Performance-Based Design

Ronald O. Hamburger, SE
Simpson Gumpertz & Heger

January 16-17, 2014 - University of California, Los Angeles

FEMA P-58
Next Generation Performance-Based Design Criteria

R.O. Hamburger, SE
Senior Principal
Simpson Gumpertz & Heger

Project Purpose

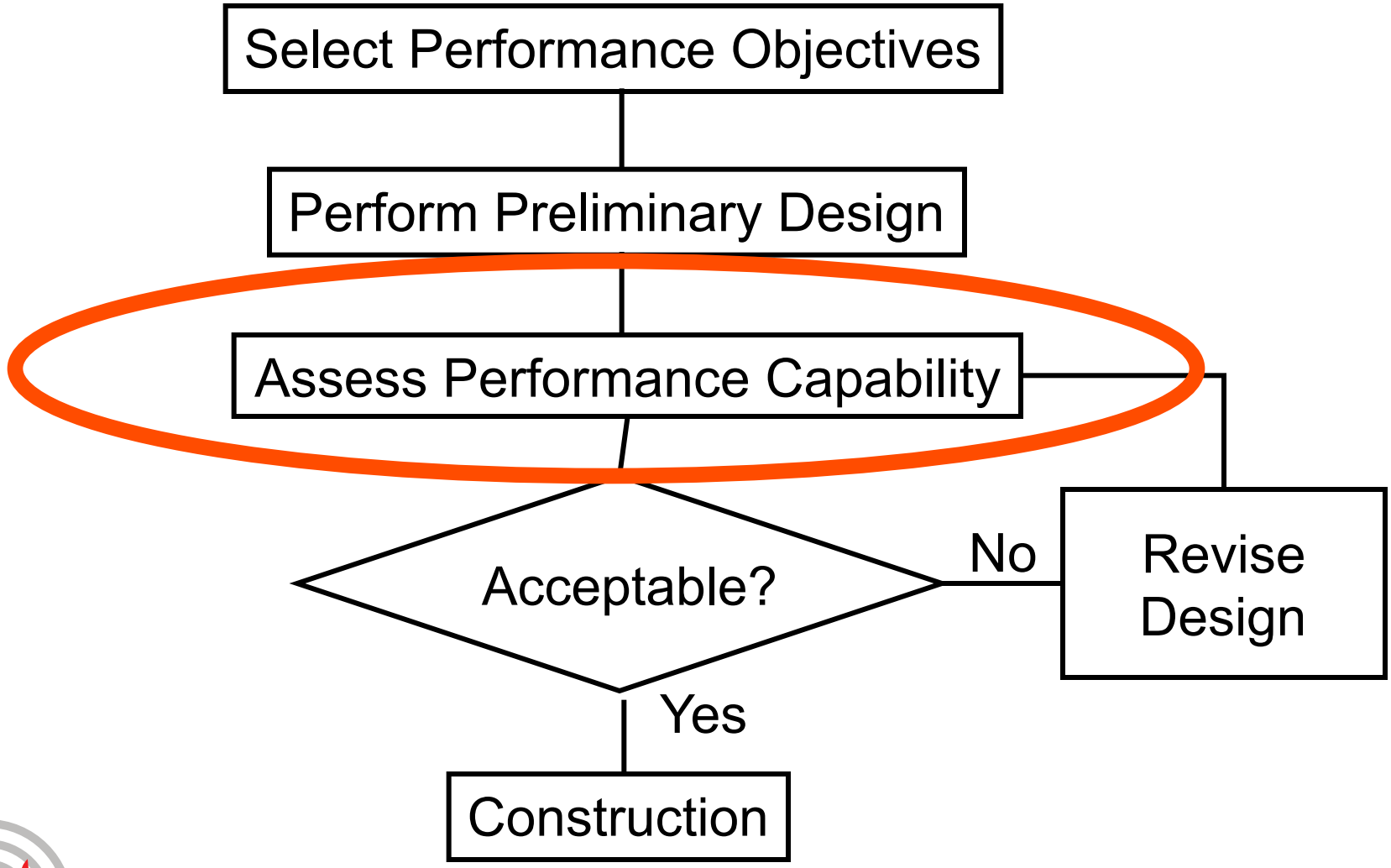
ASCE 41
Seismic Rehabilitation

- Extend the capability provided by FEMA 273/274 (ASCE 41)
  - New buildings
  - Enhanced treatment of nonstructural performance
  - System rather than component acceptance
  - Define reliability
  - Address decision-making needs

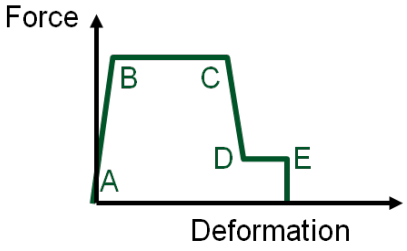
Project Purpose

- Encourage more earthquake-resistant buildings by enabling design for:
  - Better performance
  - Reduced cost or other benefits
- Enable improvement of the prescriptive code criteria without waiting for lessons from future earthquakes

The P-58 Methodology

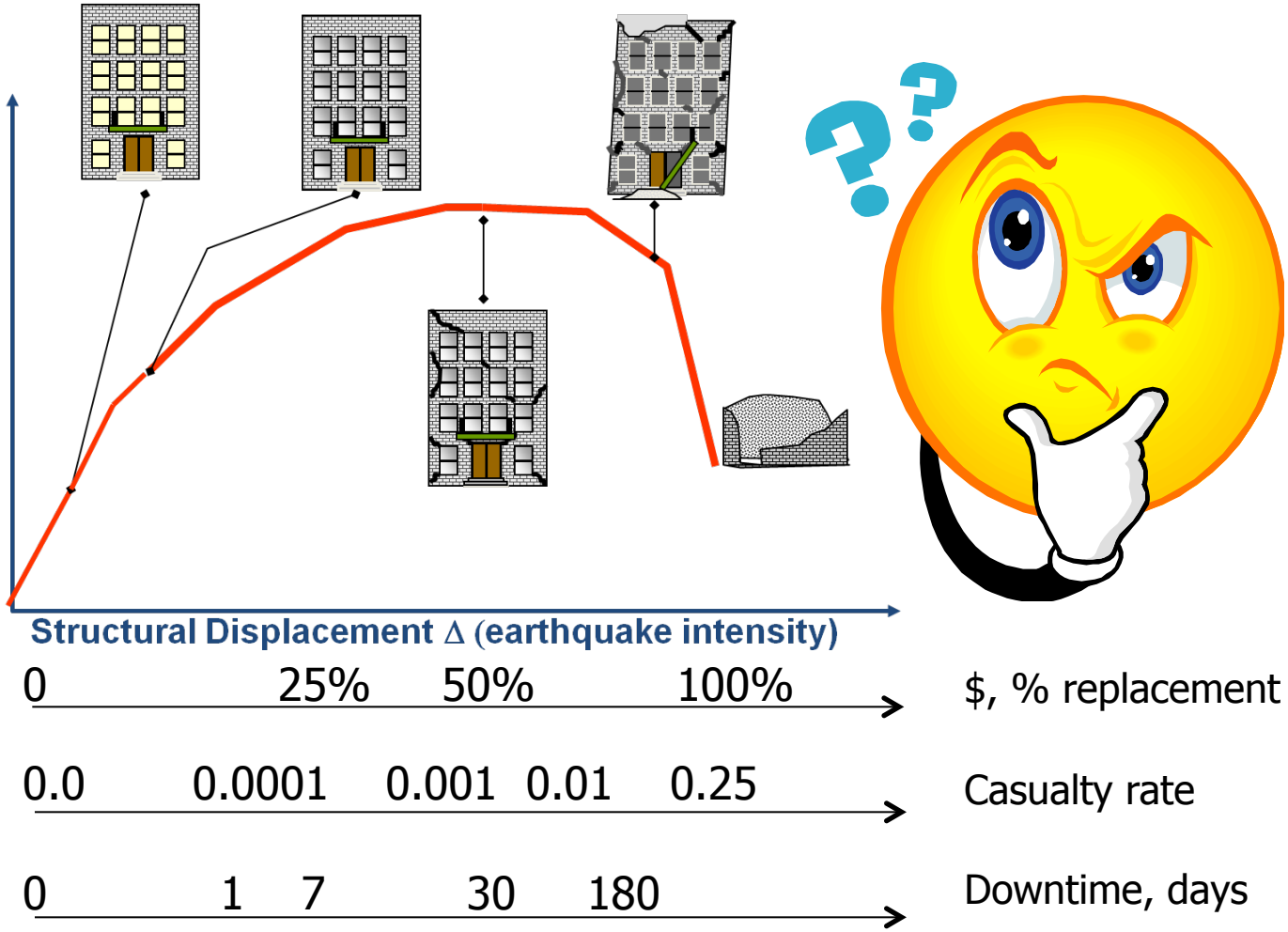


Information the User Needs



Acceptance Criteria

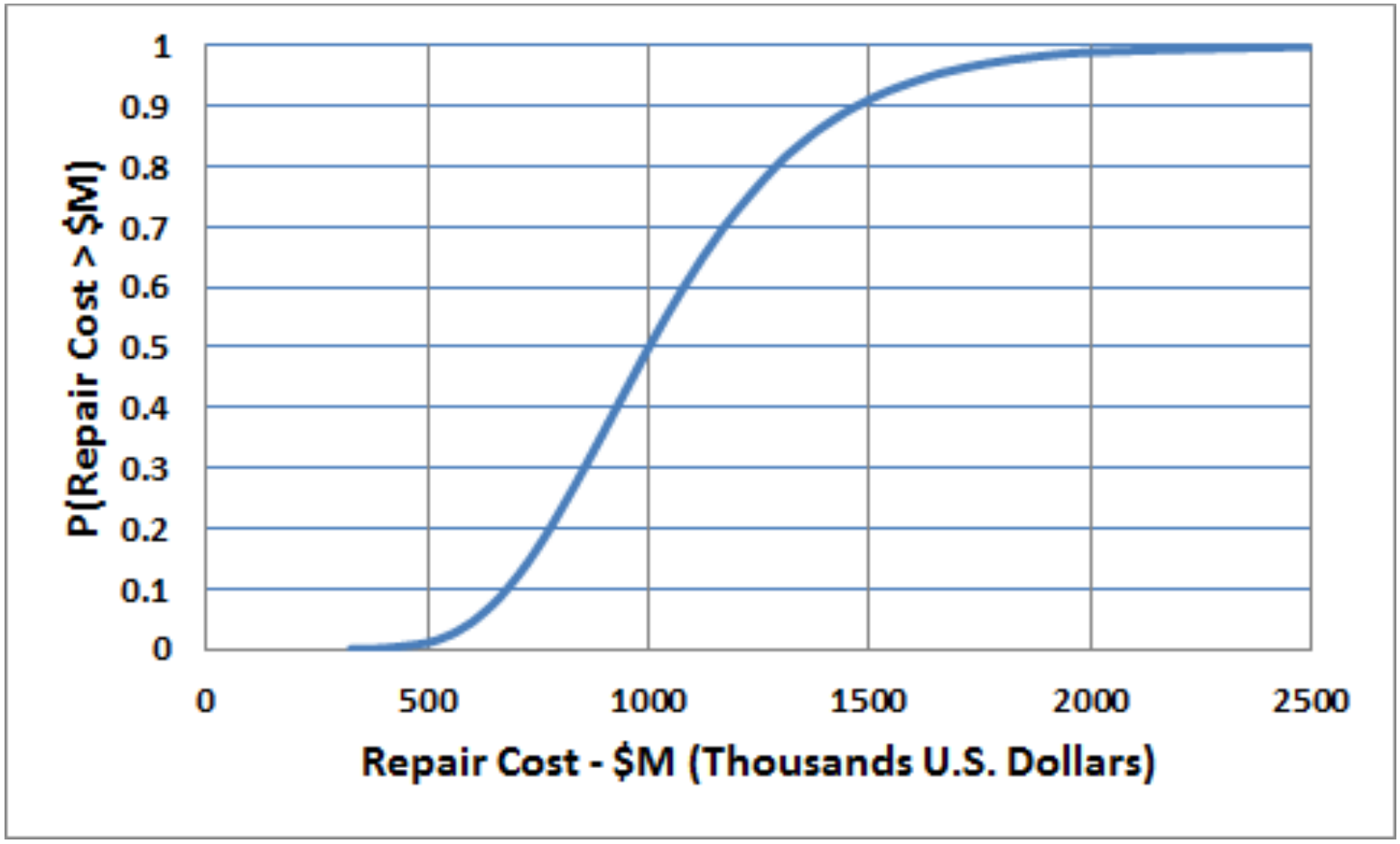
Component Tests



FEMA P-58

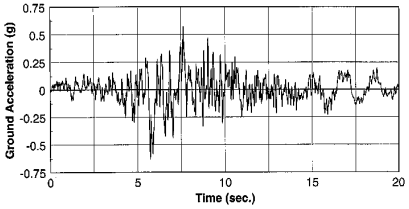
- Probabilistic rather than Deterministic
- The probable consequences of building response to earthquakes, including:
  - Casualties (deaths & serious injuries)
  - Direct economic loss (repair and replacement costs)
  - Indirect economic and social loss (red tags, repair and reoccupancy time)
  - Energy and Carbon consequences of poor performance

Expression of Performance

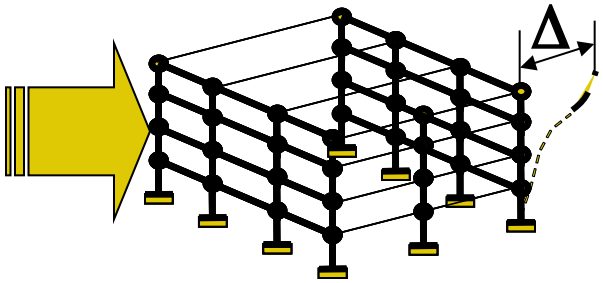


Loss Distribution

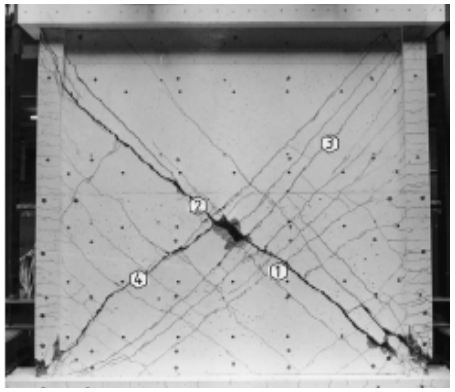
Predicting Performance



Ground Motion



Structural Response



Damage

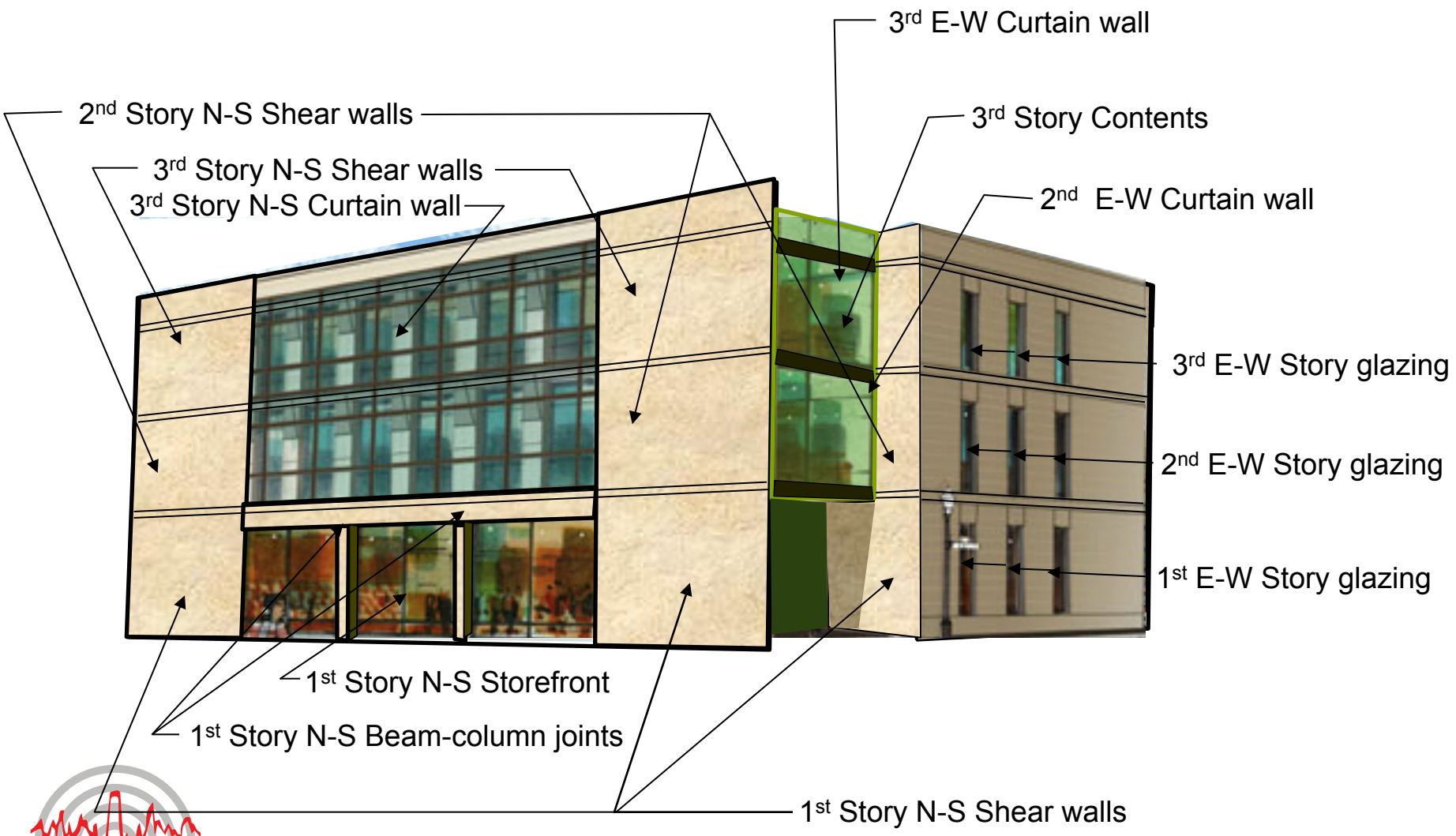
NORTHRIDGE 20 SYMPOSIUM

3 Types of Assessments

- Intensity-based:
  - What are the probable losses if my building experiences an earthquake of given intensity?
- Scenario-based
  - What are the probable losses if my building is subjected to a given magnitude earthquake on a particular fault (or at a particular distance?)
- Time-based
  - What are the probable losses over a period of time considering all earthquakes that may occur?

THE PROCESS

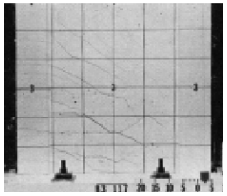
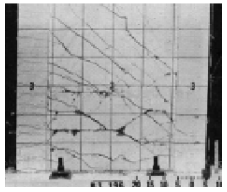
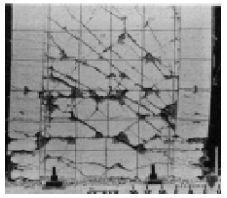
Building Performance Model



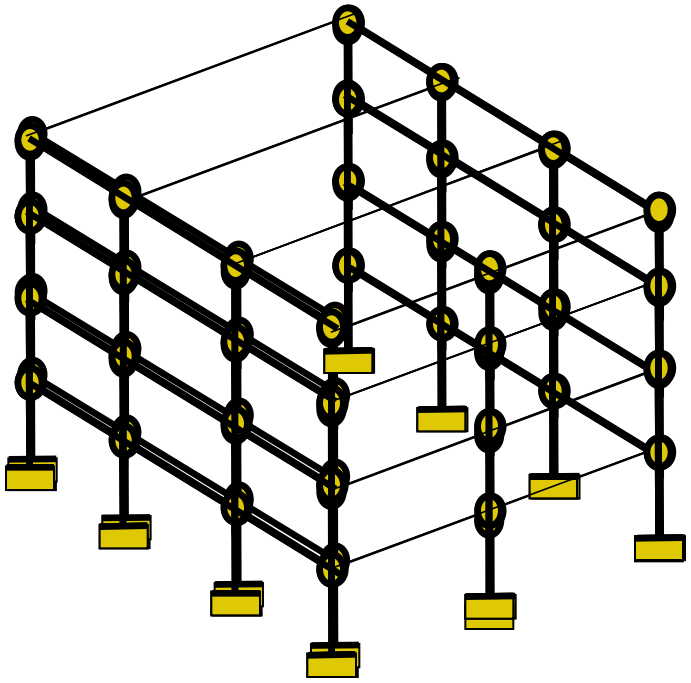
Fragility Specification

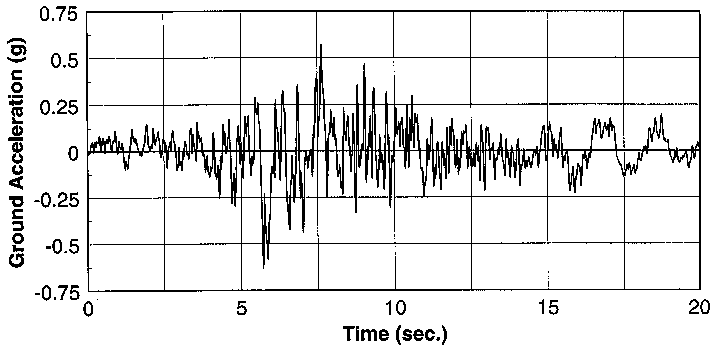
Fragility Specification

B1044.000 Reinforced Concrete Shearwalls

BASIC COMPOSITION	Reinforced concrete and finishes both sides		
Units for basic quantities	Square feet of wall area		
DAMAGES STATES, FRAGILIITES, AND CONSEQUENCE FUNCTIONS			
	DS1	DS2	DS3
DESCRIPTION	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

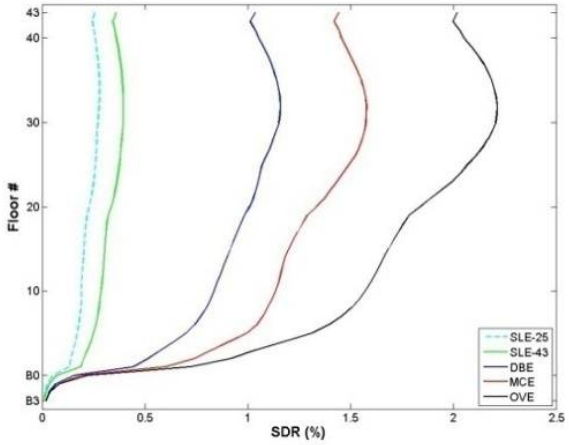
Analysis

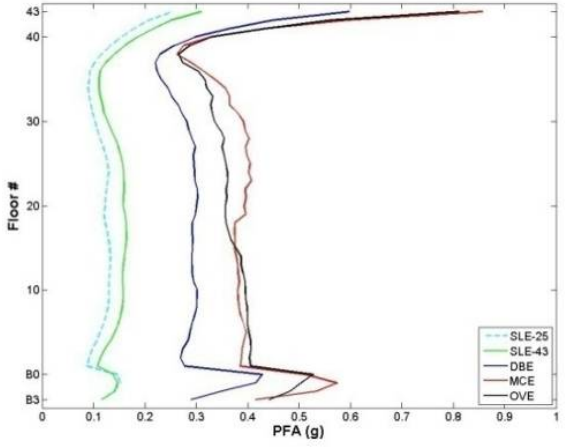




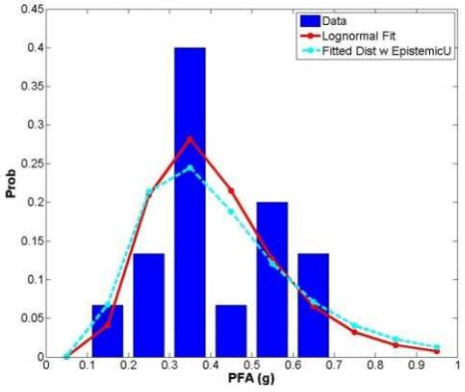
Peak Ground Acceleration	Drift Ratio
0.2g	1.0%
0.5g	2%
1.0g	5%

Analysis Results





- Predict median values and σ for:
  - Story drift
  - Floor acceleration
  - Floor velocity

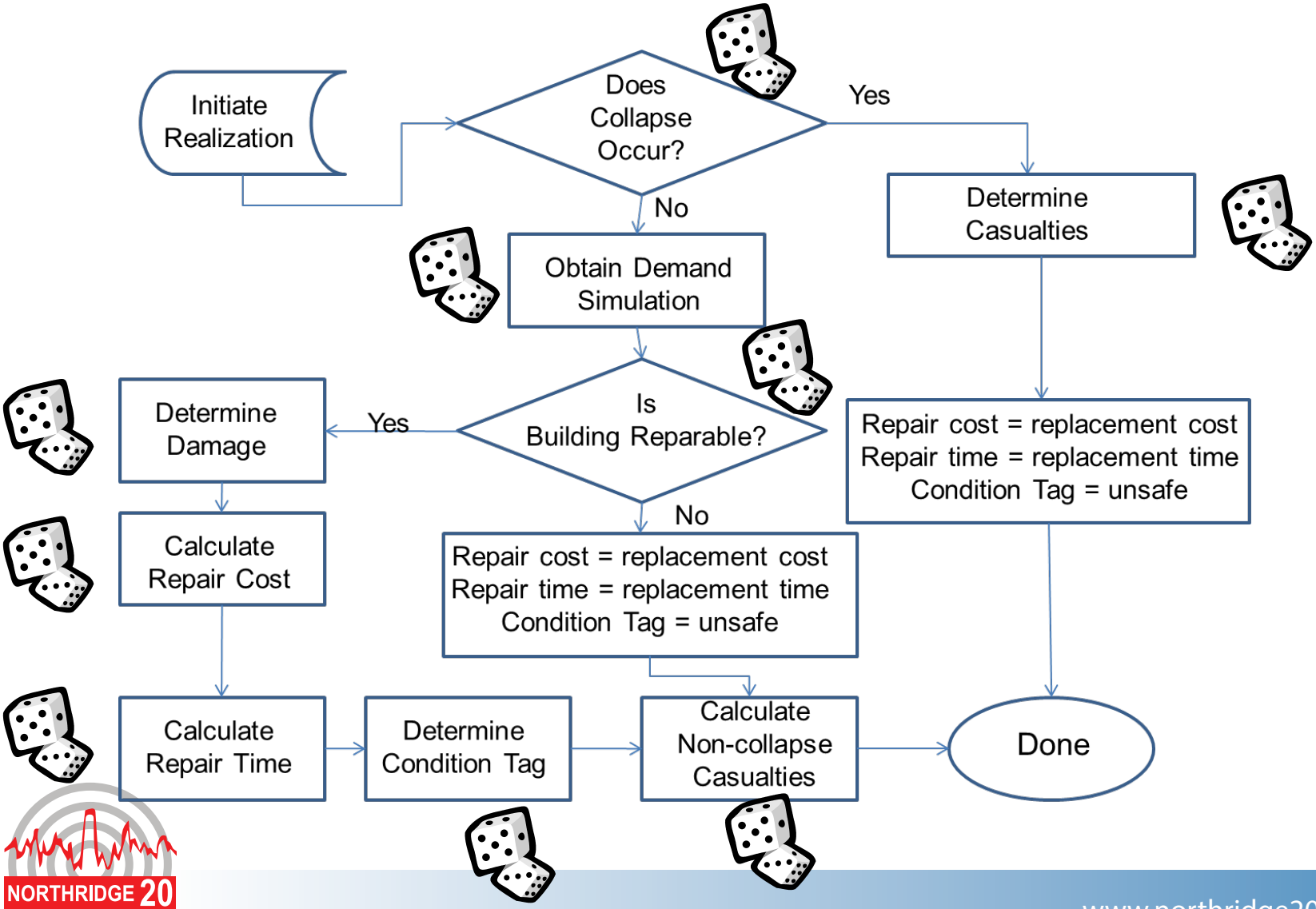


Loss Assessment Procedure

- Generate a series of 1,000s of synthetic analysis results "realizations" consistent with:
  - Statistical median and variability
  - Correlation of demand parameters

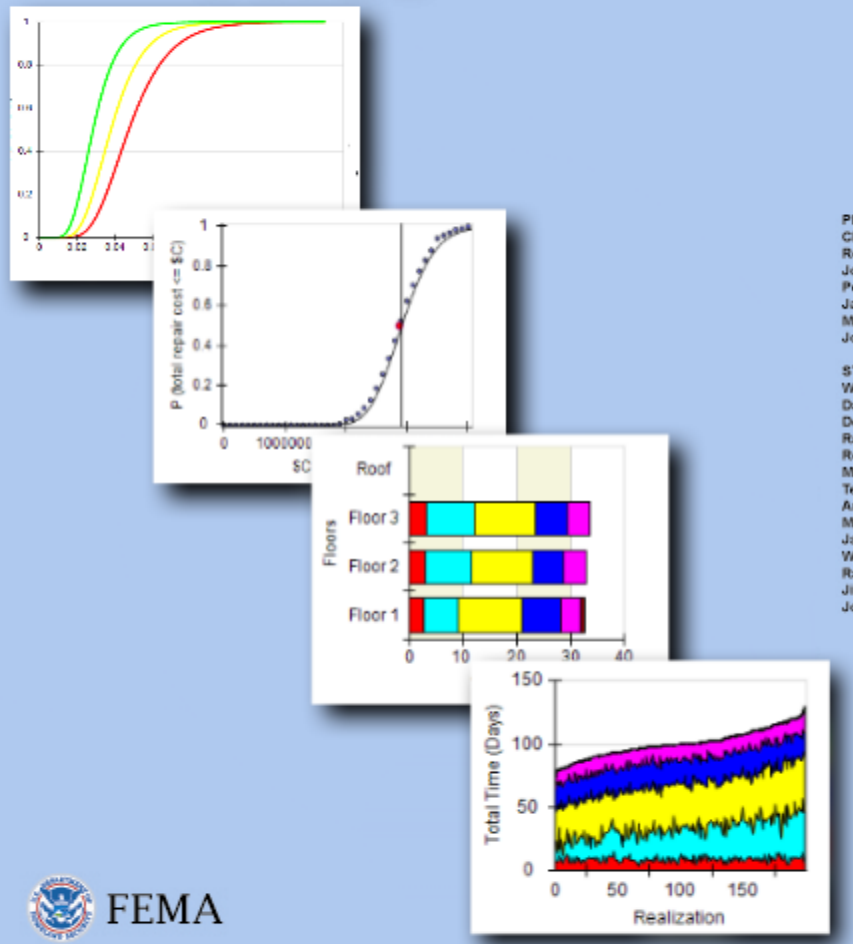
  observed in actual analyses

For Each Realization We Compute Building Performance



PACT Performance Assessment Calculation Tool

Beta Version 2.0



ATC-58 Guidelines for Seismic Performance Assessment of Buildings

Prepared for:
DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY
Mike Mahoney, FEMA Project Officer
Bob Hanson, FEMA Technical Monitor

PROJECT MANAGEMENT COMMITTEE
Christopher Rojahn (Project Executive Director)
Ronald O. Hamburger (Project Technical Director)
John Gillengerten
Peter J. May
Jack P. Moehle
Maryann T. Phipps
Jon A. Heintz

STEERING COMMITTEE
William T. Holmes (Chair)
Daniel P. Abrams
Deborah B. Beck
Randall Berdine
Roger D. Borcherdt
Michel Bruneau
Terry Dooley
Amr Elnashai
Mohammed Ettouney
Jack Hayes
William J. Petak
Randy Schreitmueller
Jim W. Sealy
Jon Traw

STRUCTURAL PERFORMANCE PRODUCTS TEAM
Andrew Whittaker (Team Leader)
Gregory Deierlein
John Hooper
Andrew T. Merovich

NONSTRUCTURAL PERFORMANCE PRODUCTS TEAM
Robert E. Bachman (Team Leader)
David Bonowitz
Philip J. Caldwell
Andre Filiatrault
Robert P. Kennedy
Helmut Krawinkler
Manos Maragakis
Gary McGavin
Eduardo Miranda
Keith Porter

RISK MANAGEMENT PRODUCTS TEAM
Craig D. Comartin (Team Leader)
Brian J. Meacham (Associate Team Leader)
C. Allin Cornell
Gee Hecksher
Charles Kircher
Farzad Naeim

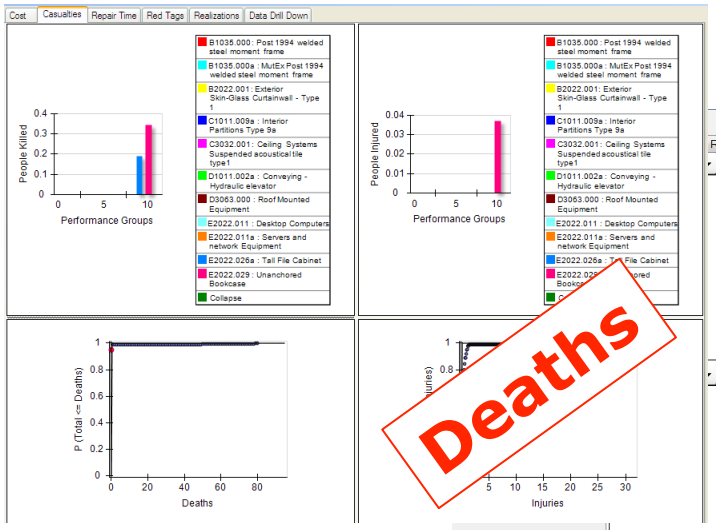
PACT was developed by:
Farzad Naeim
Arzhang Alimoradi
Scott Hagie
Craig Comartin

Based on a prototype by:
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER
Jack P. Moehle
T.Y. Yang

FEMA

ATC
Applied Technology Council

Performance



Deaths

Dollars

Downtime

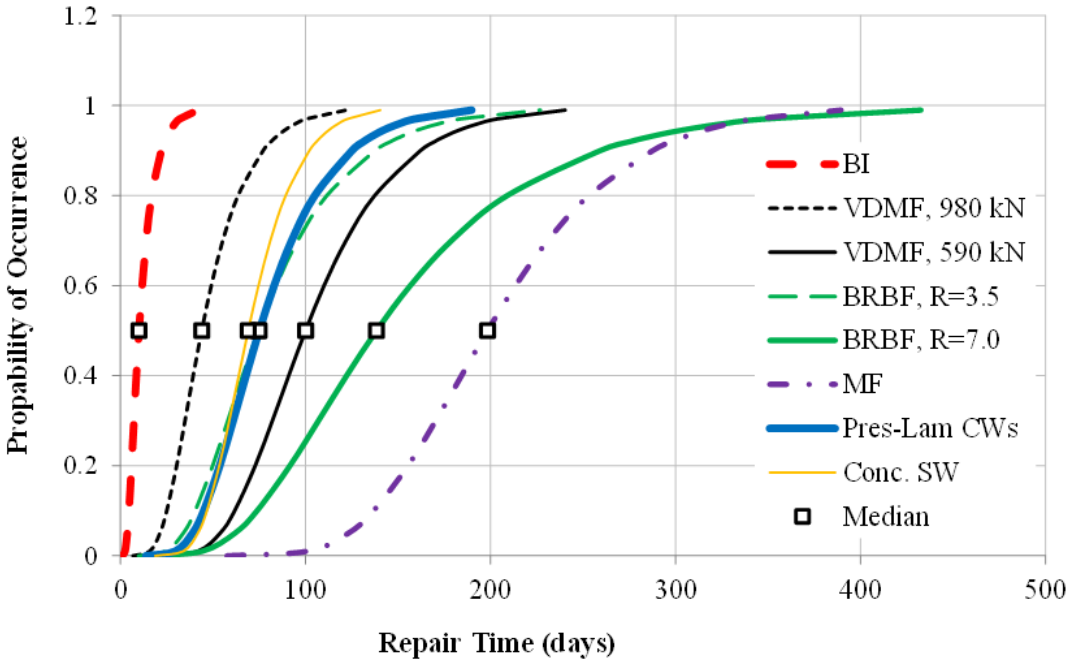
Some lessons learned

- ATC 63-2/3 project
  - Performance assessments of low and mid rise building of comparable occupancy but different occupancy category
    - Hospital (Occ IV) – MOB (Occ II)
    - EOC (Occ IV) – Commercial Office (Occ II)
    - Steel Moment Frame
    - Concrete Shear Wall
- Nonstructural damage predominates losses

Some lessons learned

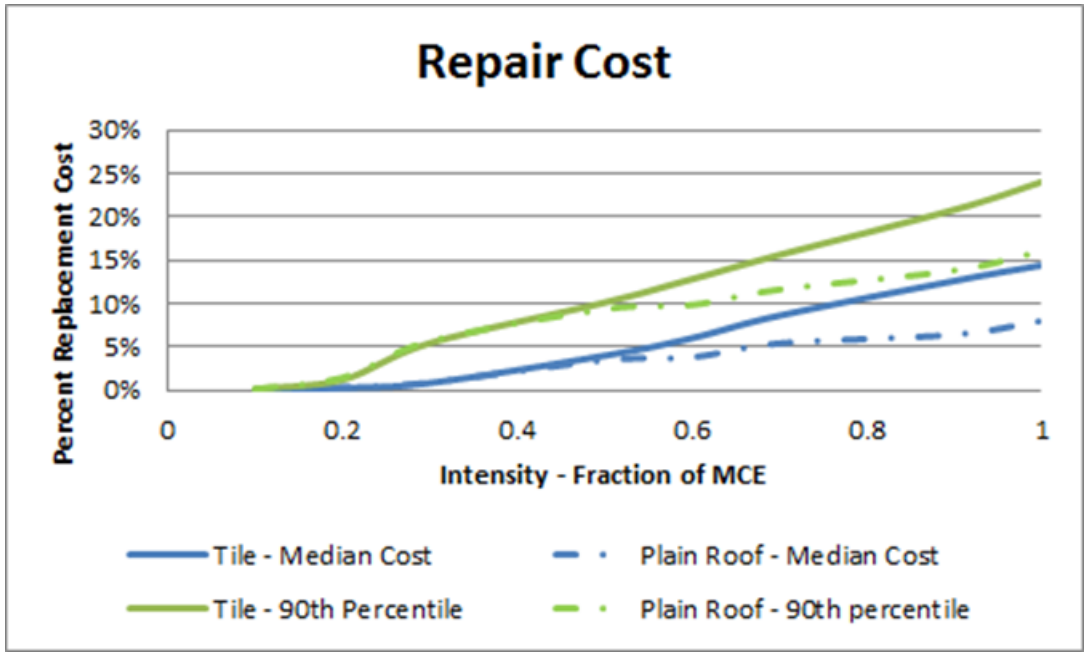
- Current code procedures do not provide adequate protection for Occupancy IV facilities
  - Cladding, stairs and other displacement-sensitive components are equally likely to fail
    - Buildings have lower drift, but components are designed with lower drift tolerance
  - Anchorage of components is equally likely to fail
    - I_p=1.5 used for nonstructural bracing
    - I=1.5 and tighter drift means structure can transmit more force

Some lessons learned



- Different structural systems, all designed to the same criteria, have far different likely losses

Some lessons learned



- Predicted losses are larger than experienced in past earthquakes, but match commentary expectations

Planned Future Activities

- Add “green” module to PACT
- “Tune” the procedure to past earthquake data
- Update and enhance fragilities
- Determine expected performance for buildings of different types and occupancies
- Develop simplified design rules for different performance
- Arrange for integration with BIM/Analysis tools

Questions?