National Institute of Standards and Technology
National Construction Safety Team Act
Annual Report

Fiscal Year (FY) 2013

Summary

This annual report to Congress for fiscal year (FY) 2013 is required by the National Construction Safety Team (NCST) Act.

Most notably, during FY 2013, the National Institute of Standards and Technology (NIST) completed its investigation of the tornado that struck Joplin, MO, on May 22, 2011, and published its final report as a draft for public comment. In FY 2011, NIST Director Patrick Gallagher established a Team under the NCST Act to conduct the technical investigation of the May 22, 2011, Joplin tornado with the primary objectives to:

- Determine the tornado hazard characteristics and associated wind fields in the context of historical data;
- Determine the pattern, location, and cause of fatalities and injuries, and associated performance of emergency communications systems and public response;
- Determine the response of residential, commercial, and critical buildings, including the performance of designated safe areas;
- Determine the performance of lifelines as it relates to the continuity of operations of residential, commercial, and critical buildings; and,
- Identify, as specifically as possible, areas in current building, fire, and emergency communications codes, standards, and practices that warrant revision.

The draft final report, released for public comment on November 21, 2013, included 16 recommendations for improvement to codes, standards, and practices. Those recommendations address:

- Needed improvements in national performance standards and methods for critical structures,
- Installing tornado shelters in new and existing multi-family residential, commercial, and other larger buildings (hospitals, schools, large retail stores, and other commercial spaces); and
- National codes and standards for clear, consistent and accurate emergency communications, and joint planning to ensure that those communications are delivered and received.

The public comment period closed on January 6, 2014. NIST will consider the comments received, make modifications to the report as warranted, and release its final report in March, 2014. For a summary of the study, see: http://www.nist.gov/el/disasterstudies/joplin-112113.cfm.

NIST also conducted a preliminary reconnaissance of the tornado that struck Moore, OK, on May 20, 2013. Major portions of that effort were completed in FY 2013 and culminated in NIST Special Publication (SP) 1164 (*Preliminary Reconnaissance of the May 20, 2013 Newcastle-Moore Tornado in Oklahoma*[1]). NIST SP 1164, published on December 3, 2013, includes observations that are consistent with the draft recommendations in the May 22, 2011, Joplin Tornado investigation report.

[1] http://www.nist.gov/customcf/get_pdf.cfm?pub_id=914721

Reflecting discussions with House Science Committee staff and the members of the National Construction Safety Team Advisory Committee (Advisory Committee), NIST updated its decision criteria and guidelines that provide a rational basis for evaluating whether NIST should conduct an NCST study. The revisions specifically broaden consideration for buildings-related damage that is non-structural but that carries consequences to the resilience of the community.

One meeting of the Advisory Committee was held during the fiscal year, on December 10, 2012, (http://www.nist.gov/el/disasterstudies/ncst/upload/NCSTACfinalMtgSummary_10Dec2012.pdf). That meeting focused on progress made in – and issues in conducting – the May 22, 2011, Joplin Tornado investigation, the development of the disaster and failure events data repository, and other disaster- and failure-related work by NIST. In that meeting, NIST also responded to and discussed the Advisory Committee's most recent recommendations to NIST at the November 7, 2011, Advisory Committee meeting.

Introduction

In October 2002, the NCST Act (P.L. 107-231) was signed into law by President George W. Bush and authorizes the Director of NIST to establish and deploy Teams to investigate events leading to failure of a building or buildings that result in substantial loss of life or that pose significant potential for substantial loss of life.

The purpose of these investigations is to improve the safety and structural integrity of buildings in the United States (U.S.). A Team shall:

(A) Establish the likely technical cause or causes of the building failure;
(B) Evaluate the technical aspects of evacuation and emergency response procedures;
(C) Recommend as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to subparagraphs (A) and (B); and,
(D) Recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve the evacuation and emergency response procedures, based on the findings and recommendations of the investigation.

Under Section 10 of the NCST Act, NIST is to provide an annual report to the House of Representatives Committee on Science, Space, and Technology and to the Senate Committee on Commerce, Science, and Transportation by February 15 of each year. This report is to include:

(1) A summary of the investigations conducted by Teams during the prior fiscal year;
(2) A summary of recommendations made by the Teams in reports issued under Section 8 of the NCST Act during the prior fiscal year and a description of the extent to which those recommendations have been implemented; and
(3) A description of the actions taken to improve building safety and structural integrity by the NIST during the prior fiscal year in response to reports issued under Section 8 of the NCST Act.

This report summarizes NIST's activities under the NCST Act for FY 2013. Summaries of NIST's non-NCST activities of interest are provided in the Appendix A and Appendix B.

1. Investigations Conducted Under the NCST Act during FY 2013

NIST completed its NCST investigation of the May 22, 2011, Joplin, Missouri, tornado and published its draft final report for public comment on November 21, 2013.

On May 22, 2011, a massive tornado impacted Joplin, MO. The tornado was rated EF 5, the most powerful on the Enhanced Fujita tornado scale. According to the National Weather Service (NWS), the multiple-vortex storm impacted an area approximately three-quarters of a mile wide by 14 miles long, destroyed some 8,000 buildings in its path, killed 161 people, and injured over 1,000. This makes it the single deadliest tornado in the U.S. in the 61 years that official records have been kept.

NIST sent four researchers/engineers to Joplin from May 25-28, 2011, to conduct a preliminary reconnaissance of building performance and emergency communications during the tornado. Based on the recommendations of the preliminary reconnaissance and analysis of the additional criteria set forth in the regulations implementing the NCST Act, the NIST Director established a Team under the NCST Act to conduct a more comprehensive study of the impacts of the disaster. The primary objectives of the Team's investigation of the May 22, 2011, Joplin Tornado were to:

- Determine the tornado hazard characteristics and associated wind fields in the context of historical data.
- Determine the pattern, location, and cause of fatalities and injuries, and associated performance of emergency communications systems and public response.
- Determine the response of residential, commercial, and critical buildings, including the performance of designated safe areas.
- Determine the performance of lifelines as it relates to the continuity of operations of residential, commercial, and critical buildings.
- Identify, as specifically as possible, areas in current building, fire, and emergency communications codes, standards, and practices that warrant revision.

The draft final report issued on November 21, 2013, includes 47 findings and 16 recommendations that provide the technical basis for:

- Assessing tornado hazard probabilities at the local, regional, and national levels;
- Improving emergency communications systems and public response to those communications; and,
- Improving tornado-resilient design and construction of buildings and structures, including residential buildings, designated safe areas within buildings, and lifeline facilities as related to maintaining building operations.

Specifically, the NIST draft report calls for:

- Developing national performance-based standards for tornado-resistant design of buildings and infrastructure, as well as design methods to achieve those standards, and require that critical facilities such as hospitals, be designed to remain operational in the event of a tornado;
- Installing tornado shelters in new and existing multi-family residential, commercial, and other larger buildings (hospitals, schools, large retail stores, and other commercial spaces with assembly occupancies) and as part of this effort, develop and implement uniform national guidelines to help communities site, design, install, and operate those shelters; and
- Creating national codes and standards for clear, consistent and accurate emergency communications and then ensuring that emergency managers, the National Weather Service (NWS), and the news media in local communities have a joint plan for delivering those messages quickly and persuasively during tornados.

Details are available in the draft final report, *Technical Investigation of the May 22, 2011, Tornado in Joplin, Missouri.*[2] NIST released the report at briefings for the Joplin community and the media on November 21, 2013; the public comment period closed on January 6, 2014. NIST expects to release a final version of its report on March 28, 2014. (NIST also issued a *progress report*[3] earlier in FY 2013.)

2. Summary of Recommendations Made by Teams in Reports Issued Under Section 8 of the NCST Act during FY 2013

During FY 2013, NIST issued a draft final report for public comment on its May 22, 2011, Joplin Tornado investigation. The final report is expected to be issued on March 28, 2014, after receipt and consideration of public comments. In its draft final report, NIST made 16 recommendations for improving how buildings and shelters are designed, constructed and maintained in tornado-prone regions; and for improving the emergency communications that warn of imminent threat from tornadoes.

A major recommendation made in the report is "the development and adoption of nationally accepted performance-based standards for the tornado-resistant design of buildings and infrastructure to ensure the resiliency of communities to tornado hazards." This includes a call for designing and constructing essential buildings—such as hospitals and emergency operations centers—and infrastructure to remain operational in the event of a tornado. Additionally, the draft final report recommends the development of methods that will ensure all building components and systems meet the proposed performance objectives; uniform national guidelines be developed that enable communities to create the safest and most effective public sheltering strategies; shelters be installed in new and existing multi-family residential and commercial buildings, schools and in buildings with assembly occupancies (such as theaters and places of worship) located in tornado hazard areas; nationally accepted codes and standards, as well as uniform guidance for clear, consistent and accurate emergency communications; and future research and development of technologies and strategies to advance tornado wind measurements, strengthen emergency communications, increase warning time, derive more accurate tornado hazard maps and significantly improve public response during tornado events.

NIST also issued observations from the preliminary reconnaissance of the May 20, 2013, Newcastle-Moore tornado in Oklahoma which support the recommendations made in the draft final report of the May 22, 2011, Joplin Tornado investigation.

3. Actions Taken to Improve Building Safety and Structural Integrity during FY 2013 in Response to Reports Issued Under Section 8 of the NCST Act

In its *Final Report on the Collapse of the World Trade Center Towers*,[4] NIST recommended that "progressive collapse be prevented in building through the development and nationwide adoption of consensus standards and code provisions." In FY 2012, based on a proposal from NIST, a new ASCE/SEI Standards Committee called the "Disproportionate Collapse Mitigation Standard" Committee was established. This new voluntary standards committee plans to draft a standard that would address NIST's recommendation within the next three years. This would add to the long list

[2] http://www.nist.gov/el/disasterstudies/weather/joplinpubliccomments.cfm
[3] Progress Report National Institute of Standards and Technology (NIST); Technical Investigation of the May 22, 2011, Tornado in Joplin, Missouri - http://www.nist.gov/manuscript-publication-search.cfm?pub_id=912461
[4] http://www.nist.gov/customcf/get_pdf.cfm?pub_id=909017

of actions that have been taken to improve building safety and structural integrity as a result of NCST investigations. Additional information about changes to building codes and standards can be found at http://www.nist.gov/el/disasterstudies/wtc/wtc_recommendations.cfm

For actions taken by NIST to improve building safety and structural integrity during FY 2013 in response to studies conducted under other NIST authorities, see Appendix A.

4. Other NIST Activities Related to the NCST Act

Reflecting discussions with House Science Committee staff and the members of the NCST Advisory Committee, NIST updated its decision criteria and guidelines that provide a rational basis for evaluating whether NIST should conduct a study either under the NCST Act regulations or other non-NCST NIST authorities (see Appendix C). The updates specifically broaden consideration for – and give greater weight to a loss of non-structural buildings-related damage that causes loss in building functionality which directly affects the resilience of the community. A summary of other NIST non-NCST activities related to disasters and failures is given in Appendix D.

Appendix A

Studies Conducted and Actions Taken by NIST to Improve Building Safety and Structural Integrity under Legal Authorities other than the NCST Act in FY 2013

A.1 Studies Conducted

Newcastle-Moore, Oklahoma, Tornado

In FY 2013, NIST conducted a preliminary reconnaissance of the EF 5 tornado that struck Moore, OK, and surrounding areas on May 20, 2013. The tornado caused 24 fatalities, including seven schoolchildren who were taking shelter in their designated tornado safety area at the Plaza Towers Elementary School. Approximately 2,400 buildings were damaged or destroyed, including two elementary schools and the only hospital in the City of Moore.

At the time of the Newcastle-Moore tornado, NIST was nearing completion of its technical investigation of the EF 5 tornado that struck Joplin, Missouri, on May 22, 2011. NIST conducted a preliminary reconnaissance of the May 20, 2013, Newcastle-Moore tornado, to see if an investigation of this tornado was warranted. The results of the preliminary reconnaissance were that a separate investigation of the Newcastle-Moore tornado was not warranted but that some of the information obtained by the preliminary reconnaissance team was pertinent to the Joplin investigation. The objectives of the Newcastle-Moore Tornado preliminary reconnaissance were therefore limited to:

- Collecting data and information on the performance of the emergency communications systems immediately prior to and during the tornado; and
- Collecting data and information on the response of critical and educational facilities (specifically, the Moore Medical Center and Briarwood and Plaza Towers Elementary Schools) to the tornado, including emergency operations, the physical performance of the buildings and designated safe areas, and life safety outcomes.

The preliminary reconnaissance was conducted in cooperation with the NOAA's National Severe Storms Laboratory. The preliminary reconnaissance Team documented the physical damage to understand the performance of buildings and designated safe areas, as well as life safety outcomes. In addition, NIST interviewed first responders, emergency managers, NWS meteorologists, teachers and staff at the elementary schools, staff from the Moore Medical Center, and others. Details are available in the report, *Preliminary Reconnaissance of the May 20, 2013, Newcastle-Moore Tornado in Oklahoma*.[5] Observations from the preliminary reconnaissance of the Newcastle-Moore tornado support the recommendations made in the draft final report of the Joplin tornado investigation.

Hurricane Sandy

NIST's non-NCST Act work in the hurricane area included assignment in early FY 2013 of a staff member to participate in the Federal Emergency Management Agency (FEMA)'s Mitigation Assessment Team (MAT) study to examine the storm surge and flood effects from Hurricane Sandy (October 2012) on critical facilities in the affected area (New York and New Jersey). NIST's contribution to the FEMA MAT's Hurricane Sandy effort culminated in the co-authorship of the

[5] http://www.nist.gov/manuscript-publication-search.cfm?pub_id=914721

FEMA MAT report[6] that was released on November 27, 2013.

In late October 2012, Hurricane Sandy impacted the United States. The hurricane caused tens of billions of dollars in damage and killed 131 people in eight states[7]. There were several unique aspects of this event. The flood levels experienced exceeded design-level in many locations, based on FEMA's Flood Insurance Rate Maps and codes and standards adopted by local jurisdictions. The flood event impacted a dense urban area with complex interdependent infrastructure (much of which is located underground) and critical facilities. The loss of the infrastructure caused substantial disruption to the community and to building functionality. NIST participated in the FEMA MAT study to examine the storm surge and flood effects from Hurricane Sandy on critical facilities in the most affected areas (New York and New Jersey).
The primary objectives of NIST's role in the study were to:

- 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.
- Examine the effect of cascading infrastructure failures on the performance and recovery of critical facilities.

The collected data included information on the performance and design criteria for American Society of Civil Engineers (ASCE) 7 Risk Category IV facilities, such as hospitals, data centers, facilities for power and communication, and emergency response facilities. These observations are important for evaluating the concurrent failure of multiple critical facilities within a community. In addition to contributing expertise to the MAT, the findings will provide additional value as a case study for NIST research on community resilience.

A.2 Actions Taken to Improve Building Safety and Structural Integrity

NIST's Disaster and Failure Studies Program coordinates its efforts with the NIST Engineering Laboratory's Codes and Standards Program to promote, enable, and track the adoption of NCST investigation recommendations, as well as other NIST studies' recommendations, through improved standards, codes, and practices and through any research and other appropriate actions based on study findings to improve building safety and structural design. NIST issued its final report on the Sofa Super Store fire that occurred in Charleston, SC, in March 2011. The final report included recommendations that have resulted in several code changes and proposed changes. See: http://www.nist.gov/el/disasterstudies/fire/upload/RecommendationsCharlestonSofaStoreFire.pdf

In FY 2013, NIST worked with the ICC's Code Technology Committee (CTC) to move forward with three code change proposals responsive to the recommendations of NIST's study. Proposed code requirements associated with recordkeeping, periodic inspections and sprinkler system protection for retail, manufacturing and storage occupancies that display, fabricate or store upholstered furniture or mattresses were successful at ICC public hearings. ICC code changes will be effective in 2015 I-Codes (International Fire Code and International Existing Building Code).

[6] http://www.fema.gov/media-library/assets/documents/85922
[7] http://www.reuters.com/article/2012/11/16/us-storm-sandy-deaths-idUSBRE8AF0ZX201211

Appendix B

Disaster and Failure Events Data Repository

NIST made progress in FY 2013 in the development of a Disaster and Failure Events Data Repository that will serve as an archival database of significant hazard events. The repository, which is accessible on NIST's website, will also help ensure that this valuable information is organized and maintained to enable the study and analysis of, and comparison with, subsequent severe disaster events. The repository will contain information gathered during NCST investigations as well as other NIST-led studies. It may also be populated with information from non-NIST events.

The data repository is being established in three phases:

- Phase 1 (launched August 2011) includes data from NIST's six-year investigation of the collapses of three buildings at New York City's World Trade Center (WTC 1, 2 and 7) on September 11, 2001.
- Phase 2 significantly advanced the data repository in FY 2013, including major development work on database software from Purdue University that will offer enhanced features and enable easy and appropriate accessibility. The data repository will also support the National Earthquake Hazards Reduction Program (NEHRP). The repository will next be populated with datasets from the 2010 earthquake in Chile and the 2011 Joplin, MO, tornado investigation that will serve as a pilot for this new software. NIST plans an initial release of the Chile and Joplin datasets on the NIST website in FY 2014. In FY 2013, work began to obtain data previously collected by other organizations.
- Phase 3 involves the implementation plan for the repository, which includes:
  - Finalizing user requirements and the creation of a system design document;
  - Developing standard data collection systems for different kinds of events;
  - Selecting the operating platform based on user requirements;
  - Populating the repository with selected high-impact data from historical and future events;
  - Developing a plan to maintain, update, operate and improve accessibility of the repository; and,
  - Establishing a process for stakeholder outreach.

In addition to providing high-value information for researchers and the building community, the repository will speed NIST's response to public requests for information. NIST's smartphone, i-Pad and tablet computer-based application developed in FY 2013 for collecting Wildland Urban Interface (WUI) fire data will facilitate the integration of this information within the repository's structure.

Appendix C

Screening Criteria and Summary Assessment for Disaster Failure Studies[8]

Date **Event**
General Principles and Summary Assessment for Preliminary Reconnaissance
Responses to Questions Addressing General Principles
1. What is the unique new knowledge that would be potentially gained from this study?
2. What is the anticipated potential impact on standards, codes and practices?
3. Do we have sufficient resources (people and funding) to support a study? If there is an existing study in the same hazard area, what is the impact on the current study?
4. What is a current assessment of how site conditions would affect safety for a field deployment? Would current site conditions affect the timing of the field deployment?
5. Is there a request for NIST to conduct a study by others (local, state, Federal)? If so, would NIST provide complementary expertise or would NIST provide unique expertise that would not be available otherwise?
6. Does NIST have primary authority? If so, would NIST collaborate with other agencies where NIST provides complementary expertise or would NIST have primary authority and/or provide unique expertise that would not be available otherwise?
Summary Assessment:

[8] NIST uses the screening criteria and summary assessment to aid in the decision on whether to conduct a preliminary reconnaissance of a disaster or failure event. Depending on the specifics of the event and the objectives of NIST, a preliminary reconnaissance may be conducted under one of the NIST authorities which include the NCST Act. See http://www.nist.gov/el/disasterstudies/upload/NISTDisasterandFailureStudiesFactsheet111212.pdf for more information about NIST Disaster and Failure Studies Program and other NIST statutory authorities.

Date and Event Description			
Preliminary Reconnaissance Criteria[9]	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[10]	0 to 3	4 to 9	>10
C. Regional context[11]	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	$< 1 \times 10^6$ ft lb/sec	1×10^6 to 1×10^7 ft lb/sec	$> 1 \times 10^7$ ft lb/sec
4. Consequences to Resilience[12]			
A. Failure during Construction or in Service[13]	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[14]	Minimal physical damage and/or loss of function	Moderate physical damage and/or loss of function	Severe physical damage and/or loss of function

[9] NIST will monitor event information and continue to screen the event against preliminary reconnaissance criteria as data become available.
[10] May include scales from a neighborhood to an entire metropolitan area or county
[11] Greater than community context to multi-state
[12] Resilience refers to the ability of buildings, infrastructure lifelines, and communities to withstand the hazard(s) and recover rapidly with minimal effects on life safety, continuity of operations and business interruption. In addition to resilience of buildings and infrastructure lifelines, disaster resilience includes the preparedness of the community's emergency response, evacuation and social systems.
[13] Failure during Construction excludes construction equipment failures. Failure in Service refers to an event while the facility is in active use, cause of failure unknown.
[14] Building systems includes all the systems necessary for its functional operation, including building envelope, structural, fire and life safety, mechanical, electrical, plumbing, security, communication and IT systems.

C. Transportation & Utility Systems[15]	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[16]			
A. Evacuation	Normal evacuation	Moderate evacuation challenges	Severe evacuation challenges
B. Emergency Response	Normal operations	Moderate operational challenges	Severe operational challenges
Score: __/__ = __ Sum	__ x 1	__ x 3	__ x 5

6. International Events			
A. Codes, standards and enforcement	No building codes, standards, or enforcement	Building codes and standards, with minimal enforcement	Building codes and standards, with enforcement
B. Construction practices similar to the US	Minimally similar	Moderately similar	Significantly similar
Total Score: (From 1-4) __x__ = __ Sum	$(0.8)^n$	$(0.9)^n$	$(1.0)^n$

- **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 6. The factor applied to the Total Score is the product of all three factors.**

[15] Transportation systems include aviation, highway infrastructure, maritime systems, mass transit and passenger rail, pipeline systems and freight rail. Utility systems include water supply, wastewater, electricity, natural gas and communication.

[16] To be evaluated separately to determine if evacuation and/or emergency response members are needed on the team.

Appendix D

Other NIST Non-NCST Act Activities Related to Disasters and Failures

Other NIST non-NCST Act work in related areas – including wind, earthquake, and Wildland-Urban Interface (WUI) fire – also advanced during FY 2013. Especially noteworthy were the publication of several important reports and sponsorship of meetings to help set priorities and advance research and standards approaches to disaster and resilience issues. These included:

- Publication of *Developing Guidelines and Standards for Disaster Resilience of the Built Environment: A Research Needs Assessment* [17] (March 2013). Two national workshops were convened in 2011 to assist NIST with identifying critical gaps and needs in tools and metrics for assessing the resilience of the built environment. This report presents the technical gaps and research needs for developing standards on community resilience planning, metrics, and tools for assessing facility and community resilience.

- Publication of *Framework for Addressing the National Wildland Urban Interface Problem – Determining Fire and Ember Exposure Zones Using a WUI Hazard Scale* [18] (January 2013). WUI fires offer a unique challenge to the firefighting and fire protection engineering communities, with more than 46 million residential structures in the United States in areas at risk. A scale needs to be created to help quantify the severity of WUI exposure to help form the technical foundation for a set of building code requirements aimed at providing a level of structure ignition protection commensurate with the expected exposure from fire and embers. This report proposes a scale that could be used to determine exposure zones for new and existing WUI communities. Additionally, the proposed NIST exposure scale can be linked to first responder and homeowner safety.

- Publication of *Wildland-Urban Interface Fire Research Needs- Summary Report* [19] (May 2013). Based on a 2012 workshop organized by NIST, this report identifies a set of research needs aimed at preventing or managing this growing threat to about 70,000 communities located in wildland-urban interface. The top three recommended topics warranting sustained research efforts focus on:
  - Developing standards and tests of building performance that improve the "survivability" of structures exposed to WUI fires;
  - "Hardening" buildings, so that they resist ignition—by flames, embers and heat; and
  - Improving the understanding of "how vegetation, topography, climate and construction cause structure ignition and spread of fires."

[17] http://www.nist.gov/manuscript-publication-search.cfm?pub_id=912299
[18] http://www.nist.gov/manuscript-publication-search.cfm?pub_id=910443
[19] http://www.nist.gov/manuscript-publication-search.cfm?pub_id=913016