

Resilient Design for Functional Recovery: Expectations for Current California Buildings and Approaches to More Resilient Design

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SP3 / where research meets practice

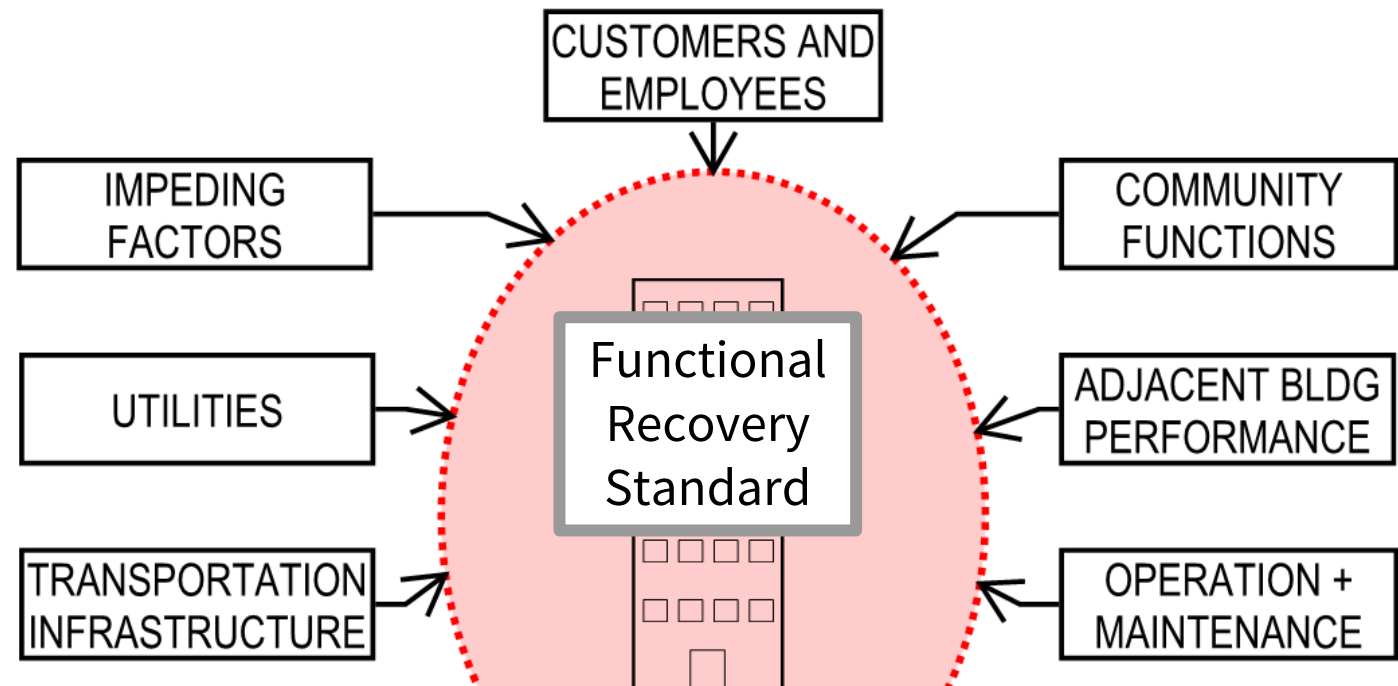
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SEAOC Convention | August 29, 2019

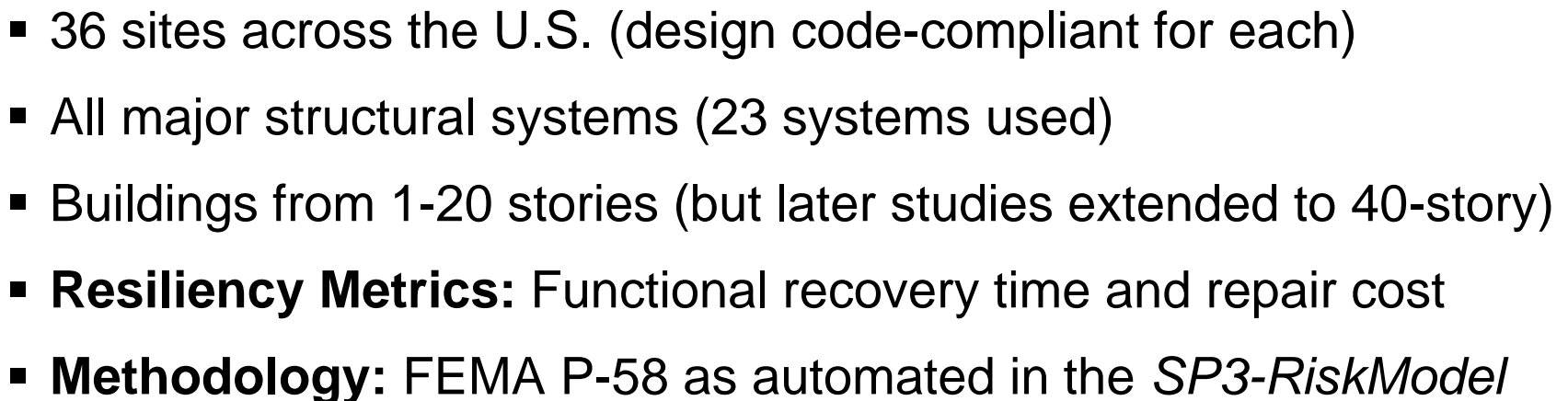
- These are unprecedented times and our profession is rising to the occasion.
- The public/legislators have become aware that the Code goal is just safety and they want more than “safe but disposable”.
- All levels of government are now looking at “design for Functional Recovery”:
 - ✓ **Federal:** NIST/FEMA mandate and a report to Congress is due in ~9 months.
 - ✓ **State:** California AB-393 on a Functional Recovery Standard
 - ✓ **Local:** San Francisco tall building study and ongoing discussions

- New technology is now available/vetted, enabling structural engineers to evaluate performance beyond safety (cost, time)
 - ✓ Research overall last several decades (e.g. PEER).
 - ✓ Release of FEMA P-58 in 2012 (\$16M invested to date)
 - ✓ Release of enabling SP3 software in 2014
 - ✓ P-58/SP3 use, vetting, and iteration for the past 5 years by most of large west coast firms (elective use on many projects)
 - ✓ We can now consider repair costs/time directly and quantitatively in design; this was not possible 10 years ago.
- **Opportunity:** The combination of this societal need and new technology creates a remarkable situation and opportunity. Structural engineers are well-equipped to meet this new challenge of design for Functional Recovery.

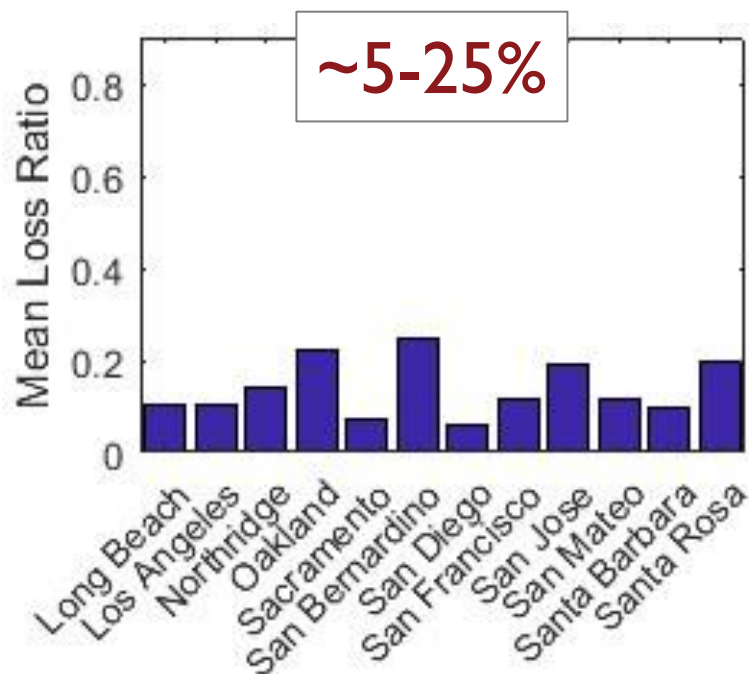
- Scope:
 - ✓ Design of new and individual buildings
 - ✓ Focus on more resilient design (how to do electively now, and how to develop a Functional Recovery Standard for use in Code requirements)



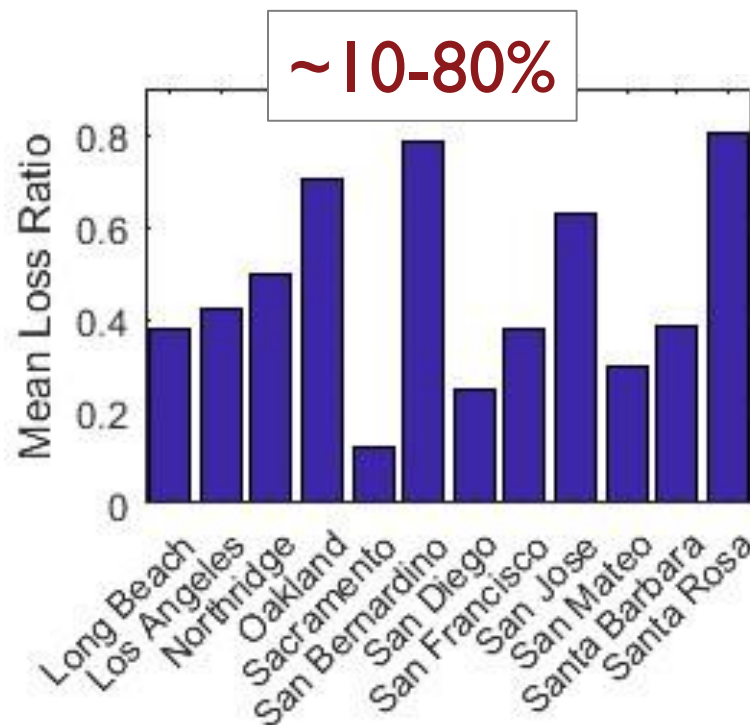
- 1) Starting point – expected loss and downtime in new buildings
 - 2) How can we design for faster recovery?
 - ✓ Code nobs (like 1e and Risk Category IV)
 - ✓ Direct resilient design
 - 3) The path forward and developing Code requirements for Functional Recovery
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- **Note:** These topics are timely and many groups working on this right now, so we intentionally kept additional time for discussion/coordination at the end of these talks.



Sample Results – 8-Story Steel SMF at 12 CA Cities:

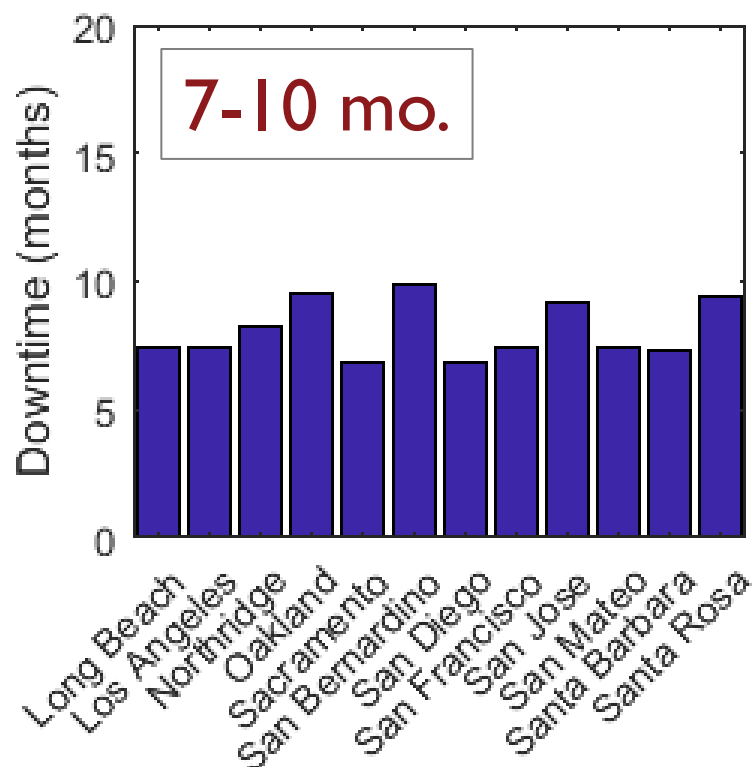


Design (10% in 50 yrs)

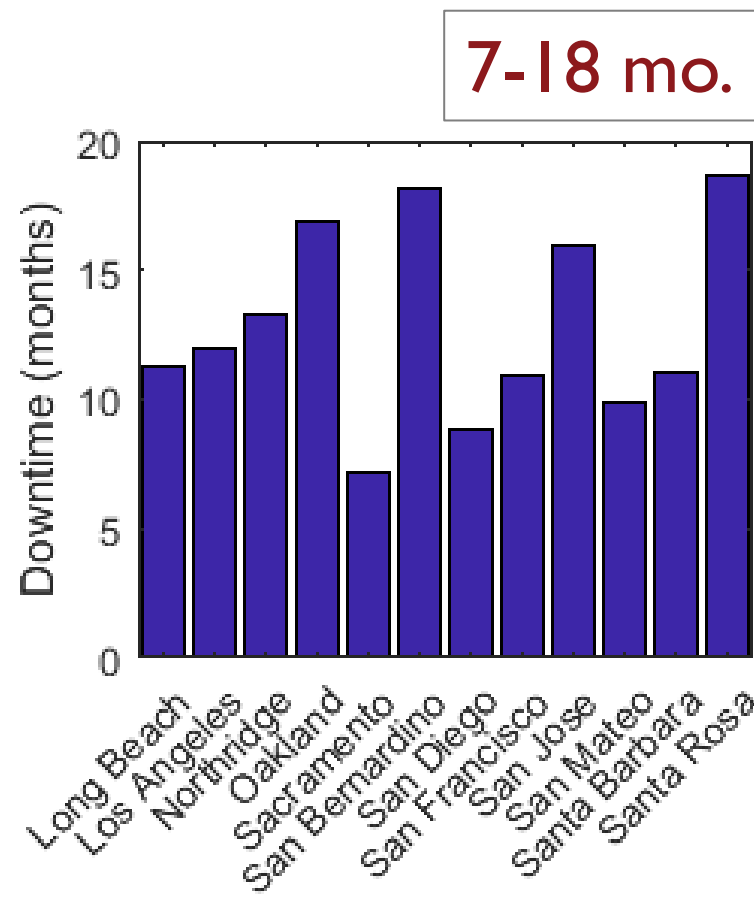


MCE (2% in 50 yrs)

Sample Results – 8-Story Steel SMF at 12 CA Cities:



Design (10% in 50 yrs)



MCE (2% in 50 yrs)

Summary for a Wide Range of Building Types:

- **Functional Recovery Time:** 6-12 months for design event and up to 2 years for MCE (repair time without impeding factors are ~1-6 months for design event and ~1 year for MCE)
- **Repair Costs:** 5-25% mean loss for design event and 10-80% loss for MCE (huge ranges!).
- **Safety:** Expected to be safe (per 1989 and 1994), but this was not assessed in this study.

Comparable Findings from ATC-58 Volume 5:

- **Functional Recovery Time:** ~1.5 months for design level without impeding factors (so ~7-8 months if we add the delay before repairs can begin)
- **Repair Costs:** ~10% for design level

What is the Resilience of New Code Buildings?

Code Resilience is Highly Building/Site-Specific:



Building A:

New 8
Office



Take-Away: FEMA P-58 gives granular building-specific and site-specific risk information and resilience varies widely under current code.

RCMF Office in
Los Angeles



Building Design

A

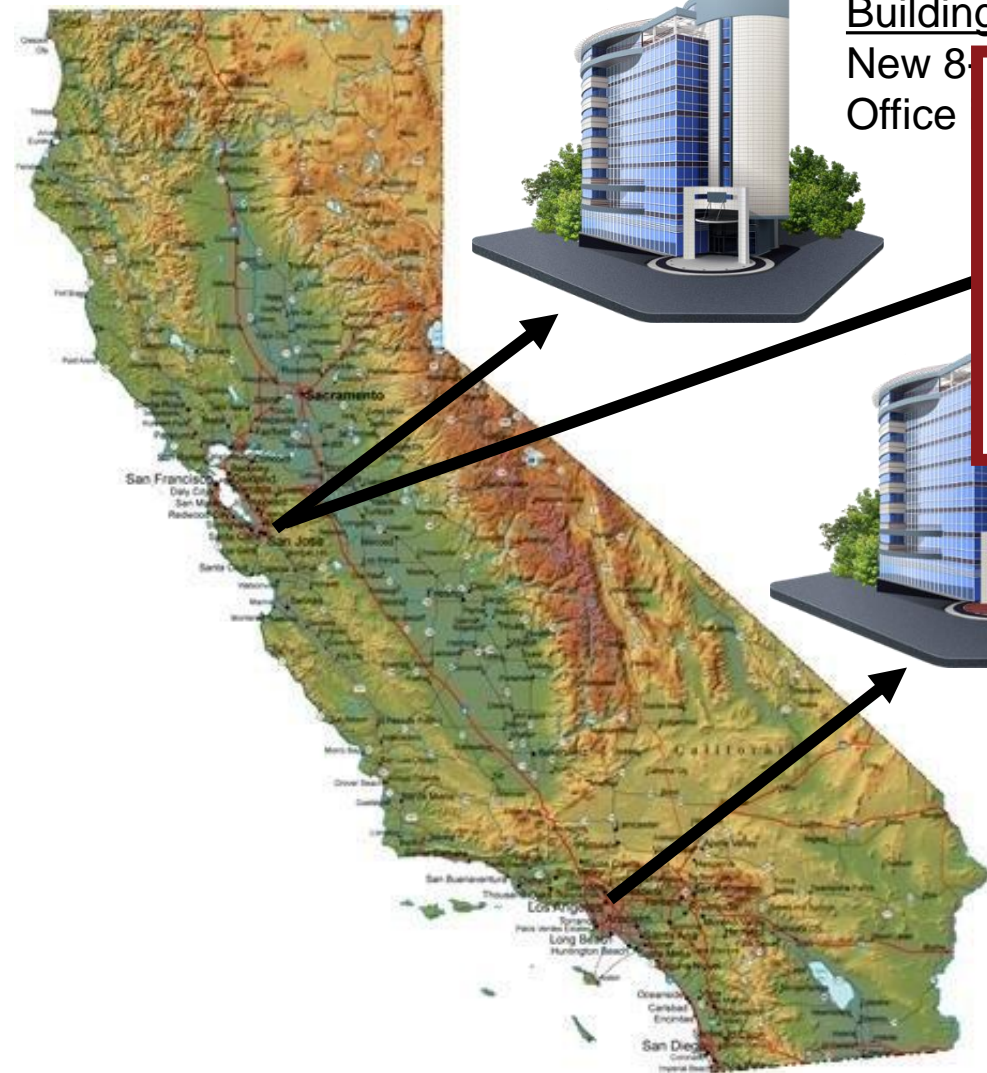
10in50 yr PGA (g) 0.53

Sd1 (g) 0.60

Strength (g) 0.11

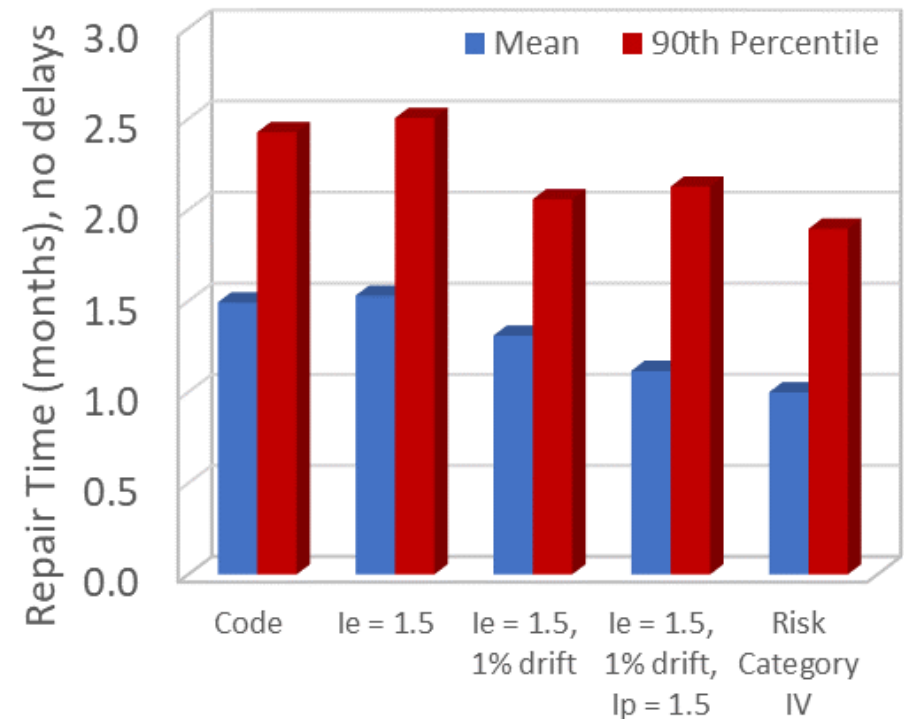
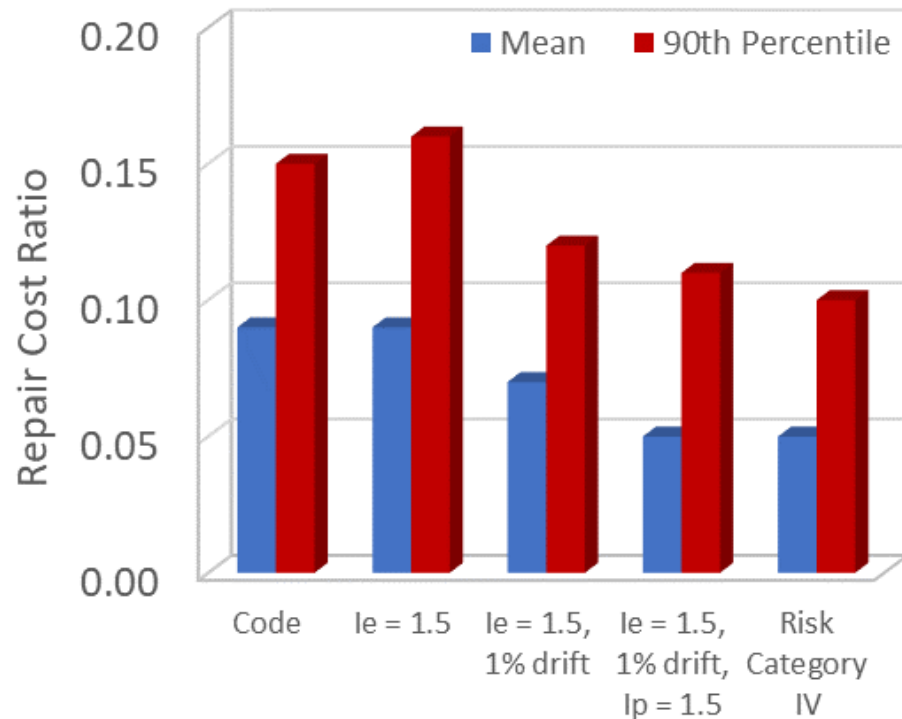
Period (s) 1.64

Mean Loss 0.27



Current Code Knobs:

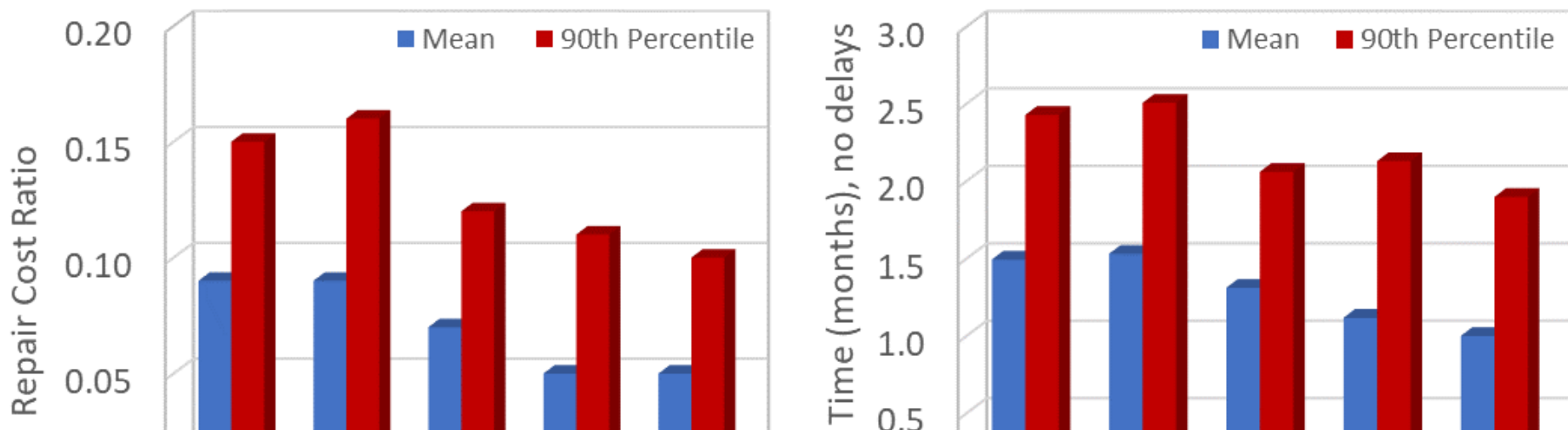
- The natural first step toward resilient design is to see what our current “code knobs” can do (strength, stiffness, risk category).



Example 8-story steel frame office in LA

Current Code Knobs:

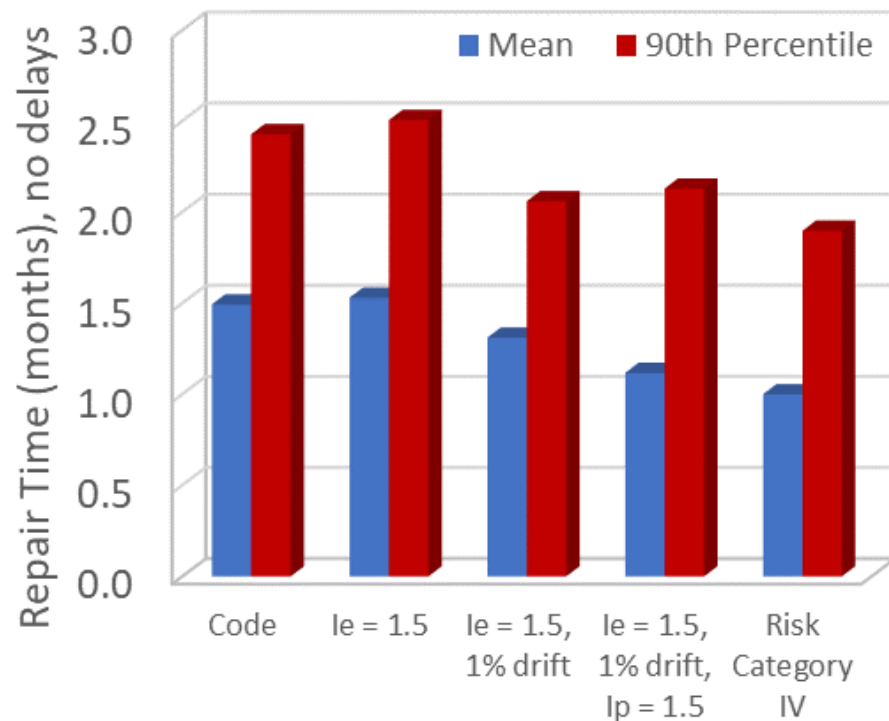
- The natural first step toward resilient design is to see what our current “code knobs” can do (strength, stiffness, risk category).



Comparable Findings from ATC-58 Vol. 5 Match These Results:

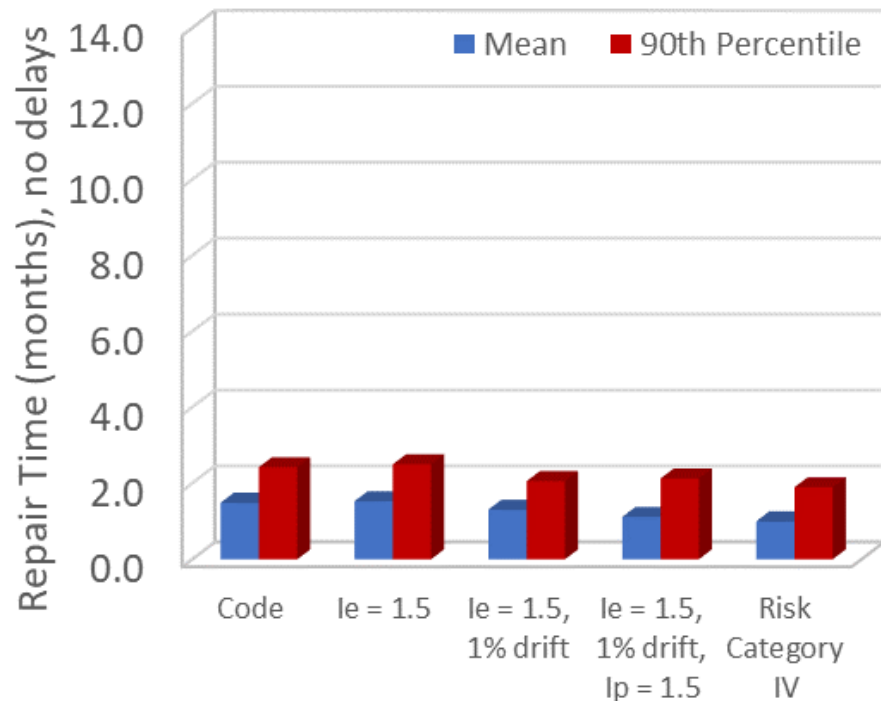
- **Functional Recovery Time:** RC IV reduces repair times from 1.5 to 1.0 months
- **Repair Costs:** RC IV reduces repair costs from 10% to 5%.

Current Code Knobs:

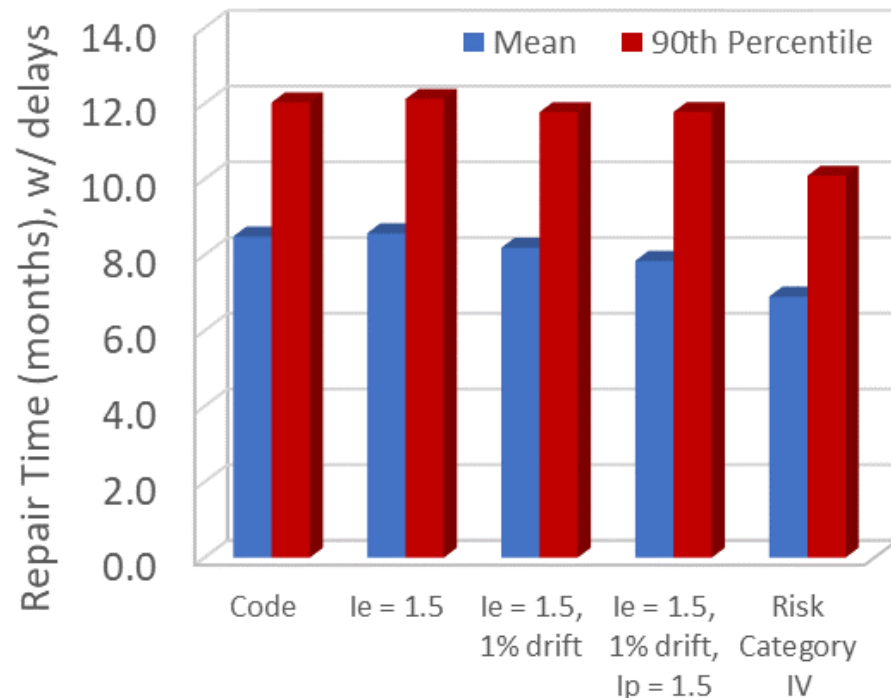


Current Code Knobs:

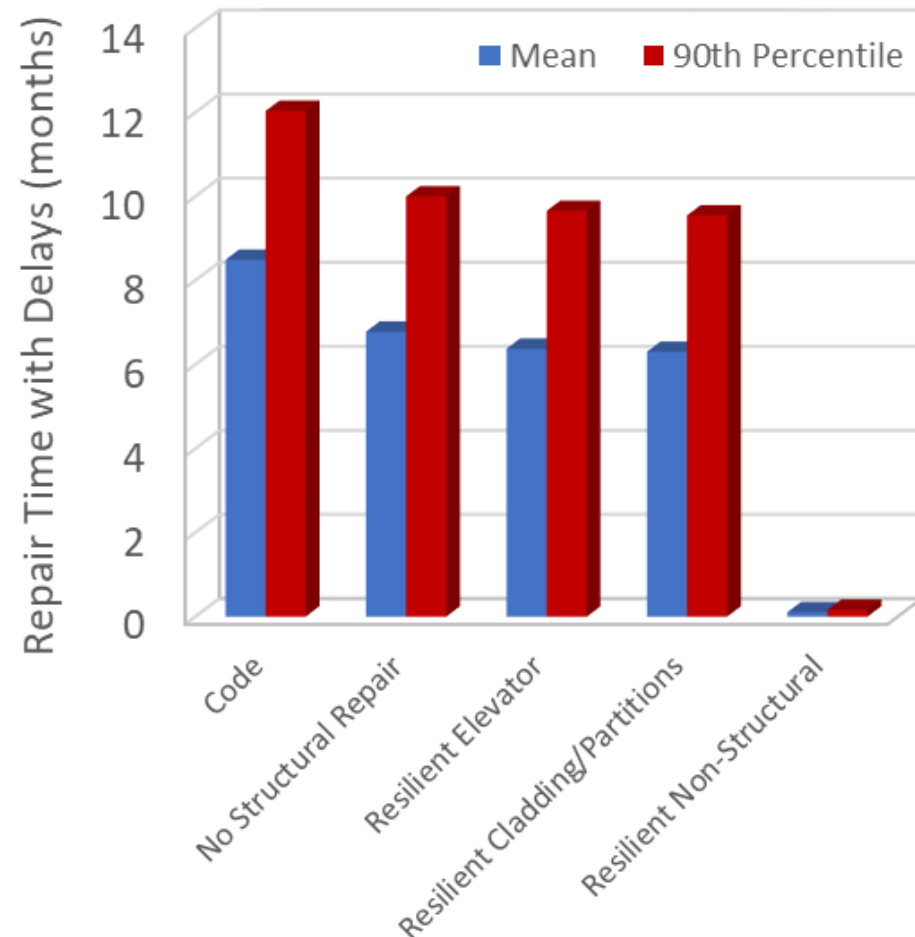
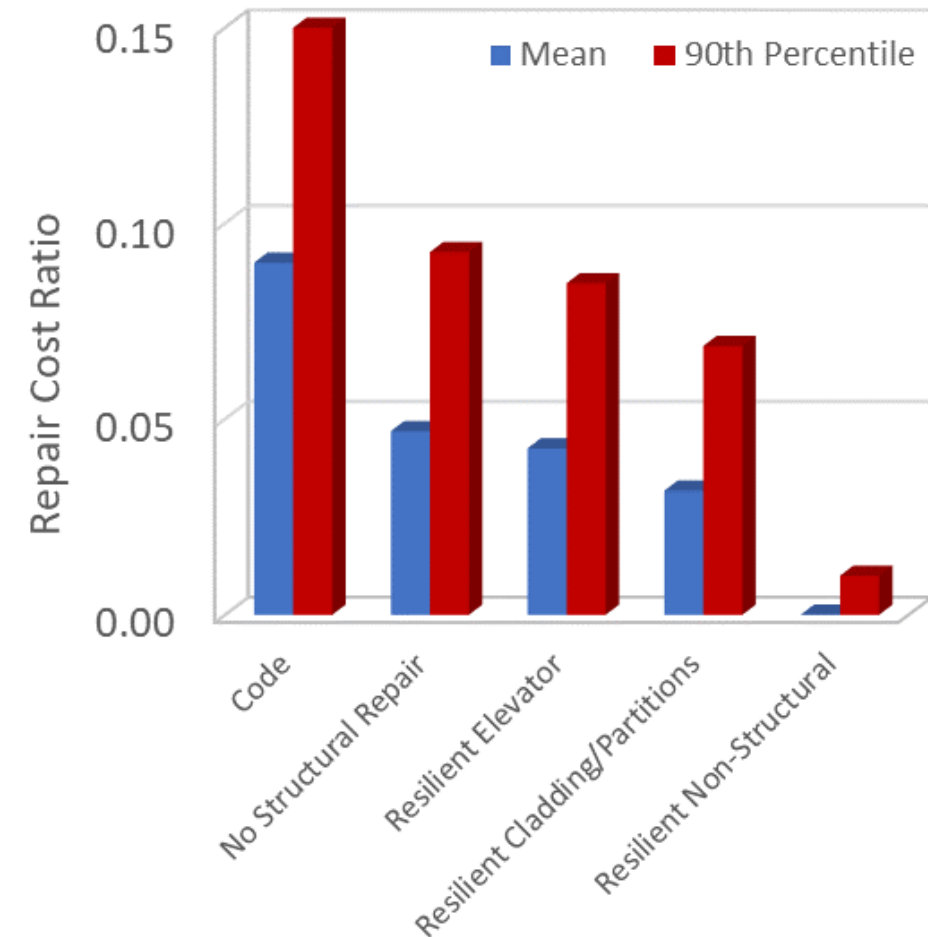
No Delays to Start Repair



With Delays Before Repair

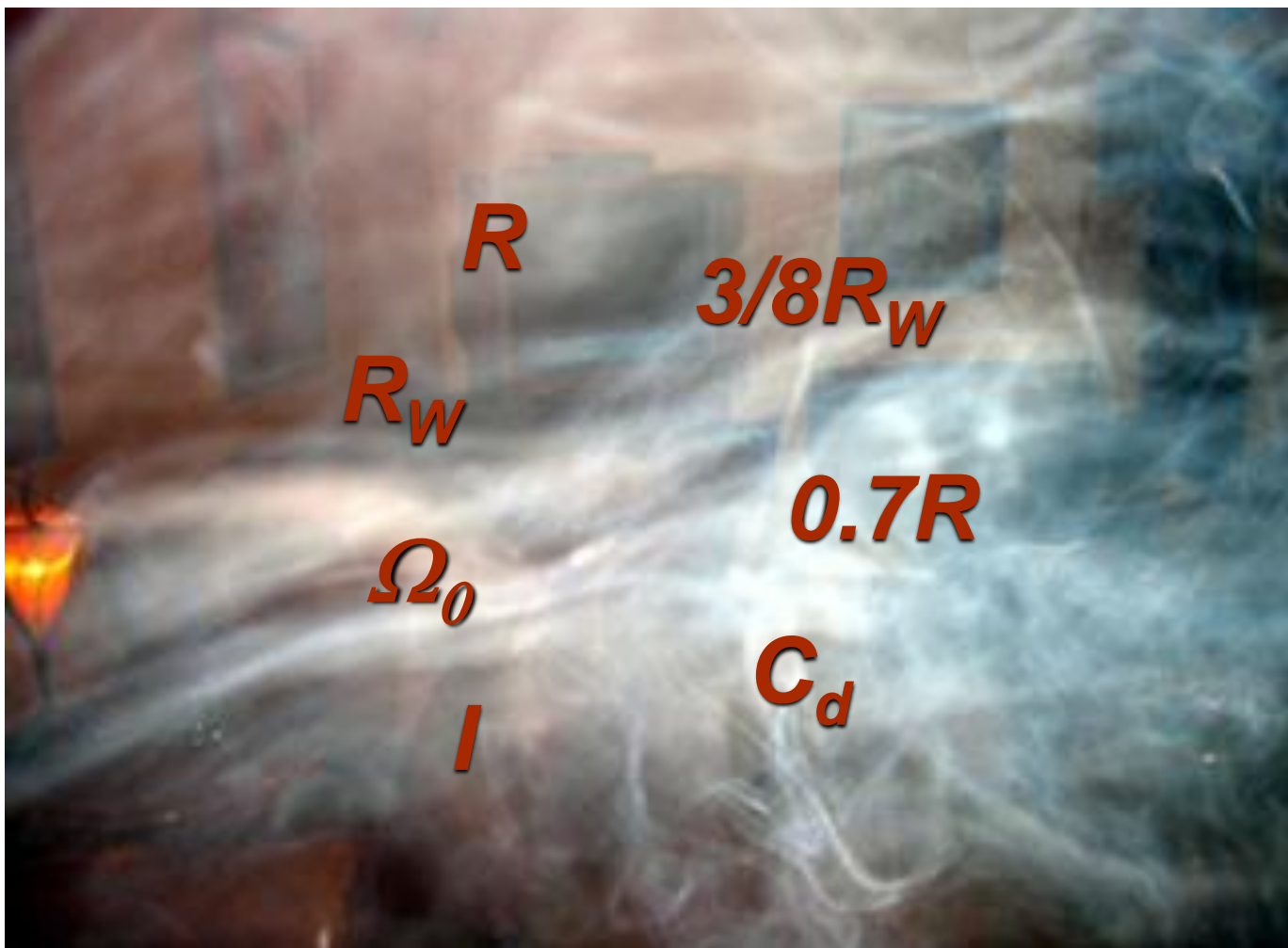


Direct/Targeted Resilient Design:



- Code-compliant buildings are not resilient (because the RC II design goal is just about safety).
- Society seems to want “functional recovery,” not just safety.
- Risk Category IV design is shown to reduce repair cost/time, but FEMA P-58 assessments predict that this performance benefit is not enough for days/weeks goal.
- FEMA P-58 can be used for direct resilient design because it quantifies cause-and-effect between design decisions and resulting performance (repair time and repair cost). It is already being used electively for this now.
- **Possible Problem:** We don't yet have prescriptive design requirements that can be shown to deliver recovery times that society seems to want (e.g. up and running in a week).

Review of Code Revision Process for Safety:



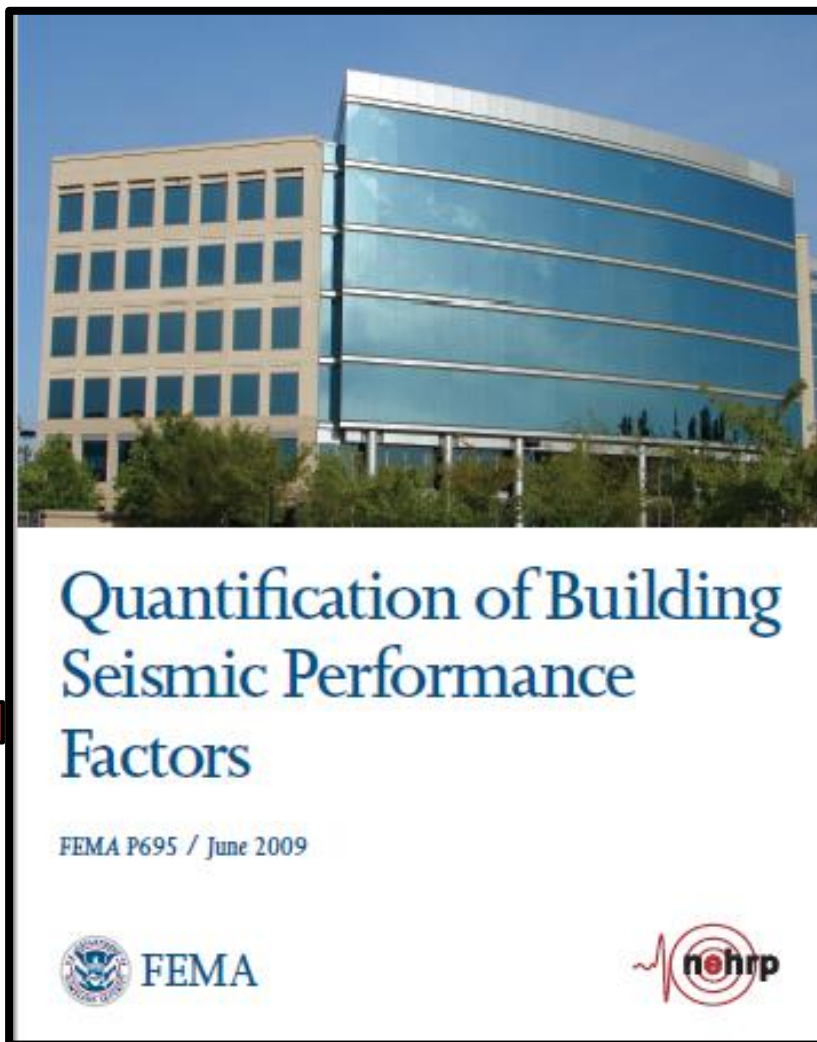
Review of Code Revision Process for Safety:

Table 1.3-2 Target Reliability (Conditional Probability of Failure) for Structural Stability Caused by Earthquake

Risk Category	Conditional Probability of Failure Caused by the MCE_R Shaking Hazard (%)
I & II	10
III	5
IV	2.5

Lots of Analysis Runs
for Lots of Design Cases

Prescriptive Design
Requirements for the Code



Similar use of FEMA P-58 for Functional Recovery Provisions:

	PHASE 1			PHASE 2				PHASE 3		
	DAYS			WEEKS				MONTHS		
	0	1	2-5	1-4	4-8	8-12	4	4-24	24+	
CRITICAL FACILITIES										
GROUP 1A							X			
GROUP 1B					O		X			
GROUP 1C								X		
INTERMEDIATE FACILITIES										
GROUP 2A		O						X		
GROUP 2B									X	
GROUP 2C									X	
REMAINING BUILDINGS										
GROUP 3A				(N)		(E)			X	
GROUP 3B									X	
GROUP 3C									X	

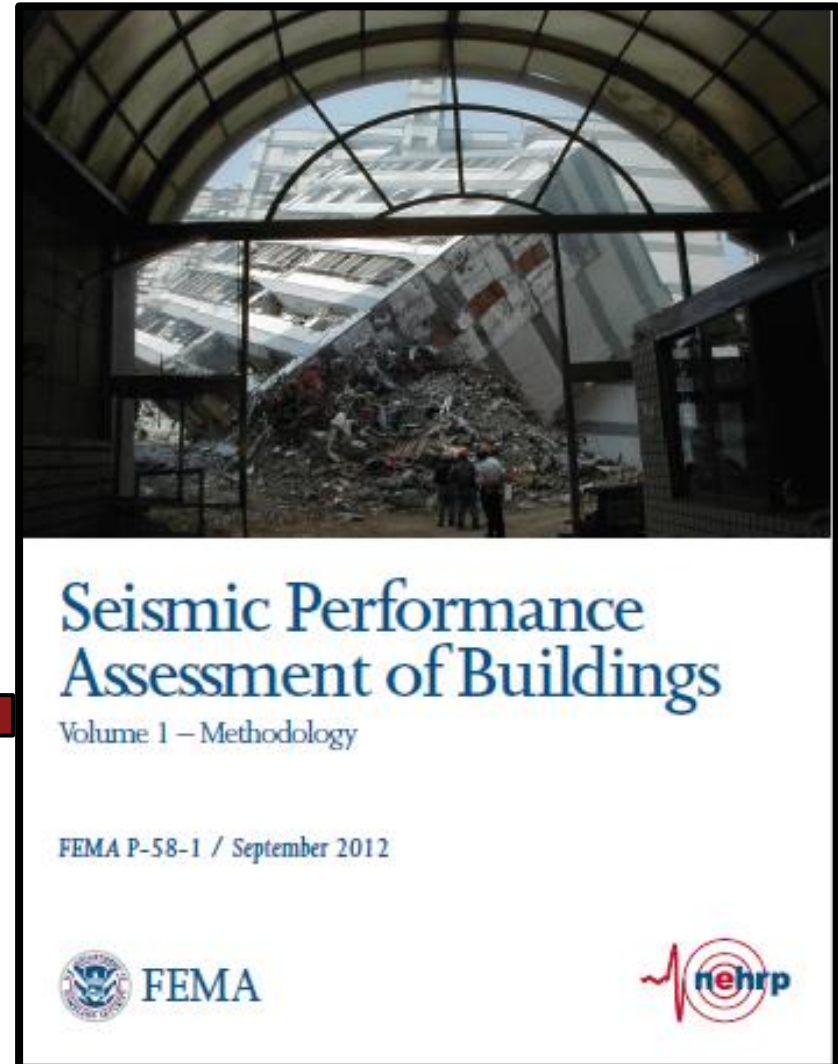
☐ RETROFIT PERFORMANCE OBJECTIVE
☒ COMMUNITY DESIRED PERFORMANCE
☒ ANTICIPATED PERFORMANCE FOR 90% RESTORATION IN EXISTING CONDITION

FIGURE BASED ON NIST COMMUNITY RESILIENCE PLANNING GUIDE

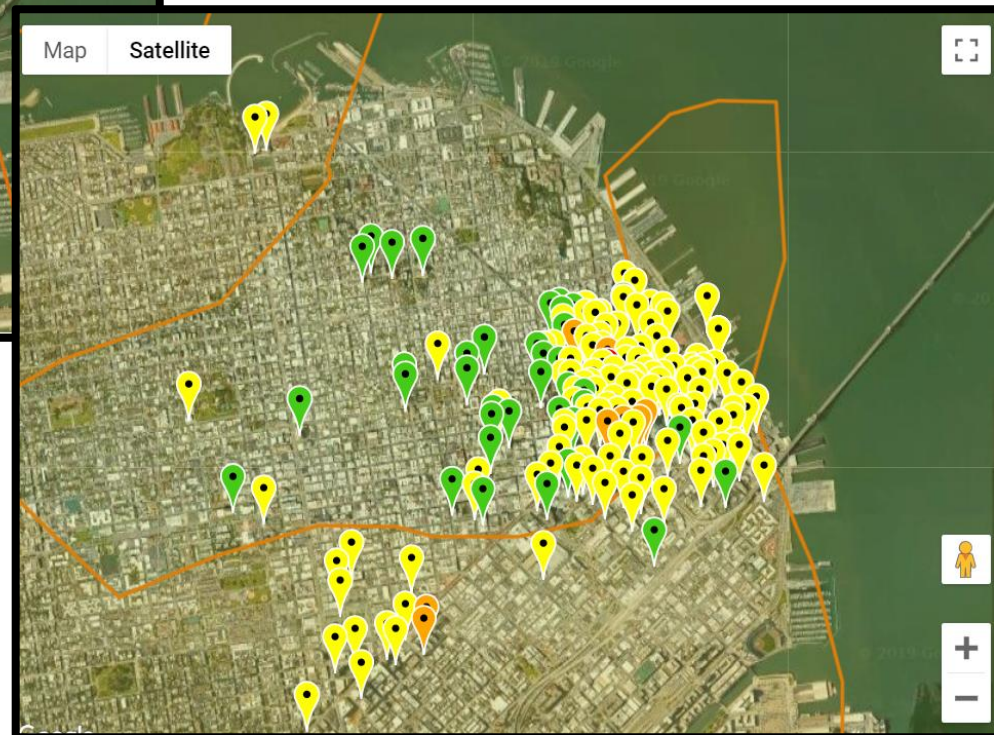
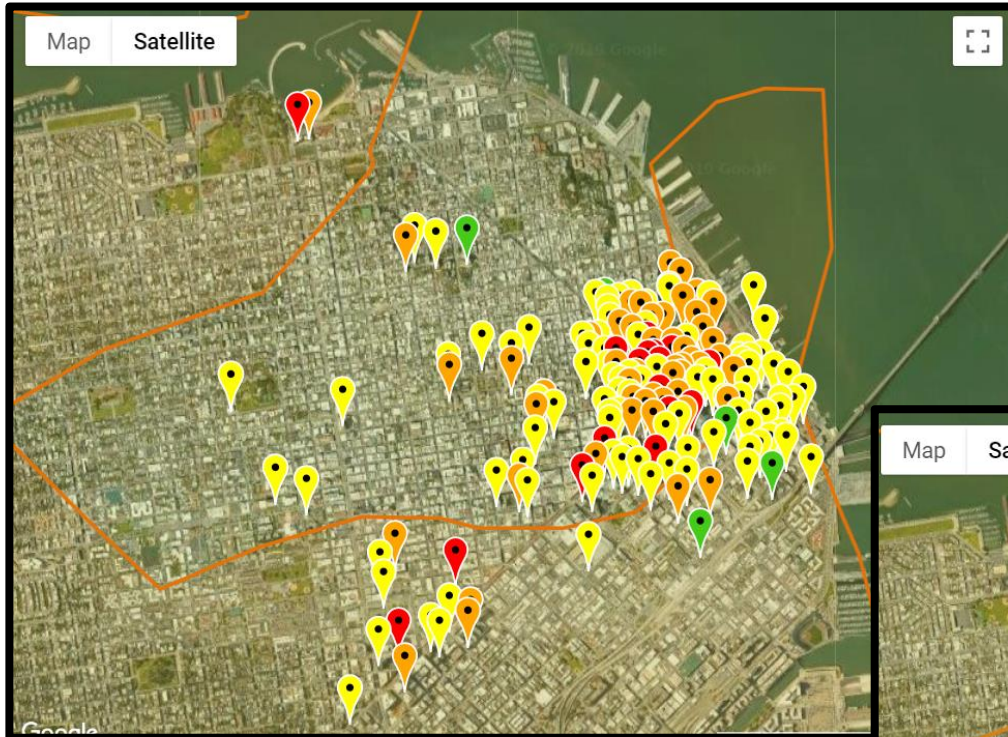
AWS

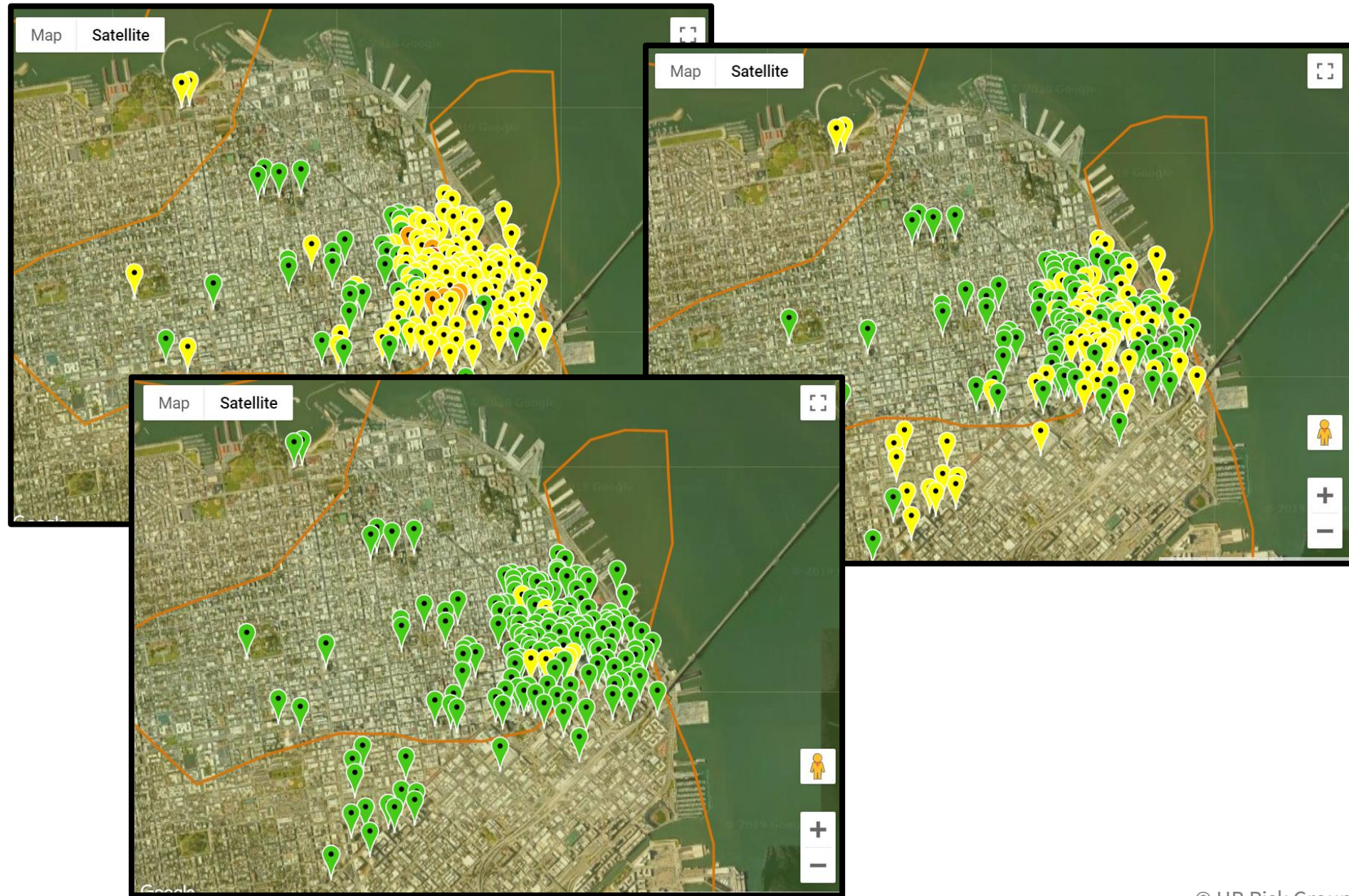
Lots of Analysis Runs
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Prescriptive Design
Requirements for the Code



- FEMA is funding ongoing work to support this type of work.
- ATC-138 project is currently starting to run FEMA P-58 assessments to determine functional recovery code requirements.
- Components of project:
 - ✓ Determine functional recovery objectives (with others)
 - ✓ Define allowable and unallowable damage (goal is not no damage)
 - ✓ Run huge parametric study using FEMA P-58
 - Large set of building designs – all major building types, occupancies, many locations, many heights, etc.
 - Vary design requirements to quantify the effects on functional recovery (Ie, Ip, drift limit, etc.)
 - ✓ Use to provide recommendations on Code requirements for functional recovery.





- Do ATC-138 fuller study in this fiscal year (but aim to front-load the work and stay in sync with other efforts).
- Do all of this work in close collaboration with those working on Functional Recovery approaches and standards (NIST/FEMA, SEAOC, EERI, CA/Nazarian, etc.).

- Code compliant buildings are shown to:
 - ✓ have damage/loss and substantial downtime even for design ground shaking (even though we expect them to be safe)
 - ✓ have highly-variable resilience (because code does not control loss/downtime)
- Risk Category IV design requirements are shown to reduce damage, loss, and repair times, but don't look to consistently deliver what may be wanted (e.g. function in days/weeks).
- FEMA P-58 can be used directly for resilient design for functional recovery and is already being used electively for this (by iteratively meeting a loss/downtime target, just like we do for safety design).
- Work is in-progress to create Code design requirements that can reliably deliver quick functional recovery (coordination is critical).
 - ✓ ATC-138 project
 - ✓ Many groups like NIST/FEMA, SEAOC, EERI, CA/Nazarian, etc.

- Thank you for your time.
- Our goal is to support adoption of resilience-based design for Functional Recovery, and overall seismic risk assessment, and we welcome feedback and suggestions.
- Time for questions and discussion!

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