
The Horizon For Next-Generation Performance Assessment Of Buildings Is Here: FEMA P-58

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Contents

- Background Context
- Next-generation concepts
- Example results
- Products/handouts

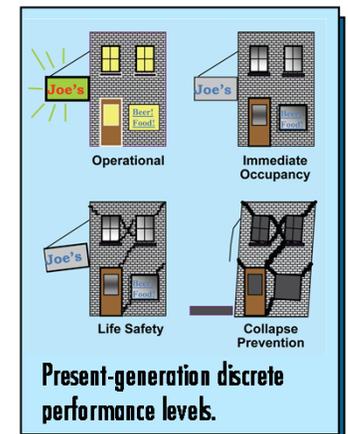
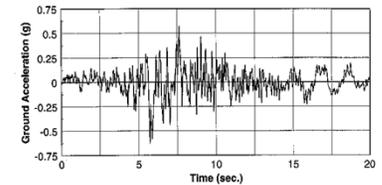
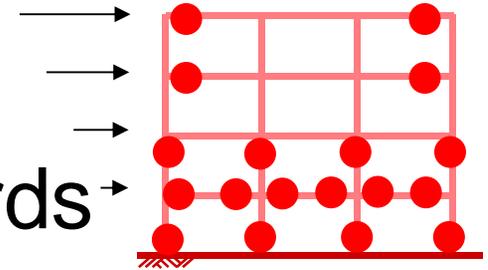
Project Context

- Present-generation procedures
 - FEMA 273 *NEHRP Guidelines for Seismic Rehabilitation of Buildings* (1997)
 - ASCE 41-06 *Seismic Rehabilitation of Existing Buildings* (2007)



Present-Generation Assessment

- LSP, LDP, NSP, NDP
- Max of 3 or average of 7 records
- Using plastic hinge rotation limits to judge performance
 - Clear mechanism – Collapse
 - Isolated hinge locations - ??
 - What if one record causes collapse?
- Report to building owner
 - Collapse Prevention ??



Project Context

- Present-generation procedures
 - FEMA 273 (1997)
 - ASCE 41-06 (2007)
- FEMA began planning program for enhanced procedures (1998)
- FEMA 349 Action Plan (EERI, 2000)
- ATC-58 Project initiated in 2001

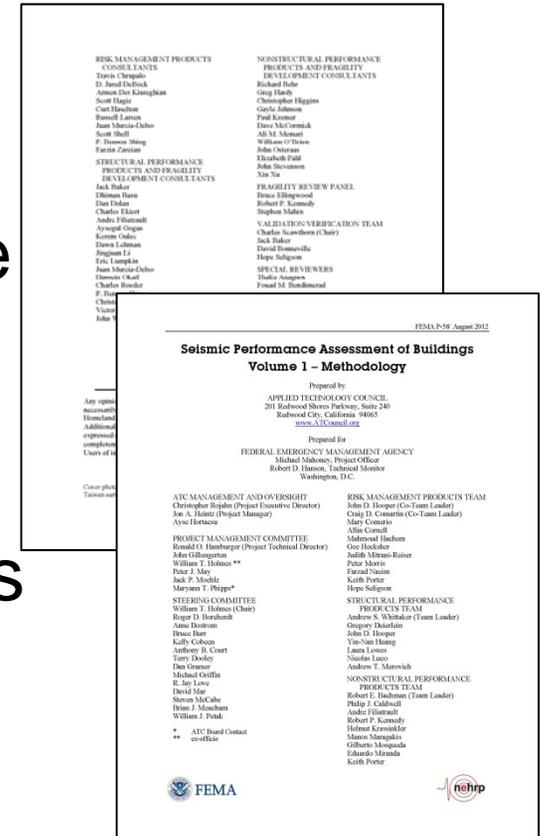


Need for Next-Generation

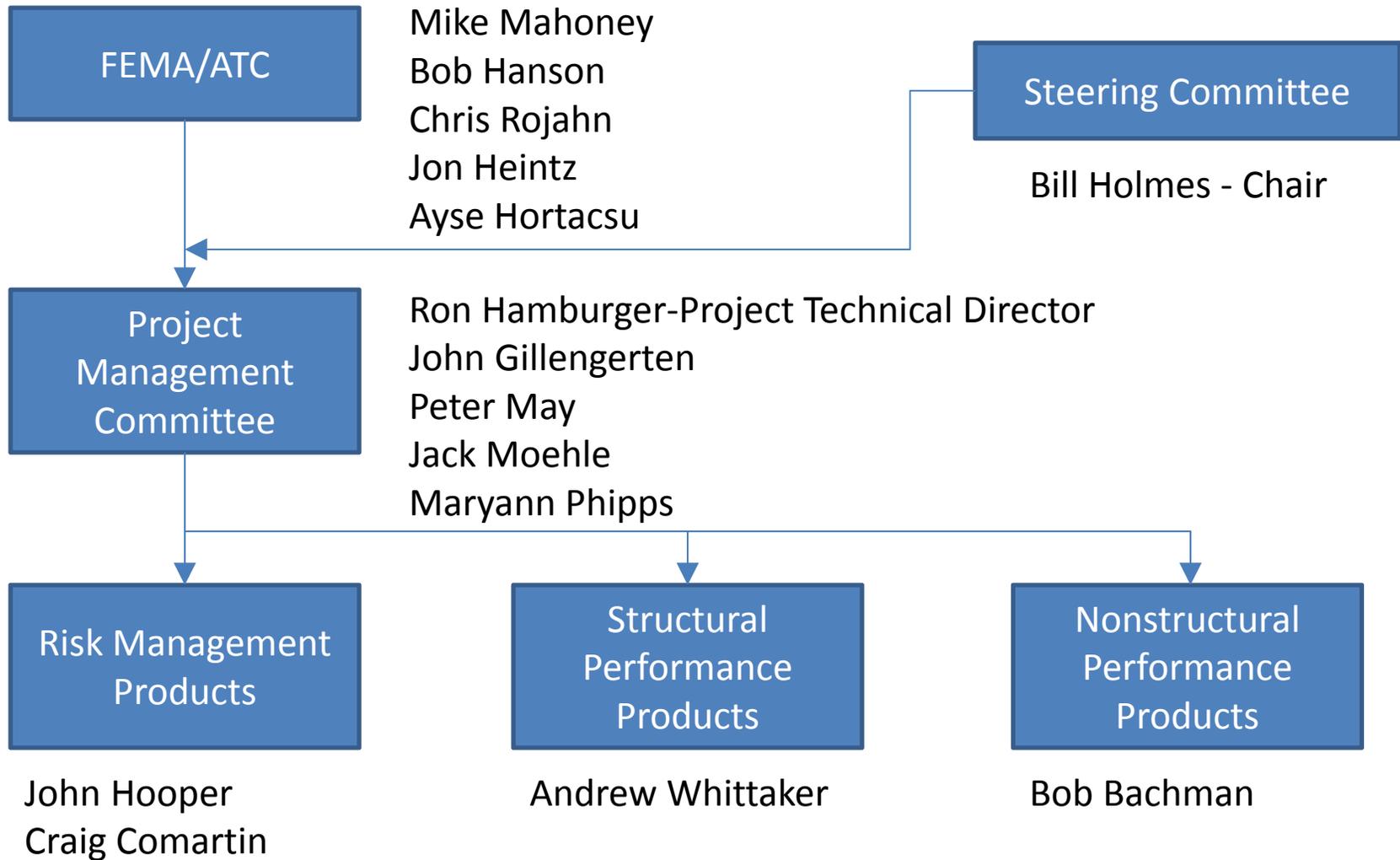
- ATC-58 Project Purpose
 - Develop a framework to account for variability and uncertainty
 - Assess performance on a global rather than local level
 - Expand procedures to explicitly assess nonstructural performance
 - Revise discrete performance levels into measures that are more meaningful for decision-making

Project Team

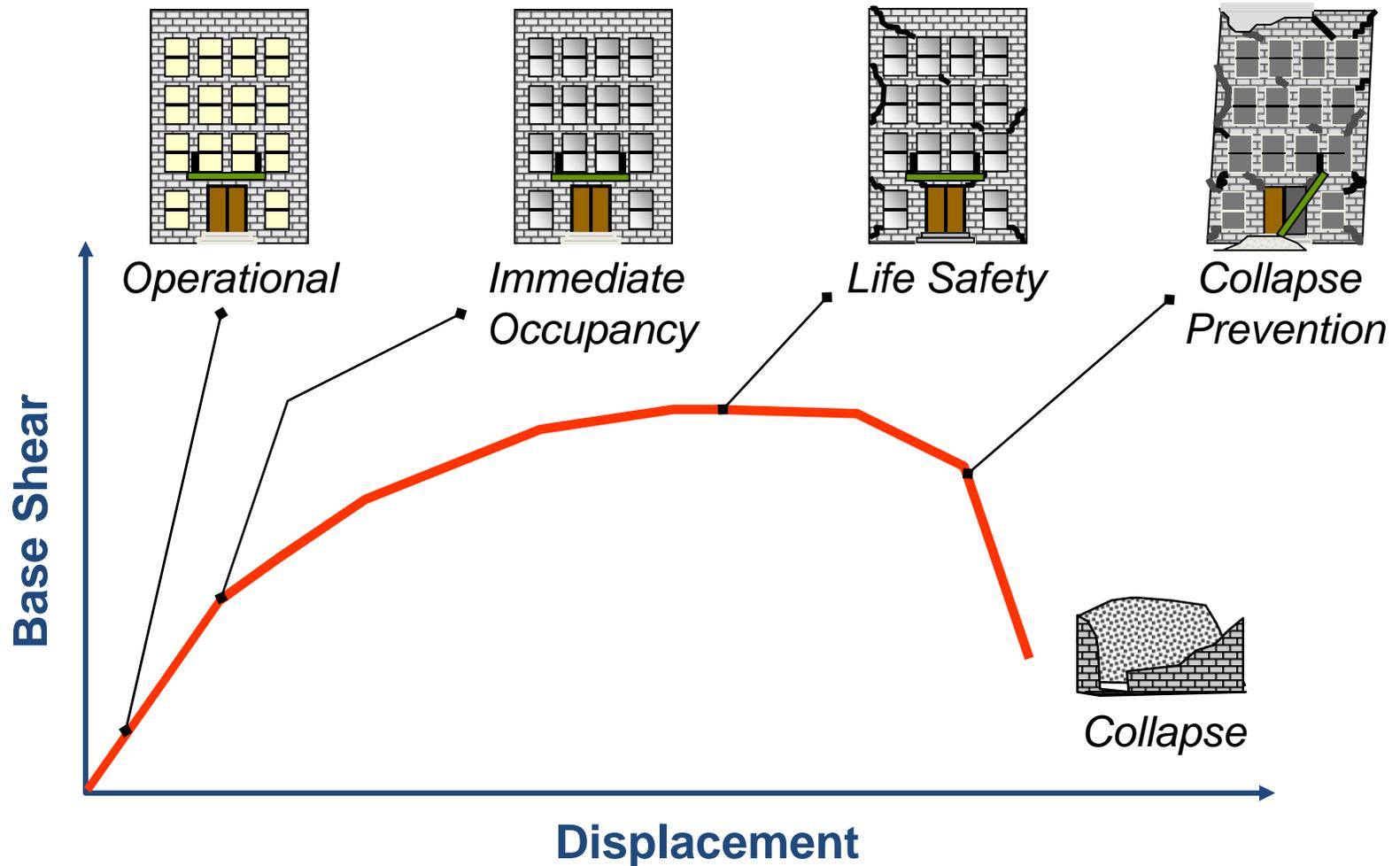
- More than 130 consultants across 16 teams
 - Project Management Committee
 - Project Steering Committee
 - Risk Management Products
 - Structural Performance Products
 - Nonstructural Performance Products



Project Team



Next Generation Performance Continuum



Next Generation Performance Metrics

- Probable consequences and explicit consideration of uncertainty
 - Casualties
 - Repair costs
 - Repair time
 - Unsafe placarding



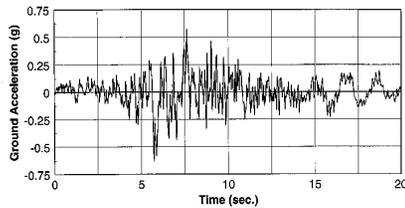
Task Name	Duration	Start	End
1. Project plan for risk assessment	1 day	01/01/00	01/01/00
2. Phase 1 - Strategic Plan	21 days	01/01/00	01/21/00
3. Risk assessment	4 days	01/01/00	01/05/00
4. Risk assessment - initial review	1 day	01/01/00	01/01/00
5. Risk assessment - final review	1 day	01/01/00	01/01/00
6. Risk assessment - final review	1 day	01/01/00	01/01/00
7. Risk assessment - final review	1 day	01/01/00	01/01/00
8. Risk assessment - final review	1 day	01/01/00	01/01/00
9. Risk assessment - final review	1 day	01/01/00	01/01/00
10. Risk assessment - final review	1 day	01/01/00	01/01/00
11. Risk assessment - final review	1 day	01/01/00	01/01/00
12. Risk assessment - final review	1 day	01/01/00	01/01/00
13. Risk assessment - final review	1 day	01/01/00	01/01/00
14. Risk assessment - final review	1 day	01/01/00	01/01/00
15. Risk assessment - final review	1 day	01/01/00	01/01/00
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17. Risk assessment - final review	1 day	01/01/00	01/01/00
18. Risk assessment - final review	1 day	01/01/00	01/01/00
19. Risk assessment - final review	1 day	01/01/00	01/01/00
20. Risk assessment - final review	1 day	01/01/00	01/01/00
21. Risk assessment - final review	1 day	01/01/00	01/01/00
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24. Risk assessment - final review	1 day	01/01/00	01/01/00
25. Risk assessment - final review	1 day	01/01/00	01/01/00
26. Risk assessment - final review	1 day	01/01/00	01/01/00
27. Risk assessment - final review	1 day	01/01/00	01/01/00
28. Risk assessment - final review	1 day	01/01/00	01/01/00
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30. Risk assessment - final review	1 day	01/01/00	01/01/00



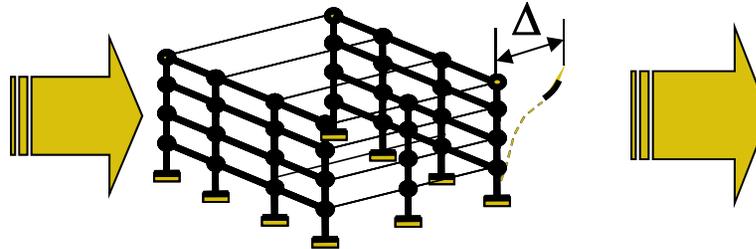
Assessment Types

- Intensity-based
 - Performance given a specific acceleration response spectrum
- Scenario-based
 - Performance given a specific earthquake scenario, e.g. repeat of 1906 San Andreas event
- Time-based
 - Performance over a period of time, considering all possible earthquakes, and their individual probabilities of occurrence

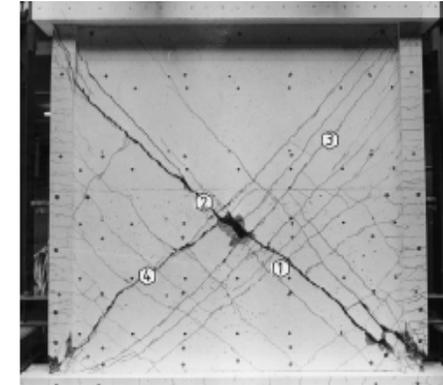
Next Generation Assessment Process



Ground Motion



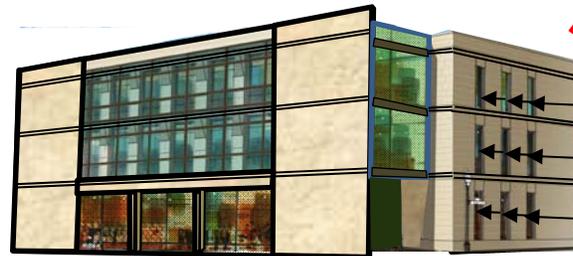
Structural Response



Damage

Fragility Specifications			
17844.000 Reinforced Concrete Slabwalls			
DESCRIPTION	Reinforced concrete wall. Substrate: brick masonry. Support: fixed wall to rim.		
DAMAGE STATES, FAILURE MODES, AND CORRELATION FUNCTIONS			
DAMAGE STATE	NO	NO	NO
	Partial cracks = 0.04"	Partial cracks = 0.04"	Partial cracks = 0.04"
REMARKS	1.0%	1.0%	1.0%
ICM	0.2	0.2	0.4
COMPARISON	75%		
REMARKS	Partial cracks reach other walls cause partial crack slab	Reinforcing bars concrete. Partial cracks reach 100' ground. Partial cracks reach other walls cause partial crack slab	Other: 25' cover existing wall. Reinforcing bars. Partial crack slab
CORRELATION FUNCTIONS			
Max. consequence of failure probability	\$4,000 per sq ft up to 1000 sq ft	\$4,000 per sq ft up to 1000 sq ft	\$4,000 per sq ft up to 1000 sq ft
Max. consequence of repair probability	\$2,000 per sq ft up to 4000 sq ft	\$2,000 per sq ft up to 4000 sq ft	\$2,000 per sq ft up to 4000 sq ft
Repair probability	0.2	0.2	0.2
REPAIR PROBABILITY CORRELATION	none	none	none

Fragility Spec

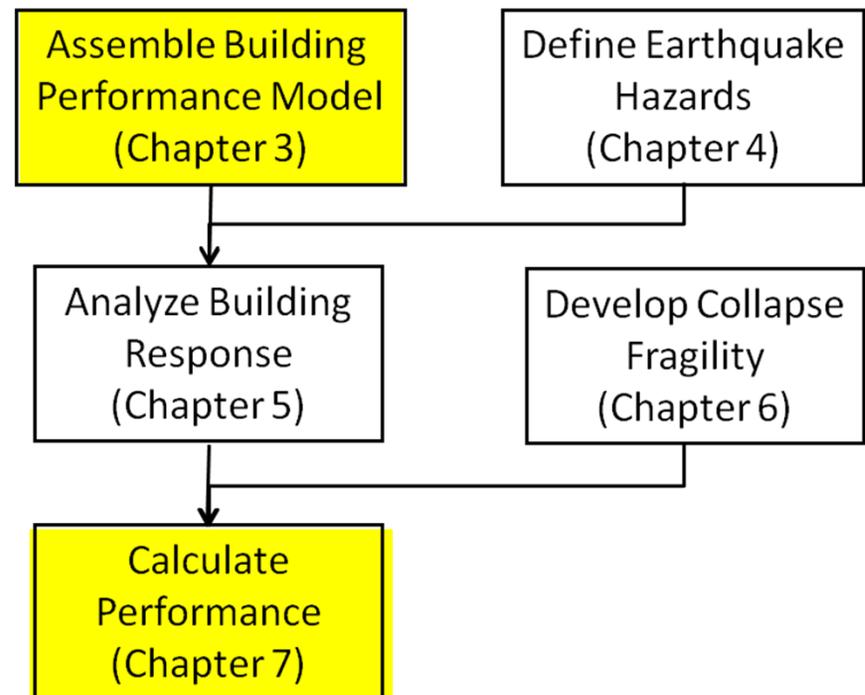


Building Performance Model

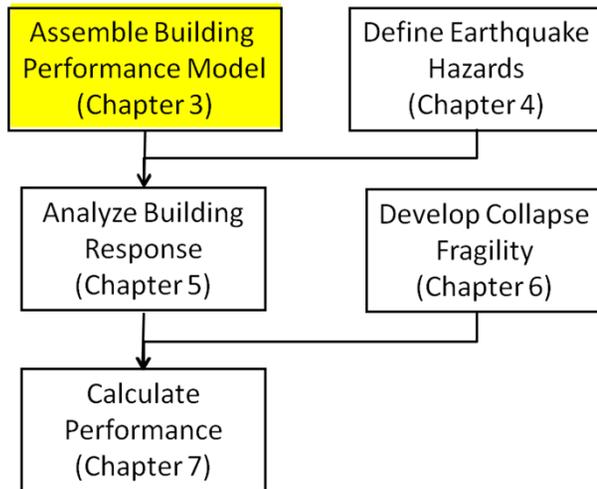


Consequences

THE PROCESS



Assemble Building Performance Model



■ Methodical Building Description

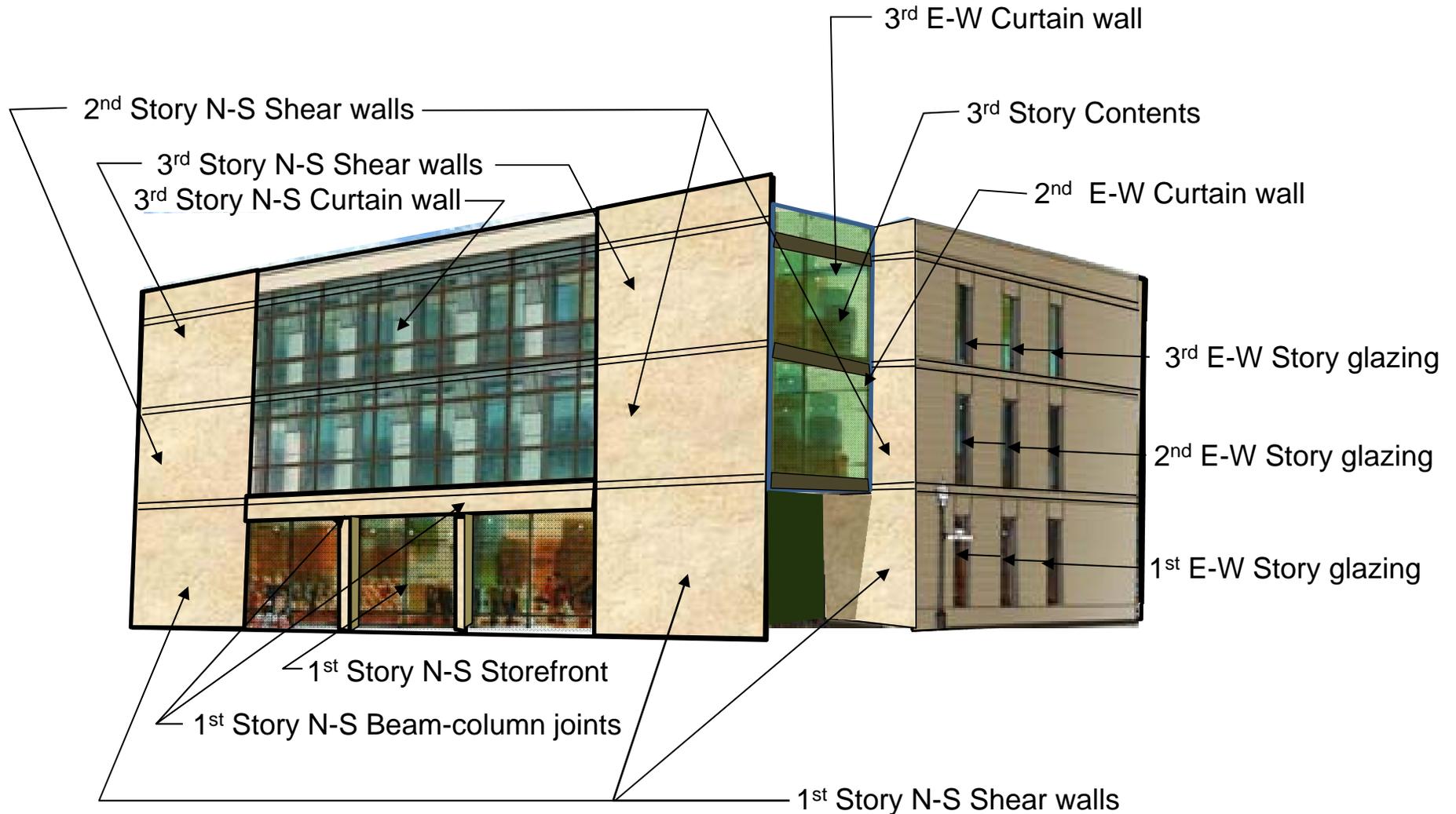
– Structural & Nonstructural Components

- Type
- Location
- Quantity
- Damage states
- Fragility relationships
- Damage consequences

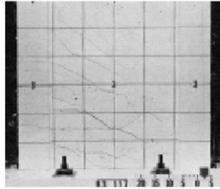
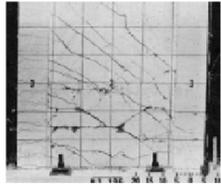
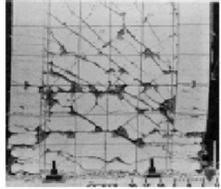
– Occupancy

- People at risk
- Locations
- Time of day

Building Performance Model

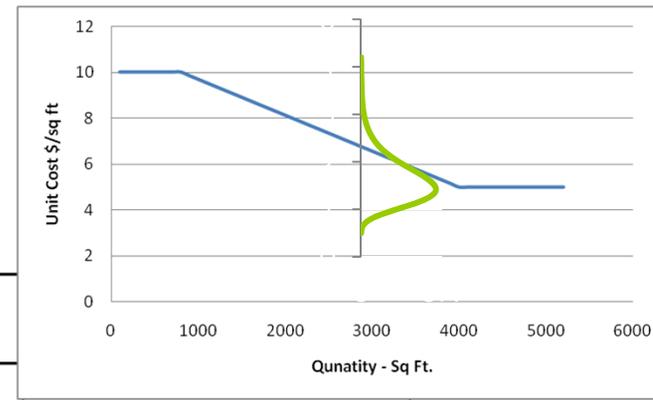


Fragility Specifications

<u>Fragility Specification</u> B1044.000 Reinforced Concrete Shearwalls			
BASIC COMPOSITION	Reinforced concrete and finishes both sides		
Units for basic quantities	Square feet of wall area		
DAMAGES STATES, FRAGILITIES, AND CONSEQUENCE FUNCTIONS			
DESCRIPTION	DS1	DS2	DS3
	Flexural cracks < 3/16" Shear (diagonal) cracks < 1/16"	Flexural cracks > 1/4" Shear (diagonal) cracks > 1/8"	Max. crack widths >3/8" Significant spalling/ loose cover
ILLUSTRATION (example photo or drawing)			
MEDIAN DEMAND	1.5%	3.0%	5.0%
BETA	0.2	0.3	0.4
CORRELATION (%)	70%		
DAMAGE FUNCTIONS	Patch cracks each side with caulk Paint each side	Remove loose concrete Patch spalls with NS grout Patch cracks each side with caulk Paint each side	Shore Demo existing wall Replace Patch and paint
CONSEQUENCE FUNCTION			
Max. consequence up to lower quantity	\$4.00 per sq ft up to 800 sq ft	\$10.00 per sq ft up to 800 sq ft	\$50.00 per sq ft up to 200 sq ft
Min consequence over upper quantity	\$2.00 per sq ft over 4000 sq ft	\$5.00 per sq ft over to 4000 sq ft	\$30.00 per sq ft over 2000 sq ft
Beta (consequence)	0.2	0.3	0.3
TIMEFRAME TO ADDRESS CONSEQUENCES	days	weeks	months

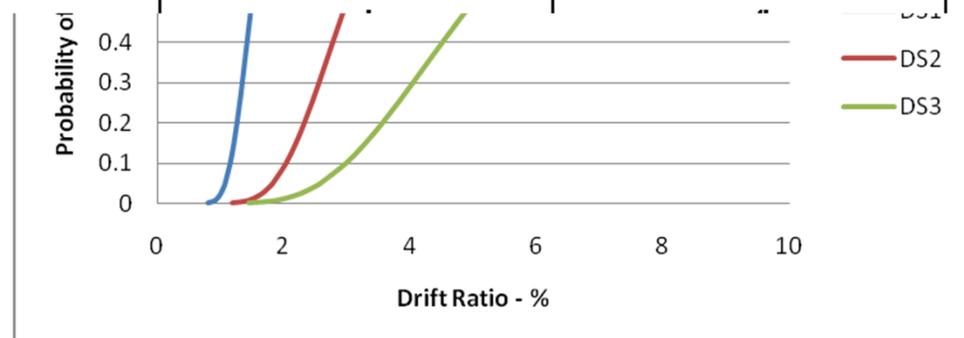
Fragility Specification

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Units for basic quantities	Square feet of wall area		
DAMAGES STATES, FRAGILITIES, AND CONSEQUENCE FUNCTIONS			
DESCRIPTION	DS1 Flexural cracks < 3/16" Shear (diagonal) cracks < 1/16"	DS2 Flexural cracks > 1/4" Shear (diagonal) cracks > 1/8"	DS3 Max. crack widths > 3/8" Significant spalling/ loose cover
ILLUSTRATION (optional photo or drawing)			



MEDIAN DEMAND	1.5%
BETA	0.2

CONSEQUENCE FUNCTION	DS1	DS2	DS3
Max. consequence up to lower quantity	\$4.00 per sq ft up to 800 sq ft	\$10.00 per sq ft up to 800 sq ft	\$50.00 per sq ft up to 200 sq ft
Min. consequence over upper quantity	\$2.00 per sq ft over 4000 sq ft	\$5.00 per sq ft over to 4000 sq ft	\$30.00 per sq ft over 2000 sq ft
Beta (consequence)	0.2	0.3	0.3

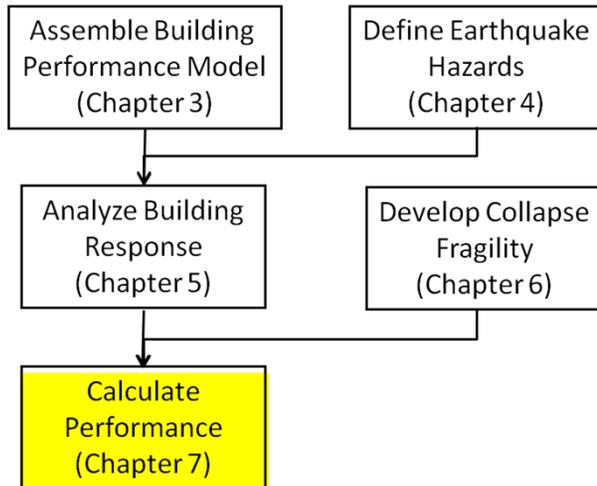


Provided Fragility Specifications

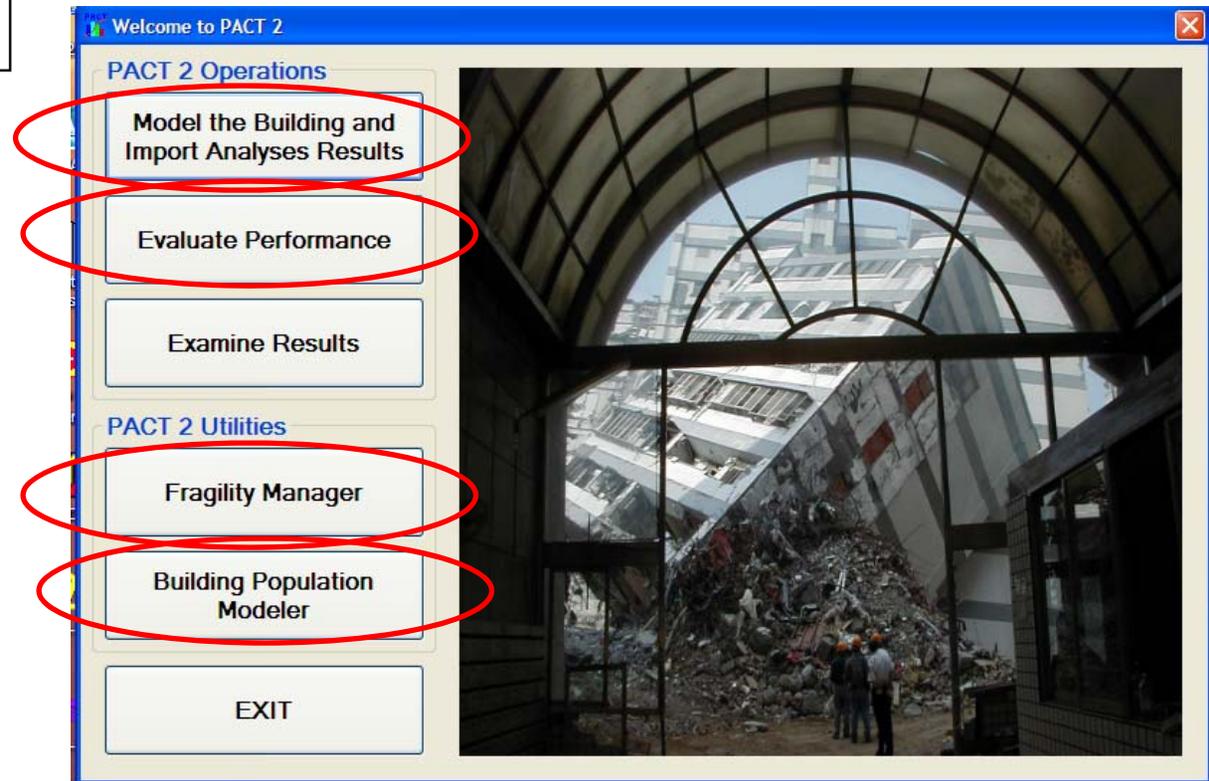
More than 700 building elements

- Steel
 - Moment frame
 - Braced frame
- Concrete
 - Moment frame
 - Slender walls
 - Squat walls
 - Coupling beams
- Masonry walls
 - Shear controlled
 - Flexural Controlled
- Light Framed
 - Wood
 - CFS
- Cladding
- Partitions
- Roofing
- Plumbing
- Mechanical/HVAC
- Elevators
- Electrical Equipment
- Lighting
- Contents

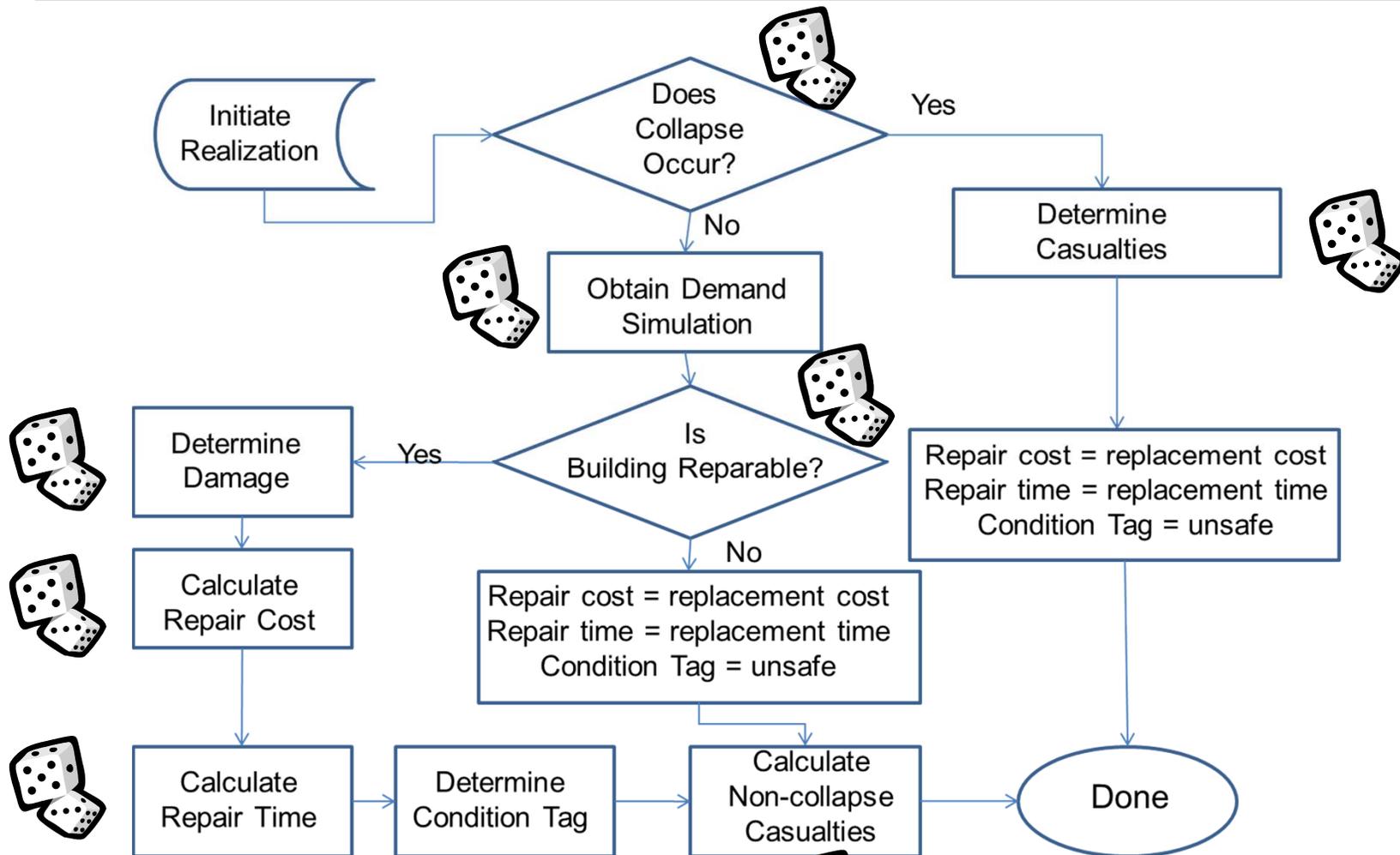
Calculate Performance



- Performance Assessment Calculation Tool (PACT)

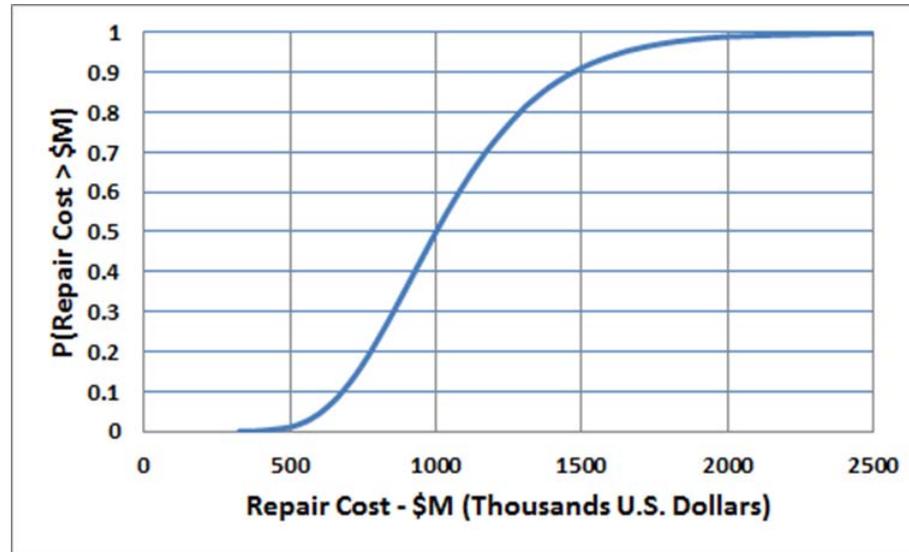


For Each Realization We Compute Building Performance

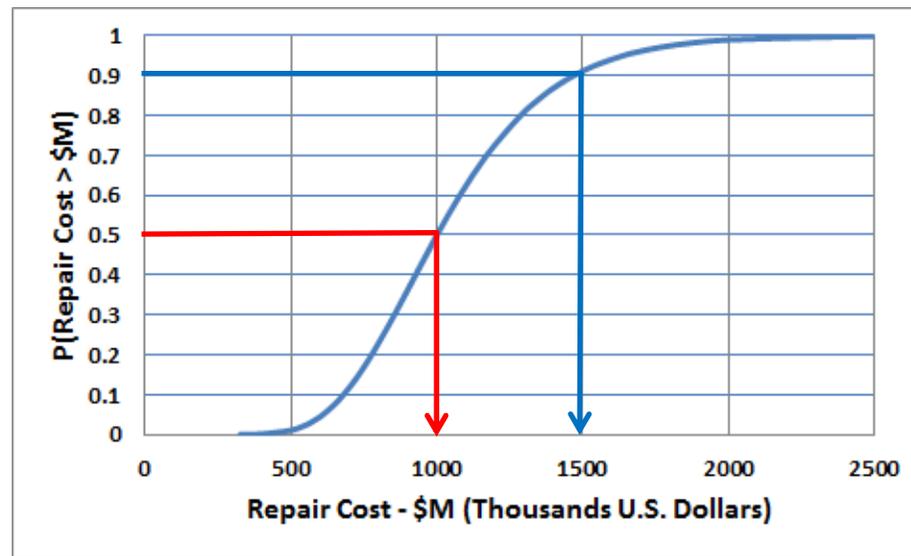


Intensity- and Scenario-Based Assessment Results

- Losses computed for 100s to 1000s of realizations
- For each performance measure, realizations are assembled into performance functions

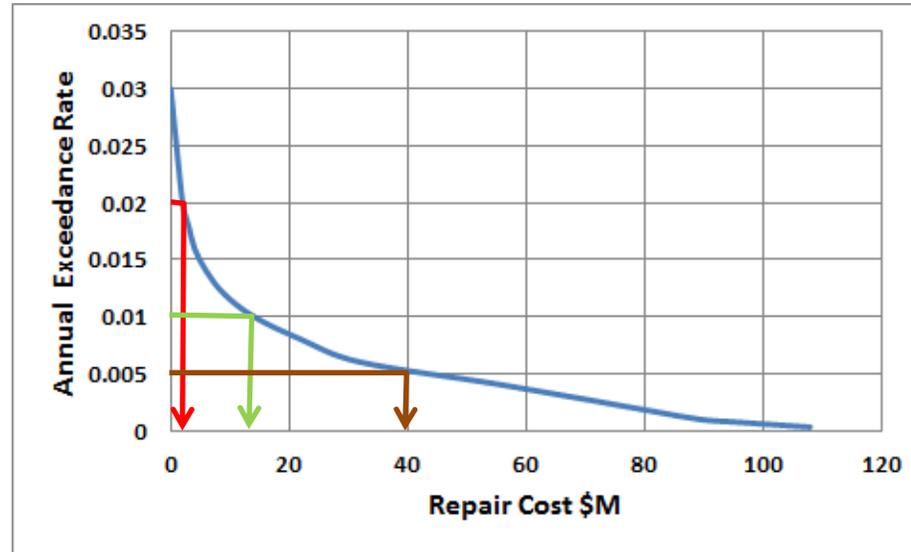


Scenario or Intensity Assessments



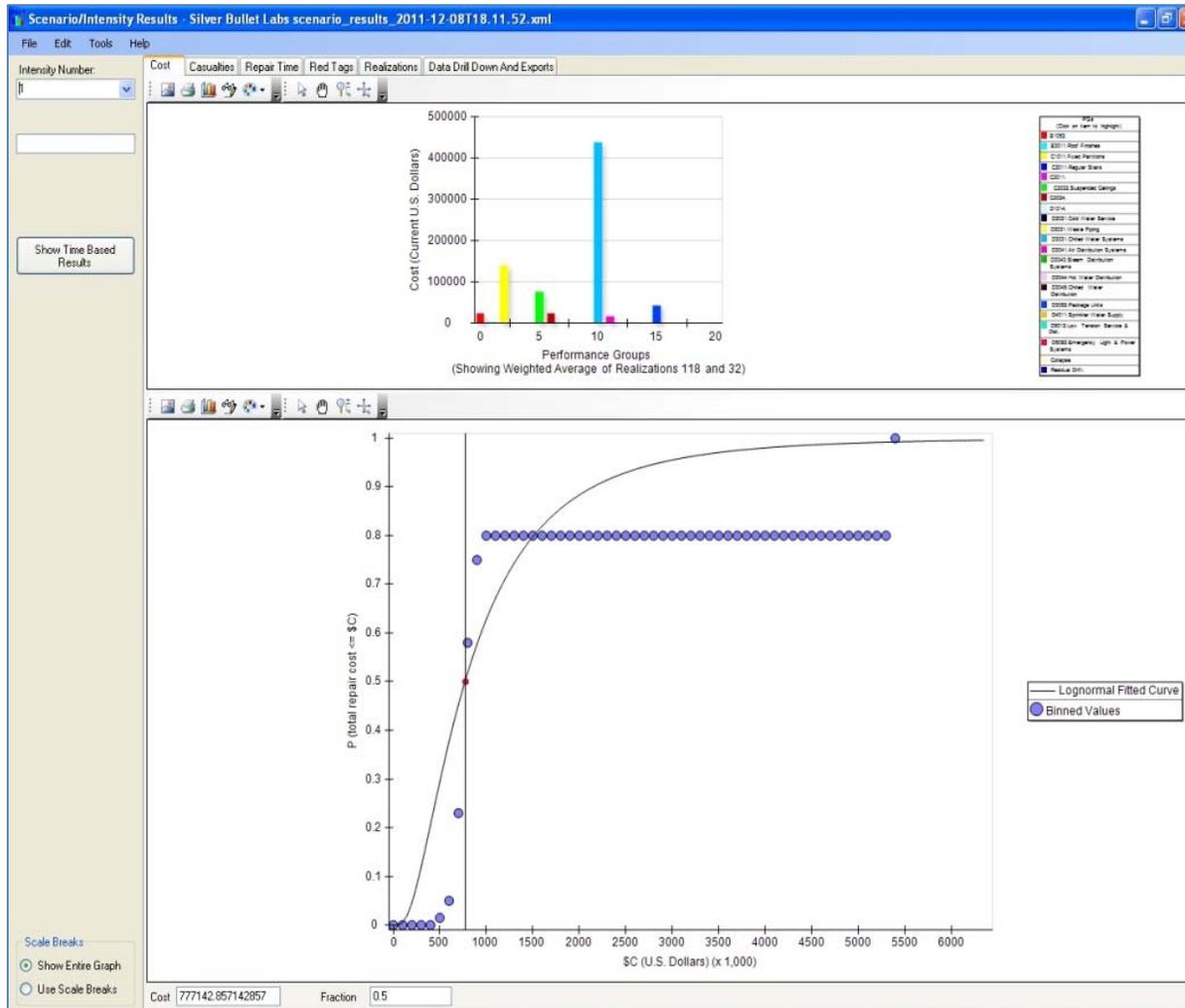
- 50% probability that repair cost will not exceed \$1M
 - Expected repair cost is \$1.0M
- 90% probability repair costs will not exceed \$1.5M
 - Probable Maximum Loss (PML) is \$1.5M

Time-based Assessment



- 50-year loss \$2,000
- 100-year loss \$14,000
- 200-year loss \$40,000
- Average annual loss \$540

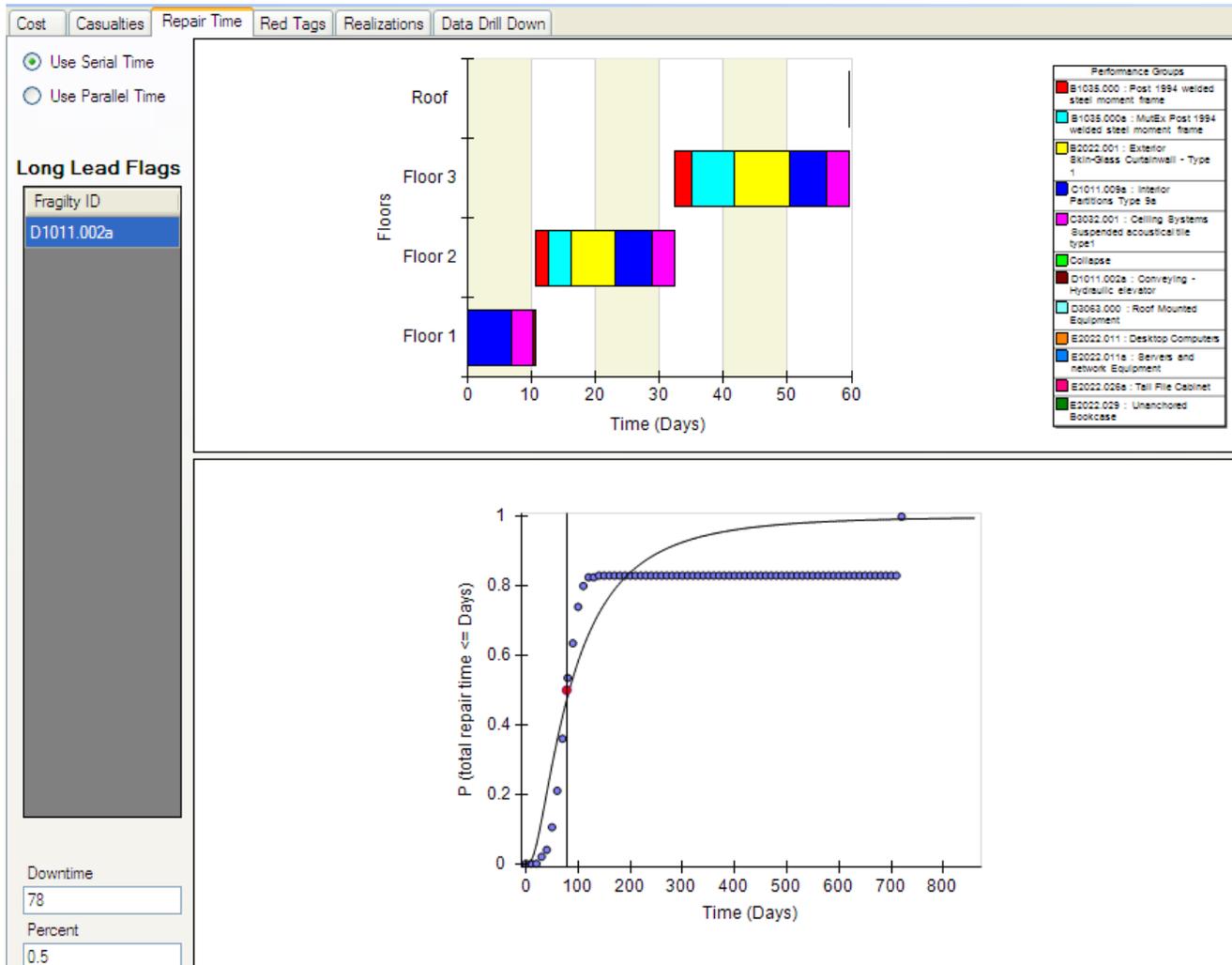
Repair Cost



- Breakdown of contributing elements

- Loss Curve

Downtime



- Breakdown of contributing elements

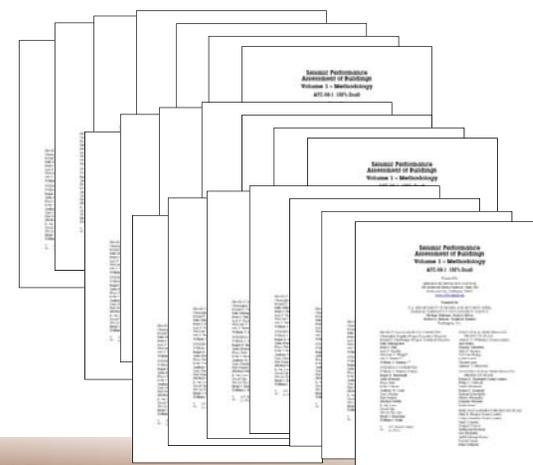
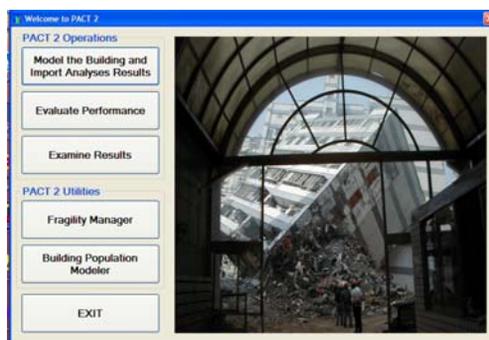
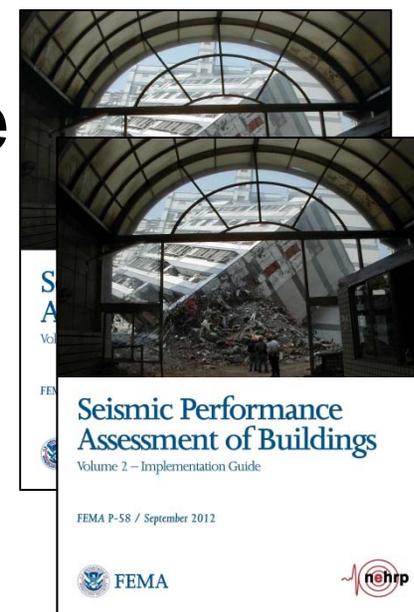
- Loss Curve

Use of Next-Generation Performance Assessment

- Demonstrate that performance is not certain
- Perform cost-benefit studies on alternative design and retrofit criteria
- Determine appropriate insurance premiums
- Form the basis for property rating systems
- Benchmark code performance
- Evaluate the adequacy of building practices without the occurrence of earthquakes

ATC-58 Products

- FEMA P-58 Seismic Performance Assessment of Buildings (2012)
 - Volume 1 – Methodology
 - Volume 2 – Implementation Guide
 - Volume 3 – Electronic Materials
 - Background Documents

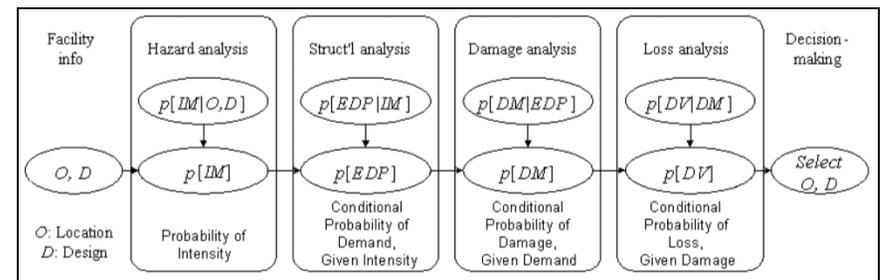


Special Acknowledgments

- Pacific Earthquake Engineering

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Thank you!