Resilient Design for Functional Recovery: Recent Traction in the S.E. Profession, New Technical Developments, and Proposed Next Steps

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Collaborators and Funding:

ATC-138 Project Team (FEMA-funded), NIST funding for Cook/Liel,

David Bonowitz and leading Structural Engineers pioneering resilient design (named later).

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SEAOC Convention | September 23, 2021

Motivation/Background

- The public/legislators have become aware that the Code goal is just safety and they want more than “safe but disposable” (stemming from a lot of the work in Los Angeles).
- All levels of government are looking at “design for Functional Recovery”:
  - ✓ **Federal:** NIST/FEMA mandate and report to Congress earlier this year. [and many discussions around this about creating a Functional Recovery Design Standard]
  - ✓ **State:** California AB-1329 on a Functional Recovery Standard
  - ✓ **Local:** San Francisco tall building study and ongoing discussions
- We now also have the technology to quantify resilience using FEMA P-58 (in terms of repair costs and repair times), and use directly for design.
- **Opportunity:** The combination of this societal desire/interest and new technology creates a remarkable situation and opportunity. Structural engineers are well-equipped to meet this new challenge of design for Functional Recovery (and can do it with a quantitative analysis method).
- These are unprecedented times and our SE profession is rising to the occasion.

Outline

- The Anatomy of the Resilient Design Movement
- Recent Traction and Structural Engineering Leadership
- New Technical Developments in Assessing Functional Recovery
- Summary and Proposed Next Steps
- Q&A

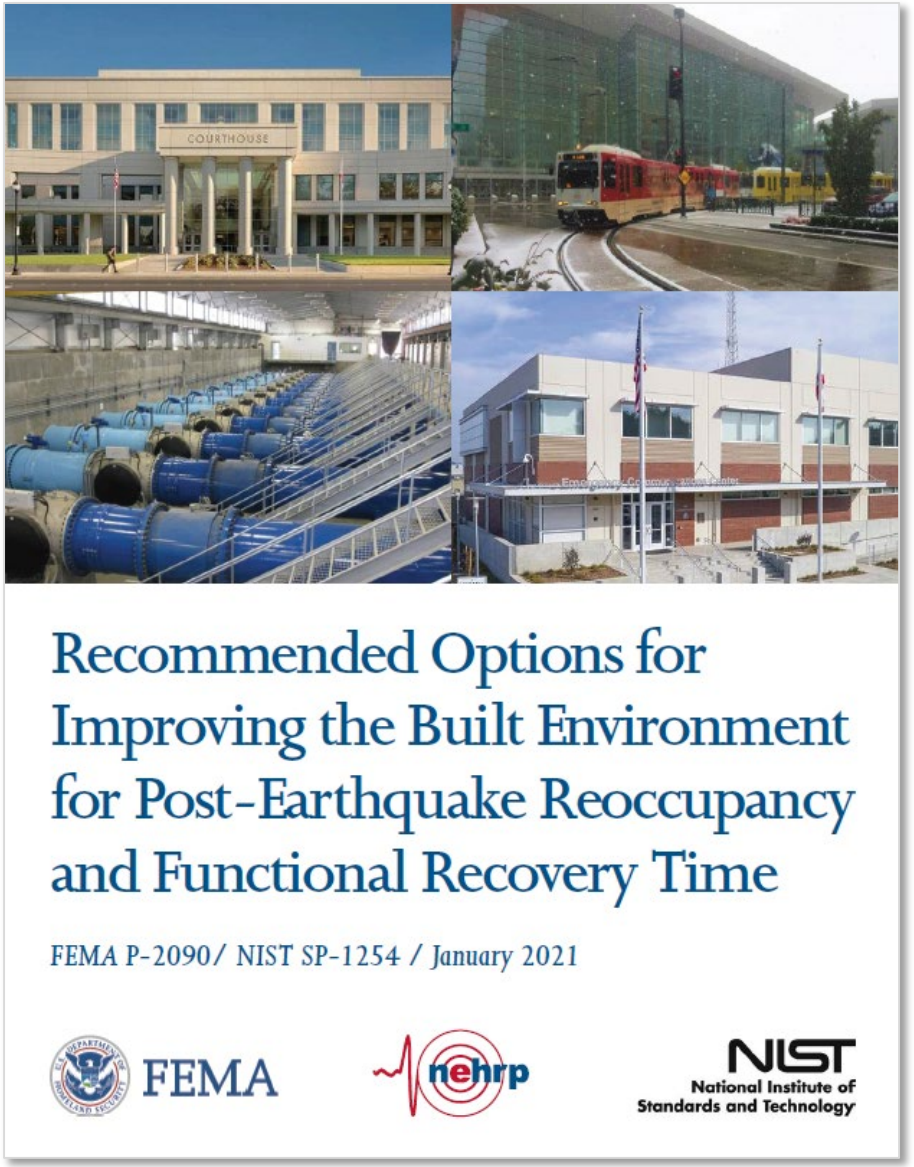
Anatomy of the Resilient Design Movement

Top-Down Push for Resilient Design:

- **Federal:** NEHRP Reauthorization with mandate to look at building function, NIST Immediate Occupancy report, NIST/FEMA Functional Recovery report.

*"**Functional recovery** is a post-earthquake performance state in which a building or lifeline infrastructure system is maintained, or restored, to safely and adequately support the **basic intended functions** associated with the pre-earthquake use or occupancy of a building…"*

[Suggest attending the next ATC morning session on this NIST-FEMA project!**]**

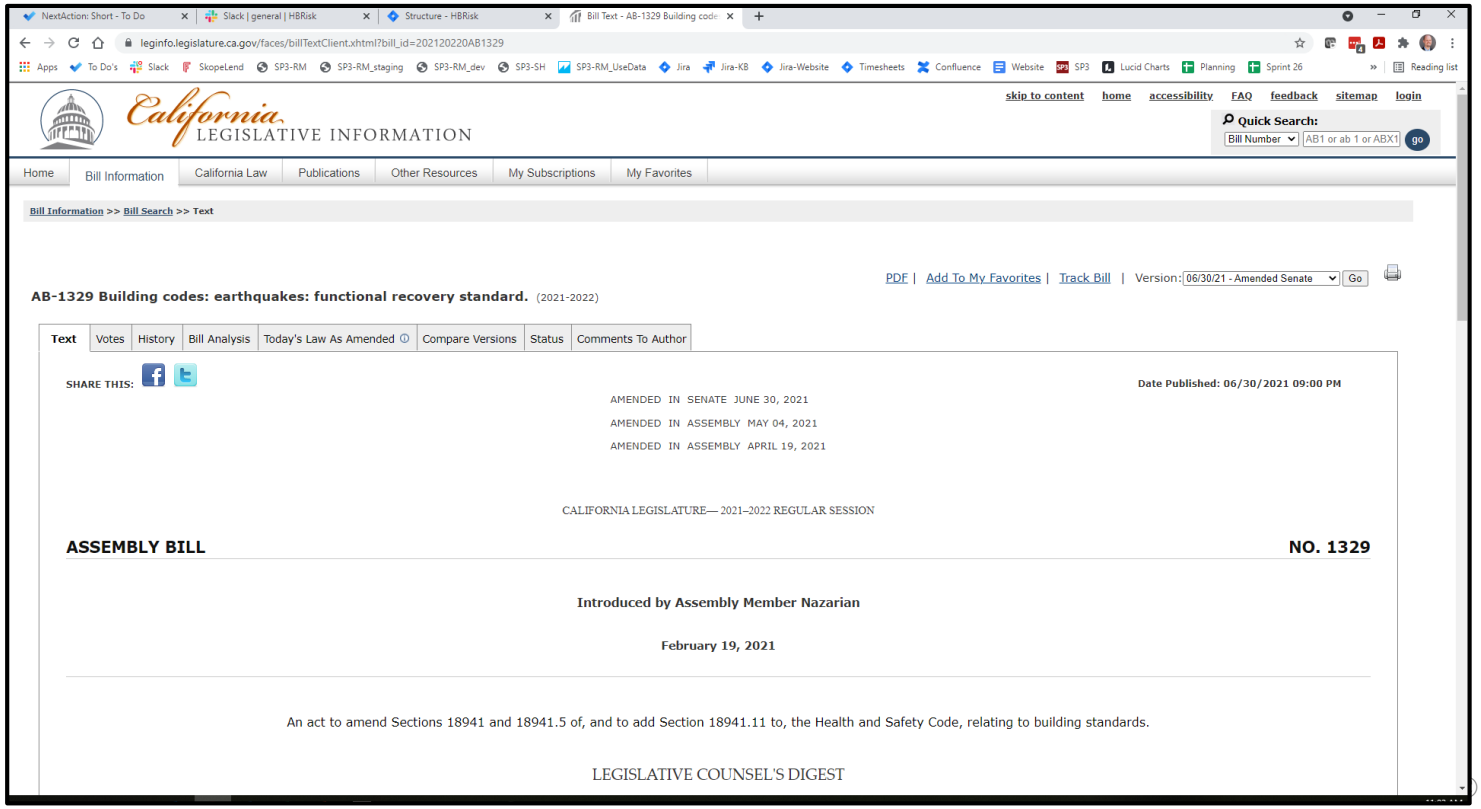


Anatomy of the Resilient Design Movement

Top-Down Push for Resilient Design:

- **State:** California Assembly Bill AB-1329, entitled *"Functional Recovery Standard"*.

"(b) (1) During the 2024 triennial code adoption cycle, the California Building Standards Commission and the Department of Housing and Community Development, acting in accordance with Section 17921, shall develop, adopt, approve, codify, and publish building standards that require buildings not already under the authority of a different state agency to be designed and built to a functional recovery standard for earthquake loads."



leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220AB1329

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AB-1329 Building codes: earthquakes: functional recovery standard. (2021-2022)

Text | Votes | History | Bill Analysis | Today's Law As Amended | Compare Versions | Status | Comments To Author

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Date Published: 06/30/2021 09:00 PM

AMENDED IN SENATE JUNE 30, 2021

AMENDED IN ASSEMBLY MAY 04, 2021

AMENDED IN ASSEMBLY APRIL 19, 2021

CALIFORNIA LEGISLATURE— 2021–2022 REGULAR SESSION

ASSEMBLY BILL **NO. 1329**

Introduced by Assembly Member Nazarian

February 19, 2021

An act to amend Sections 18941 and 18941.5 of, and to add Section 18941.11 to, the Health and Safety Code, relating to building standards.

LEGISLATIVE COUNSEL'S DIGEST

Anatomy of the Resilient Design Movement

Bottom-Up Push for Resilient Design:

- The structural engineering community has not just been waiting around for a building code requirement change.
- Visionary structural engineers are already pushing ahead and leading in this area by designing for post-earthquake function electively on projects.
- Goals of resilient design projects are typically:
  - **Time:** Reduce time for building to regain function (business disruption)
  - **Cost:** Reduce damage and needed repair costs.

Example #1: SF Affordable Housing

- **Project:** Casa Adelante (9-story affordable housing)
- **Engineers:** Mar Structural Design

Example #2: CA State Office in Sacramento

- **Project:** 11-story office for State of California
- **Engineer:** KPFF

Ex. #3: Oregon Treasury Resilience Building

- **Project:** 2-story base-isolated
- **Engineers:** KPFF (Portland)

Example #4: Bluxome SF Offices

- **Project:** 5-Story SF Office
- **Engineers:** ZFA

Example #5: Stanford Biomedical Building

- **Project:** Stanford Biomedical Innovations Building
- **Engineers:** Rutherford & Chekene

Example #6: Watson Land Company

- **Project:** Portfolio of tilt-up warehouse buildings
- **Engineer:** HSA Associates
- **Owner:** Watson Land Company

Ex #7: UCSF Center for Vision Neurosciences

- **Project:** 12-story office/out-patient
- **Engineers:** Forell Elsesser

Example #8: Electric Utility Operation Center

- **Project:** EOC, data center, and office
- **Engineers:** KPFF (Portland)

Example #9: 181 Fremont

- **Project:** 57-story mixed use
- **Engineer:** Arup

Example #10: Roseville City Hall

- **Project:** 4-story precast post-tensioned hybrid moment frame
- **Engineers:** Buehler Engineers

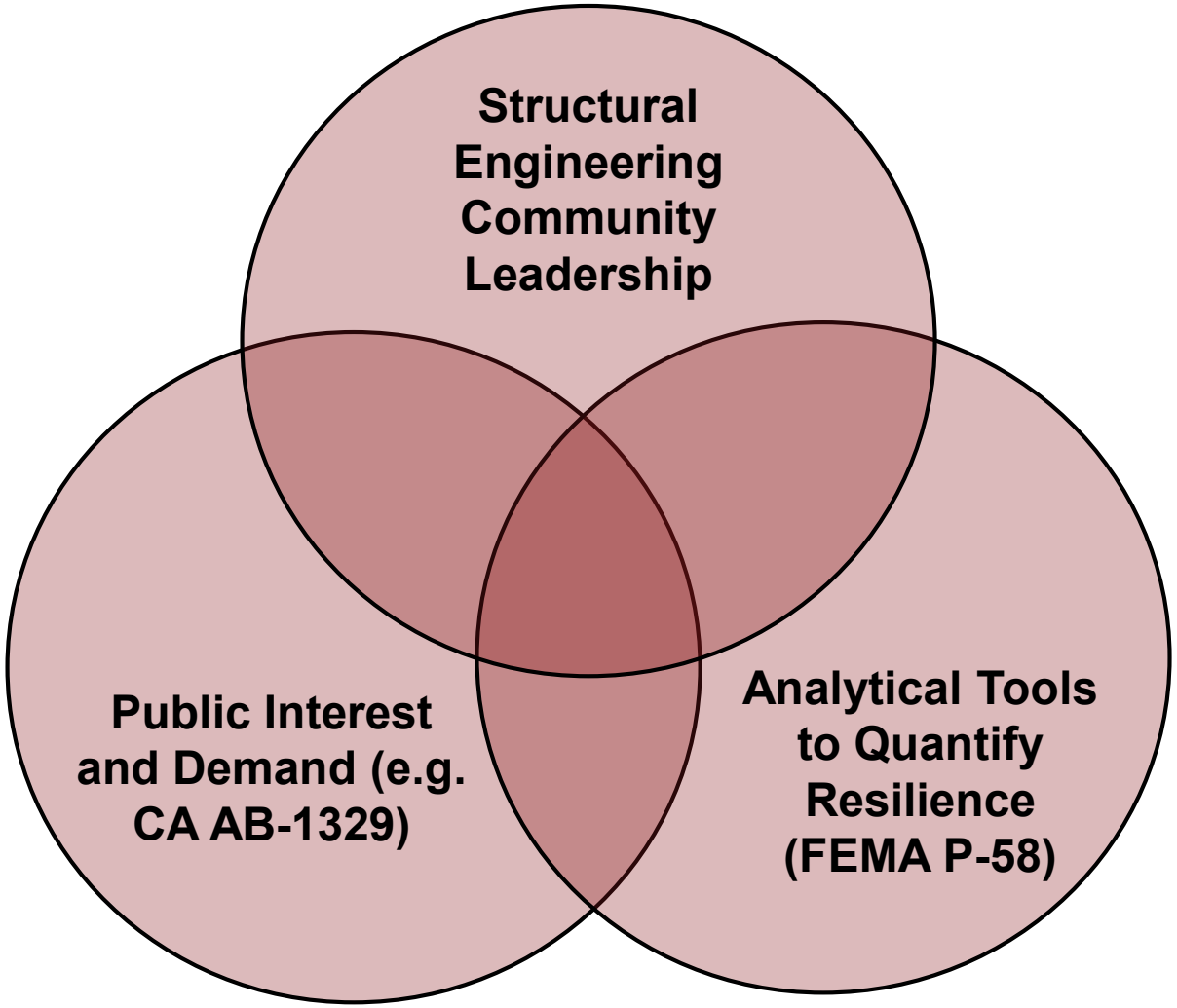
Example #11: Long Beach Civic Center

- **Project:** Long Beach Civic Center (two 11-story buildings – city offices, city council, Port of Long Beach)
- **Engineers:** Nabih Youssef and SOM

Figure Source: SOM/NYASE 2016 SEAOC presentation

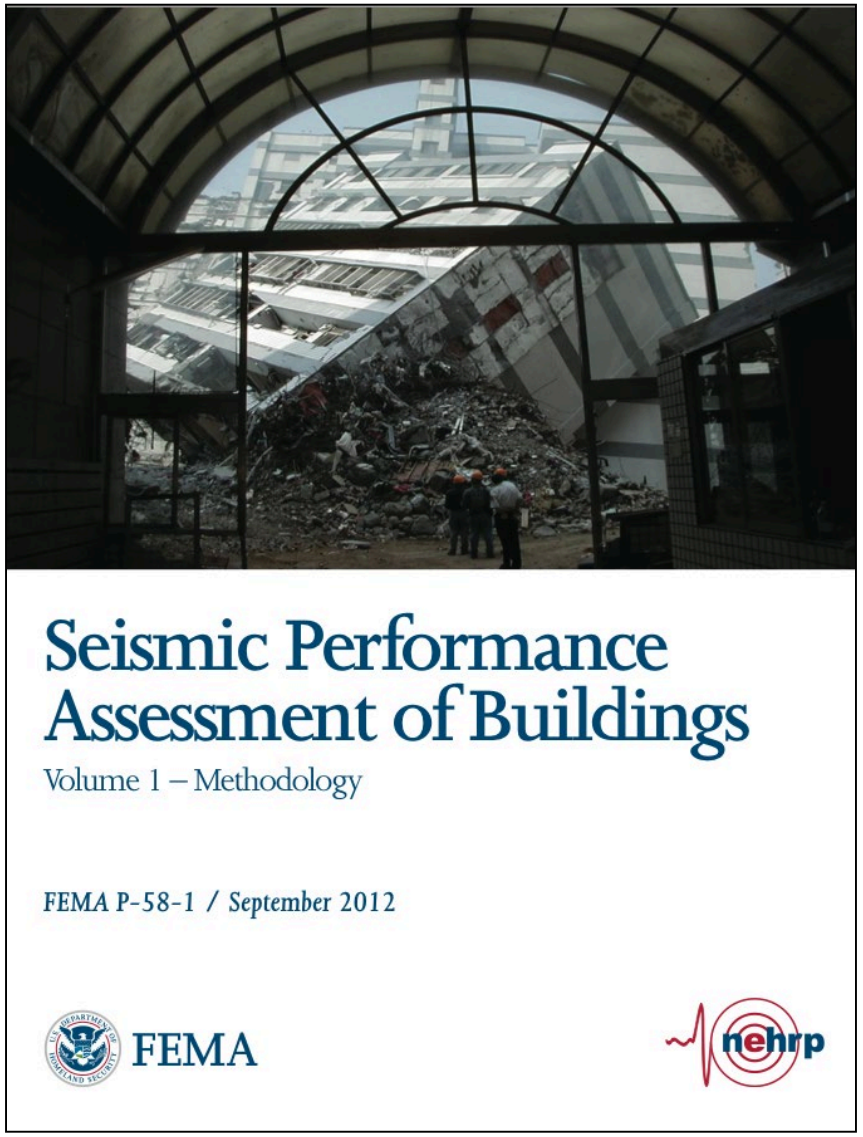
Anatomy of the Resilient Design Movement

Summary of Anatomy of the Resilient Design Movement:

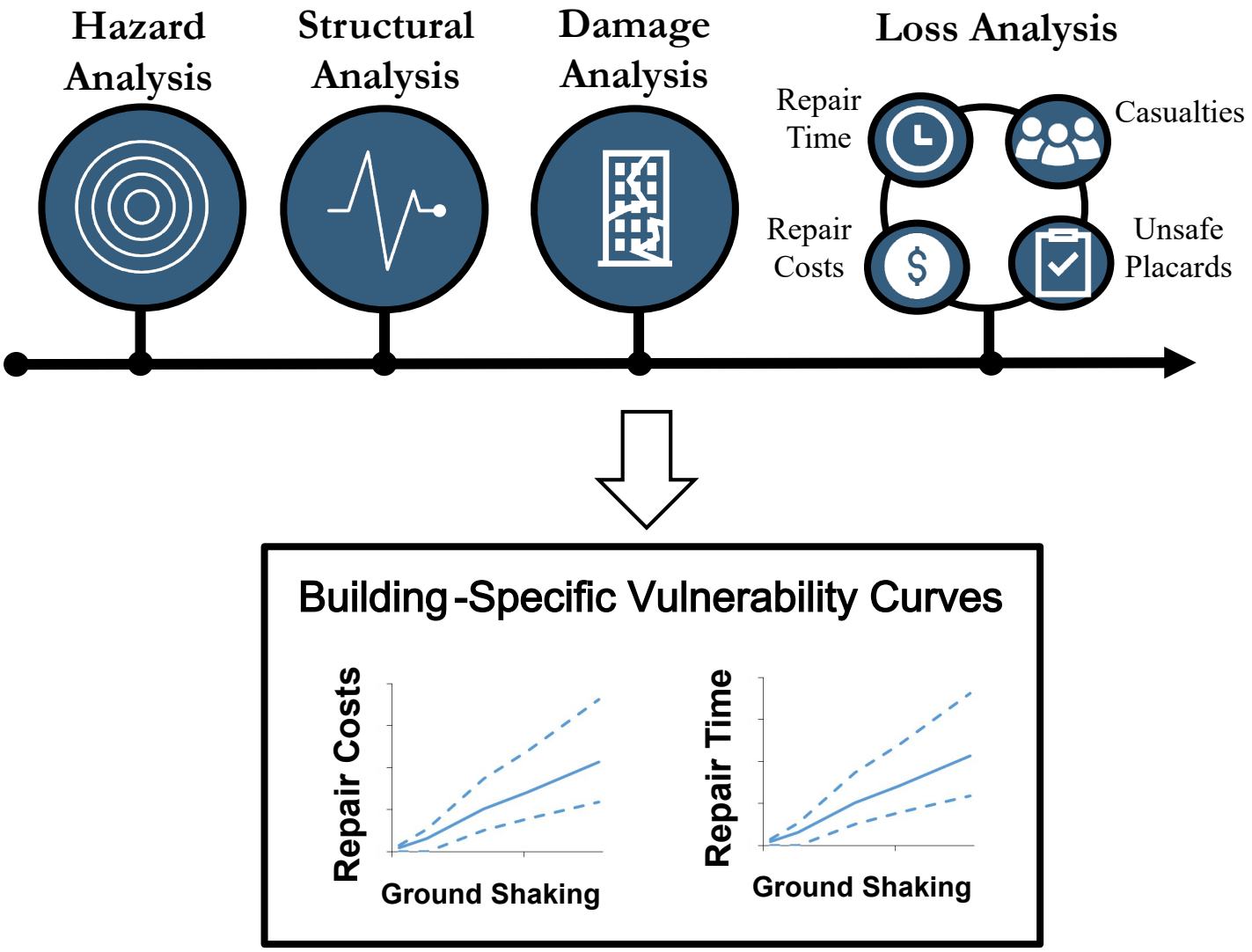


FEMA P-58 and New Developments

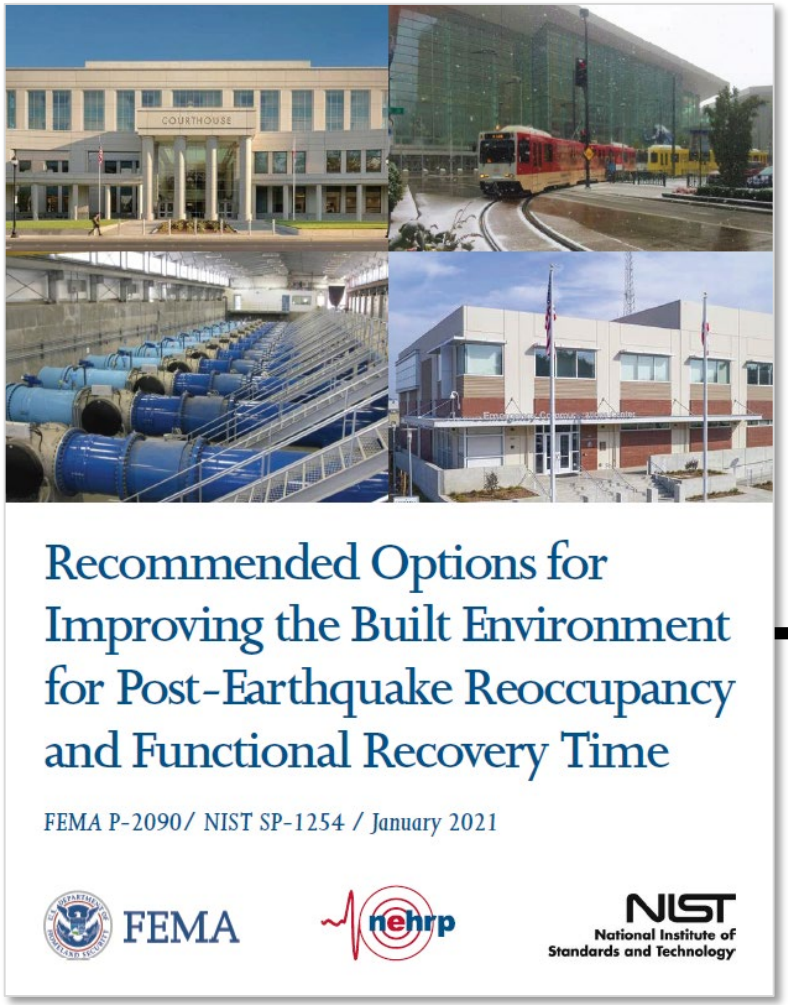
- FEMA P-58 is a probabilistic performance prediction methodology (15 year, $16M+ invested, ~100+ on the team)
- FEMA P-58 is tailored for building-specific analysis
- FEMA P-58 was released in 2012, then used/vetted in structural engineering industry from 2014 to present (~7 years of vetting and refinement).
- FEMA P-58 output results:
  - Repair costs
  - Repair time (+ recovery time)
  - Safety: Fatality & Injury

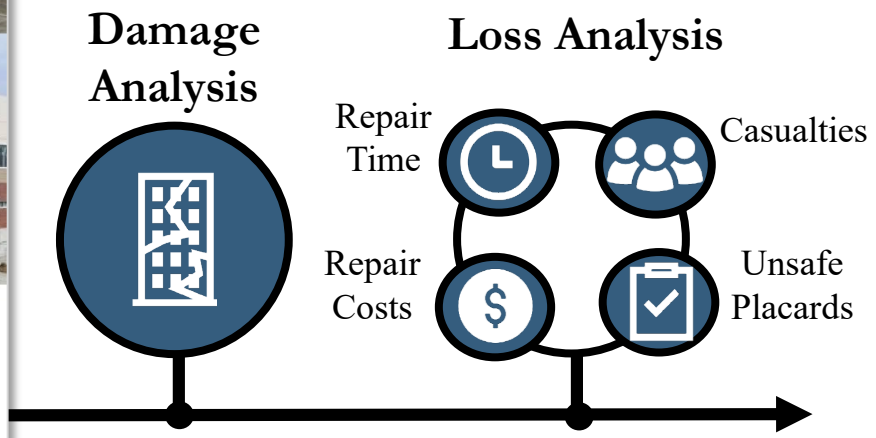


FEMA P-58 and New Developments

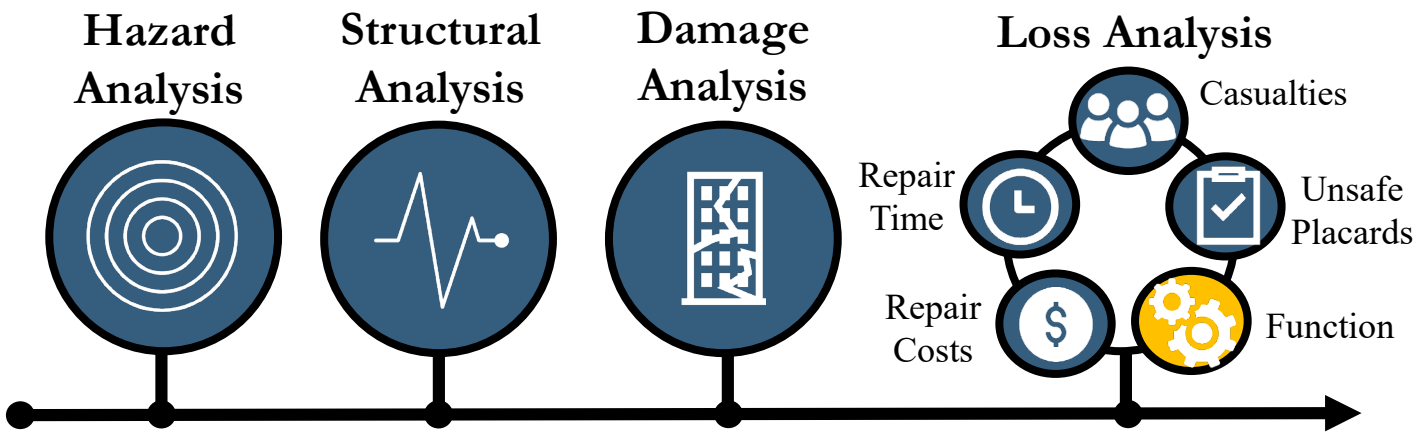


FEMA P-58 and New Developments





FEMA P-58 and New Developments

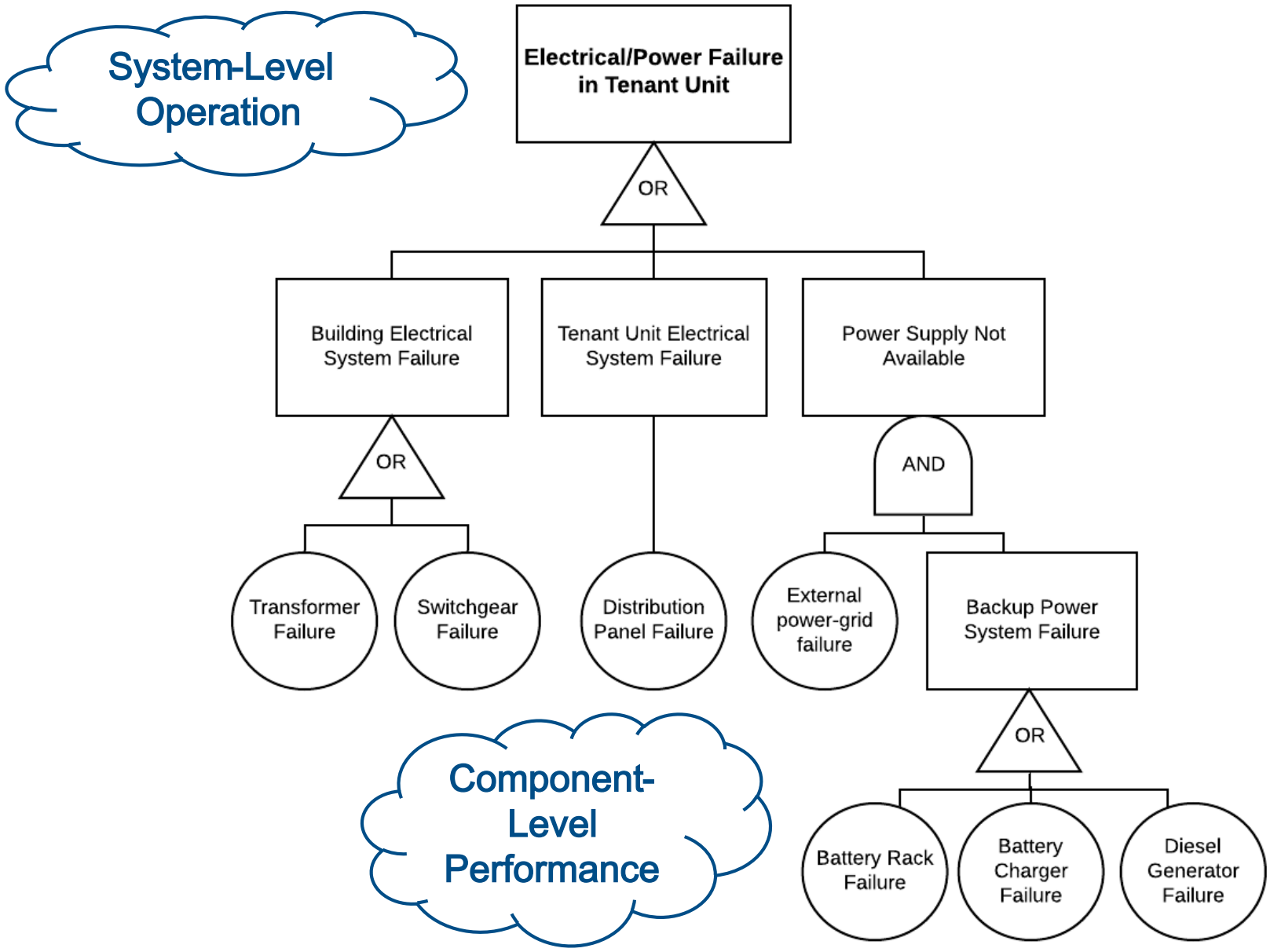


**This new functionality is ready for use (ATC-138 Beta) and will be announced by ATC/FEMA/NIST shortly.

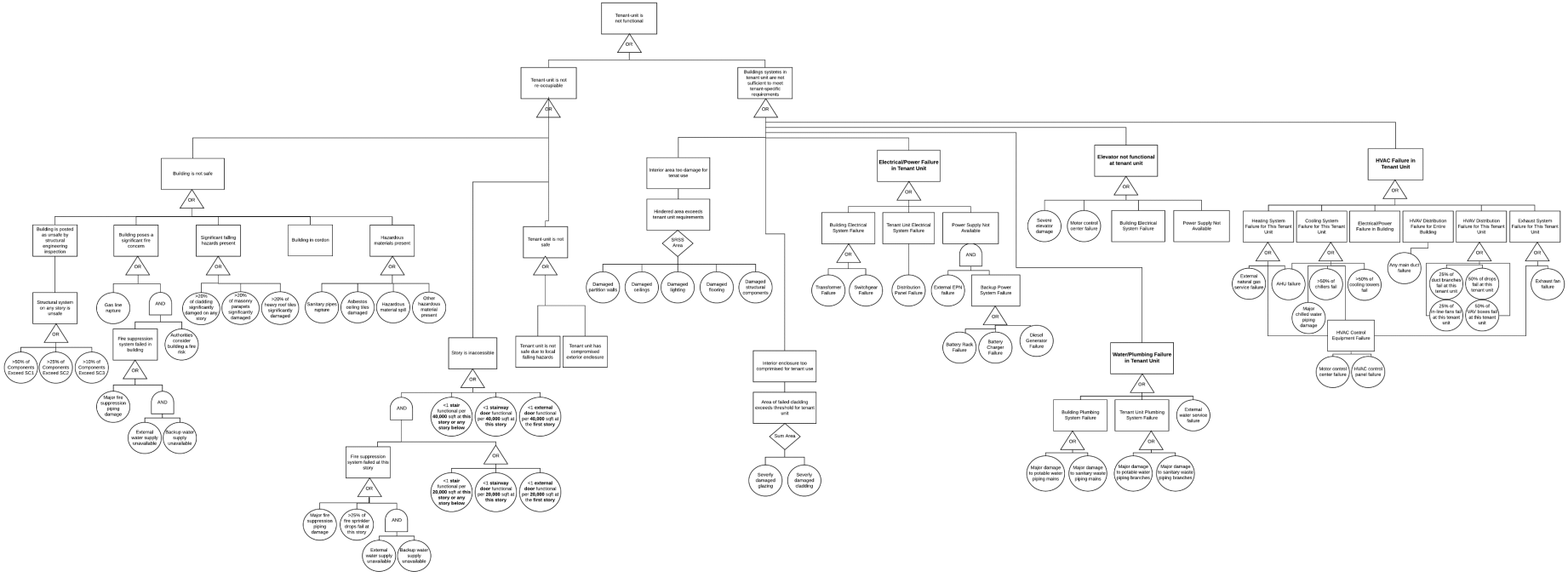
A journal paper and draft report will be available to document the method, and source code is available.

It is also available in the SP3 software.

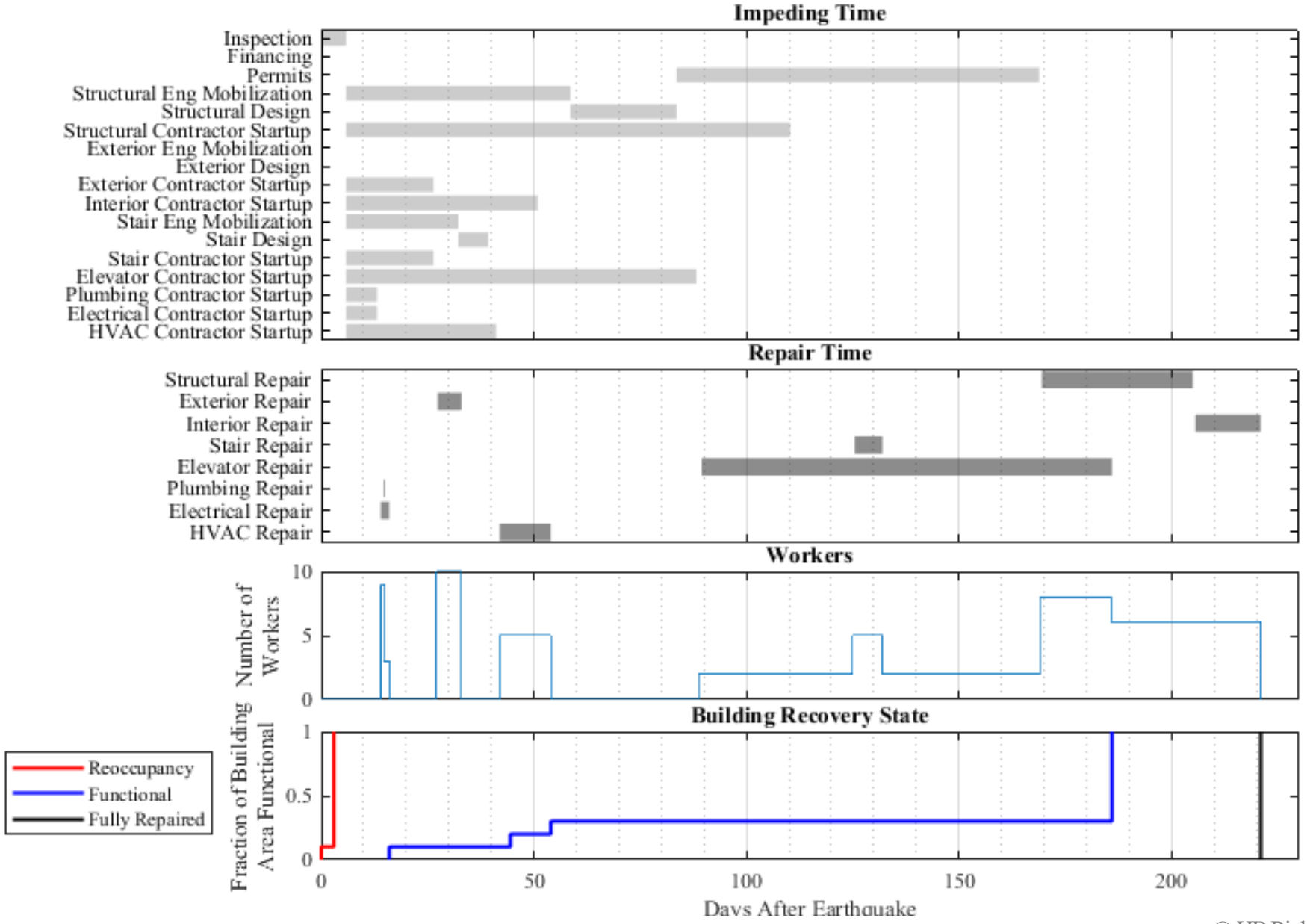
FEMA P-58 and New Developments



FEMA P-58 and New Developments



FEMA P-58 and New Developments



Summary

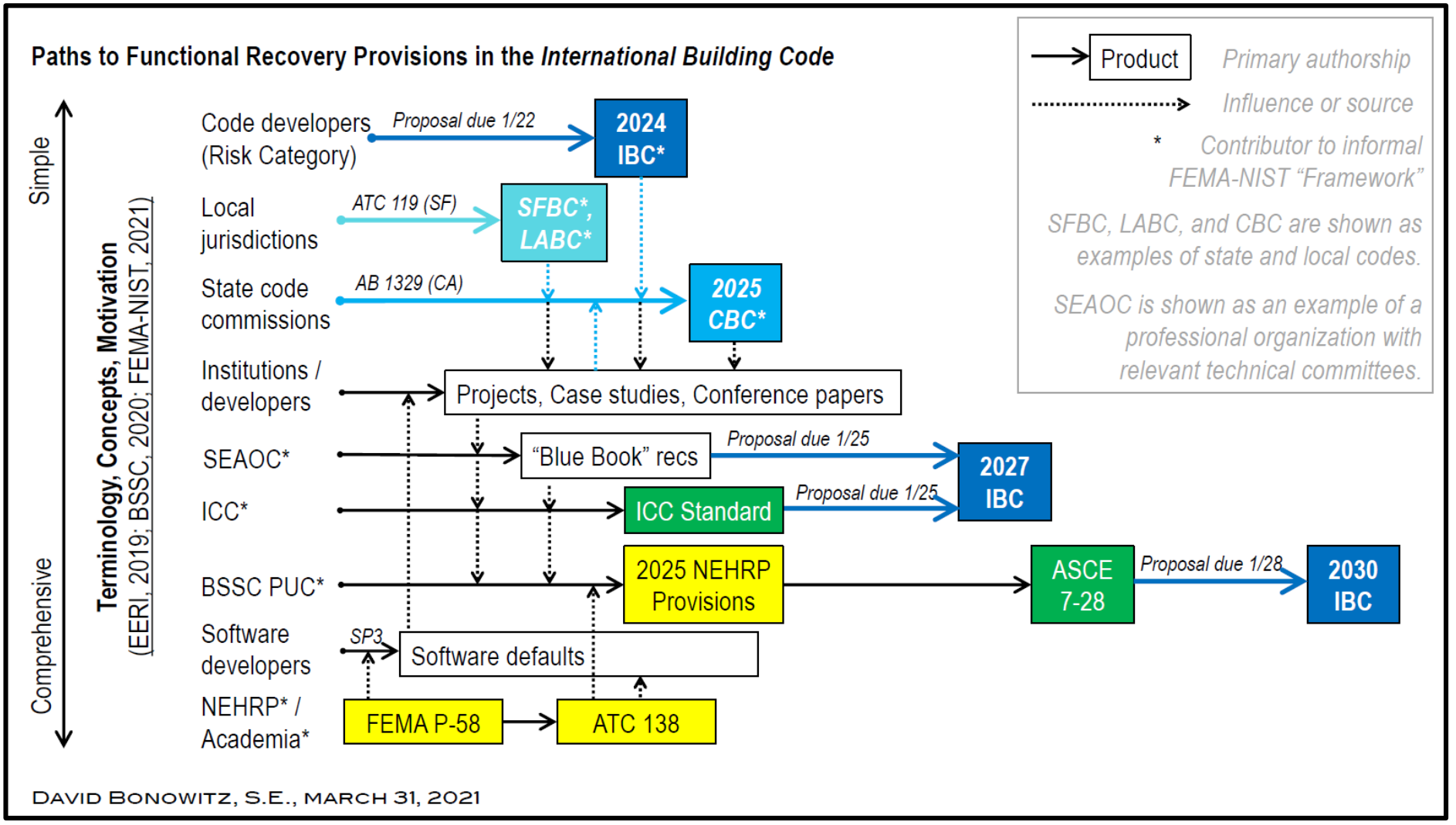
- Code design achieves the safety goals well (per past EQ history), but has not aimed to provide post-earthquake function (so results in ~ 4-12+ months downtime for a design earthquake).
- FEMA P-58 can be used to design directly to meet functional recovery goals (with recent technical developments supporting this even further).
- Even though not mandated, engineers are electively designing for resilience right now (less damage, quicker recovery, less repair cost). [also using FEMA P-58 extensively for risk assessment (PML+)]
- Engineers are creative people, so we are finding that they can provide quicker recovery times with minimal or no added costs (~0-1% construction cost). They just need to add quick recovery to their design goals and be intentional to design for it!

Proposed Next Steps

- We propose two next steps to keep pushing forward this resilient design movement:
  - ✓ **Step 1: Leaders keep leading.** As the leading members of our structural engineering community do this for individual projects, this is "showing the way" and helping work out how this may be done broadly for more/all buildings in the future.
  - ✓ **Step 2: Work toward resilient design requirements.** There are many discussions ongoing about what code design requirements may look like for resilient design for functional recovery. We provide some suggestions for this, and most importantly, propose that this be done in a coordinated way together.

Proposed Next Steps

Step 2: Possible Paths to Codification (Bonowitz, with permission):



Proposed Next Steps

Step 2: We propose coordinated effort to create design requirements

- Options for Prescriptive Requirements:

  a) **Use current code knobs.**

  - This would definitely be easier (e.g. assign more to Risk Category IV).
  - However, even Risk Category IV has been shown to be better but not result in the days/weeks functionality goals commonly used (ATC Vol. 5, 2018 Wade SEAOC).
  - Using this approach would create a notable disconnect between leading practice (11 examples shown here) and such a prescriptive requirement.

  b) **Create requirements specifically for function.** Create design requirements targeting function, in way consistent with NIST/FEMA proposed direction, and use best available information to do this.

  - This would be more effort, but would result in design requirements that we think will give the short recovery times that we likely want (days/weeks).
  - The new FEMA P-58 extensions (through NIST and ATC-138/FEMA) provide an analytical approach that we can use for this (fully consistent with NIST/FEMA).

- **We propose that we pursue Option B in a coordinated manner together.

Proposed Next Steps

Step 2: We propose coordinated effort to create design requirements

- To do this, it would be really good if we figure out how to coordinate all efforts on this (ATC/FEMA, NIST, SEAOC, EERI, BSSC, ICC, researchers, etc., …).
- A proposed outline of this development process would be:
  1) Create clear functional recovery time goals (days/weeks/months), and ground motion levels for which those goals must be met.
  2) Create a clear definition of allowable damage for function to be maintained, in manner that is fully consistent with NIST-FEMA report to Congress (draft done in the technical development described earlier, on the ATC-138 project).
  3) Complete a large set of analytical studies, leveraging the new FEMA-P-58-based functional recovery time methods; this can relate design requirements to the functional recovery time outcomes. Do these studies for various building systems, heights, occupancies, levels of seismicity, etc.
  4) Use the results of the above studies and generalize them to create prescriptive design requirements that meet recovery time goals. Write these requirements in a format that is consistent with the current ASCE 7, and therefore, easy to implement as a code change (e.g. in terms of Ie, Ip for various systems, drift limits, etc.).

Proposed Next Steps

Step 2: We propose coordinated effort to create design requirements

- We propose that the structure or design requirements would be:
  - ✓ Prescriptive requirements as defaults.
  - ✓ “Alternate Means” provision to allow more creative/advanced design (so people can also keep doing resilient design as they are now).
- For immediate next steps, how to we coordinate these developments among the many groups trying to work on this? Let’s discuss ideas in Q&A session as possible!

Questions and Discussion!

- 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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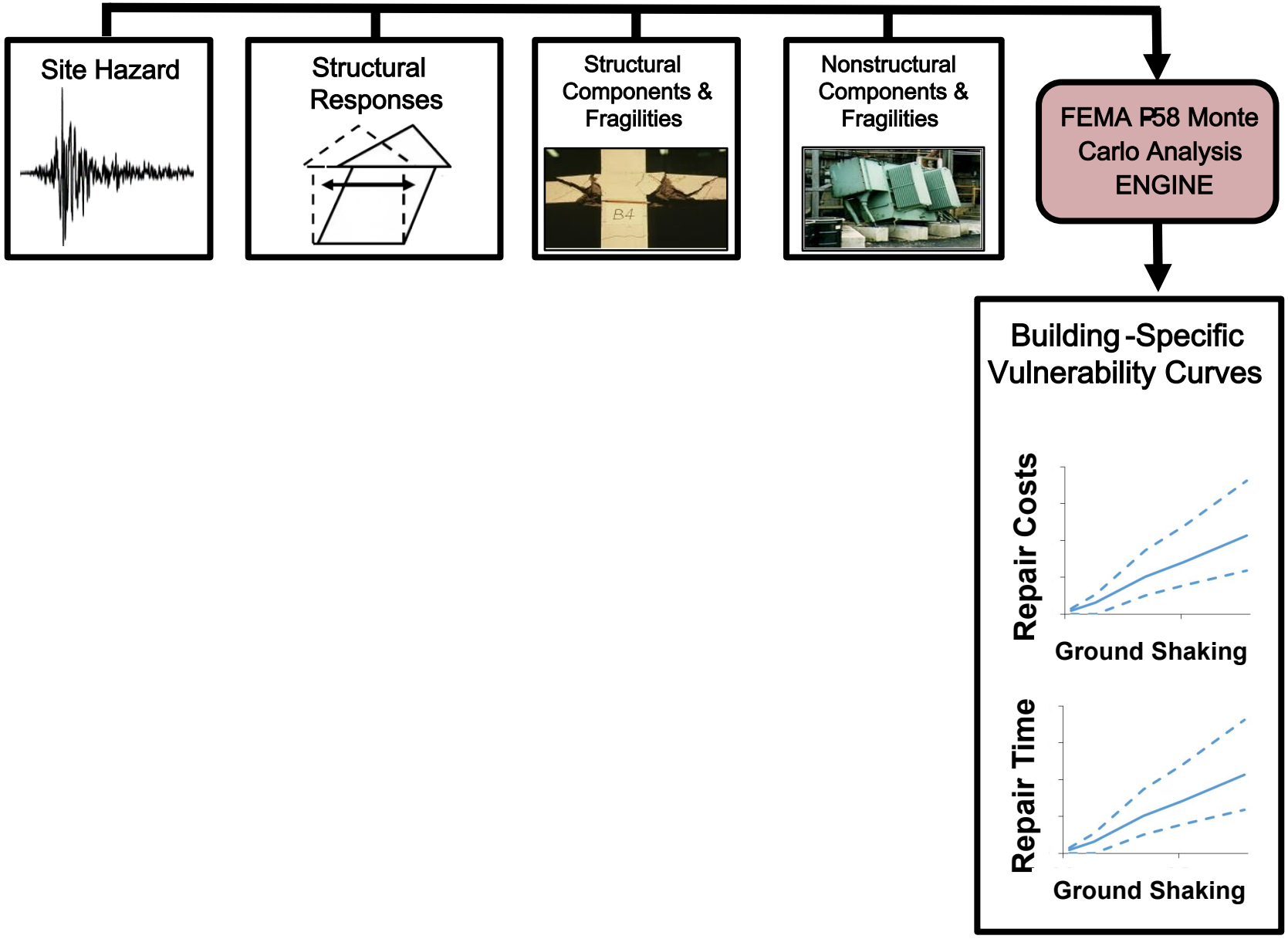
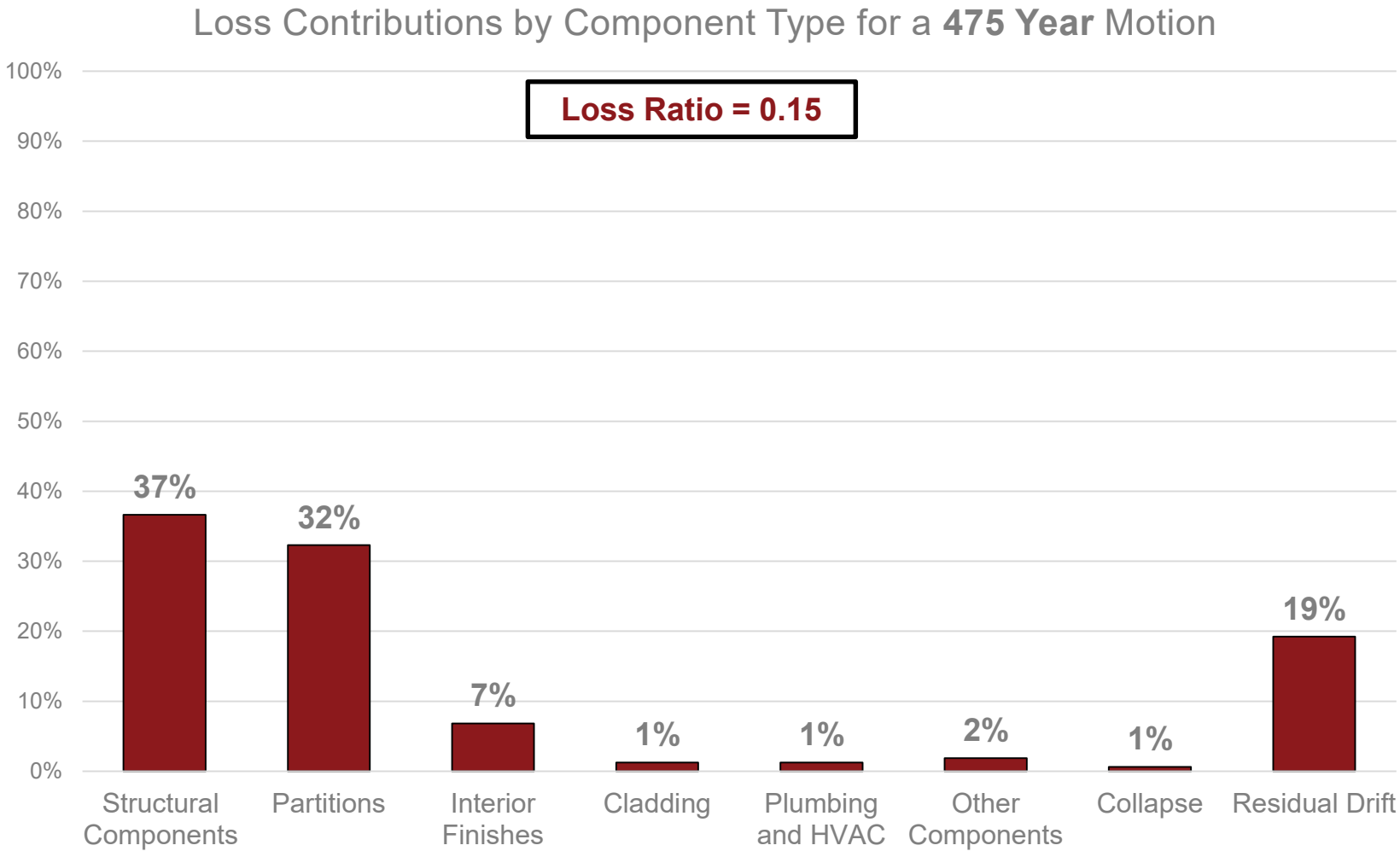
EXTRA SLIDES

FEMA P-58 and Use for Resilient Design



FEMA P-58 and Use for Resilient Design

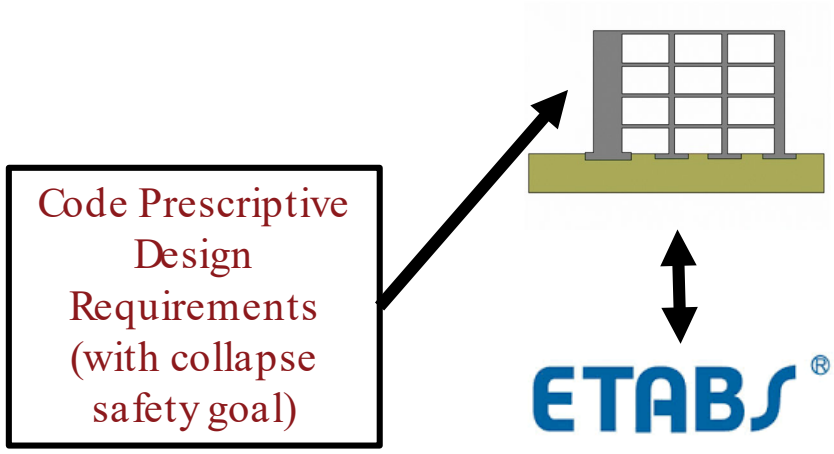
8-story concrete frame in Los Angeles



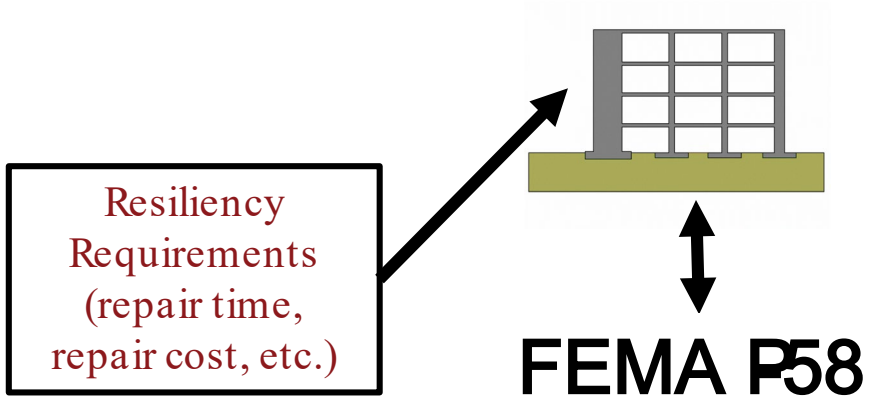
FEMA P-58 and Use for Resilient Design

- What Resilient Design is not:
  - What we typically call performance-based design (uses better analysis, but the goal is still code compliance, focused on safety) – e.g. LA Tall Buildings, PEER TBI, etc.
  - Designing for enhanced code (e.g. Risk Category IV) and then praying that it gives us what we want.
- Resilient Design is:
  - Setting performance goal beyond just safety (e.g. building functional in a week).
  - Iteratively designing until you meet your resilience goals (using FEMA P-58 analysis to quantify effects of design changes).

Code Design Process:



Resilient Design Process (same with different goals):



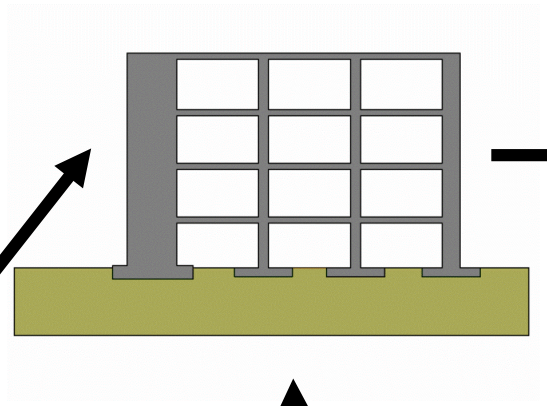
FEMA P-58 and Use for Resilient Design

- Common Resilient Design goals are:
  - The building can be quickly reoccupied (e.g. in one week after a DE)
  - The building can quickly regain function (e.g. “Functional Recovery” in month)
  - The repair costs are limited (e.g. less than 5% repair cost for a DE)
  - The goal is not “no damage.” Damage is accepted but needs to be controlled such that building can be reoccupied and can regain basic function quickly.
- In general, resilient design requires the following:
  - Structural: No structural damage that requires repair before building can function (not no structural damage). [selection of structural system, more strength, lower drift limits]
  - Non-structural (drift): Non-structural drift-sensitive damage is low enough that building can function. [lower drift limits, higher capacity components]
  - Non-structural (acceleration): Non-structural acceleration-sensitive damage is low enough that building can function. [stronger anchorages, reduce floor accelerations]
  - Residual Drifts: Residual drifts are low enough that building can function. [selection of structural system, strength and drift design]

FEMA P-58 and Use for Resilient Design

- Let's look in more detail at direct resilient design using FEMA P-58…

Resiliency Requirements (for DE):
- Reoccupancy in a week
- Building functional in a month
- Repair cost < 5%



FEMA P58

Design "knobs":
- Structural system selection
- Design strength (Ie)
- Design drift limit
- Anchorage and equipment design (Ip)

- Gravity system design
- Cladding design
- Elevator design
- More design of anchorage and equipment
- …can go as deep as you like…

Structural Engineering Leadership

Summary of Anatomy of the Resilient Design Movement: