Resilience-Based Seismic Design: Current Design Approach, Technical Developments, and a Look Into the Future

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[and discussion of project work by many others]

15th ATC US-Japan Workshop on Structural Engineering and Resiliency

How Do We Design U.S. Buildings Today?

- Building Life Safety:
  - This is the focus (intent of the building code).
  - **Result:** Probably do fairly well here (?).
- Building Closure and Business Disruption:
  - Not considered is design process.
  - **Result:** Not controlled. Likely "months" at design-level, possible demolition ("years") at maximum-level.
- Building Damage and Repair Costs:
  - Not considered is design process.
  - **Result:** Not controlled. Presume 20% loss at design-level, possible demolition at maximum-level.

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Question #2: Is this how we should design buildings?

- Building Damage and Repair Costs:
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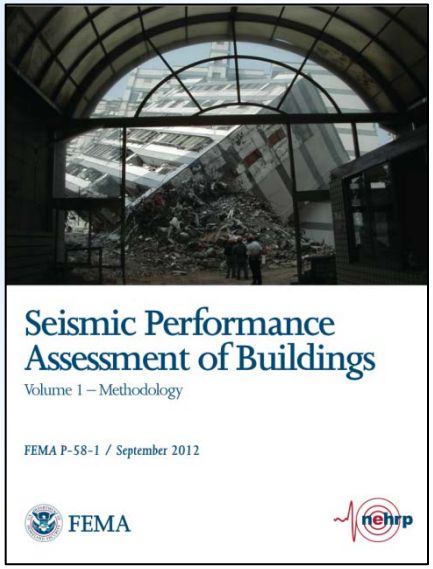
What If ?

- What if we…
  - …had a robust analysis method that could estimate monetary losses, closure time, and fatalities/injuries?
  - …had an analysis method detailed enough so we can clearly see the effects of our design decisions?
  - …had this analysis stream-lined so we can do the initial analysis in hours (rather than days/weeks) and then refine the analysis as needed?
  - …had a building rating system (USRC) that packages this all into an easily communicated result? [Heintz]
- How would this change our thinking?

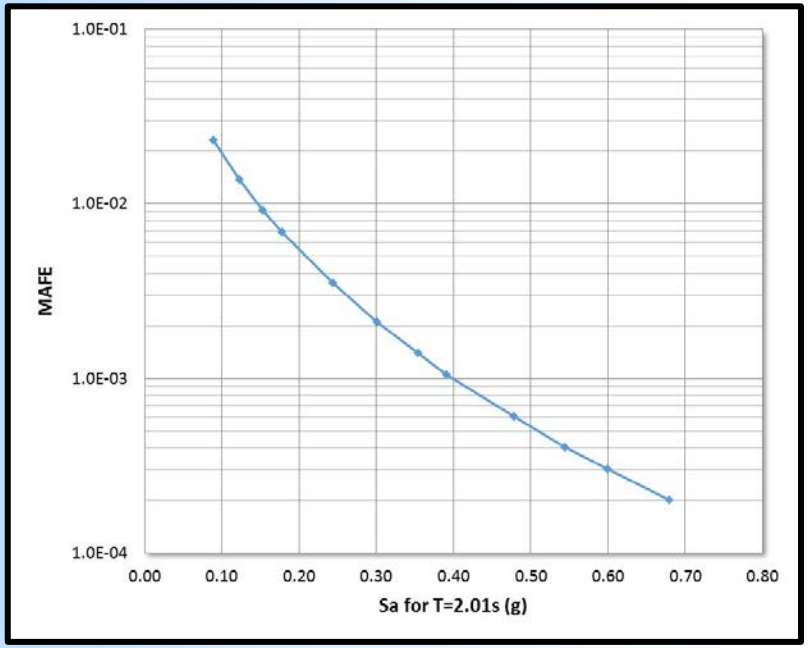
Overview of FEMA P-58

- P-58 is a performance prediction methodology based on a 10-year FEMA study (enabled by much previous research).
- P-58 is an alternative to other experience-based or judgment-based methods (e.g. HAZUS, ATC-13, etc.).
- P-58 is tailored to building-specific analysis (cause + effect).
- ATC is currently working on another 5-year effort to further advance the methodology, implementation, ease of use.
- FEMA P-58 Output Results:
  - Losses [$]
  - Fatalities & injuries [safety]
  - Repair time & red tagging [business disruption]



FEMA P-58: Methodology

- Hazard and Ground Motions
  - Soil and hazard curve
  - Ground motions (if needed)



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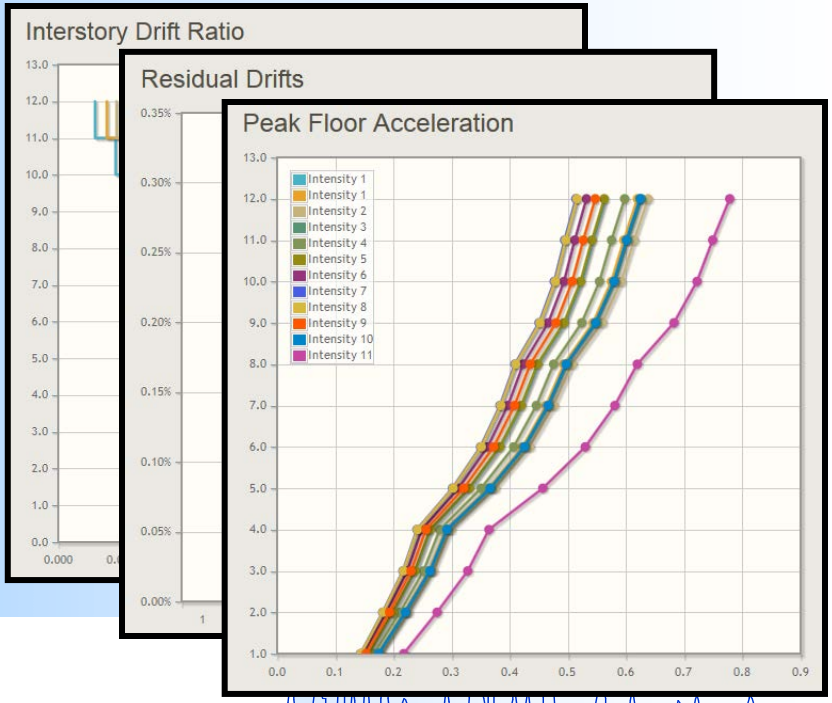

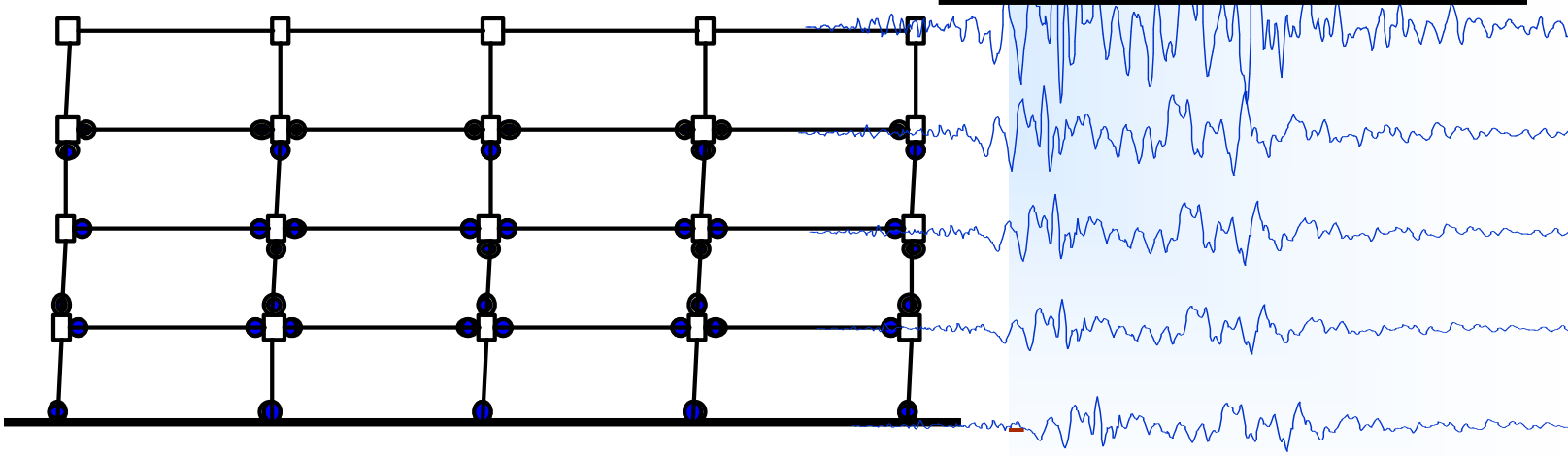

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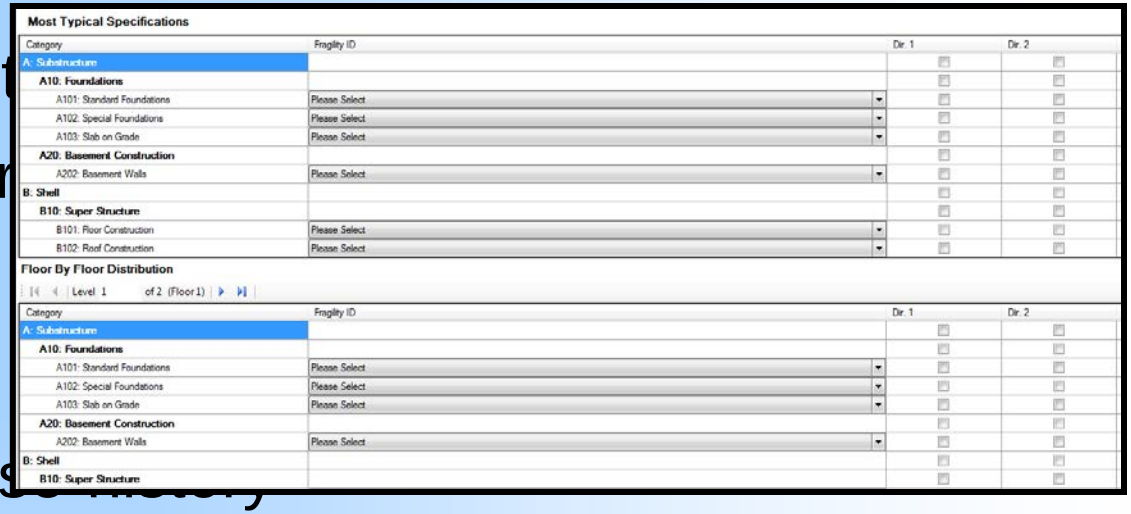

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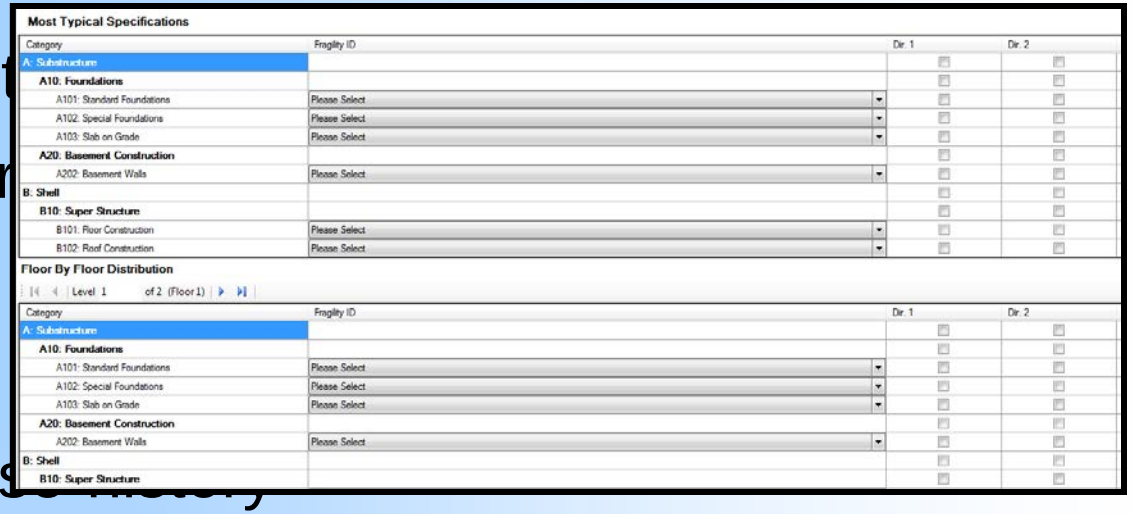

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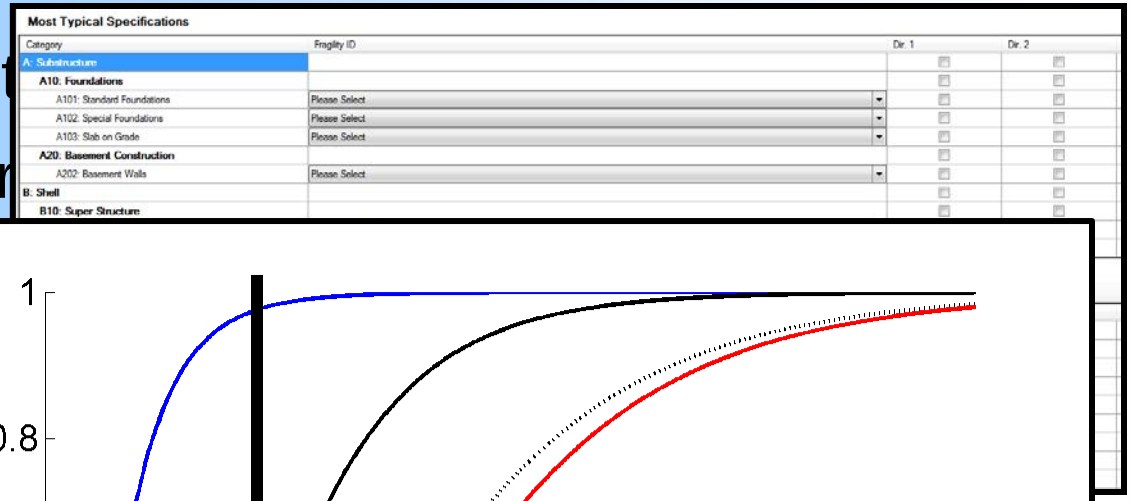

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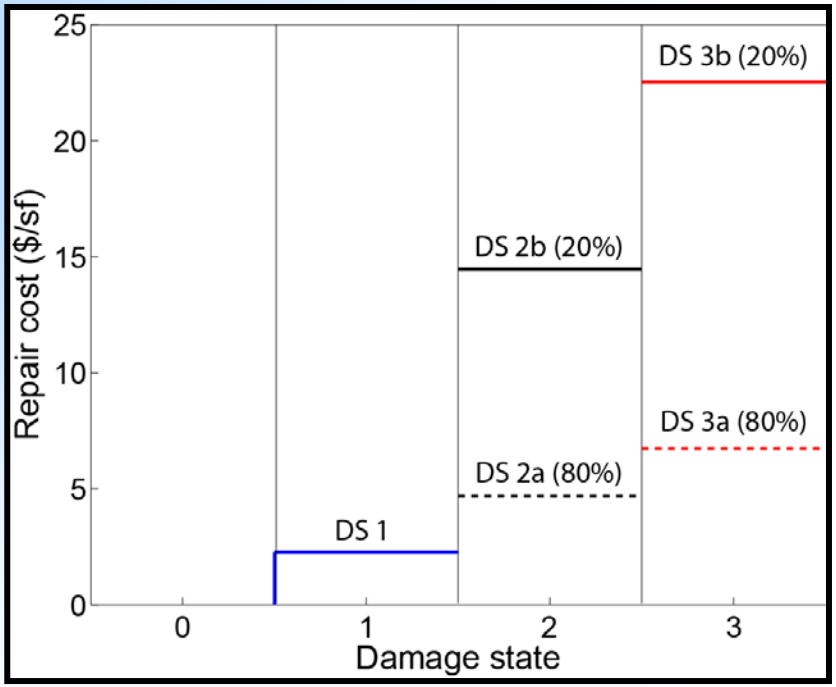

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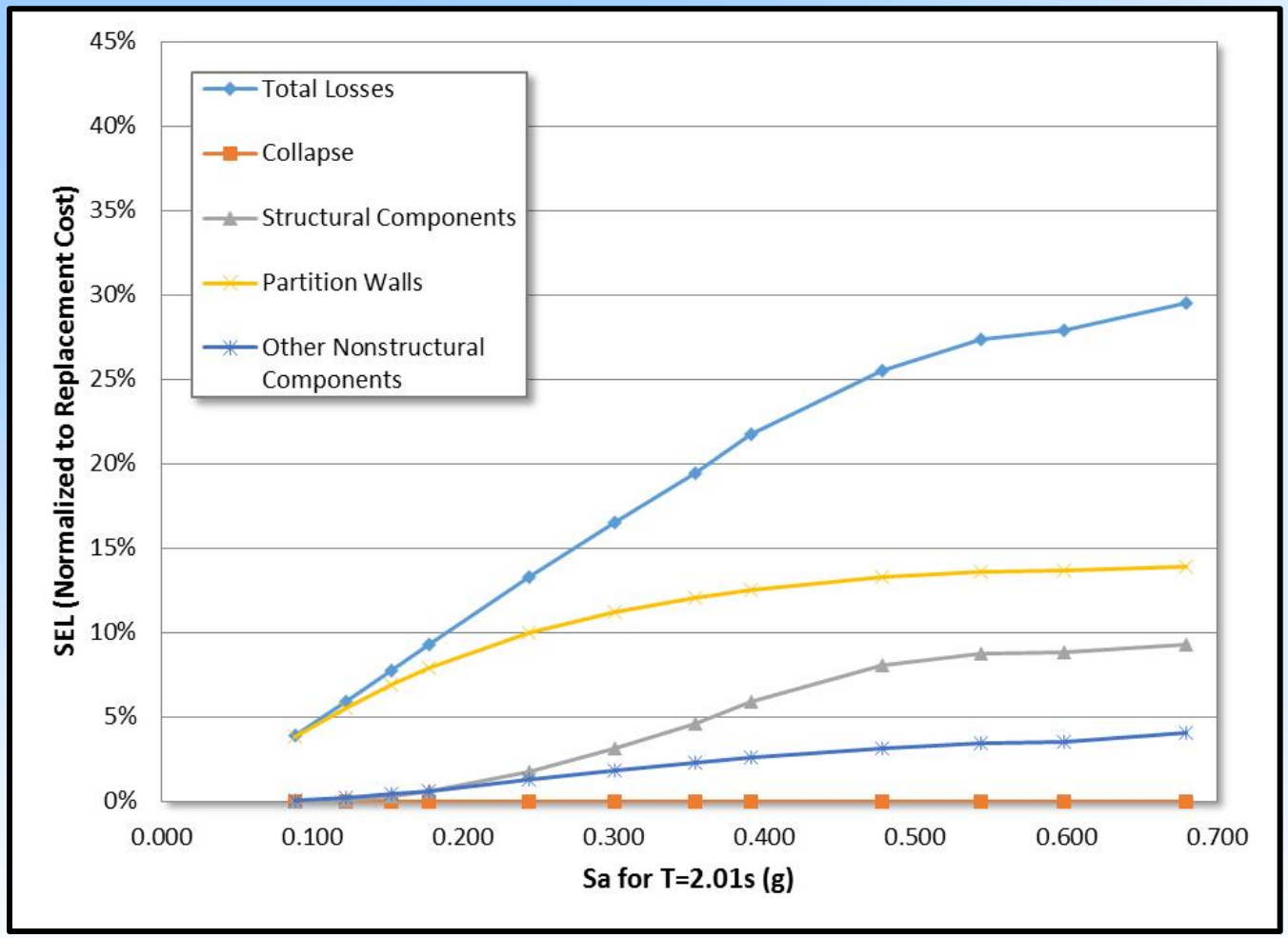
Monte Carlo Simulation used ("roll dice" thousands of times).

Each "dice roll" gives a single observation of losses and other consequences.

Full set of "dice rolls" provides solid statistical information on performance (e.g. 10,000 at 14 levels = 140,000 runs).

FEMA P-58: Output Examples

- Sample results (12-story RC frame):



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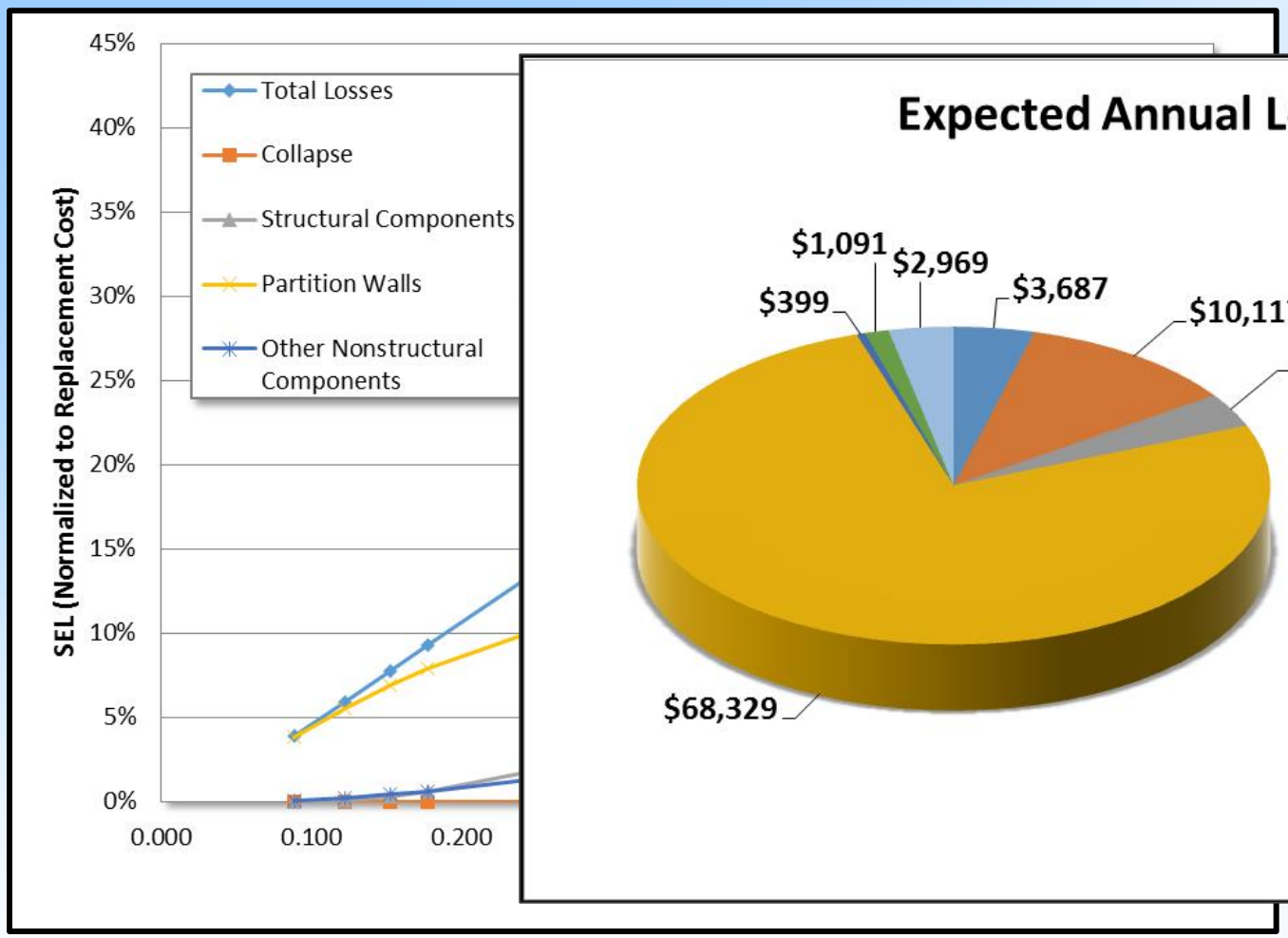
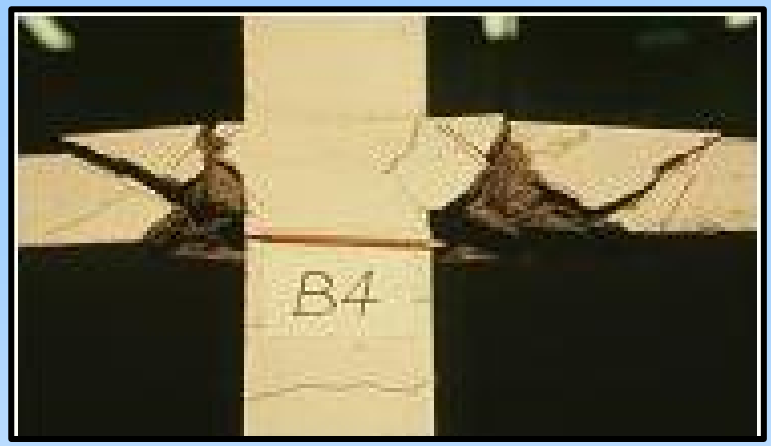


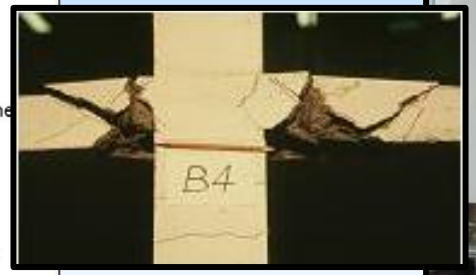
FEMA P-58: Output Examples

- Dig as deep as you like…



FEMA P-58: Benefits

- Objective process based on data and research.
- Quantitative performance information:
  - Solid statistical basis.
  - Sensitive enough to inform design decisions (cause + effect).
  - Tools to communicate with owners.
  - Dig as deep as you like.



FEMA P-58: Perceived "Difficulty"

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I need to hire a geotech to do this…?

I need to do a response-history analysis…?

I need to count and enter every foot of partition wall and other contents…?

Software Needs and Contribution

- A barrier to widespread FEMA P-58 adoption has been related to software and ease-of-use (high cost of entry).
- ATC/FEMA have created a great methodology but are not in the business of maintaining software (for the long-term).
- **Need:** For our profession to move forward with FEMA P-58 methods, an enabling software is needed.

- **Our Contribution:** In February, we decided to fill this role by creating/maintaining a user-friendly software for P-58.
- **Our Goal:** Help enable adoption of FEMA P-58 in practice.
- **ATC Coordination:** We have been in coordination with ATC from the start (so all pulling in same direction).

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Soil and hazard curves embedded.

Simplified method embedded (only need period, mode shape, yield drift).

Structural and non-structural contents estimates and pre-populated.

Two-level structure:
(1) Simple (prelim. design, basic rating, PML)
(2) Refine and go as deep as you like (full new PBD).

What If ?

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  - …had a robust methodology that can estimate monetary losses, closure time, and fatalities/injuries?
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  - …had a building rating system (USRC) that packages this all into an easily communicated result? [Heintz]
- How does this change our thinking?

Discussion: Back to my Initial Question…

Question: Given all these recent technical developments, is this still how we should design buildings?

- Current Design:
  - **Safety:** Probably decent.
  - **Building Closure:** Not controlled. Likely "months" at design-level, possible demolition ("years") at maximum-level.
  - **Repair Costs:** Not controlled. Presume 20% loss at design-level, possible demolition at maximum-level.
- Exciting time of development (FEMA P-58, software, USRC, etc.). How do we leverage this to achieve a more resilient infrastructure?
- What are our policy recommendations for:
  - The design of all buildings?
  - The municipality (or State of CA) worried about widespread building damage and businesses closure affecting the city/region?
  - Owner-elected improved design to protect business or assets?
  - Other?

Closing

- Thank you for your attention and feedback!
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