Disaster Resilience: Authorities and Capabilities

Jason D. Averill

Acting Chief, Materials and Structural Systems Division

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Outline of Talk

- Brief History and Background
- Authorities
  - National Construction Safety Team (NCST) Act
  - National Earthquake Hazard Reduction Program (NEHRP)
  - National Windstorm Impact Reduction Program (NWIRP)
  - NIST Fire Research
- NIST Community Resilience
- Discussion

Disaster Resilience

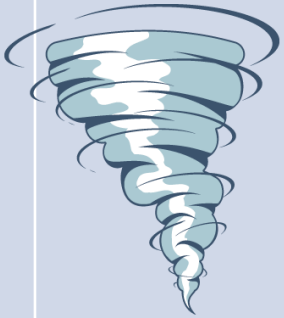
- PPD 21: Resilience is “the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions.”
- Natural and man-made disasters cause an average of $57B in annual costs, while single events have caused >$100B losses.
- Current approach of response and recovery is inefficient and ineffective.
- Changing the paradigm requires holistic, science-based understanding of interrelationships between social and engineered systems with focus on preparation and mitigation.
- NIST has a variety of authorities and capabilities to address these problems

NIST and the National Disaster Response Framework (NDRF)

- NIST supports the Department of Commerce role in the National Response Framework
  - Primary capabilities in Engineering Laboratory
  - Additional capabilities in
    - Materials Measurement Laboratory
    - Physical Measurement Laboratory
    - Law Enforcement Standards Office
  - Coordinate through DOC Recovery Coordinator

Disaster and Failure Studies at NIST

Earthquakes	Hurricanes	Construction & Building	Tornadoes	Fires
San Fernando, CA (1971)	Camille, MS/LA (1969)	Skyline Plaza Apartments, Bailey's Crossroads, VA (1973)	Jarrell, TX (1997)	DuPont Plaza Hotel, San Juan, PR (1986)
Mexico City, Mexico (1985)	Alicia, Galveston, TX (1983)	Willow Island Cooling Tower, WV (1978)	Spencer, SD (1998)	First Interstate Bank Building, Los Angeles, CA (1988)
Loma Prieta, CA (1989)	Hugo, SC (1989)	Kansas City Hyatt Regency, Kansas City, MO (1981)	Oklahoma City, OK (1999)	Loma Prieta Earthquake, CA (1989)
Northridge, CA (1994)	Andrew, FL (1992)	Riley Road Interchange, East Chicago, IN (1982)	Joplin, MO (2011)	Hillhaven Nursing Home (1989)
Kobe, Japan (1995)	Hurricanes Mitch and Georges, LAC (1998)	Harbor Cay Condominium, Cocoa Beach, FL (1981)	Moore OK (2013)	Pulaski Building, Washington, DC (1990)
Kocaeli, Turkey (1999)	Hurricanes Katrina and Rita (2005)	L'Ambiance Plaza, Hartford, CT (1987)		Happyland Social Club, Bronx, NY (1990)
Maule, Chile (2010)		Ashland Oil Tank Collapse, Floreffe, PA (1988)		Oakland Hills, CA (1991)
Christchurch, NZ (2011)		U.S. Embassy, Moscow, USSR (1987)		Watts St, New York City (1994)
		Murrah Federal Building, Oklahoma City, OK (1995)		Northridge Earthquake, CA (1994)
		World Trade Center Disaster, New York, NY (2001)		Kobe, Japan (1995)
		Dallas Cowboys Indoor Practice Facility, May 2009		Vandalia St, New York City (1998)
				Cherry Road, Washington, DC (1999)
				Keokuk, IA (1999)
				Houston, TX (2000)
				Phoenix, AZ (2001)
				Cook County Administration Building Fire (2003)
				The Station Nightclub, RI (2003)
				Charleston, SC, Sofa Super Store Fire (2007)
				Witch Creek & Guejito, CA, WUI Fire (2007)
				Amarillo, TX, WUI Fire (2011)
				San Francisco, CA (2012) *



* ongoing

National Construction Safety Team (NCST)

- **Public Law 107-231, Oct. 01, 2002**
  - "*…provides for the establishment of Teams to assess building performance and emergency response and evacuation procedures in the wake of any building failure that has resulted in substantial loss of life or that posed significant potential of substantial loss of life*."
  - Investigations conducted under this authority are "*…to improve the safety and structural integrity of buildings in the United States."*

- **Investigative tools unique to NCST**
  - Subpoena authority
  - NIST Investigator Credentials
    - Facilitate collaboration with local authorities for timely access to disaster sites for survey and collection of perishable field performance data (need for access is always secondary to rescue and recovery operation by local authorities and safety)

NCST Advisory Committee

- Advise the NIST Director on:
  - Functions and composition of NCST Teams;
  - Deployment procedures;
  - Investigation reports.
- Between 5 and 10 appointed members, reflecting “the wide diversity of technical disciplines and competencies involved in the National Construction Safety Teams investigations”
- Provide to Congress annually, a report that includes:
  - “(1) an evaluation of Team activities, along with recommendations to improve the operation and effectiveness of Teams and
  - (2) an assessment of the implementation of the recommendations of Teams and of the advisory committee.”

Decision-making for Deployment and Investigations

Implementation of Recommendations

Monitoring

Training

Disaster or Failure

Assessment / Decision Criteria

Yes

Recommendation to NIST Director

No

Assessment Record

Yes

Preliminary Reconnaissance

Yes

Recommendation to NIST Director

No

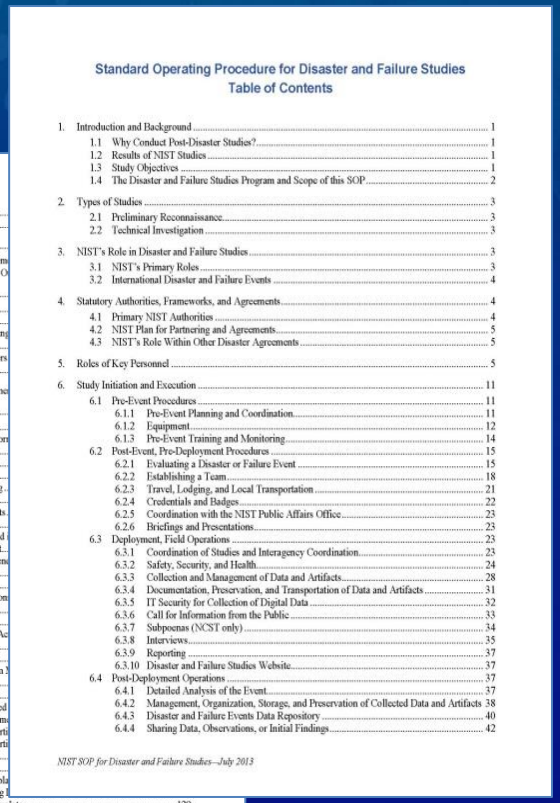
Recon Report

Yes

Technical Investigation

Technical Report / Recommendations

Implementation of Recommendations



Standard Operating Procedure for Disaster and Failure Studies
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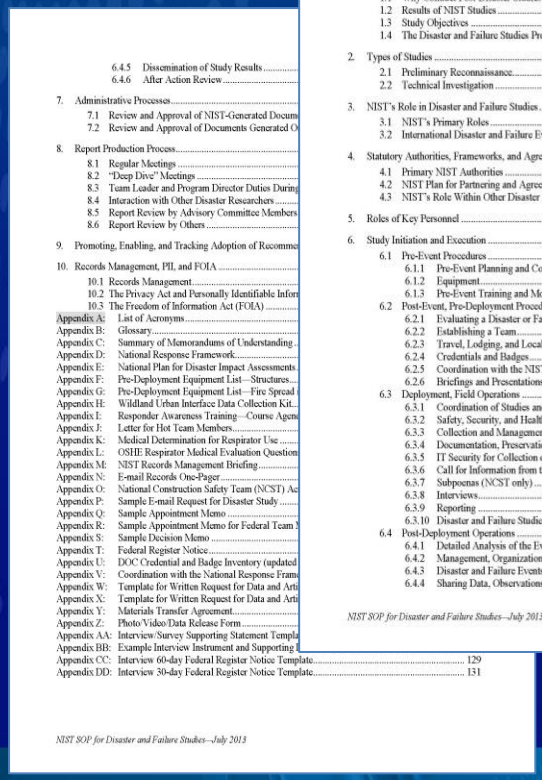


Decision Criteria and Guidelines

- Provide a rational basis for evaluating the need for an investigation and considers many factors, including:
  - substantial loss of life or disabling injury;
  - significant potential for loss of life (exposed population);
  - level of hazard;
  - consequences to resilience;
  - evacuation/emergency response challenges;
  - applicability of international events (code enforcement; similarity of practices);
  - unique new knowledge that may potentially be gained;
  - potential impact on standards, codes, and practices;
  - safety of field personnel.

Preliminary Reconnaissance Screening Criteria

Preliminary Reconnaissance Criteria	Date and Event Description: Low (1)	Med (3)	High (5)
1. Substantial Loss of Life or Disabling Injury			
A. Facility context	0	1 to 2	>2
B. Community context	0 to 3	4 to 9	>10
C. Regional context	0 to 5	6 to 19	>20
2. Significant Potential for Substantial Loss of Life: Exposed Population			
A. Facility context	<100	100 to 499	≥500
B. Community context	<1 000	1 000 to 9 999	≥10 000
C. Regional context	<100 000	100 000 to 999 999	≥1 000 000
3. Hazard and/or Failure Event(s)			
A. Earthquake	≤ MMI IV	MMI V to VII	≥MMI VIII
B. Hurricane at Landfall	≤Cat 3	Cat 4	Cat 5
C. Tornado	≤EF3	EF4	EF5
D. Coastal Inundation	< 3 ft	3 to 9 ft	≥ 10 ft
E. Fire Spread in Structures	Fire spread not beyond area of origin	Fire spread throughout a structure	Fire spread beyond structure of origin
F. Wildland Urban Interface Fire (WUI)	High Forest Service Fire Danger Rating	Very High Forest Service Fire Danger Rating	Extreme Forest Service Fire Danger Rating
G. Blast	< 99 lbs. TNT-equivalent	100 - 999 lbs. TNT-equivalent	> 1000 lbs. TNT-equivalent
H. Impact	< 1 x 10^6 ft lb/sec	1 x 10^6 to 1 x 10^7 ft lb/sec	> 1 x 10^7 ft lb/sec
4. Consequences to Resilience			
A. Failure during Construction or in Service	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
B. Engineered Building Systems	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
C. Transportation & Utility Systems	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
D. Non-Engineered Building Systems	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function
Score: __/__ = __ **Sum**	__ x 1	__ x 3	__ x 5
5. Evacuation and Emergency Response			
A. Evacuation	Normal evacuation	Moderate evacuation challenges	Severe evacuation challenges
B. Emergency Response	Normal operations	Moderate operational challenges	Severe operational challenges

Memoranda of Understanding

- Bureau of Alcohol, Tobacco, and Firearms
- Chemical Safety Board
- Department of Energy
- Federal Emergency Management Agency
- International Code Council
- National Association of State Fire Marshals
- National Fire Protection Association
- National Highway Traffic Administration
- National Oceanic and Atmospheric Administration
- National Science Foundation
- United States Fire Administration

Recent NCST Investigations and Subsequent Impacts

- **World Trade Center (2001 – 2005/2008)**

  U.S. model building codes changes adopted for fire proofing; fire resistance rating; structural integrity; occupant evacuation & fire service access elevators; active fire protection systems; emergency responder communications.

- **Station Nightclub Fire (2003 - 2005)**

  Requirements on automatic sprinklers, restricted festival seating in new and existing buildings, crowd managers for existing and new assembly occupancies, and egress inspection recordkeeping adopted in NFPA 101 (Life safety Code)

- **Joplin Tornado (2011 – 2014)**

  Recommendations for standard/code requirements for tornado-resistant design for buildings, code requirements for tornado shelters in many more buildings, and standards and codes for clear, consistent, and accurate emergency communications

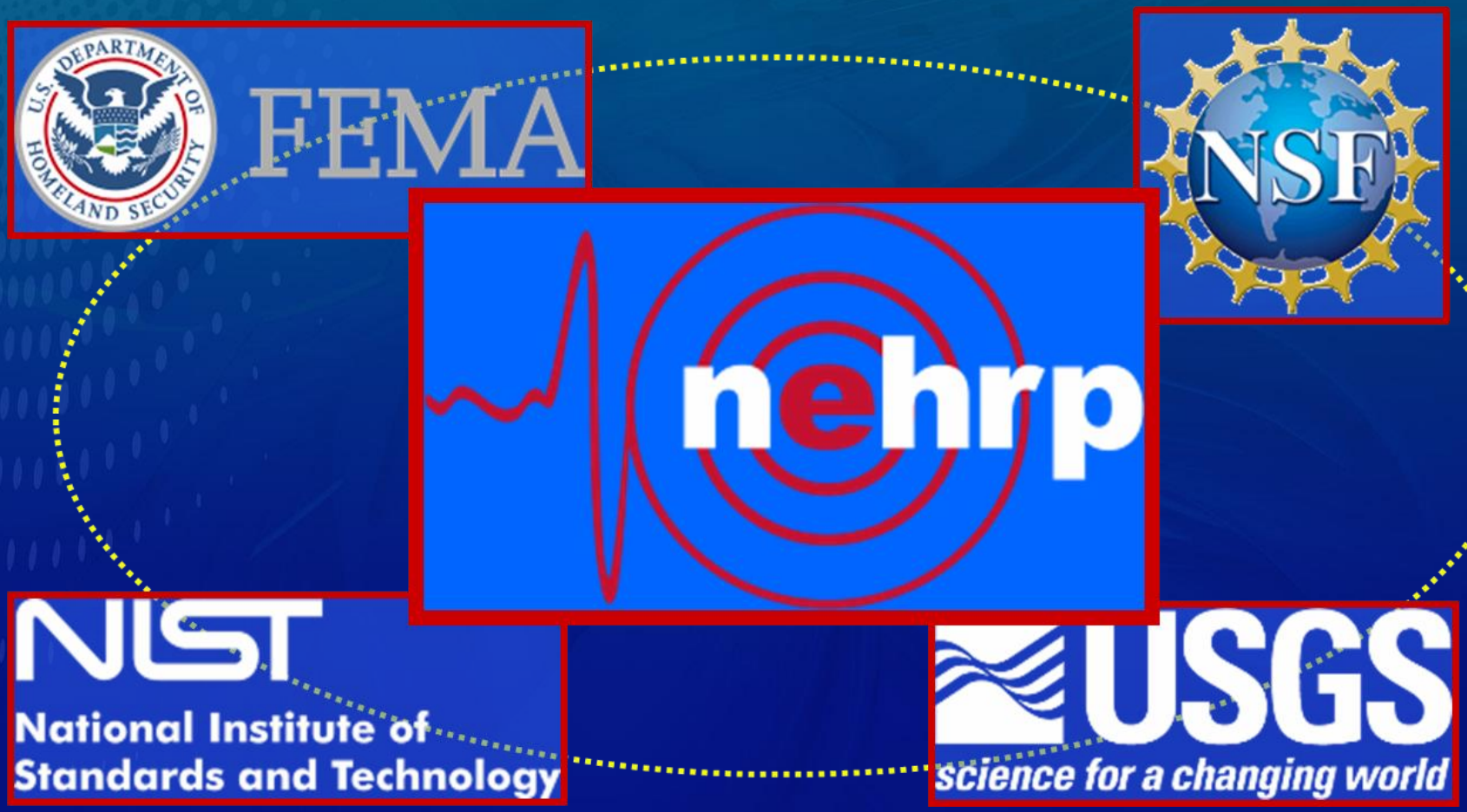
Benefits of NCST Investigations

- **Programmatic Benefits**
  - Unique, “real world” performance data
  - Extend state of the art, capability of staff

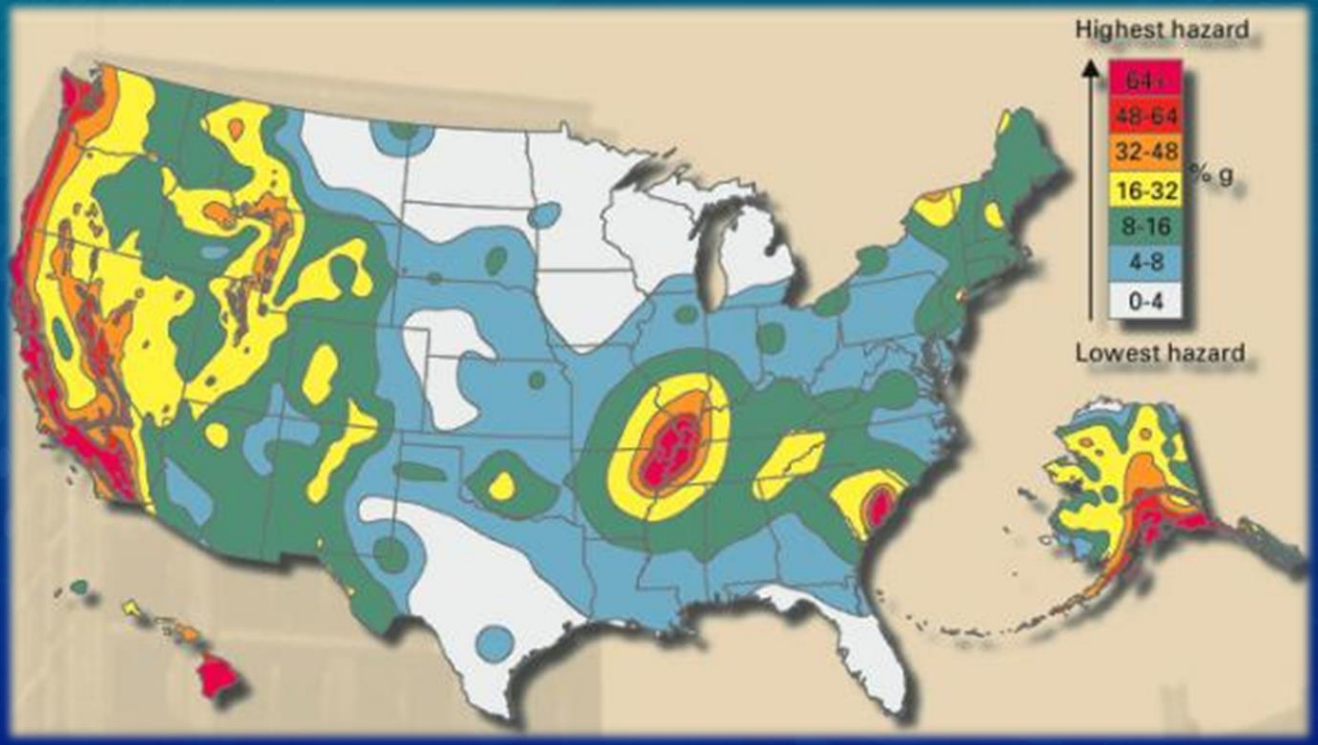
- **Consistent with NIST ‘s and EL’s Missions**
  - *“Meeting measurement science and standards needs for construction in ways that enhance economic prosperity and improve quality of life”*
  - *“promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.”*

National Earthquake Hazards Reduction Program

A Statutory Multi-Agency Partnership



Earthquake Risk in the U.S.



2006 NRC Report:

- 42 states have some risk
- 18 states have moderate to high risk
- > 75M Americans live in urban areas with moderate to high risk
- Estimated value of structures in all states prone to earthquake damage ~ $10T

NEHRP Historical Overview

- Authorized by Congress in 1978 "…to reduce the risks of life and property from future earthquakes in the United States…"
- Typically re-authorized on 2 – 5 year cycles following formal Congressional hearings – but current authorized budgets (PL 108-360) expired at end of FY 2009.
- Program has no authority to establish or enforce building codes and regulations, or to conduct post-earthquake response and recovery operations.

Current NEHRP Overview

- NIST designated as NEHRP Lead Agency
- Interagency Coordinating Committee (ICC):

  Chaired by NIST Director, includes NEHRP agency principals , OMB, & OSTP.

  Responsible to Congress for program management and implementation, including annual report to Congress.

- Advisory Committee on Earthquake Hazards Reduction (ACEHR):

  Provides advice to NIST Director on relevant developments in sciences and engineering, program effectiveness, needed program revisions, management, and implementation.

  Biennial reports to NIST Director (in role as ICC Chairperson) required.

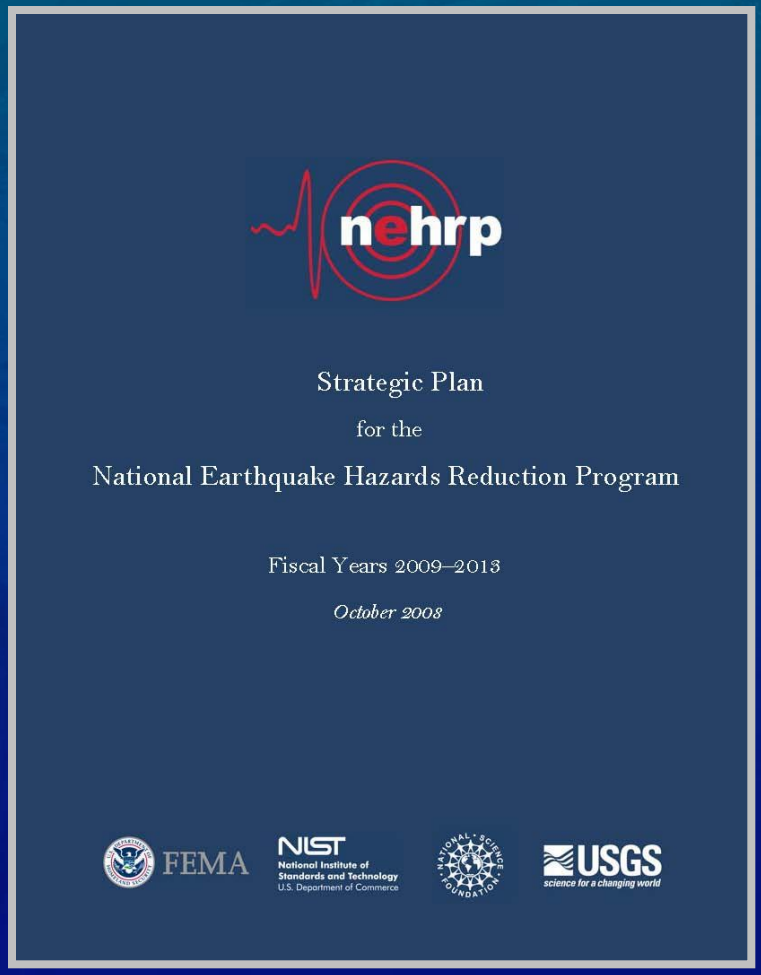
Chile 2010 (Jay Harris Photo)

Major NEHRP Technical Activities

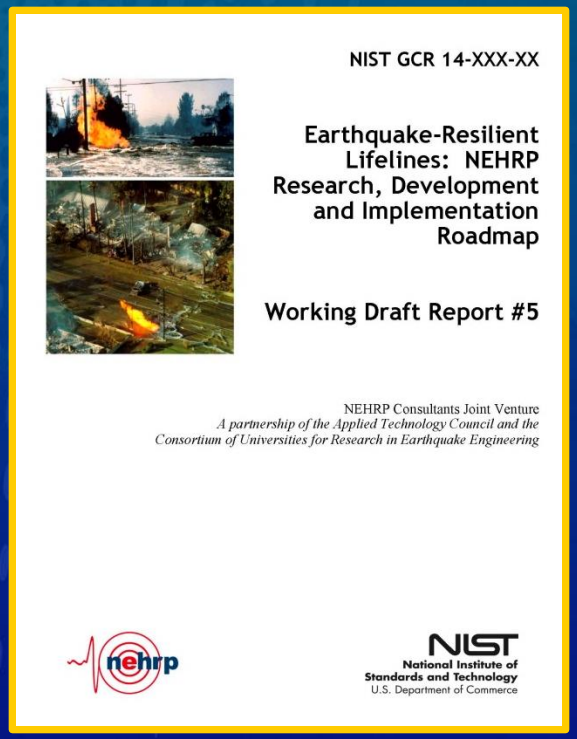
- **Interdisciplinary research**
  - NSF, USGS, NIST, FEMA
- **Monitor earthquake activity**
  - USGS, NSF
- **Earthquake-resistant design and construction**
  - NIST, FEMA
- **Public education**
  - All

NEHRP Strategic Plan

- Executive Summary
- Introduction – Background (History, Prior Accomplishments)
- Vision / Mission / Strategic Planning Principles
- Goals / Objectives / Outcomes
- Strategic Priorities
- Summary
- Appendices



Earthquake-Resilient Lifelines Research & Implementation Roadmap



Work performed by NEHRP Consultants Joint Venture

- "Lifelines" include electric power, telecommunications, water, transportation, gas and other critical utilities
- Major workshop conducted 7-8 May 2014
- Project technical committee members and workshop attendees strongly agree on:
  - Lifelines lack an "umbrella organization" to establish performance goals
  - Lifelines affected by many hazards and solutions often broadly effective

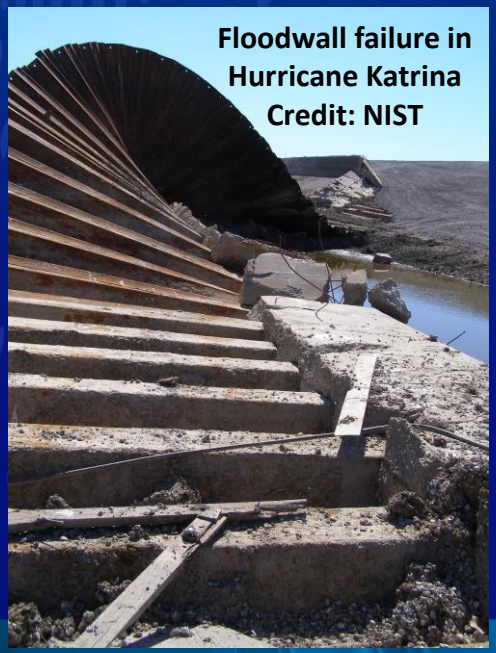
Bittle (Older) Reinforced Concrete Buildings

- Life safety risk due to poor performance of pre-1970's reinforced concrete buildings has been well documented.
- All four NEHRP agencies have sponsored research and implementation work on this topic:
  - Over 1,500 at-risk buildings in LA
  - Working towards improved assessment and evaluation methods, including simplified screening tools to identify collapse-hazard buildings

Work performed with NEHRP Consultants Joint Venture

Wind and Storm Surge

- Windstorms and coastal inundation caused $250B in US property loss from 1996-2012 (NOAA estimate in 2012 dollars).
  - — Hurricanes,
  - — coastal flooding,
  - — tornados,
  - — straight line winds



Floodwall failure in Hurricane Katrina Credit: NIST

Bridge decks failure due to storm surge and wave action in Hurricane Katrina. Credit: NIST

National Windstorm Impact Reduction Program (NWIRP)

- Created by the National Windstorm Impact Reduction Act of 2004 (PL 108-360)
- Objective
  - "*achievement of major measurable reductions in losses of life and property from windstorms*"


Photo credit: NIST


Photo credit: NIST

NWIRP Agencies

- **Lead Agency:**

  White House Office of Science and Technology Policy (OSTP)

- **Interagency Working Group**

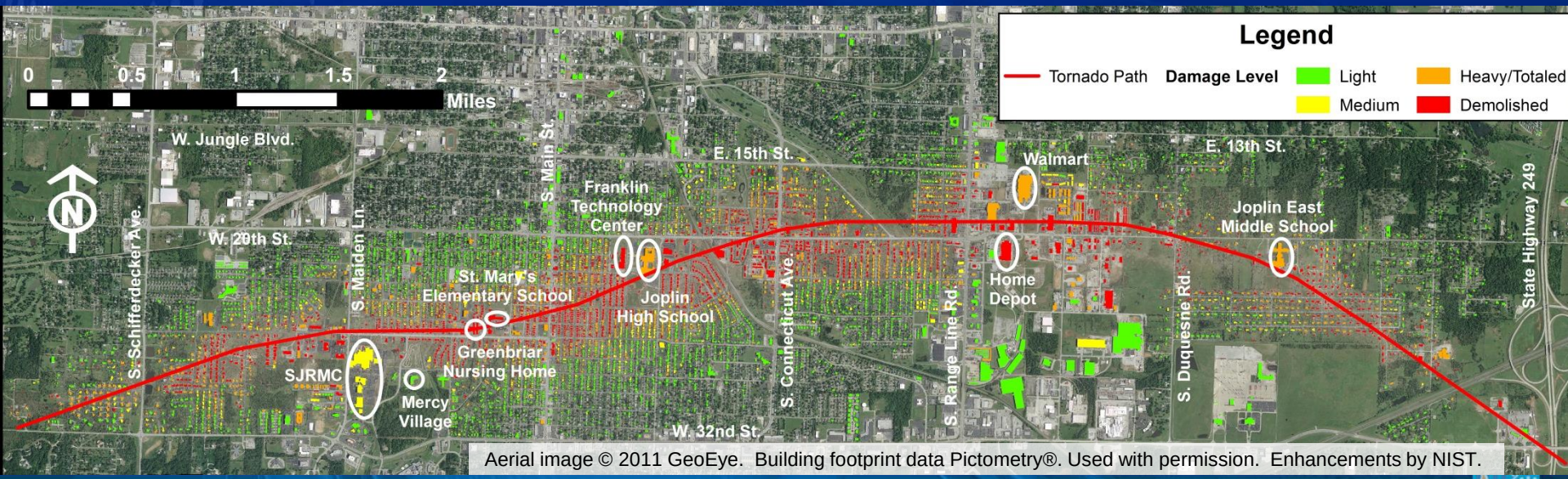
  NIST, NOAA, FEMA, and NSF

- **NIST responsibilities (PL 108-360, Section 204(c)(1)):**
  - Support R&D to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines

Joplin Tornado - Deadliest and Costliest Single Tornado on Record

The Event:

- Tornado warning issued at 5:17 PM CDT, May 22, 2011. Touched down at 5:34 PM. Official tornado warning time: 17 minutes (> 14 minutes national average)
- Track length about 22 miles long (6 miles in City of Joplin)
- Intensity varied along track. Officially rated EF-5 (highest category on the Enhanced Fujita Tornado Intensity Scale), with estimated maximum wind speeds of 200+ mph



Aerial image © 2011 GeoEye. Building footprint data Pictometry®. Used with permission. Enhancements by NIST.

Extent of Building-Related Damage

Buildings Damaged	Residential	**7,411 (43% sustained *heavy/totaled or demolished classification)***
	Non–Residential	**553 (1 of 2 major hospitals, 10 public and several parochial schools, 28 churches, 2 fire stations, and numerous commercial facilities)**
Fatalities	Total	**161**
	All Building–Related	**135 (of 161, or 83.8% of total fatalities)**
	Residential-Related	**80 (of 135, or 59% of building–related fatalities)**
Insured Losses (as of April 30, 2012)	Residential	**$0.552 billion**
	Commercial	**$1.228 billion**

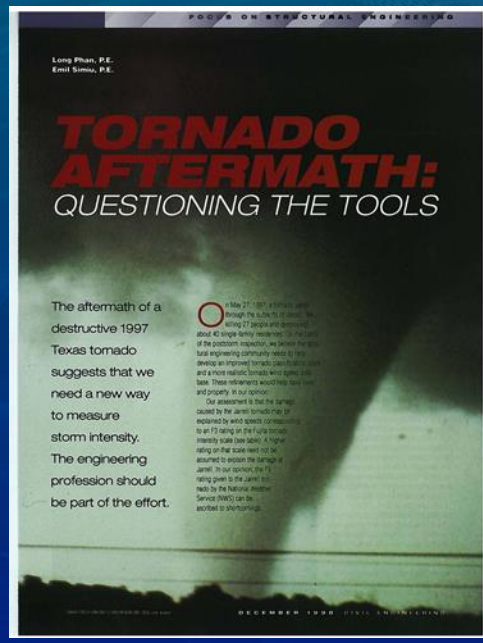
Extent of Damage to Lifelines

Electricity	Step-down Substations	**1 destroyed, 2 damaged**	~ 20,000 customers lost electrical power immediately after the May 22, 2011 tornado
	Distribution Poles/Transmission Towers	**~ 4,000 damaged**	
	Transformers	**1,500 damaged**	
	Transmission/Distribution Lines	**110 miles downed**	
Water	Service Lines	**~4,000 damaged/leaked**	Drastic decrease in water pressure and loss of water from the two elevated storage tanks within 2 hours
	Fire-Service Lines	**~25 broken**	
Gas	Gas Meters	**~ 3,500 damaged**	~ 3,500 customers affected
	Gas Main	**~ 55,000 ft damaged**	

NIST Wind Research Impacts

Enhanced Fujita (EF) Scale

- NIST's study of the 1997 Jarrell, Texas tornado identifies weaknesses with the existing Fujita Scale
- Subsequent collaboration with Texas Tech U. and NOAA OFCM led to creation of Enhanced Fujita tornado scale
- NOAA National Weather Service adopts EF scale in 2007 as the nation's official tornado intensity scale



ASCE 7 Wind Load Provisions

- NIST contributions to this national standard include
  - Database-assisted design (DAD)
  - Relationship between the Saffir-Simpson Hurricane Scale winds and design wind speeds
  - Wind directionality effects in structural design

Nuclear Industry Safety for Extreme Wind Hazards

- Developed technical basis for regulatory guidance on hurricane and tornado missiles (i.e, windborne projectiles)
- NIST study issued as NUREG/CR-7004 in 2011

NWIRP/NEHRP Legislation Status

- Legislation has been considered in both the House and Senate recently which would:
  - Reauthorize NWIRP (and NEHRP)
  - Make NIST lead agency for NWIRP
  - Identify NIST as lead Federal agency to coordinate all post-storm investigations
  - Create combined Interagency Coordinating Committee for NWIRP and NEHRP (NIST, NSF, FEMA, USGS, NOAA)

Fire Research Authorities and Capabilities

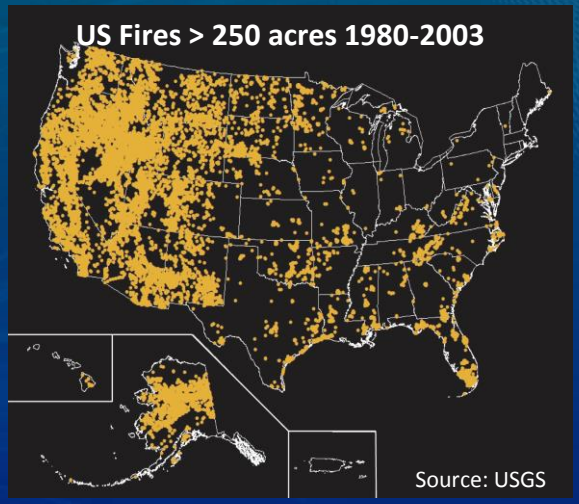
- **Research and fire investigations are authorized within the NIST Organic Act (15 U.S.C. 278f (a))**

- **Four Thrust Areas:**
  - Fire Service Response
  - *Wildland Urban Interface Fires*
  - Residential Fire Safety
  - Performance Based Design Methods

Wildland-Urban Interface Fires

Massive Exposure

- 39% of US homes in WUI (60% new homes)
- >4,400 high risk communities



Significant Drivers

- Fuel accumulation
- Climate change

Recent NIST WUI Post-Fire Studies

	Trails Community during Witch Fire, San Diego, CA	Tanglewood Complex Fire, Amarillo, TX	Waldo Canyon Fire, Colorado Springs, CO
Year	2007	2011	2012
Buildings Destroyed/ Total	74 / 250	35 / 150	350 / 1000
Team	NIST, USFS, and CALFire	NIST, USFS, and TX FS	NIST, USFS, and CSFD
Fire duration (~80% loss)	6 hours	6 hours	6 hours
Principal Findings	• 0.2 building lost/min • Pre-staged data collection efforts key • Data acquisition methodology needed	• 0.1 building lost/min • Exposure varies locally • Pre-fire data key • Data acquisition training needed	• 1 building lost/min • FD pre-planning needed

Post-Fire Data Collection

Basic System (WUI 1)

- Identify number of structures lost
- Structures grouped by incident
- iPhone/iPad application (Beta tested at Waldo Fire, CO)
- WUI data collection being explored with: Colorado/ Northern California/ Florida/ Georgia/ Virginia/ North Carolina

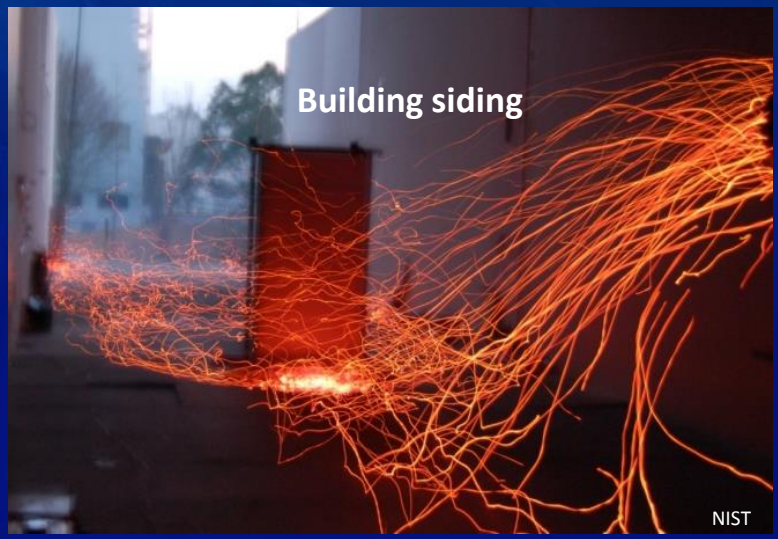
Advanced System (WUI 2)

- Identify structure and landscaping attributes, exposure, and defensive actions
- Document pre-fire environment to fully characterize WUI hazards
- GIS linked property parcels and digital photos
- **Tablet** (Beta tested by TX FS)

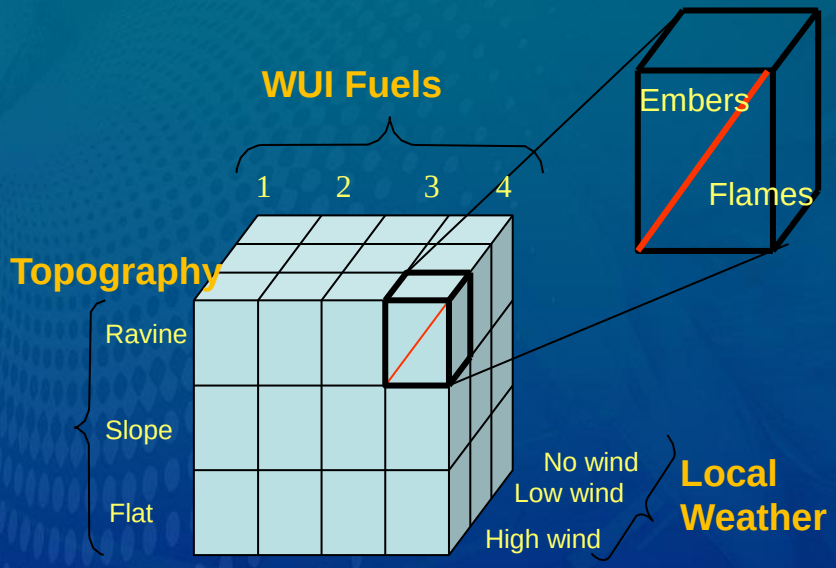
Hardening Vulnerable Building and Community Elements

- **Using laboratory tests to translate field study findings to standard test methods**
  - Ember generation
  - Material performance

NIST's ember generator in the FRI's wind tunnel (Japan)



WUI Fire Hazard Scale



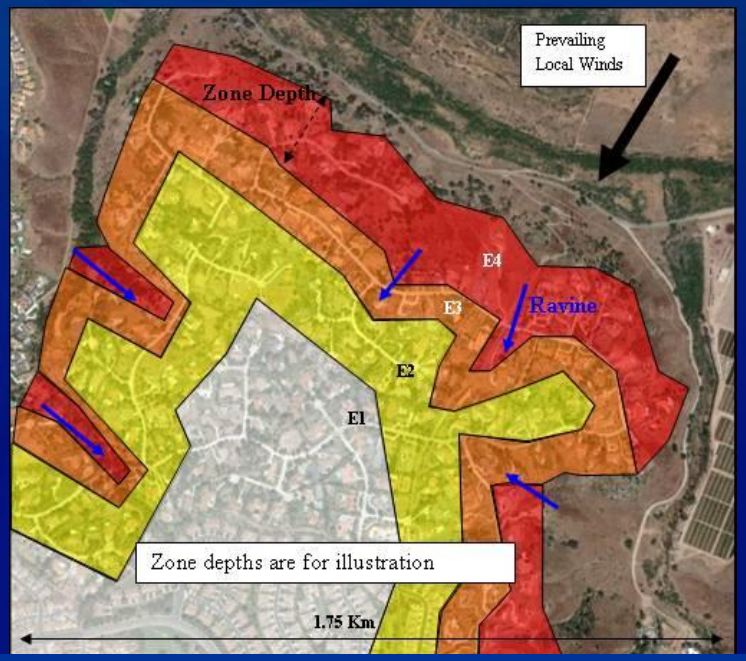
- Measure expected hazard from flame and ember exposure locally
- Account for local fuel type, topography, and weather
- Populate the Hazard "Cube" and quantify WUI fire risks

WUI Fire Hazard Scale

Ember Zone (mass flux)

< 1 g/m²-s	< 5 g/m²-s	TBD	TBD
E1	E2	E3	E4
F1	F2	F3	F4
<0.1 W/cm²	< 1 W/cm²	1 - 2 W/cm²	> 2 W/cm²

Flame Zone (heat flux)



Illustrative ember exposure zones in a WUI Community

NIST Community Resilience Program

- A resilience-based approach will provide the framework and guidance needed to break the cycle of destruction and recovery.
  - Regional Workshops
    - ✓ April 7, 2014 – Gaithersburg, MD – Overview and scope
    - July 30, 2014 – Hoboken, NJ – Framework and charter
    - October 2014 – Oklahoma
    - January 2015 – *Western US*
    - April 2015 – *Gulf Coast*
    - July 2015 – *West Coast*
  - Disaster Resilience Framework v.1 available in 2015
  - Model Resilience Guidelines for critical buildings and infrastructure v.1

Community Resilience Research

- Establish the Community Resilience Center of Excellence
- Computational models to assess and support:
  - Building and infrastructure lifeline interdependencies and cascading effects of failures among infrastructure systems and buildings
  - Decision making for planning, risk mitigation, response, and recovery with specific consideration of corresponding infrastructure system performance
  - Impact and consequences of emergency response to disasters and community engagement in disaster recovery efforts
- Community resilience data to capture:
  - Metrics that quantify the state and improvement of community resilience with regards to the built environment and societal needs
  - Foundational data for model development and basic phenomenological understanding
  - Datasets for modeling validation and inputs for modeling applications

Opportunities for Improvement

- Managing Stakeholder Expectations
- Managing Disruption
- Managing Readiness
- Pending authorizations