



# Disaster and Failure Studies Program Update

NCST Advisory  
Committee  
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# Presentation Outline

- Brief Program Refresher
- Recent Disasters and NIST Actions
- Procedures for Conducting Studies
- Support Contract



# NIST Disaster and Failure Studies

## Results

- Probable technical cause
- Lessons learned: successes and failures
- Improvements to standards, codes, practices, technologies
- Future research priorities

*A program focus: Develop and maintain archival disaster and failure database of hazards, performance of buildings and infrastructure, evacuation and emergency response, and related factors (e.g., mitigation, response)*



# Typical Study Objectives

- Establishing likely technical factor(s)s responsible for damage, failure/successful performance of buildings/infrastructure in aftermath of disaster/failure event.
- Evaluating technical aspects of evacuation and emergency response procedures that contributed to extent of injuries and fatalities sustained during the event.
- Determining procedures and practices that were used in design, construction, operation and maintenance of buildings/infrastructure.
- Recommending, as necessary, specific improvements to standards, codes, and practices as well as any research and other appropriate actions based on study findings.

*NIST promotes, enables, and tracks adoption of recommendations through improved standards, codes, and practices as well as any research and other appropriate actions based on study findings.*



# NIST Authorities and Roles

- ***NIST Act (1901, as amended)***: This law provides for structural investigations; fire investigations; and research in engineering, pure and applied mathematics, statistics, computer science, materials science, and the physical sciences to include materials, mechanisms, structures, equipment, appliances, and systems.
- ***NCST Act (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.
- ***NEHRP Reauthorization Act (2004)***: the National Earthquake Hazards Reduction Program (NEHRP) Reauthorization Act, authorizes NIST to ensure that NEHRP includes the necessary steps to promote the implementation of earthquake hazard reduction measures by Federal, State, and local governments, national standards and model building code organizations, architects and engineers, and others with a role in planning and constructing buildings and lifelines.
- ***National Windstorm Impact Reduction Act (2004)***: provides for the establishment of the National Windstorm Impact Reduction Program (NWIRP), with the objective to achieve major measurable reductions in losses of life and property from windstorms. NIST responsibilities under the act include support for research and development to improve building codes and standards and practices for design and construction of buildings, structures, and lifelines.
- ***National Response Framework***: structural and fire safety; disaster operations and situation assessment; urban and industrial analysis; recovery.



# NIST Disaster and Failure Studies

| Earthquakes                                                                                                                                                                                                                                     | Hurricanes                                                                                                                                                                                                                                | Construction/<br>Building                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Tornadoes                                                                                                     | Fires                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>San Fernando, CA (1971)</p> <p>Mexico City, Mexico (1985)</p> <p>Loma Prieta, CA (1989)</p> <p>Northridge, CA (1994)</p> <p>Kobe, Japan (1995)</p> <p>Kocaeli, Turkey (1999)</p> <p>Maule, Chile (2010)*</p> <p>Christchurch, NZ (2011)*</p> | <p>Camille, MS/LA (1969)</p> <p>Alicia, Galveston, TX (1983)</p> <p>Hugo, SC (1989)</p> <p>Andrew, FL (1992)</p> <p>Hurricanes Mitch and Georges, LAC (1998)</p> <p>Hurricanes Katrina and Rita (2005)</p> <p>Hurricane Sandy (2012)*</p> | <p>Skyline Plaza Apartments, Bailey's Crossroads, VA (1973)</p> <p>Willow Island Cooling Tower, WV (1978)</p> <p>Kansas City Hyatt Regency, Kansas City, MO (1981)</p> <p>Riley Road Interchange, East Chicago, IN (1982)</p> <p>Harbor Cay Condominium, Cocoa Beach, FL (1981)</p> <p>L'Ambiance Plaza, Hartford, CT (1987)</p> <p>Ashland Oil Tank Collapse, Floreffe, PA (1988)</p> <p>U.S. Embassy, Moscow, USSR (1987)</p> <p>Murrah Federal Building, Oklahoma City, OK (1995)</p> <p>World Trade Center Disaster, New York, NY (2001)</p> <p>Dallas Cowboys Indoor Practice Facility, May 2009</p> | <p>Jarrell, TX (1997)</p> <p>Spencer, SD (1998)</p> <p>Oklahoma City, OK (1999)</p> <p>Joplin, MO (2011)*</p> | <p>DuPont Plaza Hotel, San Juan, PR (1986)</p> <p>First Interstate Bank Building, Los Angeles, CA (1988)</p> <p>Loma Prieta Earthquake, CA (1989)</p> <p>Hillhaven Nursing Home (1989)</p> <p>Pulaski Building, Washington, DC (1990)</p> <p>Happyland Social Club, Bronx, NY (1990)</p> <p>Oakland Hills, CA (1991)</p> <p>Hokkaido, Japan (1993)</p> <p>Watts St, New York City (1994)</p> <p>Northridge Earthquake, CA (1994)</p> <p>Kobe, Japan (1995)</p> <p>Vandalia St, New York City (1998)</p> <p>Cherry Road, Washington, DC (1999)</p> <p>Keokuk, IA (1999)</p> <p>Houston, TX (2000)</p> <p>Phoenix, AZ (2001)</p> <p>Cook County Administration Building Fire (2003)</p> <p>The Station Nightclub, RI (2003)</p> <p>Charleston, SC, Sofa Super Store Fire (2007)</p> <p>Witch Creek &amp; Guejito, CA, WUI Fire (2007)</p> <p>Amarillo, TX, WUI Fire (2011)</p> |



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\* Ongoing

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# Types of NIST Disaster and Failure Studies

- ***Preliminary Reconnaissance:*** a field study at a disaster or failure site to gather information and to help determine if a technical investigation is warranted.
- ***Technical Investigation:*** a fact-finding study that will likely result in recommendations for improvements to standards, codes, and practices and/or new knowledge. Studies may range anywhere from:
  - limited scope, i.e., *based on data collection and interpretation, modest analytical efforts, and judgment of technical experts,*  
to
  - extensive scope, i.e., *based on in-depth technical study—including extensive use of data, models, analytical and computational tools, laboratory and/or field experiments, and/or interviews.*



# NIST's Role in Disaster and Failure Studies

- NIST may use any one or a combination of the study options below in conducting a preliminary reconnaissance or a technical investigation:
  - **NIST may lead post-event studies.** These studies may involve a preliminary reconnaissance followed by a technical study that may include the characterization of the hazard, the safety and performance of buildings and structures, and the associated emergency response and evacuation procedures. Private sector experts may be involved in these studies through contracts. Other public sector experts may also be involved in these studies.
  - **NIST may coordinate or participate in post-event studies.** These studies may involve significant participation and/or coordination by other federal agencies with mission responsibilities and expertise.
  - **NIST may sponsor or participate in private sector-led post-event studies.** These studies may involve preliminary reconnaissance followed by a technical study that is limited in scope. NIST participation may be limited to guidance, oversight, and/or serving as a technical expert. These studies may involve significant private sector leadership and participation augmented with public sector experts.
  - **NIST may provide technical assistance in the reconstruction process for international disaster and failure events** at the request of U.S. agencies, industry, private organizations, governments of other nations, or international organizations.



# International Disaster and Failure Events

- NIST may conduct reconnaissance of international disaster or failure events when lessons can be learned for the U.S.
- NIST involvement in international disaster and failure studies generally are undertaken:
  - in cooperation with other U.S. agencies, industry or private organizations, governments of other nations, or international organizations
  - for the purpose of establishing or improving codes, standards, and practices in the U.S.
- The decision criteria and guidelines for conducting studies are not intended to preclude situations where NIST is requested by other U.S. agencies, industry, private organizations, governments of other nations, or international organizations to provide technical assistance, on a reimbursable basis, in the reconstruction process for international disaster and failure events.



# NIST Decision Criteria and Guidelines

- NIST has developed Decision Criteria and Guidelines that provide a rational basis for evaluating whether NIST should conduct a study.
  - NIST considers staff availability, resource availability, staff safety, and the quality and adequacy of information and artifacts available to conduct a meaningful study.
  - To the extent practicable, NIST will deploy a team in a timely manner after a disaster or failure event.
- If the Congress or the Administration issues a directive to respond to an event, NIST will consider conducting a technical investigation with scope that ranges anywhere from limited to extensive as appropriate to the event.
- The decision criteria and procedures may be refined as NIST gains experience with their use.



# Categories of Decision Criteria

- Substantial Loss of Life or Disabling Injury
- Significant Potential for Loss of Life: Exposed Population
- Level of Hazard
- Consequences (Extent of Damage and Loss of Functionality)
- Need for NIST involvement
- Stakeholder Concern
- Evacuation / Emergency Response Challenges
- International Events



# Preliminary Reconnaissance Criteria

| Preliminary Reconnaissance Criteria                                  | Low (1)                                                                                | Med (3)                                                                       | High (5)                                                               |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------|
| <b>1. Substantial Loss of Life or Disabling Injury</b>               |                                                                                        |                                                                               |                                                                        |
| Single or adjacent structures                                        | 0                                                                                      | 1 to 2                                                                        | >2                                                                     |
| Community (city, county, metropolitan area)                          | 0 to 3                                                                                 | 4 to 9                                                                        | >10                                                                    |
| Region (state to multi-state)                                        | 0 to 5                                                                                 | 6 to 19                                                                       | >20                                                                    |
| <b>2. Significant Potential for Loss of Life: Exposed Population</b> |                                                                                        |                                                                               |                                                                        |
| Single structure (occupancy)                                         | <100                                                                                   | 100 to 499                                                                    | ≥500                                                                   |
| Community (city, county, metropolitan area)                          | <1 000                                                                                 | 1 000 to 9 999                                                                | ≥10 000                                                                |
| Region (state to multi-state)                                        | <100 000                                                                               | 100 000 to 999 999                                                            | ≥1 000 000                                                             |
| <b>3. Actual Hazard</b>                                              |                                                                                        |                                                                               |                                                                        |
| Earthquake                                                           | ≤ MMI IV                                                                               | MMI V to VII                                                                  | ≥MMI VIII                                                              |
| Hurricane at Landfall                                                | ≤Cat 3                                                                                 | Cat 4                                                                         | Cat 5                                                                  |
| Tornado                                                              | ≤EF3                                                                                   | EF4                                                                           | EF5                                                                    |
| Coastal Inundation                                                   | < 3 ft                                                                                 | 3 to 9 ft                                                                     | ≥ 10 ft                                                                |
| Fire Spread in a Structure                                           | Fire spread not beyond area of origin                                                  | Fire spread throughout a structure                                            | Fire spread beyond structure of origin                                 |
| Wildland Urban Interface (WUI)                                       | High Forest Service Fire Danger Rating                                                 | Very High Forest Service Fire Danger Rating                                   | Extreme Forest Service Fire Danger Rating                              |
| Blast                                                                | < 99 lbs. TNT-equivalent                                                               | 100 - 999 lbs. TNT-equivalent                                                 | >1000 lbs. TNT-equivalent                                              |
| Impact                                                               | < 1 x 10 <sup>6</sup> ft lb/sec                                                        | 1 x 10 <sup>6</sup> to 1 x 10 <sup>7</sup> ft lb/sec                          | > 1 x 10 <sup>7</sup> ft lb/sec                                        |
| <b>4. Consequences (damage and functionality)</b>                    |                                                                                        |                                                                               |                                                                        |
| Failure during Construction                                          | Local structural failure                                                               | Partial structural collapse                                                   | Total structural collapse                                              |
| Engineered Building Structures                                       | Minimal nonstructural damage                                                           | Significant nonstructural damage<br>Minimal structural damage                 | Significant structural damage or collapse                              |
| Transportation & Utility Structures                                  | Minimal nonstructural damage                                                           | Minimal structural damage<br>Partial loss of function                         | Significant structural damage or collapse<br>Complete loss of function |
| Non-Engineered Building Structures                                   | Minimal nonstructural damage                                                           | Minimal structural damage                                                     | Significant structural damage or collapse                              |
| <b>5. Need for NIST Involvement</b>                                  |                                                                                        |                                                                               |                                                                        |
| NIST Authority                                                       | Addressed by other authorities – and their mission responsibility and agency expertise | Collaboration with other agencies where NIST provides complementary expertise | NIST has primary authority and/or expertise                            |
| <b>Score</b>                                                         | <b>Sum</b>                                                                             | <b>___ x 1</b>                                                                | <b>___ x 3</b>                                                         |
|                                                                      |                                                                                        |                                                                               | <b>___ x 5</b>                                                         |

# Preliminary Reconnaissance Criteria (2)

| Preliminary Reconnaissance Criteria                                                     | Low (1)                                      | Med (3)                                          | High (5)                                       |
|-----------------------------------------------------------------------------------------|----------------------------------------------|--------------------------------------------------|------------------------------------------------|
| <b>6. Stakeholder Concern</b>                                                           |                                              |                                                  |                                                |
| Federal disaster declaration                                                            | N/A                                          | Declaration;<br>Minimal structural damage        | Declaration;<br>Significant structural damage  |
| Request by other Authorities (local, state, federal)                                    | None                                         | NIST provides complementary expertise            | NIST has primary expertise                     |
| Public Interest.                                                                        | Local news                                   | State or regional news                           | National news                                  |
| Unique event with potential broad implications for similar or other types of structures | Minimal impact                               | Moderate impact                                  | Significant impact                             |
| <b>Score</b> <b>Sum</b>                                                                 | __ x 1                                       | __ x 3                                           | __ x 5                                         |
|                                                                                         |                                              |                                                  |                                                |
| <b>Total Score</b> <b>Total Sum</b>                                                     | __ x 1                                       | __ x 3                                           | __ x 5                                         |
|                                                                                         |                                              |                                                  |                                                |
| <b>7. Evacuation and Emergency Response</b>                                             |                                              |                                                  |                                                |
| Evacuation                                                                              | Normal evacuation                            | Moderate evacuation challenges                   | Significant evacuation challenges              |
| Emergency Response                                                                      | Normal operations                            | Moderate operational challenges                  | Significant operational challenges             |
| <b>Score</b> <b>Sum</b>                                                                 | __ x 1                                       | __ x 3                                           | __ x 5                                         |
|                                                                                         |                                              |                                                  |                                                |
| <b>8. International Events*</b>                                                         |                                              |                                                  |                                                |
| Codes, standards and enforcement                                                        | No building codes, standards, or enforcement | Building codes and standards, but no enforcement | Building codes and standards, with enforcement |
| Construction practices similar to the U.S.                                              | Minimally similar                            | Moderately similar                               | Significantly similar                          |
| <b>Total Score: (From 1-6) __ x __ = __</b> <b>Sum</b>                                  | (0.7) <sup>n</sup>                           | (0.9) <sup>n</sup>                               | (1.0) <sup>n</sup>                             |

\* n is 0,1, or 2, depending on the number of selected items under each ranking category (i.e., Low, Med, or High) for Criteria 8. The factor applied to the Total Score is the product of all three factors.



# Application of the Decision Criteria

- Weighted score  $\geq 4.0$  – A preliminary reconnaissance will be conducted
- Weighted score  $\leq 3.0$  – A preliminary reconnaissance will not be conducted
- Weighted score between 3.0 and 4.0 – Additional factor in Decision Criteria will be used to determine whether a preliminary reconnaissance will be conducted



# Recent Disasters and NIST Criteria Scores

- Disasters that were evaluated against the criteria since last Committee meeting (11/7/11)
- Calculated preliminary reconnaissance criteria scores
- NIST action on Hurricane Sandy



# “Leap Day” Tornado Outbreak (2/28-29/12)

- 42 confirmed tornadoes (NE, KS, MO, IL, KY, IN, TN) (NOAA)
- 1 EF4 (Harrisburg, IL) (NOAA)
- 15 fatalities (NOAA and other news sources)



# March Tornado Outbreak (3/2-3/12)

- 70 confirmed tornadoes (NOAA)
- 2 EF4 (Henryville, IN and West Liberty, KY) (NOAA)
- 40 fatalities (NOAA and other news sources)



Source: FEMA



Source: FEMA



# Waldo Canyon Wildfire (CO) (6/23 – 7/10/12)

- Fire started 4 miles NW of Colorado Springs (Wikipedia)
- 346 homes destroyed (The Gazette)
- Burned area – 28.5 square miles (InciWeb.org)
- 2 fatalities (The Gazette)



# Cheverly, MD Warehouse Collapse (6/29/12)

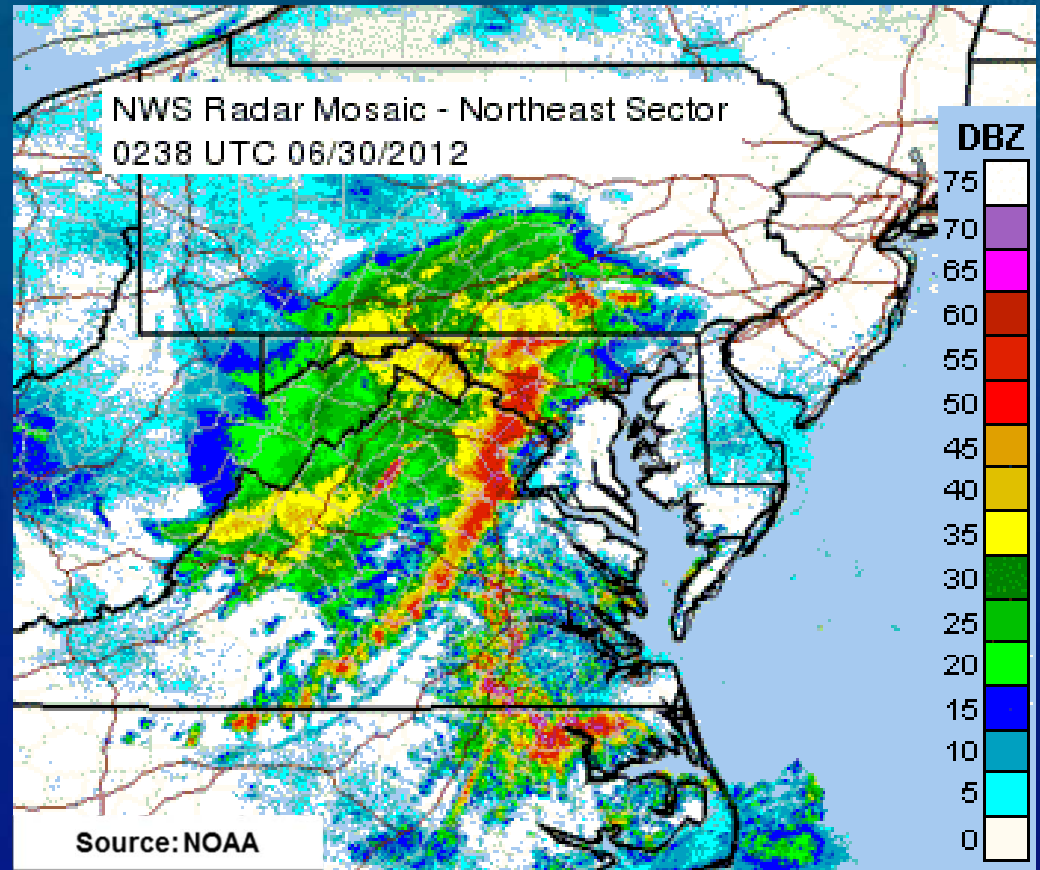
- Document warehouse
- Shelves 50 feet high, 100 yards long
- Hit accidentally by forklift, causing “domino” collapse
- One worker killed

(Source: Washington Post)



# Mid-Atlantic Derecho (6/29/12)

- The Derecho produced (70-90) mph wind gusts (NOAA)
- Over 3.7 million customers lost power (Chicago Tribune and other news sources)
- 22 killed in 7 states (NOAA)



# Miami-Dade College Parking Garage Collapse (10/10/12)

- \$22.5 million, 5 story garage under construction
- Cause still under investigation
- 4 workers killed

(Source: Miami Herald)



# Hurricane Sandy (10/29/12)

- Damage in US estimated over \$71 billion (11/27 Reuters)
- 8.5 million combined total peak outages (Dept of Energy)
- 131 killed in eight states (11/16 Reuters)
- 2<sup>nd</sup> costliest US hurricane since 1900 (National Hurricane Center)



# Tamweel Tower Fire (Dubai) (11/18/12)

- 34-floor residential high-rise
- Fire spread through flammable cladding
- Investigation ongoing, faulty AC unit on service floor suspect

(Source: [emirates247.com](http://emirates247.com))



## Recent Disasters

| Date  | Event                              | Total Weighted Score |
|-------|------------------------------------|----------------------|
| 2/12  | Leap day tornado outbreak          | 3.0                  |
| 3/12  | IN and KY tornado outbreak         | 3.0                  |
| 6/12  | Waldo Canyon Wildfire (CO)         | 3.0                  |
| 6/12  | Cheverly, MD Building Collapse     | 2.0                  |
| 6/12  | Mid-Atlantic Derecho               | 3.3                  |
| 10/12 | Miami-Dade Parking Garage Collapse | 2.5                  |
| 10/12 | Hurricane Sandy                    | 3.3                  |
| 11/12 | Tamweel Tower Fire (Dubai)         | 3.0                  |



# Similarities Between Hurricanes Katrina and Sandy

- Damage to residential structures due to coastal inundation
- Damage to electrical distribution and transportation systems
- Many findings and recommendations from NIST's Hurricane Katrina and Rita Study applicable to Sandy
  - ⇒ Technical investigation to determine causes not necessary
- Some unique aspects of Hurricane Sandy
  - Greater than design level storm surge
  - Storm surge effects on dense urban area with extensive underground transportation and other infrastructure



# Hurricane Sandy

- Dr. Therese McAllister (NIST) participating on FEMA's Mitigation Assessment Team (MAT)
- NIST's Objective within the MAT
  1. Collect data/observations on the performance of critical facilities and infrastructure systems in the affected area to support the development of resilience metrics for buildings in a dense urban community.
  2. Examine the effect of cascading infrastructure failures on the performance and recovery of critical facilities.
- FEMA's MAT Report scheduled to be finalized in September 2013



# Hurricane Sandy: New York State Ready Commission

- Dr. Shyam Sunder, Director, NIST Engineering Laboratory, serving on Ready Commission
- Launched by Governor Andrew Cuomo in the aftermath of recent major storms
- Will recommend ways to ensure critical systems and services are prepared for future natural disasters and other emergencies
- Preliminary recommendations are due on January 3, 2013



# Recent Significant Code Change Activities Based on NIST Non-NCST Studies – Collapse of the Dallas Cowboys Practice Facility

- NIST's recommendation addressed three aspects of design of fabric-covered frame structures: (1) use of the fabric to provide lateral bracing to the frames; (2) determination of appropriate enclosure classification for calculating design wind loads; and (3) ability of the structural system to maintain overall structural integrity.
- Two code changes, responsive to NIST's recommendation, were adopted by the International Code Council (ICC) for the 2015 International Building Code. These changes require that:
  - tensile membrane structures be designed according to the ASCE Standard for Tensile Membrane Structures (ASCE 55-10). Addresses aspects (1) and (3) above.
  - in membrane covered frame structures, the membrane shall not provide required lateral stability to the frames. Addresses aspect (1) above.



# Recent Significant Code Change Activities Based on NIST Non-NCST Studies – Charleston Sofa Super Store Fire

- ICC's Code Technology Committee voted to move forward with four code change proposals responsive to the recommendations of the study.
- The proposals include provisions for periodic inspections, recordkeeping, inspector qualifications, and sprinklers for some retail/mercantile occupancies that display and/or fabricate upholstered furniture and mattresses. A fifth proposal regarding change of occupancy triggers may be reworked and submitted by the January deadline.
- If approved, code changes would be effective in 2015 I-Codes (International Fire Code and International Existing Building Code)



# Procedures For Conducting Disaster and Failure Studies

- NIST has promulgated detailed regulations to implement the NCST Act
- NIST uses systematic internal procedures for conducting disaster and failure studies that are consistent with regulations under the NCST Act
- NIST is in the process of documenting those procedures in written form for use as a guide in future disaster and failure studies. These procedures include:
  - Establishing a team
  - Coordination with other agencies, organizations
  - Decision criteria
  - Safety
  - Collection of data and artifacts
  - Report production



# Disaster and Failure Studies Support Contract

- Program requires as-needed technical support
  - Conducting Disaster and Failure Studies including assistance with:
    - Collecting data and artifacts
    - Conducting simulation and modeling
    - Completing study deliverables such as reports
  - Supporting Disaster and Failure Events Data Repository
  - Supporting NIST's NCST Advisory Committee responsibilities
- NIST conducted an open competition in 2012



# Contract Award

- Team includes experts in hazard-specific areas, field data collection and analysis, database design, and administrative support
- Prime: wind, blast, impact (Applied Research Associates)
- Subcontractors:
  - Structural investigations, earthquake (Wiss Janney Elstner)
  - Fire (Rolf Jensen & Associates)
  - HUB technology (Purdue University)
  - Remote sensing, mapping (ImageCAT)





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## Questions/Discussion

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