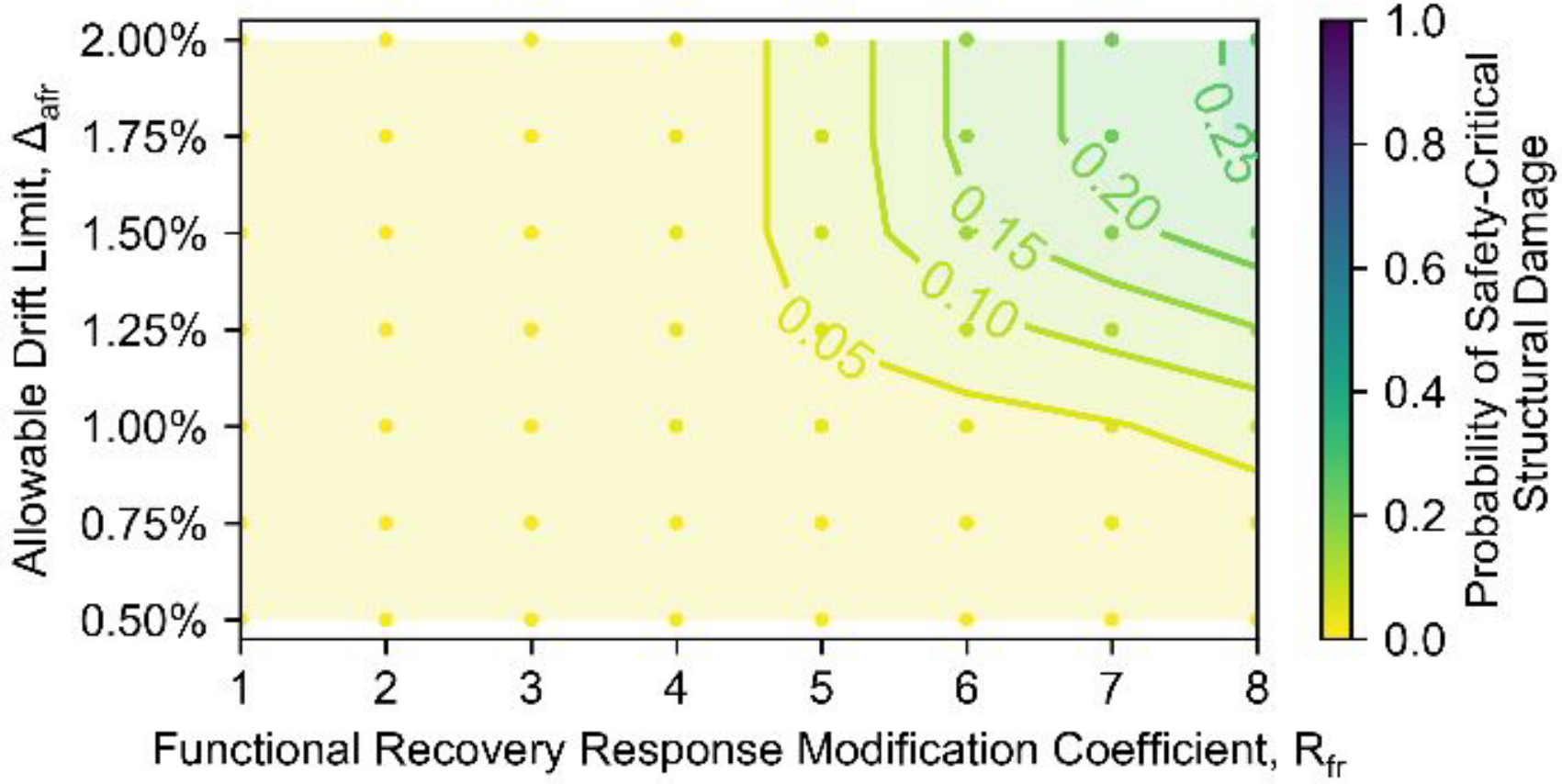
AWS

Lots of Analysis Runs for Lots of Design Cases

Prescriptive Design Requirements for the Code



Process for Qualifying a Structural System



Building Code Development Status

- National Building Provisions Efforts for Functional Recovery
  - BSSC/NIBS groups have worked on a volunteer basis for nearly three years.
  - This has resulted in a complete chapter/appendix (now in the hands of ASCE 7 Task Committee 10).

- Ongoing Work:
  - Pre-qualify as many more structural systems as we can during this code cycle! (via the “Resilient Design Coalition”)

Resilient Design Coalition

- The Resilient Design Coalition Supporters to date:
  - Charles Pankow Foundation – anchor supporter with full matching funds
  - Resilient structural system supporters

CHARLES PANKOW FOUNDATION
Building Innovation through Research

- Supported Structural Systems To Date (all are non-proprietary):
  - SpeedCore
  - Precast hybrid moment frame
  - Steel damped moment frame
  - Steel buckling-restrained braced frame (qualification report, possible refinement)
  - Wood light-frame (possible refinement)
  - Masonry Tilt-up (rigid-wall flex-diaph)

Smarter. Stronger. Steel.

CHARLES PANKOW FOUNDATION
Building Innovation through Research

Summary

- Extensive seismic risk and FR assessment methods have been developed and vetted over the past 25 years!
- These technologies are now ready for use in resilient design, and many other purposes.

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Time for Q&A!

- Thank you for your time!
- Time for questions and discussion!

- For further questions, or to provide feedback, please contact Allison at the SP3 office and she can connect you with the right person (allison@hbrisk.com).

Curt Haselton: *curt@hbrisk.com, Direct: (530) 514-8980*

www.sp3risk.com