ANSI Homeland Security Standards Panel Workshop on:

Standards for Disaster Resilience for Buildings and Physical Infrastructure Systems

Introduction to Resilience in the Built Environment

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Workshop Goals

- Identify gaps in current practice, standards, and codes that need to be addressed to enable resilient buildings and infrastructure.

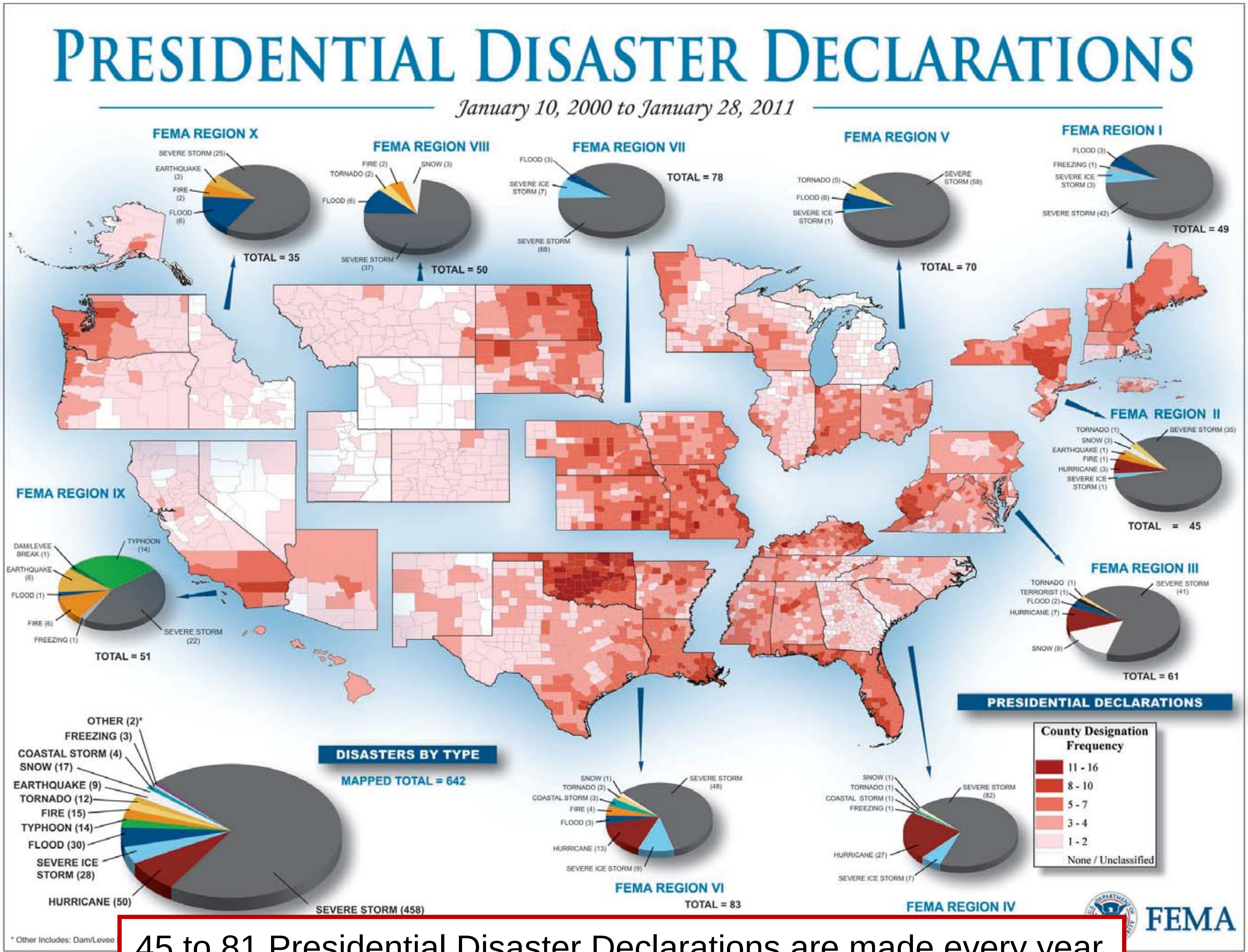
- Develop a framework for the development of standards and codes for resilient buildings and infrastructure systems .

What is the Problem?

- The Built Environment Fails in Disaster Events Repeatedly
  - The Stafford Act authorizes the President to issue a **major disaster declaration** for federal aid to states overwhelmed by natural hazards or other catastrophes.
  - The Stafford Act authorizes temporary housing, grants for immediate needs of families and individuals, the **repair of public infrastructure**, and emergency communication systems
  - Congress appropriated over $10 billion to the Disaster Relief Fund in FY2005, for the four hurricanes that struck Florida in 2004.
- Performance of the built environment is dependent on the codes and standards in place at the time of construction, enforcement, maintenance, and operation
- The built environment is highly interconnected; current codes and standards are generally independent and do not account for this interconnectedness

Defining the Built Environment

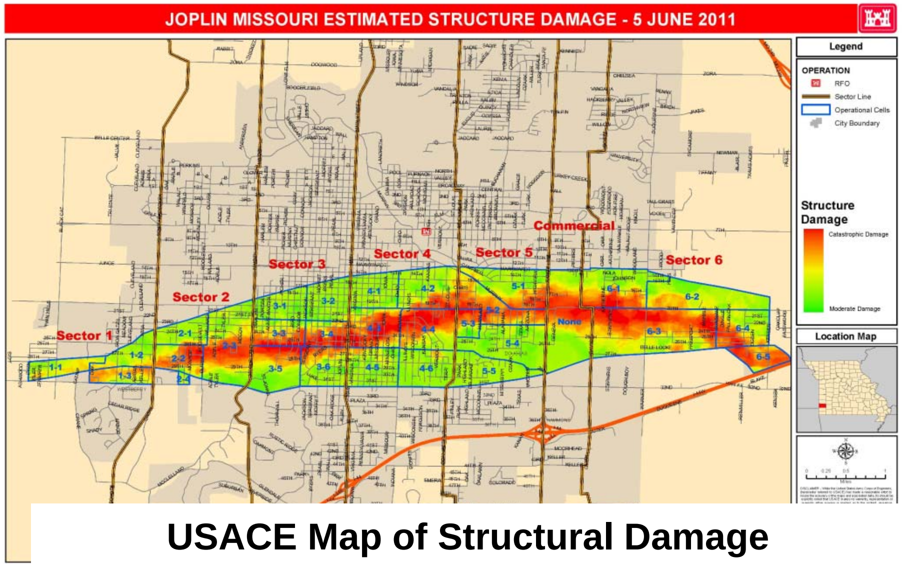
- Buildings (engineered and non-engineered)
  - All systems necessary for intended function
  - Architectural, structural, life safety, mechanical, electrical, plumbing, security, communication and IT systems
- Infrastructure or lifelines
  - Transportation - roads, bridges, tunnels, ports, rail
  - Utility plants and distribution systems - electric power, water and wastewater, fuels, communication



45 to 81 Presidential Disaster Declarations are made every year

Joplin, MO EF5 Tornado
22 May 2011

- Damage zone was about 0.75 to 1 miles (1.2 to 1.6 km) wide
- About 8000 houses, 18000 cars, and 450 businesses were destroyed
- St. John's Regional Medical Center had exterior damage and water intrusion
  - Facility will be demolished and relocated
  - Surrounding structures nearly all destroyed
- Communications and power were lost to many areas
- Cost to rebuild Joplin could reach $3 billion



USACE Map of Structural Damage

St John’s Regional Medial Center

Severe Storm in East Central Iowa
11 July 2011

Wind Event

- NWS storm survey teams assessed damage and estimated wind speeds up to 110 to 130 mph

Damage

- Wide spread power outages and downed power lines
- Many roofs were partially or fully removed
- Walls of some buildings collapsed

2011 Drought and Water System Failures Summer 2011

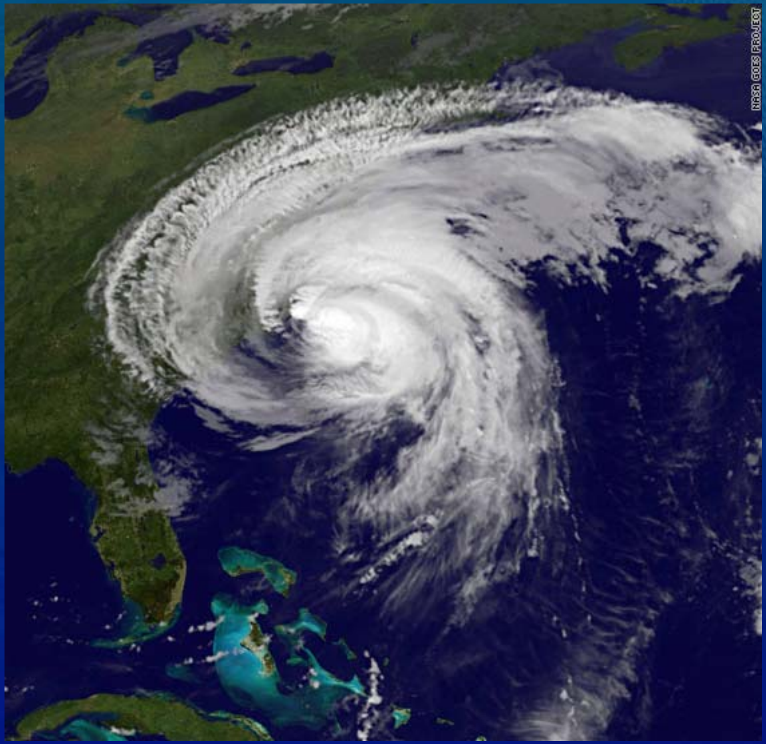
Deteriorating Infrastructure

- Older pipes are more susceptible to bursting due to combined effects of
  - Dried soils shrink away from buried pipes
  - Increased usage raises internal water pressure
- Burst rate of water pipes has risen in CA, KS, OK, TX, IN, KY, and NY
  - Aug 14, 2011 - Oklahoma City had 685 water main breaks at ~4 times normal rate.
  - Aug 23, 2011 – Houston had 847 water leaks, more than 3 times the normal.
- American Water Works Association (AWWA) projects that
  - Many water systems are 80 to 100 years old
  - Water utilities nationwide need to be replaced

Category 1 Hurricane Irene
27-28 August 2011

Storm progress

- First landfall at Outer Banks, NC
- Second landfall at Little Egg, NJ
- Third landfall as a tropical storm at Brooklyn, NY

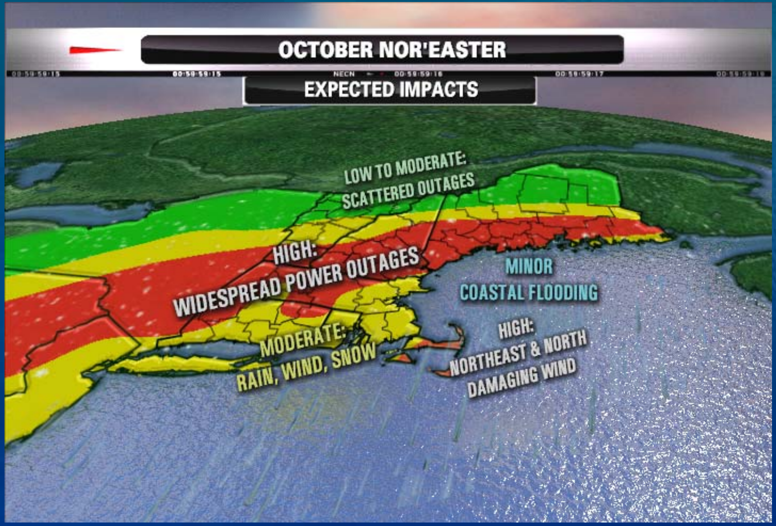


Wind and flood damage

- Over 40 million people were affected
- Over 6 million homes and businesses lost power
- New Jersey flooded roads were impassable and train lines were shut down
- Vermont had over 260 roads and bridges damaged
- Insured losses are ~$2 to 6 billion and total losses are ~$7 to 10 billion

2011 Northeast Snow Storm
29-30 October 2011

- First October snow fall over 1 inch since record keeping began in 1860
  - Maryland to Maine
  - Up to 32 in. of heavy wet snow
- Over 3,000,000 homes and businesses lost power (NJ, CN, MA)
  - Fallen trees blocked roads and damaged distribution lines
  - 1,000,000 without power 4 days later.
  - 50,000 without power in Connecticut 10 days later.
- Causes for slow rate of restoration are being examined
  - Conn. Governor launched probe of utility response
  - US Senators Lieberman and Blumenthal called for reviews of preparedness and response



Fire Following Earthquake

2008 Report for USGS and CA Geological Survey

- Ignitions would be 50% electrical , 25% gas, and 25% other causes (1994 Northridge earthquake)
- Refineries can have large fires that burn for days (2003 M8 Tokachi-oki, Japan EQ)
- Lifelines—water supply, electric power, communications, transportation—are needed to fight fire following earthquake
- Economic and business continuity impacts will be high if there are FFE

2003 Tokachi-oki Earthquake

What is Resilience?

Department of Homeland Security (DHS) Risk Lexicon, 2010

Definition: ability to adapt to changing conditions and prepare for, withstand, and rapidly recover from disruption

Sample Usage: The county was able to recover quickly from the disaster because of the resilience of governmental support systems.

Extended Definition: ability of systems, infrastructures, government, business, communities, and individuals to resist, tolerate, absorb, recover from, prepare for, or adapt to an adverse occurrence that causes harm, destruction, or loss

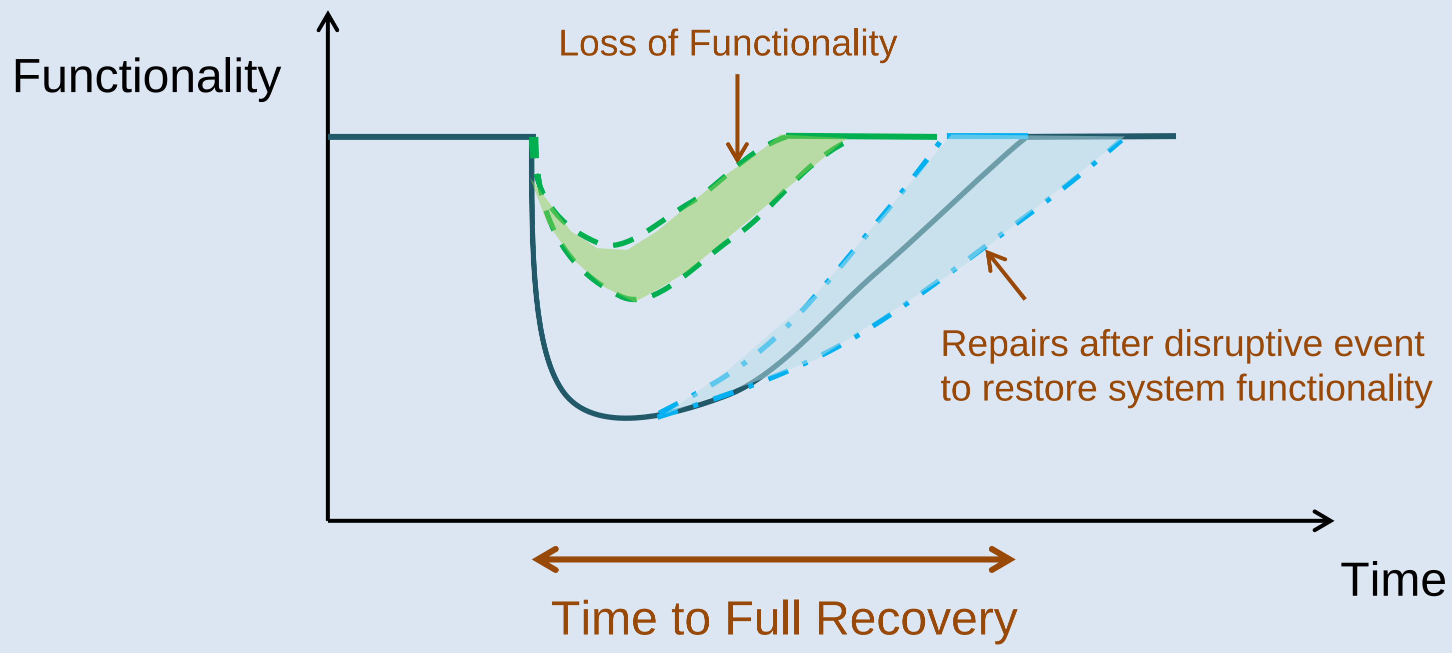
Resilience in the Built Environment

- Maintain or restore the functionality of community buildings and infrastructure systems after a hazard event within a prescribed timeframe.
- Includes ability to prepare, mitigate, resist, and recover.

Physical Infrastructure	Social, Environmental, Economic
Critical Facilities	Emergency Management
Government	Shelter
Businesses	Food
Homes	Supplies
Power	Governance
Transportation	Social services
Water	Healthcare
Communication	Economy
Fuel	Natural resources

Resilience Concept for the Built Environment

- Maintain acceptable levels of functionality during and after disruptive events
- Recover full functionality within a specified period of time



Adapted from McDaniels, et al 2008 and Bruneau, et al 2003

Formative Events and Government Responses for Resilience

Hurricane Andrew 1992

WTC Disaster 2001

Hurricane Katrina 2005

1993

FEMA
Natural hazards
Prepare, mitigate, respond, recover

2001

Patriot Act
Security against terrorism

2003

National Strategy for Physical Protection
Security for Critical Infra-structure & Key Resources

HSPD-7 Critical Infrastructure Identification, Prioritization, and Protection
Policy for Federal Departments

2005/ 2008

Grand Challenges for Disaster Reduction
Reduce vulnerability of critical infrastructure
Hazards, vulnerability, risk assessment

2009

National Infrastructure Protection Plan (NIPP)
All hazards for Critical Infrastructure & Key Resources

Critical Infrastructure & Key Resources (CIKR)

National Strategy for the Physical Protection of Critical Infrastructures and Key Assets (2003)

Strategic Objectives

- Identify and assure the protection of assets, systems, and functions deemed most critical for national public health and safety, governance, economic and national security, and public confidence.
- Assure the protection of infrastructure and assets that face a specific, imminent threat.
- Pursue collaborative measures and initiatives to assure the protection of other potential targets that may become attractive over time.

Critical Infrastructure Sectors

1. Agriculture and Food
2. Banking and Finance
3. Chemical Industry and Hazardous Materials
4. Communications
5. Critical Manufacturing
6. Defense Industrial Base
7. Emergency Services
8. Energy
9. Healthcare and Public Health
10. Information
11. Postal and Shipping
12. Transportation Systems
13. Water

Key Assets/Resources

1. Commercial Facilities
2. Dams
3. Government Facilities
4. National Monuments and Icons
5. Nuclear Reactors, Materials, Waste

DHS National Infrastructure Protection Plan (NIPP 2009)

Overarching goal:

Build a safer, more secure, and more resilient America

•Prevent or mitigate the effects of terrorist acts

•Strengthen national preparedness, timely response, and rapid recovery of CIKR

in the event of an attack, natural disaster, or other emergency.

Private Sector Responses for Resilience

2009

American Society of Civil Engineers (ASCE)
Critical Infrastructure Guidelines

American Society of Mechanical Engineers (ASME)
Prioritizing Critical Infrastructure Security/Resilience

American Water Works Association (AWWA)
All Hazards Consequence Management Plan

Technical Council on Lifeline Earthquake Engineering (TCLEE) Conference on Lifeline Earthquake Engineering in a Multi-Hazard Environment

2010

The Infrastructure Security Partnership (TISP)
White Paper on Infrastructure Resilience & Interdependencies

Pacific Earthquake Engineering Research Center (PEER)
Guidelines for Performance Based Seismic Design of Tall Buildings

2011

National Research Council
National Earthquake Resilience

Examples of:
- More than security
- Uniform facility risk
- Plans for recovery from damage
- Systems interdependencies

Standards Supporting Resilience

2006

ASCE 41-06
Seismic Rehabilitation of Existing Buildings
Performance-based seismic rehabilitation methodology

ASTM E 2506-06
Standard Guide for Developing a Cost-Effective Risk Mitigation Plan for New and Existing Constructed Facilities

2009

ANSI/ASME-ITI/AWWA J100
RAMCAP® Standard for Risk and Resilience Management of Water and Wastewater Systems

2010

ASCE 7-10
Minimum Load Requirements for Buildings and Other Structures
Performance-based procedures and risk consistency

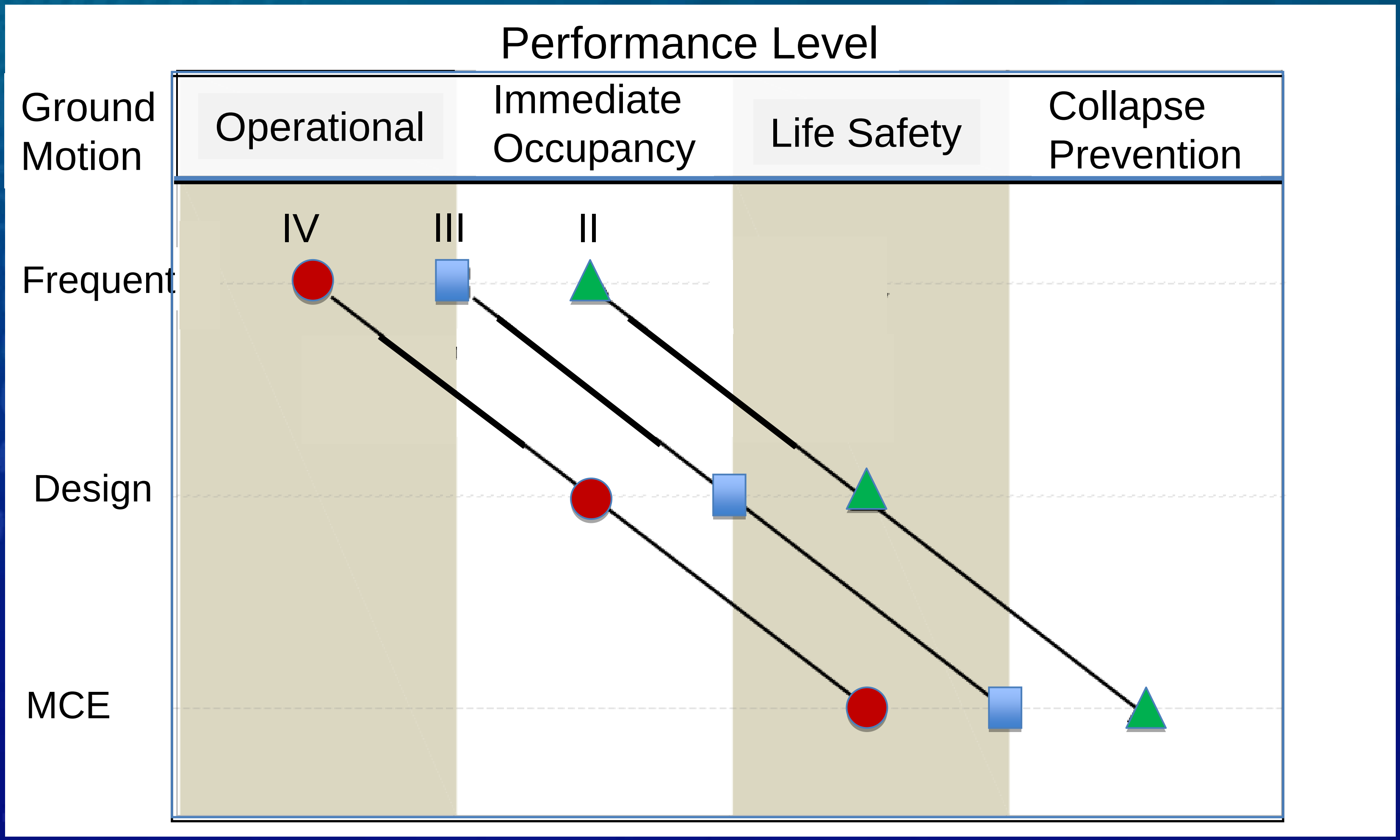
ASCE 7-10 Risk Category for Buildings and Other Structures

Risk Category	Use or Occupancy
I	Unoccupied or low risk to public
II	All others
III	House large numbers of people (assembly uses, theatres), or those with limited mobility (elementary schools, healthcare), or community utilities (power, water, wastewater, communications) or hazardous materials
IV	Essential community service facilities (hospitals, police and fire stations, emergency communications)

Occupancy category in codes relates to fire and life safety protection issues

Risk category relates structural failure and life safety or welfare

Seismic Performance Levels for Buildings
FEMA P750



Example of a Risk Consistent, Performance-Based Standard for Structures and Seismic Hazards

Target Structural Performance Levels (ASCE 41-06)

	Collapse Prevention	Life Safety	Immediate Occupancy	Operational
Damage Level	Severe	Moderate	Light	Very Light
General Structural Performance	Little residual stiffness and strength, but load bearing walls and columns function. Large permanent drifts.	Some residual strength and stiffness in all stories. Gravity load bearing elements function. No out of plane failures, some permanent drift.	No permanent drift, most of original strength and stiffness in all stories. Elevators and fire protection functional.	No permanent drift, most of original strength and stiffness in all stories. All systems important for operation are functional.
Nonstructural Component Performance	Extensive	No falling hazards; architectural damage; many utilities damaged	Equipment and contents secure, but may not operate	Negligible damage. May need to use backup systems.

What is Needed to Achieve Resilient Communities?

Status Quo

- Prescriptive codes and standards for life safety
- Poor building and infrastructure resilience performance during hazard events
- Emergency response planning but little community resilience planning
- Reliance upon federal disaster funding for recovery

Moving Forward

- Risk consistent, performance based codes and standards for resilience
- Comprehensive approach to design guidance for built environment
- Proactive planning by communities to achieve resilience
- Reduced emergency response and recovery costs

Community Performance Goals

SPUR planning for community resilience to a major earthquake

- Establish clear goals and performance objectives for disaster recovery
- Take steps now toward resilience
- Create a culture of preparedness
- Plan for long-term building

SPUR Target Performance States

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event: BUILDINGS	LIFELINES
Category A	Safe and operational	
Category B	Safe and usable during repairs	100% restored in 4 hours
Category C	Safe and usable after moderate repairs	100% restored in 4 months
X	Expected current status	

TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
CRITICAL RESPONSE FACILITIES AND SUPPORT SYSTEMS									
Hospitals								X	
Police and fire stations			X						
Emergency Operations Center									
Related utilities						X			
Roads and ports for emergency				X					
CalTrain for emergency traffic					X				
Airport for emergency traffic				X					
EMERGENCY HOUSING AND SUPPORT SYSTEMS									
95% residence shelter-in-place								X	
Emergency responder housing				X					
Public shelters							X		
90% related utilities								X	
90% roads, port facilities and public transit							X		
90% Muni and BART capacity						X			
HOUSING AND NEIGBORHOOD INFRASTRUCTURE									
Essential city service facilities							X		
Schools							X		
Medical provider offices								X	
90% neighborhood retail services									X
95% of all utilities								X	
90% roads and highways						X			
90% transit						X			
90% railroads							X		

What is Needed to Achieve Resilient Communities?

- Community Performance Goals
  - Performance goals with target states of recovery
  - Performance levels
  - Hazard levels
- Codes and Standards
  - Definitions and metrics for resilience
  - Risk consistent, performance based methodologies
  - Guidelines and pre-standards

Thank You

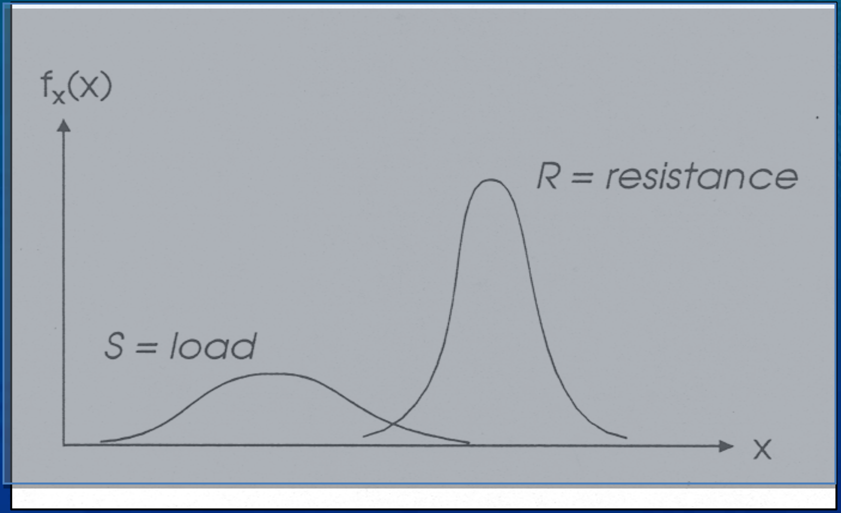
Measuring Reliability and Risk

Reliability (R) considers the ability of a system to perform its function for a specified period of time

$$R = 1 - P_F$$

where

$$P_F = P(D|H) \cdot P(H)$$



Risk includes the consequence of a failure

Risk is a function of hazard frequency and intensity (H), system damage (D), and consequences (C), where

$$Risk = H \times D \times C$$

or

$$Risk = P(C|D) \cdot P(D|H) \cdot P(H)$$

Uniform Risk

Resilient communities should have a uniform risk for its facilities rather a uniform hazard.

For the design EQ (Q_{des})

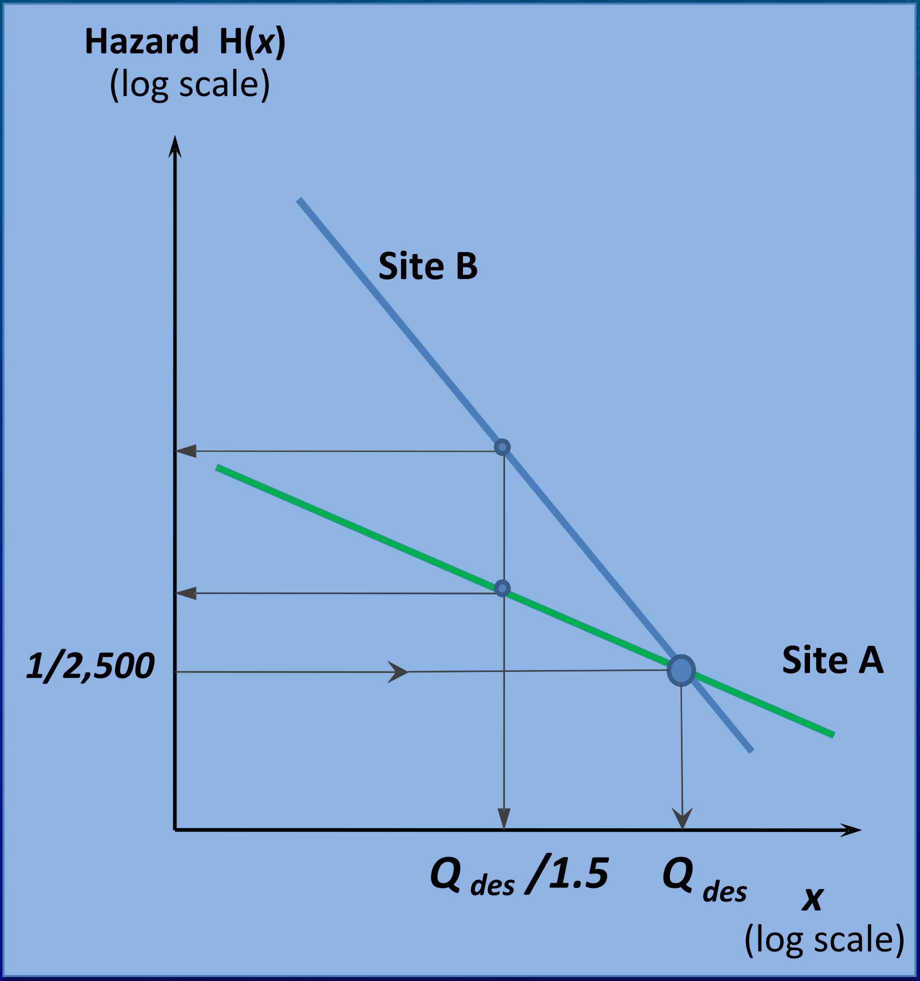
•In ASCE 7-05

- 2% prob of exceedance in 50 yrs (MRI of 2500 yr)

•In ASCE 7-95

- 10% prob of exceedance in 50 yrs (MRI of 475 yr)
- Q_{des} was assumed to provide Life Safety Performance with a 1.5 safety factor against building collapse ($Q_{des}/1.5$)

It was recognized that slope of hazard curves differed between sites and designing for a SF=1.5 did not ensure uniform safety.



Disaster Damage to the Built Environment

Hazard	Engineered buildings	Non-engineered buildings	Transportation structures	Utilities
Earthquake	Permanent drift, soft story	URM failure	Bridge collapse, road subsidence	Pipe and line failures
Hurricanes wind	Envelope damage	Envelope damage to collapse		Extensive power distribution failures
Flood and storm surge	Foundation scour	Inundation, structure uplift	Bridge deck uplift, pier/road scour	Extensive power distribution failures
Tornado	Envelope damage	Envelope damage to collapse		Pipe and line failures
Fire	Smoke damage to burnout	Smoke damage to collapse	Fire damage to collapse	Line failures
Drought	Settlement	Settlement	Settlement	Burst pipes
Snow, ice, freezing	Roof collapse	Roof collapse	Road subsidence	Extensive power distribution failures, Burst pipes
Blast	Envelope damage to collapse	Envelope damage to collapse		

ASCE 7-10 Risk Category for Buildings and Other Structures

Risk category for structural failure should be based on number of persons who would be endangered or whose welfare would be affected