THE INVESTIGATION OF THE WORLD TRADE CENTER COLLAPSE: FINDINGS, RECOMMENDATIONS, AND NEXT STEPS

HEARING

BEFORE THE

COMMITTEE ON SCIENCE
HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

OCTOBER 26, 2005

Serial No. 109–28

Printed for the use of the Committee on Science

Available via the World Wide Web: http://www.house.gov/science

U.S. GOVERNMENT PRINTING OFFICE

24–133PS WASHINGTON : 2006

For sale by the Superintendent of Documents, U.S. Government Printing Office
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CONTENTS

October 26, 2005

Appendix 1: Answers to Post-Hearing Questions

Appendix 2: Additional Material for the Record

THE INVESTIGATION OF THE WORLD TRADE CENTER COLLAPSE: FINDINGS, RECOMMENDATIONS, AND NEXT STEPS

WEDNESDAY, OCTOBER 26, 2005

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 11:09 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Sherwood Boehlert [Chairman] presiding.

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The Investigation of the World Trade Center Collapse: Findings, Recommendations and Next Steps

Wednesday October 26, 2005

11:00 AM – 1:00 PM
2318 Rayburn House Office Building (WEBCAST)

Witness List

Panel I

Ms. Sally Regenhard
Chairperson
Skyscraper Safety Campaign

Panel II

Dr. William Jeffrey
Director
National Institute of Standards and Technology (NIST)

Ms. Nancy McNabb
Director of Government Affairs
National Fire Protection Association

Dr. James R. Harris, P.E.
President, J.R.Harris and Company
Member, American Society of Civil Engineers

Mr. Henry L. Green
President
International Code Council

Mr. Glenn Corbett
Assistant Professor of Fire Science, John Jay College of Criminal Justice
Member, NIST National Construction Safety Team Advisory Board

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HEARING CHARTER

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

The Investigation of the World Trade Center Collapse: Findings, Recommendations, and Next Steps

WEDNESDAY, OCTOBER 26, 2005
11:00 A.M.—1:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On October 26, 2005, at 11 a.m., the House Committee on Science will hold a hearing on the key findings and recommendations of the National Institute of Standard and Technology's (NIST) investigation into the collapse of the World Trade Center (WTC), how building and fire code organizations plan to implement the recommendations contained in that report, and what barriers exist to the development and adoption of stronger building and fire codes.

Witnesses

The following witnesses will address the Committee:

Panel I:

Ms. Sally Regenhard, Skyscraper Safety Campaign (SSC), New York, NY. The SSC represents families and survivors of the WTC disaster and supports stronger codes and practices for buildings and first responders.

Panel II:

Dr. William Jeffrey, Director, National Institute of Standards and Technology.

Ms. Nancy McNabb, Director of Government Affairs, National Fire Protection Association (NFPA). NFPA standards are extensively referenced in the NIST recommendations on the WTC collapse.

Dr. James R. Harris, American Society of Civil Engineers (ASCE). ASCE standards are extensively referenced in the NIST recommendations on the WTC collapse.

Mr. Henry L. Green, President, International Code Council (ICC). The ICC is an association of State and local code officials, building mangers, and other parties that collectively maintain the International Building Code (IBC), the most widely used model building code in the U.S. Many of NIST's recommendations reference the IBC.

Mr. Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice, New York, NY. Mr. Corbett is a member of NIST's National Construction Safety Team Advisory Board.

Overarching Questions

The hearing will address the following overarching questions:

1. What are the most important findings and recommendations of the World Trade Center Investigation report?
2. Are the NIST recommendations framed appropriately so that they can be adopted into national model building codes?
3. What are the prospects for the adoption of the recommendations by the code organizations? What is NIST doing to promote this process? What are the possible impediments to their adoption?
4. What lessons were learned from this investigation that could be applied to improve future investigations of building failures?

Background

On September 11, 2001, terrorists crashed two fuel-laden Boeing 767s into World Trade Center (WTC) Tower 1 and Tower 2. While both 110-story buildings withstood the initial impact, the subsequent fires weakened the already damaged columns at the periphery and core of the towers, both of which collapsed. More than 25,000 people were safely evacuated from the towers, however 2,749 people were killed in the disaster. World Trade Center 7, a 47-story office building located adjacent to WTC 1 and 2, was damaged during the disaster and collapsed later that same day.

Immediately following the attack, the Federal Emergency Management Agency (FEMA) and the American Society of Civil Engineers (ASCE) began planning a building performance study of the WTC. The week of October 7, as soon as the rescue and search efforts ceased, an ASCE team under contract with FEMA known as the Building Performance Assessment Team (BPAT) went to the site and began their assessment of why the buildings had failed. This was to be a brief effort, as the study team consisted of experts who generally had volunteered their time. In January 2002, FEMA asked the National Institute of Standards and Technology (NIST) to take over the next phase of the investigation of the collapse essentially to build upon the BPAT recommendations and conduct a more thorough investigation of the events leading to the collapse.

The Science Committee held two hearings in 2002 on the WTC collapse, one on March 6 and the other on May 1. The March 6, 2002, hearing focused on how the Federal Government investigates catastrophic building failures, and what had been learned from the collapse of the WTC 1, 2 and 7. Concerns raised at the hearing included the lack of any specific federal authority, protocols, or funding for investigations of this kind. Concerns were also raised regarding the timing of the BPAT deployment (almost a month after the towers fell), its access to the site and building records, premature disposal of evidence, and FEMA's lack of regular communication with the public about the investigation.

The BPAT released its report at the May 2002 hearing. The hearing also reviewed plans for NIST to begin a more comprehensive investigation in view of the criticisms of FEMA, and provided a forum to discuss proposed legislation to give NIST the authorities necessary to conduct such an investigation. The BPAT report highlighted potential reasons for why the two towers, almost identical in design, performed differently under the stresses of the disaster. It also identified critical features that enabled so many to evacuate, and the design elements that may have played a role in the collapse and prevented people above the impacts from being able to exit the buildings. However, witnesses commented that, without a more sophisticated analysis of the evidence, no conclusions could be drawn that could be used to recommend improvements in building and fire codes to prevent future loss of life.

Also at the May 2002 hearing, the witnesses commented favorably on draft legislation being prepared by the Science Committee, based on the authorizing legislation for the National Transportation Safety Board (NTSB) to enhance NIST's existing authority to investigate building failures. On May 9, 2002, the *National Construction Safety Team Act* (NCST—H.R. 4687) was introduced by Congressman Sherwood Boehlert and Congressman Anthony Weiner. The NCST was signed into law on October 1, 2002. Under the Act, NIST is authorized to appoint a national construction safety team to determine the causes of a building's failure, evaluate the technical aspects of evacuation and emergency response, and "recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings," and propose any research needed to improve building safety and emergency response procedures." The law gives NIST subpoena power to ensure that it has access to all evidence to support an investigation, but the results of such investigations cannot be used as evidence in any subsequent litigation.

On August 21, 2002, NIST announced the appointment of a national construction safety team to investigate building and fire safety in WTC 1, 2, and 7. The project was funded through FEMA, and cost $16 million.

Building and Fire Codes

Building and fire codes are established and enforced by State and local governments, which generally base their codes on national model codes that are written by private non-profit standards development organizations (SDOs). These organizations are generally are made up of members—individuals and groups—that have an interest in construction. Generally make their money through membership payments and selling their codes.

Building and fire codes and standards are technical descriptions of constructions, materials, installations, equipment, or practices designed to achieve specific results, such as safety or strength. Standards are very specific guidelines that describe single elements of construction or safety. For example, a "fire rating" is a standard that

describes the amount of time a construction element such as a beam can be exposed to a typical fire before it breaks or fails. Other examples of building standards include hallway or stairwell widths deemed necessary to evacuate a certain number of people in a certain amount of time, or the type of steel needed for a beam to support a certain amount of weight. NIST does not write building or fire codes, but does participate in the discussions and provides technical guidance to the standards development organizations.

The most widely-used model building code in the U.S. is the International Building Code (IBC). It is currently the basis of the codes in 45 states and the District of Columbia. The IBC is developed and owned by the International Code Council (ICC). The ICC's members consist of State and local building code officials, building owners and managers, and private sector participants from construction and other industries. ICC's members are concerned with safety, but also with cost and other economic considerations, and these are reflected in the outcomes of the code meetings. The IBC is regularly updated in a deliberative, committee-driven process that takes about eighteen months. The deadline for submitting proposed changes to the IBC, which begins the next eighteen-month cycle, is March 24th, 2006.

The National Fire Protection Association (NFPA), which develops many standards related to fire safety, recently produced an alternative model building code, NFPA 5000. Experts say that implementing NFPA 5000 may be more expensive than the IBC but may result in a greater level of safety. NFPA's membership is different from that of the ICC, with strong representation by fire protection officials and fire equipment manufacturers. NFPA 5000 has not been widely adopted, but individual NFPA standards are widely used in fire codes.

The NIST Investigation

NIST's Building and Fire Research Laboratory (BFRL) carries out research in fire science, fire safety, structural, mechanical, and environmental engineering. It is the only federal laboratory dedicated to research on building design and fire safety.

The goals of the NIST WTC investigation of the WTC disaster were to investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster to serve as the basis for:

- Improvements in the way buildings are designed, constructed, maintained, and used;
- Improved tools and guidance for industry and safety officials for safer buildings and better coordination in emergencies;
- Recommended revisions to current building codes, standards, and practices, and
- Improved public safety.

The specific objectives were to:

1) Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft;
2) Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3) Assess what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2; and
4) Identify areas in current building and fire codes, standards, and practices that warrant revision.

To meet these goals, NIST assembled a team of in-house experts and outside specialists, totaling about 200 people. The team compiled and reviewed tens of thousands of documents, photographs, and films, interviewed over a thousand people who had been on the scene or who had been involved with the design, construction, and maintenance of the WTC; analyzed 236 pieces of steel taken from the wreckage; performed laboratory tests, and performed computer simulations of the sequence of events that happened from the instant of the aircraft impact to the initiation of collapse for each tower. In addition, NIST held several public meetings in New York City to report on the status of the investigation and solicit comments and additional information that might further the investigation.

In September, 2005, NIST released its draft *Final Report of the National Construction Safety Team on the Collapse of the World Trade Center Towers* for public comment. A copy of the executive summary of the report is attached. This report summarizes the findings of the investigation and includes thirty recommendations to improve the safety of tall buildings, occupants, and emergency responders. NIST will publish its final report within the next two weeks.

NIST Findings

The NIST investigation confirmed and expanded upon several of the findings by the initial FEMA BPAT study. When built, WTC 1 and WTC 2 were unlike any other skyscrapers in existence at the time, both in terms of their height and innovative structural features. These consisted of a "frame-tube" system of exterior columns on the four faces of the towers, linked to a core of columns by light-weight trusses that supported the floors. In spite of their innovative design, WTC 1 and 2 met or exceeded the requirements of the New York City building codes.

The NIST investigation determined that although the aircraft did considerable damage to the principal structural components of WTC 1 and 2, the towers were inherently robust, and would have remained standing were it not for the dislodged fireproofing which exposed the central columns to the multi-floor fires. In each tower, a different combination of impact damage and heat-weakened structural components contributed to the abrupt structural collapse. The fire safety systems in WTC 1 and 2 met or exceeded current practice at the time the towers fell, but played no safety role on September 11th because the water supplies and electrical systems were damaged by the aircraft impact. In WTC 1, the aircraft destroyed all escape routes, and 1,355 people were trapped in the upper floors when the building collapsed. In WTC 2 where evacuation had already commenced, about 3,000 got below the impact zone before the second plane crashed. One stairwell remained passable for a short period of time and eighteen people evacuated through the impact zone. The remaining 619 people perished. WTC 2 collapsed before WTC 1 because the aircraft did significantly more damage to the central columns and the fires were concentrated on the East side of the building, rather than moving around as they did in WTC 1.

Major Issues Addressed in the NIST WTC Recommendations

NIST's recommendations fall into eight groups:

- Increased Structural Integrity,
- Enhanced Fire Resistance of Structures
- New Methods for Fire Resistance Design of Structures
- Improved Active Fire Protection
- Improved Building Evacuation
- Improved Emergency Response
- Improved Procedures and Practices, and Education and Training.

These recommendations include many references to specific SDOs to modify or, in some cases, completely overhaul those standards that apply to building construction, evacuation, testing, and fire safety. NIST's recommendations also refer to less specific audiences such as building managers, building occupants, property developers, and first responders to develop procedures and best practices to protect building occupants.

The following highlights some of the key issues referenced by NIST in its recommendations:

- **Increased Structural Integrity**

The NIST investigators found that the existing methods of calculating the effect of wind and other stressors on tall towers produced markedly different results among the different tests, leading them to question whether these tests had a basis in fact and needed to be re-designed. NIST's report also focuses on the concept of "progressive collapse," where the weakening of one structural element contributes to the weakening of others. NIST raises the question of whether the current practice of testing individual building components such as columns and floor trusses gives an accurate estimate of the resilience of an entire building assembly to fire, wind, and other stressors. NIST recommends that a "structural frame" approach to fire resistance ratings be developed by the structural standards groups such as ASCE. However, progressive collapse is not well understood, and it may take time for these groups to produce a standard and describe the appropriate tests against which to judge whether structures are prone to progressive collapse.

The recommendations pertaining to structural integrity and design are directed largely at ASCE–7, and specifications developed by the American Concrete Institute (ACI) and the American Institute of Steel Construction (AISC), as well as NFPA, and urge that the latest version of these standards and specifications be adopted by the ICC and NFPA into their model building codes.

- **Improved Fire Resistance of Structures and Fire Protection**

Over the years, across the United States, there has been a gradual reduction in rigor of building codes of fire rating requirements, i.e., how long something such as a steel column can remain exposed to a fire before breaking or deforming. There has also been a decrease in the compartmentalizing requirements for working and living spaces. Large compartments in buildings allow more air to flow to fires and allow fires to spread faster. Large compartments, however, means more floor area, more tenants, and more rent for the building owner. A lower fire rating requirement allows the use of lighter and less material in construction. The loosening of these restrictions has been compensated for by increasing requirements for sprinkler systems, which have been shown to be effective in quenching typical office fires. On September 11th however, the sprinkler systems were disabled, and even in typical fires, sprinkler systems do not always work. NIST recommends greater redundancy in sprinkler systems, and more compartmentalization to restrict air flow to fires. These recommendations apply to several standards developed by NFPA.

The reduction in fire ratings has also been compensated by the use of spray-applied fire resistive materials (SFRM) on structural components. This was the foam that was applied to the columns and trusses of WTC 1 and 2 as fireproofing. After the 1993 WTC terrorist bombing, it was recommended that the spray-on fire protection on the steel components of the towers be thickened. NIST emphasizes that, were it not for the dislodging of the fireproofing from the structural steel when the aircraft flew into the towers, WTC 1 and 2 would likely have withstood the subsequent fires. The foam on WTC 1 and 2 was shaken or blown off around the cores and peripheral columns on several floors in both Towers on September 11th, meaning the columns reached critical temperatures much faster then they would have normally. NIST recommends that the performance of this type of fireproofing needs to be better understood, particularly its response to shock, aging, and method of application, and new coatings should be developed.

NIST notes in its report that both the IBC and NFPA 5000 model building codes have since changed their fire rating requirements for buildings over 420 feet from two hours to four. The report also says, however, that the technical basis for fire ratings is not strong, particularly since the typical contents of offices, and construction materials, have changed in the last 100 years. NIST recommends a comprehensive review by all fire-related SDOs of fire testing procedures to ensure that fire ratings are meaningful. Structural fire resistance is closely tied to the outcomes of work on the structural frame approach for large buildings, which NIST advocates in its report while recommending an extensive re-evaluation by national building code committees (ICC and NFPA) of the dynamics of fire, evacuation, and emergency response for skyscrapers to determine what fire ratings are needed for tall buildings. In the case of re-evaluating the tests steel and concrete assemblies, this could be an expensive proposition. A typical full-scale fire test costs $30,000 or more per test, and to validate a new test, experimental tests must to be run several times. It is not clear who should be conducting these tests.

- **Full Evacuation of Large Buildings**

After the 1993 terrorist bombing of the WTC site, it took four hours to evacuate everyone from WTC 1 and WTC 2. The standard evacuation plan for skyscrapers does not usually anticipate such a mass egress: fire-related evacuation plans assume that occupants "evacuate in place" to higher and lower floors while first responders fight the fire. Although this approach may change as a result of the events of September 11th, it may still be the most practical and safe procedure for typical skyscraper fires. Skyscraper elevators in the U.S. are not generally fireproof, nor are they intended to be used for mass evacuation. Full evacuation via stairwells takes a long time. On September 11th, with all elevators out of commission, it would have taken hours for firefighters to ascend to the affected floors to fight the fires, or assist survivors down the stairs. This fact has provoked some re-thinking of how elevators should be designed and used for emergency purposes.

WTC 1 and 2 had three stairwells each, centered at the core of the buildings. When the aircraft crashed, these stairs were destroyed. The NIST investigation found that about six percent of the people in the towers had health problems or disabilities that made taking the stairs difficult. Overall, it was found, people evacuate buildings twice as slowly as generally thought. NIST recommends structural hardening of elevators for use in large-scale emergencies, and that stairwells be spaced further apart, although it does not say by how much. NIST also recommends that stairwells should be widened to allow more people to descend as well as to allow counter flow from first responders going up the stairs. Most of the recommendations apply to NFPA 101, and the *National Model Building and Fire Codes* of the ICC.

- **Communications and Emergency Response**

For the approximately 1,000 emergency responders on the site on September 11th, this was the largest disaster they had ever experienced. Communications networks at the site were destroyed, and portable communications devices such as walkie-talkies and cellular phones were overwhelmed as dozens of first responders attempted to talk at the same time. Walkie-talkies performed inadequately, or otherwise failed to function inside the steel-concrete construction of the towers. There was no inter-operability between the New York Police Department and the New York Fire Department equipment. Although there had been significant upgrades to the fire monitoring and communications infrastructure in the WTC Complex after the 1993 terrorist bombing, incident command centers established inside the two towers by first responders were still unable to provide a sufficient assessment of the situation, or monitor and relay information to other first responders at the site for proper coordination of their activities. First responders commented later that viewers watching the disaster on television had a better grasp of the scope and nature of the crisis than did anyone at the WTC site.

NIST's recommendations on improved emergency response apply mostly to NFPA standards, but also extend to the Department of Homeland Security, and state and local jurisdictions, and first responders. NIST emphasizes that systems need to be effective for large-scale emergencies and able to function in "challenging radio frequency environments." NIST also states that better procedures are needed for integrating information from multiple sources and coordinating a unified response among different agencies and departments.

Additional Issues

- **Follow-up funding is limited**

In many instances, NIST has recommended research and testing to determine whether and how changes in building codes should be made. It is not clear this effort will receive the commitment for funding it requires. In order to implement many of NIST's recommendations, a lot of research and collaboration with SDOs and stakeholders will have to be done to provide a scientific and technical basis for the standards changes needed to meet those recommendations. NIST requested $2 million in additional funds for FY 2006 for codes and practices for buildings and first responders, but the FY 2006 appropriation has not yet been finalized. If adequate funding for NIST's research efforts is not provided, it is unclear what progress will be made on implementing those recommendations that need scientific research to be implemented.

- **Future building investigations**

It is unclear what role NIST will play in investigating future building failures. FEMA received heavy criticism at the Science Committee hearing March 6, 2002, for shortcomings in the way in which it conducted the investigation of the collapse of the World Trade Center. The passage of the *National Construction Safety Team Act* was supposed to address these shortcomings by creating the authority to investigate building failures at NIST and providing NIST with subpoena power to obtain whatever evidence it needed to complete investigations. However, in the years since September 11th, although several building failures have occurred, Hurricane Katrina being the most recent event causing structural failures, NIST has not invoked the NSTC Act to launch investigations, but rather has been called in under another agency: FEMA in the case of Katrina. NIST does not have a source of funding dedicated to pay for such activities and is apparently reluctant to act independently. Outside observers note that NIST is a research institution and may not be culturally suited to conduct investigations as does the NTSB, upon which the NCST Act was based, or the Chemical Safety and Hazards Investigation Board.

Questions for the Witnesses

Ms. Sally Regenhard, Skyscraper Safety Campaign

I invite you to open the hearing with a five-minute statement that outlines the views of the Skyscraper Safety Campaign on the investigation, its findings and the next steps that should be taken.

Dr. William Jeffrey, Director, National Institute of Standards and Technology

In your testimony, please briefly describe the most important findings and recommendations of the NIST investigation of the World Trade Center collapse and answer the following questions:

1) What specific steps is NIST taking to ensure that its recommendations are incorporated into model and local codes? What barriers has NIST confronted or does it expect to confront as part of that process and how do you plan

to overcome those barriers? What past successes can NIST draw on as part of this effort?

2) Some experts have criticized the recommendations—some arguing that they are too general and therefore hard to translate into codes, and others arguing that they are too detailed and will needlessly increase building costs. How do you respond to these criticisms?

3) What lessons have you learned in carrying out this investigation that could be applied to future investigations, including the ones being undertaken in the wake of Hurricane Katrina?

Ms. Nancy McNabb, Director of Government Affairs, National Fire Protection Association (NFPA)

In your testimony, please briefly describe the process by which NFPA writes codes and answer the following questions:

1) Does NFPA support the recommendations of the NIST study? Why or why not?

2) What specific steps will NFPA be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Dr. James R. Harris, American Society of Civil Engineers (ASCE)

In your testimony, please briefly describe the process by which ASCE writes codes and answer the following questions:

1) Does ASCE support the recommendations of the NIST study? Why or why not?

2) What specific steps will ASCE be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Mr. Henry L. Green, President, International Code Council (ICC)

In your testimony, please briefly describe the process by which ICC writes codes and answer the following questions:

1) Does ICC support the recommendations of the NIST study? Why or why not?

2) What specific steps will ICC be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

3) What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

Mr. Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice, New York, NY

1) What are the most important findings and recommendations of the NIST World Trade Center Investigation report?

2) Some experts have criticized the recommendations—some arguing that they are too general and therefore hard to translate into codes, and others arguing that they are too detailed and will needlessly increase building costs. What is your view of these criticisms?

3) What are the prospects for the adoption of the recommendations by the code organizations? What should NIST and the code and standards groups be doing to promote this process?

4) What lessons were learned from this investigation that could be applied to improve future investigations of building failures?

Attachment

Executive Summary
Extracted from

NIST NCSTAR 1 (Draft)

Federal Building and Fire Safety Investigation of the World Trade Center Disaster

Final Report of the National Construction Safety Team on the Collapses of the World Trade Center Towers (Draft)

11

EXECUTIVE SUMMARY

E.1 GENESIS OF THIS INVESTIGATION

On August 21, 2002, the National Institute of Standards and Technology (NIST) announced its building and fire safety investigation of the World Trade Center (WTC) disaster.[1] This WTC Investigation was then conducted under the authority of the National Construction Safety Team (NCST) Act, which was signed into law on October 1, 2002. A copy of the Public Law is included in Appendix A.

The goals of the investigation of the WTC disaster were:

- To investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster after terrorists flew large jet-fuel laden commercial airliners into the WTC towers.
- To serve as the basis for:
  - Improvements in the way buildings are designed, constructed, maintained, and used;
  - Improved tools and guidance for industry and safety officials;
  - Recommended revisions to current codes, standards, and practices; and
  - Improved public safety

The specific objectives were:

1. Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft and why and how WTC 7 collapsed;
2. Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response; and
3. Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2, and 7.

[1] NIST is a nonregulatory agency of the U.S. Department of Commerce. The purposes of NIST investigations are to improve the safety and structural integrity of buildings in the United States and the focus is on fact finding. NIST investigative teams are required 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. NIST does not have the statutory authority to make findings of fault or negligence by individuals or organizations. Further, no part of any report resulting from a NIST investigation into a building failure or from an investigation under the National Construction Safety Team Act may be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a, as amended by P.L. 107-231).

4. Identify, as specifically as possible, areas in current building and fire codes, standards, and practices that warrant revision

E.2 APPROACH

To meet these goals, NIST complemented its in-house expertise with an array of specialists in key technical areas. In all, about 200 staff contributed to the Investigation. NIST and its contractors compiled and reviewed tens of thousand of pages of documents; conducted interviews with over a thousand people who had been on the scene or who had been involved with the design, construction, and maintenance of the WTC; analyzed 236 pieces of steel that were obtained from the wreckage; performed laboratory tests, measured material properties, and performed computer simulations of the sequence of events that happened from the instant of aircraft impact to the initiation of collapse for each tower.

Cooperation in obtaining the resource materials and in interpreting the results came from a large number of individuals and organizations, including The Port Authority of New York and New Jersey and its contractors and consultants, Silverstein Properties and its contractors and consultants, the City of New York and its departments, the manufacturers and fabricators of the building components, the companies that insured the WTC towers, the building tenants, the aircraft manufacturers and the airlines.

The scarcity of physical evidence that is typically available in place for reconstruction of a disaster led to the following approach:

- Accumulation of copious photographic and video material. With the assistance of the media, public agencies and individual photographers, NIST acquired and organized nearly 7,000 segments of video footage, totaling in excess of 150 hours and nearly 7,000 photographs representing at least 185 photographers. This guided the Investigation Team's efforts to determine the condition of the buildings following the aircraft impact, the evolution of the fires, and the subsequent deterioration of the structure.

- Establishment of the baseline performance of the WTC towers, i.e., estimating the expected performance of the towers under normal design loads and conditions. The baseline performance analysis also helped to estimate the ability of the towers to withstand the unexpected events of September 11, 2001. Establishing the baseline performance of the towers began with the compilation and analysis of the procedures and practices used in the design, construction, operation, and maintenance of the structural, fire protection, and egress systems of the WTC towers. The additional components of the performance analysis were the standard fire resistance of the WTC truss-framed floor system, the quality and properties of the structural steels used in the towers, and the response of the WTC towers to the design gravity and wind loads.

- Conduct of four-step simulations of the behavior of each tower on September 11, 2001. Each step stretched the state of the technology and tested the limits of software tools and computer hardware. The four steps were:

  1. The aircraft impact into the tower, the resulting distribution of aviation fuel, and the damage to the structure, partitions, thermal insulation materials, and building contents.
  2. The evolution of multifloor fires.

3. The heating and consequent weakening of the structural elements by the fires.
4. The response of the damaged and heated building structure, and the progression of structural component failures leading to the initiation of the collapse of the towers.

The output of these simulations was subject to uncertainties in the as-built condition of the towers, the interior layout and furnishings, the aircraft impact, the internal damage to the towers (especially the thermal insulation for fire protection of the structural steel, which is colloquially referred to as *fireproofing*), the redistribution of the combustibles, and the response of the building structural components to the heat from the fires. To increase confidence in the simulation results, NIST used the visual evidence, eyewitness accounts from inside and outside the buildings, laboratory tests involving large fires and the heating of structural components, and formal statistical methods to identify influential parameters and quantify the variability in analysis results.

- Combination of the knowledge gained into probable collapse sequences for each tower,[2] the identification of factors that contributed to the collapses, and a list of factors that could have improved building performance or otherwise mitigated the loss of life.
- Compilation of a list of findings that respond to the first three objectives and a list of recommendations that responds to the fourth objective.

E.3 SUMMARY OF FINDINGS

Objective 1: Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft.

- The two aircraft hit the towers at high speed and did considerable damage to principal structural components: core columns, floors, and perimeter columns. However, the towers withstood the impacts and would have remained standing were it not for the dislodged insulation (fireproofing) and the subsequent multifloor fires. The robustness of the perimeter frame-tube system and the large size of the buildings helped the towers withstand the impact. The structural system redistributed loads without collapsing in places of aircraft impact, avoiding larger scale damage upon impact. The hat truss, a feature atop each tower which was intended to support a television antenna, prevented earlier collapse of the building core. In each tower, a different combination of impact damage and heat-weakened structural components contributed to the abrupt structural collapse.
- In WTC 1, the fires weakened the core columns and caused the floors on the south side of the building to sag. The floors pulled the heated south perimeter columns inward, reducing their capacity to support the building above. Their neighboring columns quickly became overloaded as columns on the south wall buckled. The top section of the building tilted to the south and began its descent. The time from aircraft impact to collapse initiation was largely

[2] The focus of the Investigation was on the sequence of events from the instant of aircraft impact to the initiation of collapse for each tower. For brevity in this report, this sequence is referred to as the "probable collapse sequence," although it does not actually include the structural behavior of the tower after the conditions for collapse initiation were reached and collapse became inevitable.

determined by how long it took for the fires to weaken the building core and to reach the south side of the building and weaken the perimeter columns and floors.

- In WTC 2, the core was damaged severely at the southeast corner and was restrained by the east and south walls via the hat truss and the floors. The steady burning fires on the east side of the building caused the floors there to sag. The floors pulled the heated east perimeter columns inward, reducing their capacity to support the building above. Their neighboring columns quickly became overloaded as columns on the east wall buckled. The top section of the building tilted to the east and to the south and began its descent. The time from aircraft impact to collapse initiation was largely determined by the time for the fires to weaken the perimeter columns and floor assemblies on the east and the south sides of the building. WTC 2 collapsed more quickly than WTC 1 because there was more aircraft damage to the building core and there were early and persistent fires on the east side of the building, where the aircraft had extensively dislodged insulation from the structural steel.

- The WTC towers likely would not have collapsed under the combined effects of aircraft impact damage and the extensive, multifloor fires if the thermal insulation had not been widely dislodged or had been only minimally dislodged by aircraft impact.

Objective 2: Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response.

- Approximately 87 percent of the estimated 17,400 occupants of the towers, and 99 percent of those located below the impact floors, evacuated successfully. In WTC 1, where the aircraft destroyed all escape routes, 1,355 people were trapped in the upper floors when the building collapsed. One hundred seven people who were below the impact floors did not survive. Since the flow of people from the building had slowed considerably 20 min before the tower collapsed, the stairwell capacity was adequate to evacuate the occupants on that morning.

- In WTC 2, before the second aircraft strike, about 3,000 people got low enough in the building to escape by a combination of self-evacuation and use of elevators. The aircraft destroyed the operation of the elevators and the use of two of the three stairways. Eighteen people from above the impact zone found a passage through the damaged third stairway and escaped. The other 619 people in or above the impact zone perished. Seven people who were below the impact floors did not survive. As in WTC 1, shortly before collapse, the flow of people from the building had slowed considerably, indicating that the stairwell capacity was adequate that morning.

- About 6 percent of the survivors described themselves as mobility impaired, with recent injury and chronic illness being the most common causes; few, however, required a wheelchair. Among the 118 decedents below the aircraft impact floors, investigators identified seven who were mobility challenged, but were unable to determine the mobility capability of the remaining 111.

- A principal factor limiting the loss of life was that the buildings were only one-third occupied at the time of the attacks. NIST estimated that if the towers had been fully occupied with

25,000 occupants each, it would have taken about 4 hours to evacuate the buildings and over 14,000 people might have perished because the stairwell capacity would not have been sufficient to evacuate that many people in the available time. Egress capacity required by current building codes is determined by single floor calculations that are independent of building height and does not consider the time for full building evacuation.

- Due to the presence of assembly use spaces at the top of each tower that were designed to accommodate over 1,000 occupants per floor for the Windows on the World restaurant complex and the Top of the Deck observation deck, the New York City Building Code would have required a minimum of four independent means of egress (stairs), one more than the three that were available in the buildings. Given the low occupancy level on September 11, 2001, NIST found that the issue of egress capacity from these places of assembly, or from elsewhere in the buildings, was not a significant factor on that day. It is conceivable that such a fourth stairwell, depending on its location and the effects of aircraft impact on its functional integrity, could have remained passable, allowing evacuation by an unknown number of additional occupants from above the floors of impact. If the buildings had been filled to their capacity with 25,000 occupants, however, the required fourth stairway would likely have mitigated the insufficient egress capacity for conducting a full building evacuation within the available time.

- Evacuation was assisted by participation in fire drills within the previous year by two-thirds of survivors and perhaps hindered by a Local Law that prevented employers from *requiring* occupants to practice using the stairways. The stairways were not easily navigated in some locations due to their design, which included "transfer hallways," where evacuees had to traverse from one stairway to another location where the stairs continued. Additionally, many occupants were unprepared for the physical challenge of full building evacuation.

- The functional integrity and survivability of the stairwells was affected by the separation of the stairwells and the structural integrity of stairwell enclosures. In the impact region of WTC 1, the stairwell separation was the smallest over the building height—clustered well within the building core—and all stairwells were destroyed by the aircraft impact. By contrast, the separation of stairwells in the impact region of WTC 2 was the largest over the building height—located along different boundaries of the building core—and one of three stairwells remained marginally passable after the aircraft impact. The shaft enclosures were fire rated but were not required to have structural integrity under typical accidental loads: there were numerous reports of stairwells obstructed by fallen debris from damaged enclosures.

- The fire safety systems (sprinklers, smoke purge, and fire alarms,) were designed to meet or exceed current practice. However, they played no role in the safety of life on September 11 because the water supplies to the sprinklers were fed by a single supply pipe that was damaged by the aircraft impact. The smoke purge systems were designed for use by the fire department after fires; they were not turned on but they also would have been ineffective due to aircraft damage. The violence of the aircraft impact served as its own alarm. In WTC 2, contradictory public address announcements contributed to occupant confusion and some delay in occupants beginning to evacuate.

- For the approximately 1,000 emergency responders on the scene, this was the largest disaster they had even seen. Despite attempts by the responding agencies to work together and perform their own tasks, the extent of the incident was well beyond their capabilities. Communications were erratic due to the high number of calls and the inadequate performance of some of the gear. Even so, there was no way to digest, test for accuracy, and disseminate the vast amount of information being received. Their jobs were complicated by the loss of command centers in WTC 7 and then in the towers after WTC 2 collapsed. With nearly all elevator service disrupted and progress up the stairs taking about 2 min per floor, it would have taken hours for the responders to reach their destinations, assist survivors, and escape had the towers not collapsed.

Objective 3: Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1 and WTC 2.

- Because of The Port Authority's establishment under a clause of the United States Constitution, its buildings were not subject to any external building code. The buildings were unlike any others previously built, both in their height and in their innovative structural features. Nevertheless, the actual design and approval process produced two buildings that generally were consistent with nearly all of the provisions of the New York City Building Code and other building codes of that time. The loads for which the buildings were designed exceeded the code requirements. The quality of the structural steels was consistent with the building specifications. The departures from the building codes and standards did not have a significant effect on the outcome of September 11.

- For the floor systems, the fire rating and insulation thickness used on the floor trusses, which together with the concrete slab served as the main source of support for the floors, were of concern from the time of initial construction. NIST found no technical basis or test data on which the thermal protection of the steel was based. On September 11, 2001, the minimum specified thickness of the insulation was adequate to delay heating of the trusses; the amount of insulation dislodged by the aircraft impact, however, was sufficient to cause the structural steel to be heated to critical levels.

- Based on four standard fire resistance tests that were conducted under a range of insulation and test conditions, NIST found the fire rating of the floor system to vary between 3/4 hour and 2 hours; in all cases, the floors continued to support the full design load without collapse for over 2 hours.

- The wind loads used for the WTC towers, which governed the structural design of the external columns and provided the baseline capacity of the structures to withstand abnormal events such as major fires or impact damage, significantly exceeded the requirements of the New York City Building Code and selected other building codes of the day. Two sets of wind load estimates for the towers obtained by independent commercial consultants in 2002, however, differed by as much as 40 percent. These estimates were based on wind tunnel tests conducted as part of insurance litigation unrelated to the Investigation.

E.4 RECOMMENDATIONS

The tragic consequences of the September 11, 2001, attacks were directly attributable to the fact that terrorists flew large jet-fuel laden commercial airliners into the WTC towers. Buildings for use by the general population are not designed to withstand attacks of such severity; building codes do not require building designs to consider aircraft impact. In our cities, there has been no experience with a disaster of such magnitude, nor has there been any in which the total collapse of a high-rise building occurred so rapidly and with little warning.

While there were unique aspects to the design of the WTC towers and the terrorist attacks of September 11, 2001, NIST has compiled a list of recommendations to improve the safety of tall buildings, occupants, and emergency responders based on its investigation of the procedures and practices that were used for the WTC towers; these procedures and practices are commonly used in the design, construction, operation, and maintenance of buildings under normal conditions. Public officials and building owners will need to determine appropriate performance requirements for those tall buildings, and selected other buildings, that are at higher risk due to their iconic status, critical function, or design.

The topics of the recommendations in eight groups are listed in Table E–1. The ordering does not reflect any priority.

The eight major groups of recommendations are:

- Increased Structural Integrity: The standards for estimating the load effects of potential hazards (e.g., progressive collapse, wind) and the design of structural systems to mitigate the effects of those hazards should be improved to enhance structural integrity.

- Enhanced Fire Resistance of Structures: The procedures and practices used to ensure the fire resistance of structures should be enhanced by improving the technical basis for construction classifications and fire resistance ratings, improving the technical basis for standard fire resistance testing methods, use of the "structural frame" approach to fire resistance ratings, and developing in-service performance requirements and conformance criteria for spray-applied fire resistive materials.

- New Methods for Fire Resistance Design of Structures: The procedures and practices used in the fire resistance design of structures should be enhanced by requiring an objective that uncontrolled fires result in burnout without local or global collapse. Performance-based methods are an alternative to prescriptive design methods. This effort should include the development and evaluation of new fire resistive coating materials and technologies and evaluation of the fire performance of conventional and high-performance structural materials. echnical and standards barriers to the introduction of new materials and technologies should be eliminated.

- Improved Active Fire Protection: Active fire protection systems (i.e., sprinklers, standpipes/ hoses, fire alarms, and smoke management systems) should be enhanced through improvements to design, performance, reliability, and redundancy of such systems.

- Improved Building Evacuation: Building evacuation should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency

communications to occupants, better occupant preparedness for evacuation during emergencies, and incorporation of appropriate egress technologies.

- Improved Emergency Response: Technologies and procedures for emergency response should be improved to enable better access to buildings, response operations, emergency communications, and command and control in large-scale emergencies.

- Improved Procedures and Practices: The procedures and practices used in the design, construction, maintenance, and operation of buildings should be improved to include encouraging code compliance by nongovernmental and quasi-governmental entities, adoption and application of egress and sprinkler requirements in codes for existing buildings, and retention and availability of building documents over the life of a building.

- Education and Training: The professional skills of building and fire safety professionals should be upgraded though a national education and training effort for fire protection engineers, structural engineers, and architects.

The recommendations call for action by specific entities regarding standards, codes and regulations, their adoption and enforcement, professional practices, education, and training; and research and development. Only when each of the entities carries out its role will the implementation of a recommendation be effective.

The recommendations do not prescribe specific systems, materials, or technologies. Instead, NIST encourages competition among alternatives that can meet performance requirements. The recommendations also do not prescribe specific threshold levels; NIST believes that this responsibility properly falls within the purview of the public policy setting process, in which the standards and codes development process plays a key role.

NIST strongly urges that immediate and serious consideration be given to these recommendations by the building and fire safety communities in order to achieve appropriate improvements in the way buildings are designed, constructed, maintained, and used and in evacuation and emergency response procedures—with the goal of making buildings, occupants, and first responders safer in future emergencies.

NIST also strongly urges building owners and public officials to (1) evaluate the safety implications of these recommendations to their existing inventory of buildings and (2) take the steps necessary to mitigate any unwarranted risks without waiting for changes to occur in codes, standards, and practices.

NIST further urges state and local agencies, well trained and managed, to rigorously enforce building codes and standards since such enforcement is critical to ensure the expected level of safety. Unless they are complied with, the best codes and standards cannot protect occupants, emergency responders, or buildings.

Table E–1. Topics of NIST recommendations for improved public safety in tall and high-risk buildings.

Recommendation Group	Recommendation Topic	Responsible Community					Application		Relation to 9/11 Outcome	
		Practices	Standards, Codes, Regulations	Adoption & Enforcement	R&D/Further Study	Education & Training	All Tall Buildings	Selected Other High-Risk Buildings	Related[a]	Unrelated[b]
Increased Structural Integrity	Prevention of progressive collapse and failure analysis of complex systems	✓	✓	✓	✓	✓	✓	✓	✓	
	Estimation of wind loads and their effects on tall buildings	✓	✓		✓		✓	✓		✓
	Allowable tall buildings sway	✓	✓		✓		✓			✓
Enhanced Fire Resistance of Structures	Fire resistance rating requirements and construction classification	✓	✓		✓		✓			✓
	Fire resistance testing of building components and extrapolation of test data to qualify untested building components		✓		✓		✓			✓
	In-service performance requirements and inspection procedures for sprayed fire resistive materials (SFRM or spray-on fireproofing)	✓	✓	✓	✓		✓			✓
	"Structural frame" approach (structural members connected to columns carry the higher fire resistance rating of the columns)		✓	✓		✓	✓	✓		✓
New Methods for Fire Resistance Design of Structures	Burnout without local or global structural collapse in uncontrolled building fires	✓	✓	✓	✓	✓	✓	✓	✓	
	Performance-based design and retrofit of structures to resist fires	✓	✓		✓	✓	✓	✓		✓
	New fire-resistive coating materials, systems, and technologies	✓	✓		✓		✓	✓	✓	
	Evaluation of high performance structural materials under conditions expected in building fires	✓			✓		✓	✓		✓
Improved Active Fire Protection	Performance and redundancy of active fire protection systems to accommodate the greater risks associated with tall buildings	✓	✓		✓		✓	✓	✓	
	Advanced fire alarm and communication systems that provide continuous, reliable, and accurate information on life safety conditions to manage the evacuation process.		✓		✓		✓		✓	
	Advanced fire/emergency control panels with more reliable information from the active fire protection systems to provide tactical decision aids		✓		✓		✓	✓	✓	
	Improved transmission to emergency responders, and off-site or black box storage, of information from building monitoring systems	✓	✓		✓		✓	✓	✓	✓

Recommendation Group	Recommendation Topic	Responsible Community					Application		Relation to 9/11 Outcome	
		Practices	Standards, Codes, Regulations	Adoption & Enforcement	R&D/Further Study	Education & Training	All Tall Buildings	Selected Other High-Risk Buildings	Related[a]	Unrelated[b]
Improved Building Evacuation	Public education campaigns to improve building occupants' preparedness for evacuation	✓	✓		✓	✓	✓		✓	✓
	Tall building design for timely full building emergency evacuation of occupants	✓	✓		✓	✓	✓	✓	✓	✓
	Design of occupant-friendly evacuation paths that maintain functionality in foreseeable emergencies	✓	✓				✓		✓	
	Planning for communication of accurate emergency information to building occupants	✓	✓			✓	✓	✓	✓	
	Evaluation of alternative evacuation technologies, to allow all occupants equal opportunity for evacuation and to facilitate emergency response access	✓	✓		✓		✓	✓	✓	
Improved Emergency Response	Fire-protected and structurally hardened elevators	✓	✓		✓		✓		✓	
	Effective emergency communications systems for large-scale emergencies	✓	✓	✓	✓	✓	✓		✓	
	Enhanced gathering, processing, and delivering of critical information to emergency responders	✓	✓	✓	✓	✓	✓	✓	✓	
	Effective and uninterrupted operation of the command and control system for large-scale building emergencies	✓	✓	✓	✓	✓	✓		✓	
Improved Procedures and Practices	Provision of code-equivalent level of safety and certification of as-designed and as-built safety by nongovernmental and quasi-governmental entities	✓	✓	✓			✓	✓		✓
	Egress and sprinkler requirements for existing buildings	✓		✓			✓	✓		✓
	Retention and off-site storage of design, construction, maintenance, and modification documents over the entire life of the building; and availability of relevant building information for use by responders in emergencies	✓	✓	✓			✓	✓	✓	
	Design professional responsibility for innovative or unusual structural and fire safety systems	✓	✓			✓	✓	✓	✓	
Continuing Education and Training	Professional cross training of fire protection engineers, architects, and structural engineers	✓	✓			✓	✓	✓	✓	
	Training in computational fire dynamics and thermostructural analysis	✓				✓	✓	✓		✓

a. If in place, could have changed the outcome on September 11, 2001.
b. Would not have changed the outcome, yet is an important building and fire safety issue that was identified during the course of the Investigation.

Chairman BOEHLERT. Good morning. This hearing is open, and we are pleased to welcome back one who strayed from the fold, Mr. Weiner of New York, who was a very valued Member of this committee, and has gone onto other pursuits, but still, fortunately, within the Congress of the United States. Mr. Weiner, welcome back.

I want to welcome everyone to this important hearing, the Committee's third on the tragic collapse of the World Trade Center. But it won't be our last. I want to promise and perhaps warn everyone at the outset that this committee will be closely monitoring the followup to the National Institute of Standards and Technology report on the events of September 11.

That means we will be watching what NIST does, what other federal agencies do, and what the code writing organizations do. We are obviously not technical experts, but we will be making sure that their recommendations are considered fully and thoroughly, that NIST is doing everything necessary to back up those recommendations, and that any decisions are fully justified by the facts.

The issues raised in NIST's report go far beyond a single horrific terrorist incident, and indeed, beyond terrorism as a phenomenon. The report raises fundamental questions about what we know about the behavior of buildings and their contents, what we know about the behavior of individuals in emergencies, and about whether buildings are well enough designed for any large emergency. This is not about making every building strong enough to survive a plane crash.

That said, NIST's conclusion that the Trade Center buildings could have survived even the massive insult of a plane crash if the fireproofing had remained in place, is at once both chilling and promising, chilling because the massive loss of life was not inevitable, promising because it is an indication we can do more to protect lives in the future.

This committee will be asking hard questions of all of our witnesses today, to make sure we do take all reasonable steps to protect lives. We will be looking into whether NIST's recommendations are written in a way that will facilitate the adoption by code groups. It appears that they do not. We will be probing whether code groups are prepared to fully and fairly review the recommendations. On that, while the initial indications in today's testimony are promising, the jury necessarily is still out.

But our tough questions should not obscure the debt of gratitude we owe to NIST. NIST took seriously the mandate from this committee, and Mr. Weiner, I want to thank you for your assistance in that, and the Nation gave it in the *National Construction Safety Team Act,* and assembled an impressive group of experts that produced a comprehensive and impressive report. But our focus now has to be on whether everyone is doing enough to translate the report into specific, concrete steps that will prevent future tragedies.

The protection of life is the highest responsibility of public officials, and our hearing today is about that responsibility, just as much as any hearing on the military or homeland security would be. But the process in this case is far more complex, because of the

way it involves the private sector and every level of government. But complexity is not an excuse for inaction.

Before I turn to the minority, I want to give a special welcome to Bill Jeffrey, who is making his first appearance before this committee. I say first public appearance, because Dr. Jeffrey has long been a valued advisor to this committee in his work at the Office of Science and Technology Policy, someone we have admired for his intelligence, open-mindedness, and candor.

We could not be more delighted with his appointment as the Director of NIST, and we very much look forward to continuing to work with him. Hopefully, after today, he will still feel that way about us. This isn't, perhaps, the topic any of us would have chosen for his maiden hearing, but there is none of greater importance, and this hearing underscores the importance of NIST and its need for greater funding. But I won't get started on that subject now; we have more than enough to deal with today.

And I also want to welcome back someone who has been so invaluable to this committee as counsel, Sally Regenhard, Chairperson of the Skyscraper Safety Committee. She is emotionally and intellectually involved in our proceedings in so many different ways, and she has been a source of strength and inspiration to us, and she is dogged in her determination, and I commend her for that. People will often ask me, "When you go to Washington, I bet you meet with lobbyists." And I say "Sure, I meet with lobbyists. Every single day. Lobbyists are people who advocate for something." And there is one of the best lobbyists in this town today in Sally Regenhard. What she is advocating for involves the protection of life.

So, with that, let me turn to Mr. Miller for any statement he might care to make, and then we will have our first panel of one, Ms. Regenhard.

[The prepared statement of Chairman Boehlert follows:]

PREPARED STATEMENT OF CHAIRMAN SHERWOOD L. BOEHLERT

I want to welcome everyone to this important hearing, this committee's third on the tragic collapse of the World Trade Center, but probably not our last. I want to promise (and perhaps warn) everyone at the outset that this committee will be closely monitoring the follow-up to the National Institute of Standards and Technology (NIST) report on the events of September 11.

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tance. And this hearing underscores the importance of NIST, and its need for greater funding. But I won't get started on that subject now; we have more than enough to deal with today. Mr. Gordon.

Mr. MILLER. Thank you, Mr. Chairman. I want to join Chairman Boehlert in welcoming everyone to this morning's hearing.

On the surface, today's topic may sound dry and technical. However, what we are talking about here really is saving lives. The sole purpose of the *National Construction Safety Team Act* is to save lives by investigating and understanding building collapses, and then improve building codes, emergency response, and evacuation procedures.

The National Institute of Standards and Technology's, NIST's, World Trade Center investigation and their recommendations are the first real result of the Act. The NIST report is a good first step, but really a lot remains to be done. We need to know what is required to translate these NIST recommendations into improved buildings and emergency response and evacuation procedures. Those changes will improve public safety, and otherwise, we would have nothing to show, except another government report sitting on a shelf. That is going to require continued oversight by this committee as the process moves forward.

I also encourage the witnesses to give us their assessment of the work that NIST has done during the last two years, and what they think could be improved. And I want to mention that I am not only interested in the subject from the Science Committee perspective, but also how it relates to the *Terrorism Risk Insurance Act,* TRIA, which is now pending before the Financial Services Committee, and whether we should consider the NIST recommendations as part of private sector preparedness, and how that affects TRIA.

Now, I would like to yield the balance of my time to a former Member of the Science Committee, Anthony Weiner. Mr. Weiner has no small interest in NIST's work on the World Trade Center investigation, both as a Member from New York City, but also, he was the co-author, along with Chairman Boehlert, of the *National Construction Safety Team Act.*

Mr. Weiner, welcome back.

[The prepared statement of Mr. Miller follows:]

PREPARED STATEMENT OF REPRESENTATIVE BRAD MILLER

I want to join Chairman Boehlert in welcoming everyone to this morning's hearing.

On the surface, today's hearing topic may sound dry and technical. However, what we're really talking about is saving lives. The sole purpose of the *National Construction Safety Team Act* is to save lives by investigating and understanding building collapses and then improve building codes, emergency response and evacuation procedures.

The National Institute of Standards and Technology's (NIST) World Trade Center (WTC) investigation and recommendations are the first case of implementation of the Act. The NIST report is a good first step, but much work remains to be done. We need to know what is required to translate the NIST recommendations into improved building codes, and emergency response and evacuation procedures. It is these changes that will improve public safety, otherwise we will have nothing more than another government report sitting on a shelf. This will also require continued oversight by the Science Committee as the process moves forward.

I'm also encourage the witnesses to give us their assessment of what NIST has done during the past two years and what they feel could be improved. I also want to mention that I'm not only interested in this subject from a Science Committee

perspective, but also how it relates to Terrorism Risk Insurance from my work on the Financial Services Committee.

Now I would like to yield the balance of my time to a former Member of the Science Committee, Anthony Weiner. Rep. Weiner not only has a parochial interest in the NIST's WTC investigation, but he was a co-author, with Chairman Boehlert, of the *National Construction Safety Team Act.*

Mr. WEINER. Thank you, Mr. Miller. I appreciate it, and thank you, Mr. Chairman, for continuing to keep the effort alive that was one of the ones that emerged after September 11 that truly drew consensus in this Congress. I want to welcome back, also, Sally Regenhard, who if it was the Boehlert-Weiner Bill, it really should have been the Boehlert-Weiner-Regenhard Bill, because she acknowledged and called all of our attention to the notion that we all agree upon now, that before September 11 and until the passage of this legislation, there was no effort by government to do any kind of forensic examination of why buildings collapse, how we make them stronger, and how we make sure that they never happen again.

That is just one of the things I think we agree upon at this point. We also agree, and from learning, from reading the report and from hearing the stories of those that were inside, and those that were engaged in the largest civic rescue in our nation's history, there were some tragic flaws in the design of the World Trade Center. There were also some remarkable design achievements that allowed the buildings to stand despite remarkable stress.

But we also, after getting the report back now, I think there is an emerging consensus on a couple of other issues as well. One is that the study doesn't go far enough. The study doesn't include the level of specificity that would truly make the report a handbook for those seeking to come up with building codes in the future. The City of New York is involved in something it hasn't done in a generation, which is rewriting its building codes. If I were to send this report to the City of New York, and they wanted to go to a reference and say, well, how do we follow up on the NIST recommendation that we improve standards for fire resistance testing. Is there a standard in this report? And the answer is no. If they want to follow up on the NIST recommendation that fire protection and suppression redundancy be built into buildings, is there a specific standard that they can take from this report? The answer is no. So, I think that we have fallen short, NIST has fallen short of making this a true reference manual for future protection of big buildings. And for those of us in New York City and other big cities, and frankly, even medium sized cities that are building buildings of greater than twenty stories, it falls short.

And I also think something else. You know, we in government have a certain tolerance for the slow pace of things. This took too long. It took too long for NIST to produce a report that really doesn't get us anywhere past the 50 yard line here. We are not in the Red Zone. We are not getting close to the place that we need to be. And I am prepared to introduce legislation, hopefully with the support of this committee and its great chairman, to say okay, let us take the next step. Let us take these general recommendations. Let us take the general forensic examination that was done on the World Trade Center. Let us take the general propositions that are suggested herein. Let us assume they are correct, but let

us take the next step. Let us produce a document that truly has some fairly specific standards. Let us incentivize, but not require—I don't believe we should have a Federal Buildings Department—that incentivizes cities, states, and localities to adopt these things, and also, allows families, allow legislators when considering things like TRIA or building codes in Skokie, Illinois or Brooklyn, New York, to have a reference guide that they can use. Only then will the true goals of our original legislation have been fulfilled, and I think that that is something that we should point towards in the future.

And I thank you again, Mr. Chairman, for allowing me to sit in. I want to thank all of the professionals at NIST. Mr. Jeffrey, I am sure by now you have gotten to know the Chairman. You and I haven't gotten to know one another. I am sure you have gotten to know Members of this committee. You would be wise to get to know Sally Regenhard very well, because whether you would like to or not, you are going to have a very big file with her name on it, and she has shown us one thing, you know, for those of us that have lost loved ones, there are many ways that people express their grief. The way Sally Regenhard and many of her friends and neighbors have expressed their grief is by making sure that there are no such disasters like this again in the future, and doing everything we can to prevent it. That is something that Chairman Boehlert and I are committed to. I know the professionals at NIST are committed to that. Now we have to go and finally get that job done.

And I thank you, Mr. Chairman.

Chairman BOEHLERT. Well, welcome back, and just let me say how pleased I am that you are finally getting to meet Dr. Jeffrey, because to know him is to like him, but more importantly, to know what he is all about and his mission and his approach to the job is to know he is determined to follow through, as we are.

This is just another hearing. This is not the final chapter in a drama about a horrific incident. We are determined to follow through, as is Dr. Jeffrey and the people at NIST working with the National Institute of Building Sciences. This is, by no means, the final chapter. This is another chapter, but we are determined to go forward working together, and we welcome you back as part of the team.

With that, let me present the first witness, and I—Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. I appreciate you calling this hearing, and am very pleased to see the results that have been achieved. It is a little known facet of NIST responsibilities to do this sort of thing, and I am very pleased with the work they have done. And I think is providing a very strong base on which to build for the future.

I want to thank all our witnesses for coming here today. In particular, I want to congratulate Dr. Jeffrey, the new NIST Director, on his first appearance before this committee, and on NIST's latest Nobel Prize for Physics, announced this month to Dr. Jan Hall, a former colleague from my days as a researcher at NIST's Joint Institute for Laboratory Astrophysics, better known as JILA at the University of Colorado. And I have known Dr. Hall for years, and he is certainly deserving of this honor. This increases Nobel Prizes to three, demonstrating that NIST continues to be a world leader

in research and theoretical work. I might also add that now that a physicist is heading the organization, I expect the output of Nobel Prizes will increase, and so, I will leave that to you as a challenge. I also wanted to congratulate Mr. Henry Green, a resident of my home State of Michigan, on his prestigious new position as President of the International Code Council, and I have had the pleasure of meeting with Mr. Green, and I am very impressed with him and his ability. I look forward to great things from him and his work on that Council.

The *National Construction Safety Team Act,* which originated in this committee, gave NIST specific authorities necessary to complete the monumental task of understanding the collapse of the World Trade Center towers. Today's hearing will give the Science Committee the chance to learn about NIST's findings and recommendations, and obtain comments from the witnesses about these recommendations and the process by which they will be implemented.

The publication of the NIST report may signal the end of the investigation itself, but it launches a new phase in that process which I hope will result in safer buildings. NIST's recommendations indicate that there are opportunities to make buildings safer and more resilient to fires and other incidents, to improve evacuation routes and procedures, and to improve emergency response. However, the task of amending the building codes is in the hands of the private sector and the State and local officials. NIST's role now becomes technical advisor to the code development process. Congress needs to understand this process, and must support the research and testing required if any of NIST's recommendations are to become common practice. Congress also needs to understand what challenges may exist in implementing NIST's recommendations. Finally, I hope we hear from NIST about how it plans to use the *National Construction Safety Team Act* in the future, because I am certain we will have other occasions that this has to be called into action.

I want to thank NIST for the good work that you have done. Keep this up as we continue to work together to make buildings safer, both during and after disasters. I will have to apologize, because I will be in and out of this committee meeting, mostly out, because I have two other committee meetings simultaneously, and we are marking up bills, so my presence is required for votes. And I apologize to the Members testifying, the witnesses testifying, and also to the Chairman, but I will be here as much as I can.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Thank you, Chairman Boehlert.

I want to thank all our witnesses for coming here today. In particular, I want to congratulate Dr. William Jeffrey, the new NIST Director, on his first appearance before this Committee, and on NIST's latest Nobel Prize for Physics, announced this month to Dr. Jan Hall, a former colleague from my days as a researcher at NIST's Joint Institute for Laboratory Astrophysics (JILA) at the University of Colorado. This increases NIST's Nobel Prizes to three, demonstrating that NIST continues to be a world leader in research and theoretical work. I also want to congratulate Mr. Henry Green, a resident of my home State of Michigan, on his prestigious new position as President of the International Code Council (ICC).

The *National Construction Safety Team Act* (NCST), which originated in this committee, gave NIST specific authorities necessary to complete the monumental task of understanding the collapse of the World Trade Center Towers. Today's hearing will give the Science Committee the chance to learn about NIST's findings and recommendations, and obtain comments from the witnesses about these recommendations and the process by which they will be implemented.

The publication of the NIST report may signal the end of the investigation itself, but it launches a new phase in a process that I hope will result in safer buildings. NIST's recommendations indicate that there are opportunities to make buildings safer and more resilient to fires and other incidents, to improve evacuation routes and procedures, and to improve emergency response. However, the task of amending the building codes is in the hands of the private sector and state and local officials. NIST's role now becomes technical advisor to the code development process. Congress needs to understand this process, and must support the research and testing required if any of NIST's recommendations are to become common practice. Congress also needs to understand what challenges may exist in implementing NIST's recommendations. Finally, I hope we hear from NIST about how it plans to use the *National Construction Safety Team Act* in the future.

Thank you to NIST for the good work you've done. Keep this up as we continue to work together to make buildings safer both during and after disasters.

Chairman BOEHLERT. Well, now that you are making some admissions, in the interest of full disclosure, while we are all very proud of that Nobel Prize in physics for NIST, in the interest of full disclosure, Dr. Ehlers is a physicist, and so, he is particularly proud.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. I want to thank the witnesses for appearing before our committee to discuss the findings and recommendations of the National Institute of Standard and Technology's (NIST) investigation into the collapse of the World Trade Center (WTC).

This committee has held two hearings in 2002 on the WTC collapse that focused on how the Federal Government investigates catastrophic building failures and the lessons learned from the collapse. Concerns raised at the hearing included the lack of any specific federal authority, protocols, or funding for investigations of any kind. As we have learned from the catastrophic damages of Hurricane Katrina, coordination among federal agencies is critical for gauging our preparedness and responding to national disasters. In order to address these concerns, it is my understanding that NIST issued a draft report for public comment that summarizes the findings of the investigation and includes thirty recommendations to improve the safety of tall buildings, occupants, and emergency responders. However, for NIST's plans to be effective, they must be implemented by standards organized and adopted by State and local authorities that set building codes and standards. I want to know how NIST intends to implement its research and recommendations for improved building codes, emergency response and evacuation procedures.

I welcome our witnesses and look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman and Ranking Member.

The events of September 11, 2001, changed our lives forever. That day changed how we Americans prepare ourselves against terrorism.

Building codes and safety regulations play a critical role during a disaster—natural or otherwise. Smart construction can mean the difference between life and death.

During an attack, the weight of collapsing building materials and heat of fire challenge even the best building designs.

The National Institute of Standards and Technology has come today to report on its findings and recommendations following its investigation into the collapse of the World Trade Center.

I hope today's discussion will underscore this key report and help the Committee understand how building and fire code organizations plan to implement the recommendations contained in that report.

I would like to extend a warm welcome to our witnesses today. Thank you, Mr. Chairman.

[The prepared statement of Mr. Carnahan follows:]

PREPARED STATEMENT OF REPRESENTATIVE RUSS CARNAHAN

Mr. Chairman and Mr. Ranking Member, thank you for hosting this important hearing.

I am eager to learn more about the National Institute of Standards and Technology report recommendations. The World Trade Center collapse was a horrific episode for our nation and this report is another appropriate measure that revisits the events and permits us to learn from the tragedy.

Building safety and emergency evacuation are issues that go well beyond the subject of terrorism. This terrible hurricane season is demonstrating all too well the effect natural disasters have on man-made structures and our communities.

I represent a congressional district in St. Louis City that runs south along the Mississippi river. Our region is near the New Madrid earthquake center, which struck the area from 1811 to 1812. These sequences are the most powerful earthquakes ever to have been felt on the North American continent. The New Madrid Fault System remains a threat to our region, and thus, I am eager to learn more about the steps our community needs to take to better prepare our structures for a possible earthquake.

To the multiple witnesses that appear before us today, thank you for your time and your efforts. I look forward to hearing your testimony.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

In looking at what are the next steps in terms of building codes and building structures and integrity, we must unfortunately review what took place on that dreadful day know as September 11th. Like most building collapses, these events were the result of a combination of factors. While the buildings were able to withstand the initial impact of the aircraft, the resulting fires that spread through the towers weakened support columns and floors that had fireproofing dislodged by the impacts. This eventually led to collapse as the perimeter columns were pulled inward by the sagging floors and buckled. According to reports, each aircraft severed perimeter columns, damaged interior core columns and knocked off fireproofing from steel as the planes penetrated the buildings. The weight carried by the severed columns was distributed to other columns. Subsequently, fires began that were initiated by the aircraft's jet fuel but were fed for the most part by the building contents and the air supply resulting from breached walls and fire-induced window breakage. These fires, in combination with the dislodged fireproofing, were responsible for a chain of events in which the building core weakened and began losing its ability to carry loads. The floors weakened and sagged from the fires, pulling inward on the perimeter columns. Floor sagging and exposure to high temperatures caused the perimeter columns to bow inward and buckle—a process that spread across the faces of the buildings which as a result caused the entire structure to collapse.

As a Member of the Committee on Homeland Security, I am very interested in hearing the testimony of our witnesses today. While there have been many theories, no one really knows when, where and if another terrorist attack will take place. It is due to this uncertainty that we must do our best to be prepared in all possible aspects of homeland security. It is my understanding that the September 20, 2005 report released by NIST includes a detailed technical analysis of the root causes of the building failures as well recommendations to improve the safety of tall buildings, occupants and emergency responders. I believe these recommendations fall into eight categories of thirty recommendations. Loosely categorized these are: 1) increased structural integrity, 2) enhanced fire resistance of structures, 3) new methods for fire resistance design, 4) improved active fire protection, 5) improved building evacuation procedures, 6) improved emergency response, 7) improved procedures and practices in the design, construction and operation of buildings; and 8) upgrading the education/training of building and fire safety professionals. In closing, I look forward to the statements and recommendations of our witnesses as they lay out a road map as to how to protect our nation's structures.

[The prepared statement of Mr. Moore follows:]

PREPARED STATEMENT OF REPRESENTATIVE DENNIS MOORE

More than four years after the devastating terrorist attacks of September 11, 2001, we still remember too well the horrible images of that morning: the citizens of New York and Washington D.C. running in fear and confusion from the site of the attacks, firemen and other safety personnel bravely ushering men and women out of harms way, and the skeletal remains of the Twin Towers silhouetted against the bright September sky.

Within hours of the attacks themselves, the Twin Towers collapsed, killing thousands of individuals trapped inside.

While there were many factors that contributed to the catastrophic loss of human life our country suffered on 9/11, an issue that demands careful scrutiny by this committee is the circumstances that contributed to the collapse of the Towers themselves.

As co-chair of the Congressional Hazards Caucus, ensuring that our buildings are properly designed and constructed to handle destructive forces, whether they are terrorist attacks, hurricanes, or tornadoes is of utmost importance to me.

I appreciate the willingness of the panel to share their opinions with the Members of the Science Committee on the findings of the National Institute of Standard and Technology's (NIST) report on the collapse of the World Trace Center and look forward to working with you in the future to ensure the continued safety and security of not only our buildings, but of the American people.

Chairman BOEHLERT. Now, with that, and no further opening statements, let me present, welcome back to the Committee, Ms. Sally Regenhard, Chairperson of the Skyscraper Safety Committee. Ms. Regenhard, the floor is yours, and she will have a very interesting statement, and so much of the commentary in her statement will lead us to provide questions to the panel that will follow.

So, Ms. Regenhard, the floor is yours.

Panel I:

STATEMENT OF SALLY REGENHARD, CHAIRPERSON, SKYSCRAPER SAFETY CAMPAIGN

Ms. REGENHARD. Okay. Thank you. Good morning, Chairman Boehlert and Members of the House Science Committee. It is truly an honor and a privilege to address you today.

I must first begin by thanking Chairman Sherwood Boehlert and this committee for listening with compassion and concern to the families of the victims of 9/11. When we first came here in March and May of 2002, we were desperately seeking leadership for an investigation of what happened to our loved ones on 9/11. We had sought this on the local level in New York City, but found no one to help us answer the painful questions regarding what happened to our loved ones in the World Trade Center on that dreaded day of infamy.

Chairman Boehlert and the Science Committee, you have redeemed our belief in the system, and renewed our faith in the process of representative government in our beloved country, and for this, we profoundly thank you. The families of the victims as well as the American public remain in your debt for your efforts in authorizing a WTC investigation through the *National Construction Safety Team Act.*

I must also begin by thanking NIST for interacting with us on a regular basis over the past three years, via conference calls and meetings, with myself and my SSC co-chair, Monica Gabrielle, who is out of the country and cannot be here today. I know that it has not always been easy to deal with me and with other victims' fami-

lies, but I appreciate the tolerance and respect shown to us by NIST. I also appreciate the vast technical research abilities of this organization and the enormous task of embarking upon the WTC investigation.

In totality, however, while some very valuable results were achieved, the overall mode and findings of the investigation was not what I had hoped for. I had certain hopes regarding NIST in the investigation, but I and others were somewhat disillusioned regarding what NIST was willing and able to do. I had hoped for more specific and comprehensive recommendations that could easily be translated into code reform and change, but this was not the case. The recommendations, I feel, are very general and lack specifics. I feel that the vagueness of the language was influenced by a need for political correctness and a general reluctance or an inability to investigate, use subpoena power, lay blame, or even point out the deadly mistakes of 9/11 in the World Trade Center.

The following are five areas of concern of the Skyscraper Safety Campaign, and these concerns have been compiled by input from my professional advisors, as well as my own experience during the last four years.

The first area of concern is the role of the Port Authority of New York and New Jersey and its exemptions from immunities and codes. The failure of the NIST investigation to comprehensively examine what role these immunities played in the design, construction, maintenance, and ultimate collapse of the World Trade Center, is of great concern to me.

Secondly, the lack of more intense emphasis on the fireproofing issues, the premature disposal of the steel evidence, the heavy reliance on computer modeling for the fire testing, and the reluctance to focus on cause, blame, and resultant implications are troubling to us.

Number three, the reliance on the voluntary cooperation of key figures in the investigation to provide needed information, putting the WTC chief structural engineer on the payroll to facilitate his involvement in the investigation, utilizing researchers to the exclusion of true investigators going into the field to obtain evidence is also problematic to me. On this last point, I want to note that I have been married to an NYPD detective sergeant for over 30 years, and I can recognize an investigation when I see one. I feel the inherent character of the NIST as a research rather than an investigative agency was a factor in this situation.

Number four, the lack of focus on evacuation issues of the World Trade Center, such as the remoteness of the exits, the behavior of fleeing persons in the stairwells, and the avoidance of first person accounts of stairwell evacuation, and the length of time it took to evacuate the building was a shortcoming.

Finally, the relative secrecy of the investigation and the withholding of all materials and documents used by NIST to arrive at the study's conclusions is very disturbing. These materials should be made available to professionals to further study and to analyze, and to question and verify the findings according to the scientific method. And they should not be locked away in the National Archives or anywhere else. I certainly hope that I could call on the

Science Committee to help unlock this information for the American public in the future.

In conclusion, for these and for other reasons, I feel that government must take a larger role in developing stronger codes and standards for building and public safety, by being a true resource to the code industry. Government representatives should be part of code writing groups, to provide advice and guidance, and to help develop standards and practices. As it stands now, it is largely a battle of the do-gooders, like me and the Skyscraper Safety Advisors, versus the business interests, in a never-ending conflict regarding public safety. The NIST investigation should not be an end. It should be just the beginning of a new era, in which we see the real and meaningful role that government must play in the safety and wellbeing of the American people. In addition to the laudable creation of the *National Construction Safety Team Act,* this participation can be an additional legacy for the innocent victims of 9/11, including my beautiful son, Probationary Firefighter Christian Michael Otto Regenhard, whose godmother is holding his picture here today. He continues to be the inspiration for the work and the accomplishments of the Skyscraper Safety Campaign.

I thank you all for this opportunity to speak to you today. God bless you all in your work.

[The prepared statement of Ms. Regenhard follows:]

PREPARED STATEMENT OF SALLY REGENHARD

Good morning Chairman Boehlert and Members of the House Science Committee. It is truly an honor and a privilege to address you today. I must first begin by thanking Chairman Sherwood Boehlert and this committee, for listening with compassion and concern to the families of the victims of 9/11. When we first came here in March and May of 2002, we were desperately seeking leadership for an investigation of what happened to our loved ones on 9/11/01. We had sought this on the local level in NYC, but found no one to help us answer the painful questions regarding what happened to our loved ones in the WTC on that dreaded day of infamy.

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The following are five areas of concern for the Skyscraper Safety Campaign: (While I have an understanding of these issues in concept, for answers to specific, technical questions, I would like to confer with two of my technical advisors who are with me here today.)

1) The role of the Port Authority of NYNJ and its' exemptions from immunities and codes. The failure of the NIST Investigation to comprehensively examine

what role these immunities had in the design, construction, maintenance and ultimate collapse of the WTC is of great concern to me.

2) The lack of more intense emphasis on fireproofing issues, premature disposal of steel evidence, the heavy reliance on computer modeling for fire testing, and the reluctance to focus on cause, blame, and resultant implications are troubling.

3) The reliance on the voluntary cooperation of key figures in the investigation to provide needed information; placing the former WTC chief structural engineer on the payroll to facilitate his involvement in the investigation, utilizing researchers to the exclusion of true investigators going into the field to obtain evidence is problematic to me. On this last point, I have been married to a NYPD detective sergeant for over 30 years, and I can recognize an Investigation when I see one. I feel the inherent character of NIST as a research rather than investigative agency was a factor in this situation.

4) The lack of focus on evacuation issues of the WTC such as remoteness of exits, behavior of fleeing persons in the stairwells, and the avoidance of first person accounts of stairwell evacuation, and length of time it took to evacuate the building was a shortcoming.

5) The relative secrecy of the investigation, and the withholding of all materials and documents used by NIST to arrive at the study's conclusions is very disturbing. These materials should be made available to professionals for further study and analysis, to question and/or duplicate the findings, according to the scientific method, and should not be locked away in the National Archives or anywhere else. I hope I can call on the Science Committee to unlock this information for the American public.

In conclusion, for these and other reasons, I feel that government must take a larger role in developing stronger codes and standards for building and public safety. Government representatives should be part of code writing groups, and help to develop standards and practices. As is stands now, it is a battle of the "do-gooders" like me and the Skyscraper Safety Advisors vs. business interests, in a never ending conflict regarding public safety. The NIST investigation should not be an end; it should be just the beginning of a new era in which we see the real and meaningful role that government must play in the safety and well being of the American people. In addition to the laudable creation of the *National Construction Safety Team Act,* this participation can be an additional legacy for the innocent victims of 9/11, including my beautiful son, Probationary Firefighter Christian Michael Otto Regenhard, who continues to be the inspiration for the work and accomplishments of the Skyscraper Safety Campaign. Thank you for this opportunity to speak today. God bless you all.

Chairman BOEHLERT. Thank you very much, and you continue to be an inspiration to this committee.

Let me point out that now, the witnesses that will follow. I hope you are going to be able to remain to listen to their testimony, and to listen to the questioning. I think you are absolutely correct in pointing out that I think it is a shared interest in being more specific, rather than vague, in the report, but NIST, I think, has done an outstanding job, and NIST correctly, as you identified in your testimony, is not an investigative agency. It is a research agency. I have found NIST to be most cooperative, but we are going to hold their feet to the fire, and we are going to make certain they follow through in their recommendations.

So, I think, hopefully, some measure of comfort will come to you from the statement of Dr. Jeffrey and his expressed determination to follow through on this. And I think you will be interested in what some of other witnesses have to say. These are people with whom you are familiar. And finally, I just hope it is not the do-gooders versus the business interests. I think we have got to have a partnership here. It is good business to make buildings safer, and that does good in the process. So, we will all work together. Thank you very much.

Ms. REGENHARD. Thank you very much.

Chairman BOEHLERT. The second panel today consists of Dr. William Jeffrey, Director of the National Institute of Standards and Technology; Ms. Nancy McNabb, Director of Government Affairs, National Fire Protection Association; Dr. James R. Harris, President, J.R. Harris and Company, Member, American Society of Civil Engineers; and Mr. Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice, Member of NIST National Construction Safety Team Advisory Board; and for the purpose of an introduction of our final witness, I call on our distinguished colleague, Mr. Schwarz of Michigan.

Mr. SCHWARZ. Thank you, Mr. Chairman. It is not frequently that I have the opportunity to introduce a constituent to his testifying before this committee, but in this case, Mr. Henry L. Green not only serves as President of the Board of Directors for the International Code Council, but as an expert in his field, and as a constituent of mine from Delta Township, which is just outside of Lansing, Michigan. In 1989, Mr. Green was appointed Executive Director of the Bureau of Construction Codes and Fire Safety for the Michigan Department of Labor and Economic Growth. Henry, they keep changing the names of the departments. That was what it was when I was in the State senate. He has worked in the Bureau for more than 20 years, serving as Building Inspector, Chief of the Barrier Free Design Division, Chief Building Inspector, and as Deputy Director before assuming his current role. He also serves on the Building Officials Code Administration, BOCA, Board of Directors, serving as President in 1997.

Mr. Chairman, Mr. Green is eminently qualified to testify before this committee, and I am equally delighted that he is here and a constituent of mine from mid-Michigan, from the 7th District. Actually, he is from Spartan Country, not Wolverine Country, but we will forgive him for that.

Chairman BOEHLERT. Mr. Green would join us at the table, and thank you very much for that eloquent introduction. I have had the pleasure of meeting Mr. Green, and I want to welcome you here. I want to welcome all of you here, and I want to thank you for being resources for this committee. I particularly want to welcome Dr. Jeffrey in his maiden public appearance before the Science Committee, in his present capacity.

Dr. Jeffrey, the floor is yours. And I would say to all our witnesses, we would ask that you try to summarize your opening statement in five minutes or so. We are not going to be all that arbitrary, but that will allow more time for questions and interaction between the panel and the Members. Dr. Jeffrey, the floor is yours.

Panel II:

STATEMENT OF DR. WILLIAM JEFFREY, DIRECTOR, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dr. JEFFREY. Thank you, Mr. Chairman, and also thank you for your warm welcome remarks.

Mr. Chairman and Members of the Committee, I am pleased to testify on the NIST investigation of the World Trade Center dis-

aster. With your permission, I have a written statement for the record, along with our final report.

Chairman BOEHLERT. Without objection, so ordered. All the statements in their entirety will be part of the official record.

Dr. JEFFREY. And I will now summarize our work to date and our plans for the future. We announced this investigation saying it would be thorough, open, and result in meaningful recommendations.

It was thorough. NIST was able to acquire and test enough steel from the buildings to have confidence in our findings. We acquired more than 7,000 photos and 150 hours of videotape. We interviewed nearly 1,200 survivors and first responders, and we gained access to key information about the building's design and construction.

It was also open. We sought public comment on our plans even before we began the investigation. We held numerous briefings for the public, published reports on our progress, and solicited comments. We sought input from an advisory committee of outside experts. We established a special liaison with the families of victims, and communicated regularly with the relevant organizations in New York City. This was no academic exercise. We were charged with developing meaningful recommendations, and we have done that. Using the recommendations from this investigation to make improvements in the way people design, maintain, and use buildings has just begun. NIST is working vigorously with the relevant communities to turn the recommendations into action.

The direct link between the terrorist-initiated airplane attacks, the ensuing fires, and the collapse of the towers was established through extensive testing, analyses, and computer modeling. Here, you see a model of the aircraft as it enters Tower 1, and the damage that was inflicted as debris and jet fuel spread over multiple floors. These models helped us to estimate the internal damage to the structure and fireproofing that was not visible in photos and videos taken from the outside.

The egress capacity required by the current building codes is based on evacuating a single floor, not an entire building. Fortunately, the towers were only one third to one half of full capacity that morning, allowing 87 percent of the occupants to evacuate. Had the buildings been full, with about 20,000 occupants each, roughly 14,000 people may have lost their lives. Radio communications were a problem due to three factors: first, the challenging radio frequency environment posed by buildings; second, the scale of operations that overwhelmed the available frequencies and exceeded the limits of the communication protocols; and third, the difficulty of transmissions between different organizations.

The recommendations we have made call for specific actions. We made our recommendations as specific as we could, identifying the parties that need to help take the next steps. The recommendations do not prescribe specific systems, materials, or technologies. Instead, NIST encourages competition among alternatives that can meet performance requirements. Within these recommendations, NIST has identified 37 specific national model codes, standards, practice guidelines, or regulations that merit consideration through an open and consensus-driven process.

NIST's response plan consists of three parts. First, the building and fire safety investigation. And today, we are releasing the final version of 43 reports documenting this investigation, and plan to release draft reports in the spring documenting our investigation of WTC 7. Second, our research and development program, and third, a dissemination and technical assistance program to facilitate adoption of the proposed changes.

As part of this effort, NIST is aggressively working with the model building code organizations and others representing State and local officials to facilitate this process. Among other things, NIST has held a major conference to focus attention on getting action on these recommendations. We have contracted with the National Institute of Building Sciences to turn the appropriate recommendations into draft code language for submission to the national model code developers, and we have assigned a staff member responsibility for following up on each and every recommendation.

Past NIST investigations have resulted in substantive improvements in building safety. For example, improvements to manufactured homes were made following our work on Hurricanes Andrew and Camille. Improvements in construction safety and inspection resulted from NIST's investigation of an apartment building under construction in Connecticut. There are many more examples of NIST's investigations resulting in improvements to building safety, and we will do everything possible to add the WTC investigation to this list.

Thank you for your support and this opportunity to update the Committee.

[The prepared statement of Dr. Jeffrey follows:]

PREPARED STATEMENT OF WILLIAM JEFFREY

Mr. Chairman, and Members of the Committee, I am William Jeffrey, Director of the National Institute of Standards and Technology. I am pleased to appear today and testify on the building and fire safety investigation of the World Trade Center disaster carried out by the National Institute of Standards and Technology (NIST).

NIST announced its building and fire safety investigation of the World Trade Center (WTC) disaster on August 21, 2002.[1] This WTC Investigation was then conducted under the authority of the *National Construction Safety Team (NCST) Act,* which was signed into law on October 1, 2002.

The goals of the investigation of the WTC disaster were:

- To investigate the building construction, the materials used, and the technical conditions that contributed to the outcome of the WTC disaster after terrorists flew large jet-fuel laden commercial airliners into the WTC towers.
- To serve as the basis for:
  - — Improvements in the way buildings are designed, constructed, maintained, and used;
  - — Improved tools and guidance for industry and safety officials;
  - — Recommended revisions to current codes, standards, and practices; and
  - — Improved public safety.

[1] NIST is a nonregulatory agency of the U.S. Department of Commerce. The purposes of NIST investigations are to improve the safety and structural integrity of buildings in the United States and the focus is on fact finding. NIST investigative teams are required 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. NIST does not have the statutory authority to make findings of fault or negligence by individuals or organizations. Further, no part of any report resulting from a NIST investigation into a building failure or from an investigation under the *National Construction Safety Team Act* may be used in any suit or action for damages arising out of any matter mentioned in such report (15 USC 281a, as amended by P.L. 107–231).

The specific objectives were:

1. Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft and why and how WTC 7 collapsed;
2. Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response;
3. Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1, 2, and 7.
4. Identify, as specifically as possible, areas in current building and fire codes, standards, and practices that warrant revision.

APPROACH

To meet these goals, NIST complemented its in-house expertise with an array of specialists in key technical areas. In all, over 200 staff contributed to the investigation. NIST and its contractors compiled and reviewed tens of thousand of pages of documents; conducted interviews with over a thousand people who had been on the scene or who had been involved with the design, construction, and maintenance of the WTC; analyzed 236 pieces of steel that were obtained from the wreckage; performed laboratory tests that measured material properties, and performed computer simulations of the sequence of events that happened from the instant of aircraft impact to the initiation of collapse for each tower.

Cooperation in obtaining the resource materials and in interpreting the results came from a large number of individuals and organizations, including The Port Authority of New York and New Jersey and its contractors and consultants, Silverstein Properties and its contractors and consultants, the City of New York and its departments, the manufacturers and fabricators of the building components, the companies that insured the WTC towers, the building tenants, the aircraft manufacturers, the airlines, and the media.

The scarcity of physical evidence that is typically available in place for reconstruction of a disaster led to the following approach:

- Accumulation of copious photographic and video material. With the assistance of the media, public agencies and individual photographers, NIST acquired and organized nearly 7,000 segments of video footage, totaling in excess of 150 hours and nearly 7,000 photographs representing at least 185 photographers. This guided the Investigation Team's efforts to determine the condition of the buildings following the aircraft impact, the evolution of the fires, and the subsequent deterioration of the structure.
- Establishment of the baseline performance of the WTC towers, i.e., estimating the expected performance of the towers under normal design loads and conditions. The baseline performance analysis also helped to estimate the ability of the towers to withstand the unexpected events of September 11, 2001. Establishing the baseline performance of the towers began with the compilation and analysis of the procedures and practices used in the design, construction, operation, and maintenance of the structural, fire protection, and egress systems of the WTC towers. The additional components of the performance analysis were the standard fire resistance of the WTC truss-framed floor system, the quality and properties of the structural steels used in the towers, and the response of the WTC towers to the design gravity and wind loads.
- Conduct simulations of the behavior of each tower on September 11, 2001, in four steps:
    1. The aircraft impact into the tower, the resulting distribution of aviation fuel, and the damage to the structure, partitions, thermal insulation materials, and building contents.
    2. The evolution of multi-floor fires.
    3. The heating and consequent weakening of the structural elements by the fires.
    4. The response of the damaged and heated building structure, and the progression of structural component failures leading to the initiation of the collapse of the towers.

For such complex structures and complex thermal and structural processes, each of these steps stretched the state of the technology and tested the limits of software tools and computer hardware. For example, the investigators advanced the state-of-the-art in the measurement of construction material properties and in structural fi-

nite element modeling. New modeling capability was developed for the mapping of fire-generated environmental temperatures onto the building structural components.

The output of the four-step simulations was subject to uncertainties in the as-built condition of the towers, the interior layout and furnishings, the aircraft impact, the internal damage to the towers (especially the thermal insulation for fire protection of the structural steel, which is colloquially referred to as fireproofing), the redistribution of the combustibles, and the response of the building structural components to the heat from the fires. To increase confidence in the simulation results, NIST used the visual evidence, eyewitness accounts from inside and outside the buildings, laboratory tests involving large fires and the heating of structural components, and formal statistical methods to identify influential parameters and quantify the variability in analysis results.

- Combination of the knowledge gained into probable collapse sequences for each tower,[2] the identification of factors that contributed to the collapse, and a list of factors that could have improved building performance or otherwise mitigated the loss of life.
- Compilation of a list of findings that respond to the first three objectives and a list of recommendations that responds to the fourth objective.

SUMMARY OF FINDINGS

Objective 1: Determine why and how WTC 1 and WTC 2 collapsed following the initial impacts of the aircraft.

- The two aircraft hit the towers at high speed and did considerable damage to principal structural components (core columns, floors, and perimeter columns) that were directly impacted by the aircraft or associated debris. However, the towers withstood the impacts and would have remained standing were it not for the dislodged insulation (fireproofing) and the subsequent multi-floor fires. The robustness of the perimeter frame-tube system and the large size of the buildings helped the towers withstand the impact. The structural system redistributed loads from places of aircraft impact, avoiding larger scale damage upon impact. The hat truss, a feature atop each tower which was intended to support a television antenna, prevented earlier collapse of the building core. In each tower, a different combination of impact damage and heat-weakened structural components contributed to the abrupt structural collapse.
- In WTC 1, the fires weakened the core columns and caused the floors on the south side of the building to sag. The floors pulled the heated south perimeter columns inward, reducing their capacity to support the building above. Their neighboring columns quickly became overloaded as columns on the south wall buckled. The top section of the building tilted to the south and began its descent. The time from aircraft impact to collapse initiation was largely determined by how long it took for the fires to weaken the building core and to reach the south side of the building and weaken the perimeter columns and floors.
- In WTC 2, the core was damaged severely at the southeast corner and was restrained by the east and south walls via the hat truss and the floors. The steady burning fires on the east side of the building caused the floors on that side to sag. The floors pulled the heated east perimeter columns inward, reducing their capacity to support the building above. Their neighboring columns quickly became overloaded as columns on the east wall buckled. The top section of the building tilted to the east and to the south and began its descent. The time from aircraft impact to collapse initiation was largely determined by the time needed for the fires to weaken the perimeter columns and floor assemblies on the east and the south sides of the building. WTC 2 collapsed more quickly than WTC 1 because there was more aircraft damage to the building core, including one of the heavily loaded corner columns, and there were early and persistent fires on the east side of the building, where the aircraft had extensively dislodged insulation from the structural steel.
- The WTC towers likely would not have collapsed under the combined effects of aircraft impact damage and the extensive, multi-floor fires that were en-

[2] The focus of the Investigation was on the sequence of events from the instant of aircraft impact to the initiation of collapse for each tower. For brevity, this sequence is referred to as the "probable collapse sequence," although it includes little analysis of the structural behavior of the tower after the conditions for collapse initiation were reached and collapse became inevitable.

countered on September 11, 2001 if the thermal insulation had not been widely dislodged or had been only minimally dislodged by aircraft impact.

- NIST found no corroborating evidence for alternative hypotheses suggesting that the WTC towers were brought down by controlled demolition using explosives planted prior to September 11, 2001. NIST also did not find any evidence that missiles were fired at or hit the towers. Instead, photographs and videos from several angles clearly showed that the collapse initiated at the fire and impact floors and that the collapse progressed from the initiating floors downward, until the dust clouds obscured the view.

Objective 2: Determine why the injuries and fatalities were so high or low depending on location, including all technical aspects of fire protection, occupant behavior, evacuation, and emergency response.

- Approximately 87 percent of the estimated 17,400 occupants of the towers, and 99 percent of those located below the impact floors, evacuated successfully. In WTC 1, where the aircraft destroyed all escape routes, 1,355 people were trapped in the upper floors when the building collapsed. One hundred seven people who were below the impact floors did not survive. Since the flow of people from the building had slowed considerably 20 minutes before the tower collapsed, the stairwell capacity was adequate to evacuate the occupants on that morning.
- In WTC 2, before the second aircraft strike, about 3,000 people got low enough in the building to escape by a combination of self-evacuation and use of elevators. The aircraft destroyed the operation of the elevators and the use of two of the three stairways. Eighteen people from above the impact zone found a passage through the damaged third stairway (Stairwell A) and escaped. The other 619 people in or above the impact zone perished. Eleven people who were below the impact floors did not survive. As in WTC 1, shortly before collapse, the flow of people from the building had slowed considerably, indicating that the stairwell capacity was adequate that morning.
- About six percent of the survivors described themselves as mobility impaired, with recent injury and chronic illness being the most common causes; few, however, required a wheelchair. Among the 118 decedents below the aircraft impact floors, investigators identified seven who were mobility impaired, but were unable to determine the mobility capability of the remaining 111.
- A principal factor limiting the loss of life was that the buildings were only one-third to one-half occupied at the time of the attacks. NIST estimated that if the towers had been fully occupied with 20,000 occupants each, it would have taken just over 3 hours to evacuate the buildings and about 14,000 people might have perished because the stairwell capacity would not have been sufficient to evacuate that many people in the available time. Egress capacity required by current building codes is determined by single floor calculations that are independent of building height and does not consider the time for full building evacuation.
- Due to the presence of assembly use spaces at the top of each tower (Windows on the World restaurant complex in WTC 1 and the Top of the Deck observation deck in WTC 2) that were designed to accommodate over 1,000 occupants per floor, the New York City Building Code would have required a minimum of four independent means of egress (stairs), one more than the three that were available in the buildings. Given the low occupancy level on September 11, 2001, NIST found that the issue of egress capacity from these places of assembly, or from elsewhere in the buildings, was not a significant factor on that day. It is conceivable that such a fourth stairwell, depending on its location and the effects of aircraft impact on its functional integrity, could have remained passable, allowing evacuation by an unknown number of additional occupants from above the floors of impact. If the buildings had been filled to their capacity with 20,000 occupants, however, the required fourth stairway would likely have mitigated the insufficient egress capacity for conducting a full building evacuation within the available time.
- Evacuation was assisted by participation in fire drills within the previous year by two-thirds of survivors and perhaps hindered by a Local Law that prevented employers from requiring occupants to practice using the stairways. The stairways were not easily navigated in some locations due to their design, which included "transfer hallways," where evacuees had to traverse from one stairway to another location where the stairs continued. Addition-

ally, many occupants were unprepared for the physical challenge of full building evacuation.

- The functional integrity and survivability of the stairwells was affected by the separation of the stairwells and the structural integrity of stairwell enclosures. In the impact region of WTC 1, the stairwell separation was the smallest over the building height—clustered well within the building core—and all stairwells were destroyed by the aircraft impact. By contrast, the separation of stairwells in the impact region of WTC 2 was the largest over the building height—located along different boundaries of the building core—and one of three stairwells remained marginally passable after the aircraft impact. The shaft enclosures were fire rated but were not required to have structural integrity under typical accidental loads: there were numerous reports of stairwells obstructed by fallen debris from damaged enclosures.
- The active fire safety systems (sprinklers, smoke purge, fire alarms, and emergency occupant communications) were designed to meet or exceed current practice. However, with the exception of the evacuation announcements, they played no role in the safety of life on September 11 because the water supplies to the sprinklers were damaged by the aircraft impact. The smoke purge systems, operated under the direction of the fire department after fires, were not turned on, but they also would have been ineffective due to aircraft damage. The violence of the aircraft impact served as its own alarm. In WTC 2, contradictory public address announcements contributed to occupant confusion and some delay in occupants beginning to evacuate.
- For the approximately 1,000 emergency responders on the scene, this was the largest disaster they had even seen. Despite attempts by the responding agencies to work together and perform their own tasks, the extent of the incident was well beyond their capabilities. Communications were erratic due to the high number of calls and the inadequate performance of some of the gear. Even so, there was no way to digest, test for accuracy, and disseminate the vast amount of information being received. Their jobs were complicated by the loss of command centers in WTC 7 and then in the towers after WTC 2 collapsed. With nearly all elevator service disrupted and progress up the stairs taking about two min. per floor, it would have taken hours for the responders to reach their destinations, assist survivors, and escape had the towers not collapsed.

Objective 3: Determine what procedures and practices were used in the design, construction, operation, and maintenance of WTC 1 and WTC 2.

- Because of The Port Authority's establishment under a clause of the United States Constitution, its buildings were not subject to any state or local building regulations. The buildings were unlike any others previously built, both in their height and in their innovative structural features. Nevertheless, the actual design and approval process produced two buildings that generally were consistent with nearly all of the provisions of the New York City Building Code and other building codes of that time that were reviewed by NIST. The loads for which the buildings were designed exceeded the New York City code requirements. The quality of the structural steels was consistent with the building specifications. The departures from the building codes and standards identified by NIST did not have a significant effect on the outcome of September 11.
- For the floor systems, the fire rating and insulation thickness used on the floor trusses, which together with the concrete slab served as the main source of support for the floors, were of concern from the time of initial construction. NIST found no technical basis or test data on which the thermal protection of the steel was based. On September 11, 2001, the minimum specified thickness of the insulation was adequate to delay heating of the trusses; the amount of insulation dislodged by the aircraft impact, however, was sufficient to cause the structural steel to be heated to critical levels.
- Based on four standard fire resistance tests that were conducted under a range of insulation and test conditions, NIST found the fire rating of the floor system to vary between ¾ hour and two hours; in all cases, the floors continued to support the full design load without collapse for over two hours.
- The wind loads used for the WTC towers, which governed the structural design of the external columns and provided the baseline capacity of the structures to withstand abnormal events such as major fires or impact damage, significantly exceeded the requirements of the New York City Building Code

and other building codes of the day that were reviewed by NIST. Two sets of wind load estimates for the towers obtained by independent commercial consultants in 2002, however, differed by as much as 40 percent. These estimates were based on wind tunnel tests conducted as part of insurance litigation unrelated to the Investigation.

RECOMMENDATIONS

The tragic consequences of the September 11, 2001, attacks were directly attributable to the fact that terrorists flew large jet-fuel laden commercial airliners into the WTC towers. Buildings for use by the general population are not designed to withstand attacks of such severity; building regulations do not require building designs to consider aircraft impact. In our cities, there has been no experience with a disaster of such magnitude, nor has there been any in which the total collapse of a high-rise building occurred so rapidly and with little warning.

While there were unique aspects to the design of the WTC towers and the terrorist attacks of September 11, 2001, NIST has compiled a list of recommendations to improve the safety of tall buildings, occupants, and emergency responders based on its investigation of the procedures and practices that were used for the WTC towers; these procedures and practices are commonly used in the design, construction, operation, and maintenance of buildings under normal conditions. Public officials and building owners will need to determine appropriate performance requirements for those tall buildings, and selected other buildings, that are at higher risk due to their iconic status, critical function, or design.

The topics of the recommendations in eight groups are listed in Table 1. A complete listing of the 30 recommendations is provided in Appendix A. The ordering does not reflect any priority.

The eight major groups of recommendations are:

- *Increased Structural Integrity:* The standards for estimating the load effects of potential hazards (e.g., progressive collapse, wind) and the design of structural systems to mitigate the effects of those hazards should be improved to enhance structural integrity.
- *Enhanced Fire Endurance of Structures:* The procedures and practices used to ensure the fire endurance of structures should be enhanced by improving the technical basis for construction classifications and fire resistance ratings, improving the technical basis for standard fire resistance testing methods, use of the "structural frame" approach to fire resistance ratings, and developing in-service performance requirements and conformance criteria for sprayed fire-resistive material.
- *New Methods for Fire Resistant Design of Structures:* The procedures and practices used in the fire resistant design of structures should be enhanced by requiring an objective that uncontrolled fires result in burnout without local or global collapse. Performance-based methods are an alternative to prescriptive design methods. This effort should include the development and evaluation of new fire resistive coating materials and technologies and evaluation of the fire performance of conventional and high-performance structural materials.
- *Improved Active Fire Protection:* Active fire protection systems (i.e., sprinklers, standpipes/hoses, fire alarms, and smoke management systems) should be enhanced through improvements to design, performance, reliability, and redundancy of such systems.
- *Improved Building Evacuation:* Building evacuation should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness for evacuation during emergencies, and incorporation of appropriate egress technologies.
- *Improved Emergency Response:* Technologies and procedures for emergency response should be improved to enable better access to buildings, response operations, emergency communications, and command and control in large-scale emergencies.
- *Improved Procedures and Practices:* The procedures and practices used in the design, construction, maintenance, and operation of buildings should be improved to include encouraging code compliance by non-governmental and quasi-governmental entities, adoption and application of egress and sprinkler requirements in codes for existing buildings, and retention and availability of building documents over the life of a building.

- *Education and Training:* The professional skills of building and fire safety professionals should be upgraded though a national education and training effort for fire protection engineers, structural engineers, architects, regulatory personnel, and emergency responders.

The recommendations call for action by specific entities regarding standards, codes and regulations, their adoption and enforcement, professional practices, education, and training; and research and development. Only when each of the entities carries out its role will the implementation of a recommendation be effective.

The recommendations do not prescribe specific systems, materials, or technologies. Instead, NIST encourages competition among alternatives that can meet performance requirements. The recommendations also do not prescribe specific threshold levels; NIST believes that this responsibility properly falls within the purview of the public policy setting process, in which the standards and codes development process plays a key role.

NIST believes the recommendations are realistic and achievable within a reasonable period of time. Only a few of the recommendations call for new requirements in standards and codes. Most of the recommendations deal with improving an existing standard or code requirement, establishing a standard for an existing practice without one, establishing the technical basis for an existing requirement, making a current requirement risk-consistent, adopting or enforcing a current requirement, or establishing a performance-based alternative to a current prescriptive requirement.

NEXT STEPS

We have strongly urged that immediate and serious consideration be given to these recommendations by the building and fire safety communities in order to achieve appropriate improvements in the way buildings are designed, constructed, maintained, and used and in evacuation and emergency response procedures-with the goal of making buildings, occupants, and first responders safer in future emergencies.

We are also strongly urging building owners and public officials to (1) evaluate the safety implications of these recommendations to their existing inventory of buildings and (2) take the steps necessary to mitigate any unwarranted risks without waiting for changes to occur in codes, standards, and practices.

We are urging state and local agencies to rigorously enforce building codes and standards since such enforcement is critical to ensure the expected level of safety. Unless they are complied with, the best codes and standards cannot protect occupants, emergency responders, or buildings.

I have assigned top priority for NIST staff to work vigorously with the building and fire safety communities to assure that there is a complete understanding of the recommendations and to provide needed technical assistance in getting the recommendations implemented. We have identified specific codes, standards, and practices affected by each of the recommendations in its summary report for the WTC towers and already begun to reach out to the responsible organizations to pave the way for a timely, expedited consideration of the recommendations. Toward this end, we held a conference September 13–15, 2005 that was attended by over 200 people, including all of the major standards and codes development organizations.

We have also awarded a contract to the National Institute of Building Sciences (NIBS) to turn many of the recommendations into code language suitable for submission of code change proposals to the two national model code developers.

In addition, we will implement a web-based system so that the public can track progress on implementing the recommendations. The web site will list each of the recommendations, the specific organization or organizations (e.g., standards and code developers, professional groups, state and local authorities) responsible for its implementation, the status of its implementation by organization, and the plans or work in progress to implement the recommendations.

We are releasing the final versions of the 43 reports on NIST's investigation of the WTC towers, totaling some 10,000 pages, today. Our current plans are to release next spring an additional five reports as drafts for public comment on the investigation of WTC 7.

Mr. Chairman, I want to thank you and the Committee again for allowing me to testify today about NIST's building and fire safety investigation of the World Trade Center disaster. I would be happy to answer any questions at this time.

Table 1. Topics of NIST recommendations for improved public safety in tall and high-risk buildings.

Recommendation Group	Recommendation Topic	Responsible Community					Application		Relation to 9/11 Outcome	
		Practices	Standards, Codes, Regulations	Adoption & Enforcement	R&D/Further Study	Education & Training	All Tall Buildings	Selected Other High-Risk Buildings	Related[a]	Unrelated[b]
Increased Structural Integrity	Prevention of progressive collapse and failure analysis of complex systems	✓	✓	✓	✓	✓	✓	✓	✓	
	Estimation of wind loads and their effects on tall buildings	✓	✓		✓		✓	✓		✓
	Allowable tall buildings sway	✓	✓		✓		✓			✓
Enhanced Fire Endurance of Structures	Fire resistance rating requirements and construction classification	✓	✓		✓		✓			✓
	Fire resistance testing of building components and extrapolation of test data to qualify untested building components		✓		✓		✓			✓
	In-service performance requirements and inspection procedures for sprayed fire-resistive material (SFRM or spray-on fireproofing)	✓	✓	✓	✓		✓			✓
	"Structural frame" approach (structural members connected to columns carry the higher fire resistance rating of the columns)		✓	✓		✓	✓	✓		✓
New Methods for Fire Resistant Design of Structures	Burnout without partial or global (total) structural collapse in uncontrolled building fires	✓	✓	✓	✓	✓	✓	✓	✓	
	Performance-based design and retrofit of structures to resist fires	✓	✓		✓	✓	✓	✓		✓
	New fire-resistive coating materials, systems, and technologies	✓	✓		✓		✓	✓	✓	
	Evaluation of high performance structural materials under conditions expected in building fires	✓			✓		✓	✓		✓
Improved Active Fire Protection	Performance and redundancy of active fire protection systems to accommodate the greater risks associated with tall buildings	✓	✓		✓		✓	✓	✓	
	Advanced fire alarm and communication systems that provide continuous, reliable, and accurate information on life safety conditions to manage the evacuation process.		✓		✓		✓		✓	
	Advanced fire/emergency control panels with more reliable information from the active fire protection systems to provide tactical decision aids		✓		✓		✓	✓	✓	
	Improved transmission to emergency responders, and off-site or black box storage, of information from building monitoring systems	✓	✓		✓		✓	✓	✓	✓

Recommendation Group	Recommendation Topic	Responsible Community					Application		Relation to 9/11 Outcome	
		Practices	Standards, Codes, Regulations	Adoption & Enforcement	R&D/Further Study	Education & Training	All Tall Buildings	Selected Other High-Risk Buildings	Related[a]	Unrelated[b]
Improved Building Evacuation	Public education and training campaigns to improve building occupants' preparedness for evacuation	✓	✓		✓	✓	✓		✓	✓
	Tall building design for timely full building emergency evacuation of occupants	✓	✓		✓	✓	✓	✓	✓	✓
	Design of occupant-friendly evacuation paths that maintain functionality in foreseeable emergencies	✓	✓				✓		✓	
	Planning for communication of accurate emergency information to building occupants	✓	✓			✓	✓	✓	✓	
	Evaluation of alternative evacuation technologies, to allow all occupants equal opportunity for evacuation and to facilitate emergency response access	✓	✓		✓		✓	✓	✓	
Improved Emergency Response	Fire-protected and structurally hardened elevators	✓	✓		✓		✓		✓	
	Effective emergency communications systems for large-scale emergencies	✓	✓	✓	✓	✓	✓		✓	
	Enhanced gathering, processing, and delivering of critical information to emergency responders	✓	✓	✓	✓	✓	✓	✓	✓	
	Effective and uninterrupted operation of the command and control system for large-scale building emergencies	✓	✓	✓	✓	✓	✓		✓	
Improved Procedures and Practices	Provision of code-equivalent level of safety and certification of as-designed and as-built safety by nongovernmental and quasi-governmental entities	✓	✓	✓			✓	✓		✓
	Egress and sprinkler requirements for existing buildings	✓		✓			✓	✓		✓
	Retention and off-site storage of design, construction, maintenance, and modification documents over the entire life of the building, and availability of relevant building information for use by responders in emergencies	✓	✓	✓			✓	✓	✓	
	Design professional responsibility for innovative or unusual structural and fire safety systems	✓	✓			✓	✓	✓	✓	
Education and Training	Professional cross training of fire protection engineers, architects, structural engineers, code enforcement officials, and fire service personnel.	✓	✓			✓	✓	✓	✓	
	Training in computational fire dynamics and thermostructural analysis	✓				✓	✓	✓		✓

a. If in place, could have changed the outcome on September 11, 2001.
b. Would not have changed the outcome, yet is an important building and fire safety issue that was identified during the course of the investigation.

Appendix A. List of Recommendations

Group 1. Increased Structural Integrity

The standards for estimating the load effects of potential hazards (e.g., progressive collapse, wind) and the design of structural systems to mitigate the effects of those hazards should be improved to enhance structural integrity.

Recommendation 1. NIST recommends that: (1) *progressive collapse* be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice; and (2) a standard methodology be developed—supported by analytical design tools and practical design guidance—to reliably predict the potential for *complex failures* in structural systems subjected to multiple hazards.

Recommendation 2. NIST recommends that nationally accepted performance standards be developed for: (1) conducting *wind tunnel testing* of prototype structures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) *estimating wind loads* and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.

Recommendation 3. NIST recommends that an appropriate criterion be developed and implemented to enhance the performance of tall buildings by *limiting how much they sway* under lateral load design conditions (e.g., winds and earthquakes).

Group 2. Enhanced Fire Endurance of Structures

The procedures and practices used to ensure the fire endurance of structures be enhanced by improving the technical basis for construction classifications and fire resistance ratings, improving the technical basis for standard fire resistance testing methods, use of the "structural frame" approach to fire resistance ratings, and developing in-service performance requirements and conformance criteria for sprayed fire-resistive materials.

Recommendation 4. NIST recommends evaluating, and where needed improving, the technical basis for determining appropriate construction classification and fire rating requirements *(especially for tall buildings)*—and making related code changes now as much as possible—by explicitly considering factors including:

- timely access by emergency responders and *full evacuation* of occupants, or the time required for burnout without local collapse;
- the extent to which *redundancy* in active fire protection (sprinkler and standpipe, fire alarm, and smoke management) systems should be credited for occupant life safety;
- the need for *redundancy* in fire protection systems that are critical to structural integrity;
- the ability of the structure and local floor systems to withstand a *maximum credible fire scenario without collapse,* recognizing that sprinklers could be compromised, not operational, or non-existent;
- *compartmentation* requirements (e.g., 12,000 ft^2 [1]) to protect the structure, including fire rated doors and automatic enclosures, and limiting air supply (e.g., thermally resistant window assemblies) to retard fire spread in buildings with large, open floor plans;
- the effect of spaces containing *unusually large fuel concentrations* for the expected occupancy of the building; and
- the extent to which fire control systems, including suppression by automatic or manual means, should be credited as part of the prevention of fire spread.

Recommendation 5. NIST recommends that the technical basis for the century-old *standard for fire resistance testing* of components, assemblies, and systems be improved through a national effort. Necessary guidance also should be developed for extrapolating the results of tested assemblies to prototypical

[1] Or a more appropriate limit, which represents a reasonable area for active firefighting operations.

building systems. A key step in fulfilling this recommendation is to establish a capability for studying and testing the components, assemblies, and systems under realistic fire and load conditions.

Recommendation 6. NIST recommends the development of criteria, test methods, and standards: (1) for the *in-service performance* of sprayed fire-resistive materials (SFRM, also commonly referred to as fireproofing or insulation) used to protect structural components; and (2) to ensure that these materials, *as-installed,* conform to conditions in tests used to establish the fire resistance rating of components, assemblies, and systems.

Recommendation 7. NIST recommends the adoption and use of the "structural frame" approach to fire resistance ratings. This approach requires that structural members—such as girders, beams, trusses and spandrels having direct connection to the columns, and bracing members designed to carry gravity loads—be fire protected to the same fire resistance rating as columns.

Group 3. New Methods for Fire Resistant Design of Structures

The procedures and practices used in the fire resistant design of structures should be enhanced by requiring an objective that uncontrolled fires result in burnout without partial or global (total) collapse. Performance-based methods are an alternative to prescriptive design methods. This effort should include the development and evaluation of new fire-resistive coating materials and technologies and evaluation of the fire performance of conventional and high-performance structural materials.

Recommendation 8. NIST recommends that the fire resistance of structures be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without partial or global (total) collapse.

Recommendation 9. NIST recommends the development of: (1) performance-based standards and code provisions, as an alternative to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse: and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the structure as a whole system.

Recommendation 10. NIST recommends the development and evaluation of *new fire-resistive coating materials, systems, and technologies* with significantly enhanced performance and durability to provide protection following major events.

Recommendation 11. NIST recommends that the performance and suitability of advanced structural steel, reinforced and pre-stressed concrete, and other high-performance material systems be evaluated for use under conditions expected in building fires.

Group 4. Improved Active Fire Protection

Active fire protection systems (i.e., sprinklers, standpipes/hoses, fire alarms, and smoke management systems) should be enhanced through improvements to design, performance, reliability, and redundancy of such systems.

Recommendation 12. NIST recommends that the performance and possibly the redundancy of active fire protection systems (sprinklers, standpipes/hoses, fire alarms, and smoke management systems) in buildings be enhanced to accommodate the *greater risks* associated with increasing building height and population, increased use of open spaces, high-risk building activities, fire department response limits, transient fuel loads, and higher threat profile.

Recommendation 13. NIST recommends that fire alarm and communications systems in buildings be developed to provide continuous, reliable, and accurate information on the status of life safety conditions at a level of detail sufficient to *manage the evacuation process* in building fire emergencies; all communication and control paths in buildings need to be designed and installed to have the same resistance to failure and increased survivability above that specified in present standards.

Recommendation 14. NIST recommends that control panels at fire/emergency command stations in buildings be adapted to accept and interpret a larger quantity of more reliable information from the active fire protection systems

that *provide tactical decision aids to fireground commanders,* including water flow rates from pressure and flow measurement devices, and that standards for their performance be developed.

Recommendation 15. NIST recommends that systems be developed and implemented for: (1) *real-time off-site secure transmission of valuable information* from fire alarm and other monitored building systems for use by emergency responders, at any location, to enhance situational awareness and response decisions and maintain safe and efficient operations; and (2) preservation of that information either off-site or in a *black box that will survive a fire or other building failure* for purposes of subsequent investigations and analysis. Standards for the performance of such systems should be developed, and their use should be required.

Group 5. Improved Building Evacuation

Building evacuation should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness regarding their roles and duties for evacuation during emergencies, and incorporation of appropriate egress technologies.

Recommendation 16. NIST recommends that public agencies, non-profit organizations concerned with building and fire safety, and building owners and managers develop and carry out *public education and training campaigns,* jointly and on a nationwide scale, to improve building occupants' preparedness for evacuation in case of building emergencies.

Recommendation 17. NIST recommends that tall buildings be designed to accommodate *timely full building evacuation* of occupants due to building-specific or large-scale emergencies such as widespread power outages, major earthquakes, tornadoes, hurricanes without sufficient advanced warning, fires, explosions, and terrorist attack. Building size, population, function, and iconic status should be taken into account in designing the egress system. Stairwell capacity and stair discharge door width should be adequate to accommodate counterflow due to emergency access by responders.

Recommendation 18. NIST recommends that egress systems be designed: (1) to *maximize remoteness of egress* components (i.e., stairs, elevators, exits) without negatively impacting the average travel distance; (2) to maintain their functional *integrity and survivability* under foreseeable building-specific or large-scale emergencies; and (3) with consistent layouts, standard signage, and guidance so that systems become *intuitive and obvious* to building occupants during evacuations.

Recommendation 19. NIST recommends that building owners, managers, and emergency responders develop a joint plan and take steps to *ensure that accurate emergency information is communicated* in a timely manner to enhance the situational awareness of building occupants and emergency responders affected by an event. This should be accomplished through better coordination of information among different emergency responder groups, efficient sharing of that information among building occupants and emergency responders, more robust design of emergency public address systems, improved emergency responder communication systems, and use of the Emergency Broadcast System (now known as the Integrated Public Alert and Warning System) and Community Emergency Alert Networks.

Recommendation 20. NIST recommends that the full range of current and *next generation evacuation technologies* should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell descent devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access.

Group 6. Improved Emergency Response

Technologies and procedures for emergency response should be improved to enable better access to buildings, response operations, emergency communications, and command and control in large-scale emergencies.

Recommendation 21. NIST recommends the *installation of fire-protected and structurally hardened elevators* to improve emergency response activities in tall buildings by providing timely emergency access to responders and allowing

evacuation of mobility impaired building occupants. Such elevators should be installed for exclusive use by emergency responders during emergencies. In tall buildings, consideration also should be given to installing such elevators for use by all occupants. The use of elevators for these purposes will require additional operating procedures and protocols, as well as a requirement for release of elevator door restrictors by emergency response personnel.

Recommendation 22. NIST recommends the installation, inspection, and testing of *emergency communications systems, radio communications, and associated operating protocols* to ensure that the systems and protocols: (1) are effective for large-scale emergencies in buildings with challenging radio frequency propagation environments; and (2) can be used to identify, locate, and track emergency responders within indoor building environments and in the field. The Federal Government should coordinate its efforts that address this need within the framework provided by the SAFECOM program of the Department of Homeland Security.

Recommendation 23. NIST recommends the establishment and implementation of detailed procedures and methods for gathering, processing, and delivering critical information through *integration of relevant voice, video, graphical, and written data* to enhance the situational awareness of all emergency responders. An *information intelligence sector*[2] should be established to coordinate the effort for each incident.

Recommendation 24. NIST recommends the establishment and implementation of codes and protocols for ensuring *effective and uninterrupted operation of the command and control system* for large-scale building emergencies.

Group 7. Improved Procedures and Practices

The procedures and practices used in the design, construction, maintenance, and operation of buildings should be improved to include encouraging code compliance by nongovernmental and quasi-governmental entities, adoption and application of egress and sprinkler requirements in codes for existing buildings, and retention and availability of building documents over the life of a building.

Recommendation 25. *Non-governmental and quasi-governmental entities* that own or lease buildings—and are not subject to building and fire safety code requirements of any governmental jurisdiction—should provide a level of safety that *equals or exceeds* the level of safety that would be provided by strict compliance with the code requirements of an appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends that as-designed and as-built safety be *certified by a qualified third party,* independent of the building owner(s). The process *should not use self-approval* for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the life of the buildings.

Recommendation 26. NIST recommends that state and local jurisdictions adopt and *aggressively enforce available provisions in building codes to ensure that egress and sprinkler requirements are met* by existing buildings. Further, occupancy requirements should be modified where needed (such as when there are assembly use spaces within an office building) to meet the requirements in model building codes.

Recommendation 27. NIST recommends that building codes should incorporate a provision that requires building owners to *retain documents,* including supporting calculations and test data, related to building design, construction, maintenance and modifications over the entire life of the building.[3] Means should be developed for offsite storage and maintenance of the documents. In addition, NIST recommends that relevant building information should be made available in suitably designed hard copy or electronic format for use by emergency responders. Such information should be easily accessible by responders during emergencies.

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[2] A group of individuals that is knowledgeable, experienced, and specifically trained in gathering, processing, and delivering information critical for emergency response operations and is ready for activation in large and/or dangerous events.

[3] The availability of inexpensive electronic storage media and tools for creating large searchable databases make this feasible.

Recommendation 28. NIST recommends that the role of the "Design Professional in Responsible Charge"[4] be clarified to ensure that: (1) *all appropriate design professionals* (including, e.g., the fire protection engineer) are part of the design team providing the standard of care when designing buildings employing innovative or unusual fire safety systems, and (2) *all appropriate design professionals* (including, e.g., the structural engineer and the fire protection engineer) are part of the design team providing the standard of care when designing the structure to resist fires, in buildings that employ innovative or unusual structural and fire safety systems.

Group 8. Education and Training

The professional skills of building and fire safety professionals should be upgraded though a national education and training effort for fire protection engineers, structural engineers, and architects. The skills of the building regulatory and fire service personnel should also be upgraded to provide sufficient understanding and the necessary skills to conduct the review, inspection, and approval tasks for which they are responsible.

Recommendation 29. NIST recommends that *continuing education curricula* be developed and programs should be implemented for (1) training fire protection engineers and architects in structural engineering principles and design, and (2) training structural engineers, architects, fire protection engineers, and code enforcement officials in modern fire protection principles and technologies, including fire-resistance design of structures, and (3) training building regulatory and fire service personnel to upgrade their understanding and skills to conduct the review, inspection, and approval tasks for which they are responsible.

Recommendation 30. NIST recommends that academic, professional short-course, and web-based training materials in the use of computational fire dynamics and thermostructural analysis tools be developed and delivered to strengthen the base of available technical capabilities and human resources.

BIOGRAPHY FOR WILLIAM JEFFREY

William Jeffrey is the 13th Director of the National Institute of Standards and Technology (NIST), sworn into the office on July 26, 2005. He was nominated by President Bush on May 25, 2005, and confirmed by the U.S. Senate on July 22, 2005.

As Director of NIST, Dr. Jeffrey oversees an array of programs that support U.S. industry and science with measurement research, standards, technology, and technical assistance that strengthen the Nation's innovation infrastructure and competitiveness. The goal is to improve manufacturing, services, trade, safety and security, and quality of life. Operating in fiscal year 2005 on a budget of about $858 million, NIST is headquartered in Gaithersburg, Md., and has additional laboratories in Boulder, Colo. NIST also jointly operates research organizations in three locations, which support world-class physics, cutting-edge biotechnology, and environmental research. NIST employs about 3,000 scientists, engineers, technicians, and support personnel. An agency of the U.S. Commerce Department's Technology Administration, NIST has extensive cooperative research programs with industry, academia, and other government agencies. Its staff is augmented by about 1,600 visiting researchers.

Dr. Jeffrey has been involved in federal science and technology programs and policy since 1988. Previous to his appointment to NIST he served as Senior Director for homeland and national security and the Assistant Director for space and aeronautics at the Office of Science and Technology Policy (OSTP) within the Executive Office of the President. Earlier, he was the Deputy Director for the Advanced Technology Office and Chief Scientist for the Tactical Technology Office with the Defense Advanced Research Projects Agency (DARPA). While at DARPA, Dr. Jeffrey advanced research programs in communications, computer network security, novel sensor development, and space operations.

[4] In projects involving a design team, the "Design Professional in Responsible Charge"—usually the lead architect—ensures that the team members use consistent design data and assumptions, coordinates overlapping specifications, and serves as the liaison to the enforcement and reviewing officials and to the owner. The term is defined in the International Building Code and in the ICC Performance Code for Buildings and Facilities (where it is the Principal Design Professional).

Prior to joining DARPA, Dr. Jeffrey was the Assistant Deputy for Technology at the Defense Airborne Reconnaissance Office, where he supervised sensor development for the Predator and Global Hawk Unmanned Aerial Vehicles and the development of common standards that allow for cross-service and cross-agency transfer of imagery and intelligence products. He also spent several years working at the Institute for Defense Analyses performing technical analyses in support of the Department of Defense.

Dr. Jeffrey received his Ph.D. in astronomy from Harvard University and his B.Sc. in physics from the Massachusetts Institute of Technology.

Chairman BOEHLERT. Thank you very much, Doctor. Thank you very much, Dr. Jeffrey. Ms. McNabb.

STATEMENT OF MS. NANCY MCNABB, DIRECTOR OF GOVERNMENT AFFAIRS, NATIONAL FIRE PROTECTION ASSOCIATION

Ms. MCNABB. Good morning, Chairman Boehlert, and Committee Members. My name is Nancy McNabb, and I am Director for Government Affairs for NFPA, the National Fire Protection Association, headquartered in Quincy, Massachusetts. I am an architect licensed in the great State of New York, and was formerly the Assistant Director for Code Development and Interpretation there. I appreciate the opportunity to address the Committee this morning regarding the report of the National Construction Safety Team on the collapse of the World Trade Center towers. Dr. Jeffrey and his team at the NIST labs have done outstanding work.

NFPA is a 109-year-old private, nonprofit organization whose mission is to reduce the burden of fire and other hazards on the quality of life. We achieve that mission by advocating consensus, codes, and standards, research, training, and education. We have approximately 79,000 members that come from 80 nations around the world.

I am here today to affirm our support for the efforts of NIST regarding their report. In most cases, resolution and implementation of their recommendations will be a long-term process. We have provided the Committee with copies of our detailed responses to the NIST study, portions of which I will speak to today.

The NIST report, the second issued under the authority of the *National Construction Safety Team Act,* shows that NIST is committed to providing a high level of scientific data and a set of recommendations for future consideration by codes and standards developers. NFPA is pleased to see the work effort of NIST resulting in positions on many controversial and sometimes unpopular subjects. However, the need to conduct more research in numerous areas is clear.

The loss of the World Trade Center complex represents an unusual set of building performance circumstances, both independent and interdependent. Fundamental questions, such as why did each tower remain standing after the initial impacts, what factors influenced the collapse of the two towers, and what features either allowed so many occupants to escape, or prevented occupants from escaping, now have some answers. Other difficult and anguishing questions, such as what was the fate of mobility-impaired occupants, and why were the local communication systems overwhelmed, and did this prevent or delay evacuation warnings to the first responders, at least now have some explanation.

In June of 2002, when the intensive three-year Federal Building and Fire Safety Investigation of the World Trade Center Disaster was initiated, our President and CEO, Jim Shannon, testified at a public hearing held in New York City that outlined the NIST objectives for their work plan, investigation approach, and intended outcomes. It would have been easy for the Federal Government to simply say this was a one time extreme event, or we do not or cannot design buildings for, or learn anything new from such extraordinary events. But that would be contrary to how the U.S. conducts its business, and how NFPA identifies needs and emerging issues for the development of new and improved safety codes and standards. Let me assure you that NIST has accomplished a great deal with their studies, analyses, and recommendations.

Even those skeptics and critics of NIST and its report in the end chose to submit constructive comments. The National Construction Safety Team Federal Advisory Committee, who provided guidance to NIST during the investigation, the engineers and scientists from NIST who provided support to this effort, and the group of private organizations who served as contractors to NIST on various aspects of the project, are to be commended. They have provided a convincing amount of evidence, rigorous analyses, hypotheses, and confirmation.

One critical test of effectiveness of the World Trade Center study will be what will happen with the 30 specific recommendations in the final report. Some of them have already been implemented in several NFPA codes. This was possible because of the open approach that NIST took with the investigation. In particular, Dr. Sunder's commitment to provide public briefings, opportunities for input during media briefings and open meetings, and making critical information available on the NIST World Trade Center website. While some changes have been made, it is important to note that it is likely that after a thorough and detailed analysis of the final recommendations, there may not be sufficient data, detail, or compelling evidence to promulgate a change to a particular safety code or standard.

For example, the ongoing debate about whether building regulations should address events associated with normal building hazards or more extreme events such as hostile acts and explosions, and what category of buildings should have these unique measures imposed upon them, will have to be settled before consensus is reached on many of the recommendations and findings.

Because of this study, NFPA codes and standards have been changed to include a number of things. A few are hourly fire resistance ratings of three and four-hour duration for tall buildings, requirements for wider stairs to address counterflow issues based on occupant load, and integration of performance-based design options. A number of long-term initiatives are also underway to address other subjects, including the protocols used to evaluate the performance of building structural systems under fire conditions. Although NIST has not indicated that the current procedures are inadequate, a review of the test methods and structural system evaluations is warranted.

One recommendation that should receive a high priority is the consideration for elevator use in high rise emergency evacuations.

NIST has led the effort in this area, with participation from the private sector, to establish the circumstances and criteria for making this a reality. And again, I have given you some of NFPA's comments on NIST's report, and a list of the changes already affected by NFPA.

Beyond this, several of the recommendations refer to specific identification and quantification of multiple threats or hazards. This implies the need for risk and hazard analyses, and the utilization of performance-based design techniques. Overall, NFPA supports these concepts for building and fire regulations. However, the design of buildings, the assessment of the existing building stock, and the preparation of emergency response plans, must be an integral part of our collective mindset.

While NFPA recognizes the benefits of risk and hazard analyses and performance-based design, we note that many of the tools and data necessary to do this on a routine basis are not yet available, nor are they sufficiently understood by all the parties that routinely make decisions about building construction, occupant safety, and emergency responder operations. We have to make sure that those who live or work in a high rise, those who design and construct a high rise, and those that come to our aid in a high rise, are aware of the limitations of our technology, procedures, and codes.

While it is too early to establish the lessons learned from the report, we have made a significant start. We have much yet to be done. Before we arrive at an appropriate best practices that will advance the level of safety in the built environment, more evaluation is necessary.

I can assure you that NFPA will continue to be thorough in reviewing, evaluating, and implementing those NIST recommendations that are directed at the broad issue of public and first responder safety. After the comprehensive study that NIST has provided to us, to learn nothing and do nothing would be delinquent.

Likewise, it would be unthinkable if the private sector fails to act with due regard for these recommendations, and if our government institutions, such as the General Services Administration, fail to recognize the opportunities to develop new building safety enhancements. NIST has provided us with a public service and a tremendous resource. It will be up to all of us to make certain that we do not waste this unique opportunity to ask ourselves new questions, learn lessons, and develop better building safety codes and standards.

Thank you again for allowing me the opportunity to present the views of NFPA this morning. I will be happy to answer any questions you may have.

[The prepared statement of Ms. McNabb follows:]

PREPARED STATEMENT OF NANCY MCNABB

Good morning Chairman Boehlert and Ranking Member Gordon and Committee Members. My name is Nancy McNabb and I am the Director for Government Affairs for NFPA (the National Fire Protection Association) headquartered in Quincy, Massachusetts. I am a licensed architect and was formerly the Assistant Director for Code Development and Interpretation for the State of New York. I appreciate the opportunity to address the Committee this morning regarding *Report of the National Construction Safety Team on the Collapse of the World Trade Center Towers.* Dr.

Shyam Sunder, Dr. William Grosshandler and their teams at the NIST labs have done outstanding work.

NFPA is a 109-year-old, private, non-profit organization whose mission is to reduce the burden of fire and other hazards on the quality of life. We achieve that mission by advocating consensus codes and standards, research, training and education. We have approximately 79,000 members that come from 80 nations around the world.

I am here today to affirm our support for the efforts of NIST regarding their report. In most cases, resolution and implementation of their recommendations will be a long-term process. We have provided the Committee with copies of our detailed responses to the NIST study, portions of which I will speak to today.

On September 11, 2001, we witnessed the most terrible acts of violence ever committed in our country. The destruction of the WTC towers, the large loss of life of building occupants and first responders demands answers from the Federal Government. The first effort directed at this loss included the Building Performance Study (BPS) that was conducted by FEMA. NFPA participated as a team member in order to contribute to the collection, observation and recommendations process surrounding the sequence of events and triggering mechanisms that resulted in the catastrophic building failures and loss of so many lives.

The FEMA study, completed in just eight months, established a series of preliminary observations including credible theories, hypotheses and a likely sequence of events that led to the progressive collapse of WTC 1, 2 and 7. As thorough as the FEMA BPS report was, almost every preliminary recommendation needed additional study. This committee recognized the need to take action and passed the National Construction Safety Team Act under Public Law 107–231 (NCSTA) in 2002 authorizing the National Institute of Standards and Technology, NIST, as the responsible agency. Congress selected the premier government scientific institution that has the capability, resources and the capacity to conduct complex building loss investigations.

The report, the second issued under the authority of the NCST, shows that NIST is committed to providing a high level of scientific data and a set of recommendations for future consideration by codes and standards developers. NFPA is pleased to see the work effort of NIST resulting in positions on many controversial and sometimes, unpopular subjects. However, the need to conduct more research in numerous areas is clear.

The loss of the WTC complex represents an unusual set of building performance circumstances, both independent and interdependent. Fundamental questions such as why did each tower remain standing after the initial aircraft impacts, what factors influenced the collapse of the two towers and what features either allowed so many occupants to escape or prevented occupants from escaping now have some answers. Other difficult and anguishing questions such as what was the fate of mobility impaired occupants, and why were the local communication systems overwhelmed and did this prevent or delay evacuation warnings to the first responders, at least now we have some explanation.

In June of 2002, when the intensive, three year Federal Building and Fire Safety Investigation of the World Trade Center Disaster was initiated, our President and CEO, Jim Shannon, testified at a public hearing held in New York City that outlined the NIST objectives for their work plan, investigation approach, and intended outcomes. It would have been easy for the Federal Government to simply say *"This was a one time, extreme event,"* or *"We do not, nor cannot design buildings for, or learn anything new from such extraordinary events,"* but that would be contrary to how the U.S. conducts its business and how NFPA identifies needs and emerging issues for the development of new and improved safety codes and standards. Let me assure you that NIST has accomplished a great deal with their studies, analyses and recommendations.

Even those skeptics and critics of NIST and its report in the end chose to submit constructive comments. The NCST Federal Advisory Committee, who provided guidance to NIST during the investigation, the engineers and scientists from NIST who provided support to this effort, and the group of private organizations who served as contractors to NIST on various aspects of the project are to be commended. They have provided a convincing amount of evidence, rigorous analyses, hypotheses and confirmation.

One critical test of the effectiveness of the WTC study will be what will happen with the 30 specific recommendations in the final report. Some of them have already been implemented in several NFPA codes. This was possible because of the open approach that NIST took with the investigation. In particular, Dr. Sunder's commitment to provide public briefings, opportunities for input during media briefings and open meetings and making critical information available on the NIST WTC website.

While some changes have been made, it is important to note that it is likely, that after a thorough and detailed analysis of the final recommendations, there may not be sufficient data, detail or compelling evidence to promulgate a change to a particular safety code or standard.

For example, the on-going debate about whether building regulations should address events associated with normal building hazards, or more extreme events such as hostile acts and explosions, and what category of buildings should have these unique measures imposed on them, will have to be settled before consensus is reached on many of the recommendations and findings.

Because of this study, NFPA codes and standards have been changed to include:

- Integration of performance-based design options.
- Retroactive requirements for installation of automatic sprinkler systems in high rise buildings.
- Hourly fire resistance ratings of three-hour and four-hour duration for tall buildings.
- Integration of the structural frame approach when determining fire resistance ratings.
- Requirements for wider stairs to address counterflow issues based on occupant load.
- Mandates for the Installation of stair descent devices for persons with mobility impairments.

A number of long-term initiatives are also underway to address other subjects including the protocols used to evaluate the performance of building structural systems under fire conditions. Although NIST has not indicated that the current procedures are inadequate, a review of the test methods and structural system evaluations is warranted.

One recommendation that should receive a high priority is the consideration for elevator use in high rise emergency evacuations. NIST has led the effort in this area with participation the private sector to establish the circumstances and criteria for making this a reality.

Exhibit A provides you with NFPA's comments to NIST's NCSTAR1 Report; Exhibit B contains a summary of changes already effected by NFPA because of the NIST study, or that are in progress at some level.

Beyond this, several of the recommendations refer to specific identification and quantification of multiple threats or hazards. This implies the need for risk and hazard analyses, and the utilization of performance-based design techniques. Overall, NFPA supports these concepts building and fire regulations. However, the design of buildings, the assessment of the existing building stock, and the preparation of emergency response plans, must be an integral part of our collective mind set.

While NFPA recognizes the benefits of risk and hazard analyses and performance-based design, we note that many of the tools and data necessary to do this on a routine basis are not yet available. Nor are they sufficiently understood by all parties that routinely make decisions about building construction, occupant safety and emergency responder operations. We have to make sure that those who live or work in a high rise, those who design and construct a high rise and those that come to our aid in a high rise are aware of the limitations of our technology, procedures and codes.

While it is too early to establish the lessons learned from the report, we have made a significant start. We have much yet to be done. Before we arrive at an appropriate "best practices" that will advance the level of safety in the built environment more evaluation is necessary.

I can assure you that NFPA will continue to be thorough in reviewing, evaluating and implementing those NIST recommendations that are directed at the broad issue of public and first responder safety. After the comprehensive study that NIST has provided to us, to learn nothing and do nothing would be delinquent.

Likewise, it would be unthinkable if the private sector fails to act with due regard for these recommendations, and if our government institutions, such as the General Services Administration, fail to recognize the opportunities to develop new building safety enhancements. NIST has provided us with a public service and a tremendous resource. It will be up to all of us to make certain that we do not waste this unique opportunity to ask ourselves new questions, learn lessons and develop better building safety codes and standards.

Thank you again for allowing me the opportunity to present the views of NFPA this morning. I will be happy to answer any questions you may have.

EXHIBIT A

NFPA COMMENTS TO NCSTAR 1 (Bound Copy)

EXHIBIT B Changes made or pending to NFPA documents or programs relating to some aspect of *The WTC* terrorist attacks

SUBJECT	CODE/STANDARD/ PROGRAM	STATUS
Hourly fire resistance ratings used on certain tall buildings established at 3 hours and 4 hours.	NFPA 5000	Completed for 2003 edition.
Increase in Stair Width from a 44 in. minimum to a 56 in. minimum when the stair handles a population of 2000 or more occupants.	NFPA 101/NFPA 5000	Completed for 2006 editions.
Mandates for installation of stair descent devices for persons with mobility impairments under certain conditions.	NFPA 101/NFPA 5000	Completed for 2006 editions.
Adoption of structural frame approach for fire resistance ratings.	NFPA 5000	Completed for 2006 edition.
Integrate performance based design options into codes.	NFPA 101/ NFPA 5000	Completed for 2000 ed of NFPA 101/2003 ed of NFPA 5000
Assure that existing buildings meet some minimum level of safety or performance	NFPA 1/NFPA 101	Completed for all editions of NFPA 101 (1913 forward) and NFPA 1 since 1992.
Review fire test standards (i.e. NFPA 251) to determine if the protocol is indicative of appropriately challenging fires.	Various	Pending as future task.
Provide enhancement features for robust building systems.	Various	Ongoing task with various completion dates.
Improved fire alarm system features. Specifically, incorporating mass evacuation alarm components and audible/directional alarm features	NFPA 72	Pending completion for the 2007 edition (available September 2006).
Improved building occupant preparedness for building emergencies	NFPA Public Education programs	Ongoing task with various completion dates and continuous updates.
Expanded use of elevators during building emergencies by occupants.	NFPA 101/NFPA 5000	Pending as future task with anticipated completion in 2007/2008.

BIOGRAPHY FOR NANCY MCNABB

Nancy McNabb is the Director Government Affairs for the National Fire Protection Association (NFPA) at their Government Affairs Office in Washington, DC. She is responsible for working with congressional and federal agencies as well as allied organizations to promote the NFPA mission about fire and life safety. Ms. McNabb joined NFPA in September 2001 as the regional manager, building code central field office, located in Dallas, TX.

Before joining NFPA, McNabb was a service coordinator for Building Officials and Code Administrators (BOCA) International, where she facilitated code adoptions, conducted trainings on code interpretations, and represented the organization at legislative hearings. Previously, she served as a staff architect for BOCA, working with building officials in New York State and providing member services throughout the region. Nancy was also Assistant Director for code development and code interpretation for the New York State Department of State, codes division.

McNabb holds a Master's degree in architecture in structures and a Bachelor's of science degree in architecture from the University of Illinois at Champaign/Urbana, as well as a Bachelor's degree in fine arts from Bradley University. She is a registered architect in New York and Pennsylvania.

Chairman BOEHLERT. Thank you very much. I couldn't agree more with you. To learn nothing and do nothing would be delinquent. I can assure you this committee will not be delinquent.

Dr. Harris.

STATEMENT OF DR. JAMES R. HARRIS, PRESIDENT, J.R. HARRIS & COMPANY

Dr. HARRIS. Good morning. I am pleased to appear on behalf of the Structural Engineering Institute of the American Society of Civil Engineers as you consider these recommendations made by the National Institute of Standards and Technology, arising from their study of the events at the World Trade Center.

ASCE/SEI has a robust program of national voluntary standards produced under a consensus process accredited by the American National Standards Institute. Changes in some of our standards are already underway that address a few of NIST's recommendations, and we plan to give each recommendation that is pertinent to the scope of our standards careful consideration.

My name is James Harris. I am President of a structural consulting firm in Denver, Colorado. I have long been involved in the development of standards for structural engineering practice here in the U.S. as well as internationally. I have chaired the ASCE/SEI committee that prepares the standard ASCE 7 Minimum Design Loads for Buildings and Other Structures for the last three editions. I am also a member of the American Concrete Institute Committee that prepares the standard for the design of building structures, and the American Institute of Steel Construction Committee that prepares the standard for the design of steel buildings.

ASCE/SEI commends NIST for their thorough study and for the thought-provoking findings and recommendations. We also commend the Congress for providing the funding for this worthwhile study. Even though the first lesson of September 11 is to direct resources to prevention of such attacks, we see important lessons from this tragedy for improving the performance of buildings in emergencies that are more ordinary than the attacks of September 11.

ASCE supports careful consideration of all of NIST's recommendations by the broad community that develops standards and building codes for this country. NIST's study built upon and

extended the work of the Building Performance Study Team that ASCE formed and FEMA supported immediately after the tragedy, and which produced their report in 2002.

The detail of NIST's study commands respect, and the events at the World Trade Center, as well as at the Pentagon that day demand our attention. The standard ASCE 7 has long included provisions for, or guidelines for resistance to progressive collapse in its commentary. We look forward to improving the technology for assessing such resistance in the process of building design. We will also participate with interested stakeholders in addressing the extent to which such properties should become mandatory requirements.

ASCE is close to issuing a draft for public comment of a standard for wind tunnel testing that will address some aspects of NIST's second recommendation. More work on building a wind resistant infrastructure is needed, as shown by recent hurricanes, and we urge the Congress to fund the recently authorized National Windstorm Mitigation Program. ASCE and the Society of Fire Protection Engineers are issuing a new edition of their joint standard on calculation methods for structural fire protection. ASCE is also preparing a new standard for blast loading on building structures, and we are participating in the panel being formed by the National Institute of Building Sciences that will look into implementation of all of the NIST recommendations.

We do see some risks if NIBS or NIST elect to bypass the standards upon which building codes rely by submitting changes directly to the major model building codes. Although the standards process takes considerable time, it builds a consensus of all affected stakeholders. A risk to be considered is backlash if change proposals are made without the necessary broad consensus. Some of the recommendations will need considerable refinement on the thorny issue of dividing the population of buildings into classes for which certain new requirements will apply.

Some of the other recommendations will require considerable time to develop a knowledge base in the affected professions. We see the NIBS panel as an important vehicle to coordinate actions in a fashion to avoid negative concerns. We also believe that NIST should continue their studies. More information is needed on the performance of fire insulation under various environments, and on the various fire scenarios that would be used in performance-based design of structures for fire resistance.

In conclusion, we welcome the opportunity to further the improvement of building safety, and we caution that the work to come will take more time than might seem necessary, now that the major study by NIST has been completed.

Thank you.

[The prepared statement of Dr. Harris follows:]

PREPARED STATEMENT OF JAMES R. HARRIS

Mr. Chairman and Members of the Committee:

Good morning. My name is James Harris, and I am pleased to appear on behalf of the Structural Engineering Institute of American Society of Civil Engineers

(ASCE/SEI)[1] as you examine *"The Investigation of the World Trade Center Collapse: Findings, Recommendations, and Next Steps"* in light of the release of findings and recommendations of the National Institute of Standards and Technology investigation.

The events at the World Trade Center in New York City on September 11, 2001, were the worst building disasters in the history of the United States. The National Institute of Standards and Technology conducted a building and fire safety investigation of the disaster under the authority of the *National Construction Safety Team Act* (15 USC 7301 et seq.). As a result of its WTC Investigation, on June 23, 2005 NIST issued a draft report with recommendations, and invited public comments on June 23, 2005.

ASCE/SEI supports a thorough review and deliberation of all of the NIST Recommendations and looks forward to further discussions clarifying the situations to which the NIST Recommendations should apply.

ASCE/SEI believes that engineers must avoid over-optimistic reassurances about building safety, and agrees that increased efforts should be focused on preventing terrorist attacks. That said, the 30 recommendations presented by NIST within eight categories address a range of issues that we at ASCE/SEI think require serious discussion. Many of the recommendations were presented by NIST as "changes to codes and standards," which some may interpret to mean that the painstaking process of developing consensus code and standard provisions should be unreasonably accelerated. We believe that the consensus process, which is already underway at ASCE/SEI for some of the concerns NIST has raised, is essential so that all aspects of an issue can be considered. All of the issues deserve further consideration in that community.

In the view of ASCE/SEI, at least some of the NIST recommendations will require development of new technologies and close examination of their effects upon the practice. At the same time, the existing codes and standards processes that are already in place, both in and outside ASCE/SEI, provide appropriate mechanisms for advancing several of these discussions. Ultimately, the implementation of these recommendations will require the development of appropriate thresholds and bounds for their application. ASCE/SEI looks forward to taking an integral role in clarifying the application of these recommendations.

In fact, some of the NIST recommendations follow actions previously initiated by ASCE/SEI. For example, with respect to Recommendation #2, ASCE/SEI is close to issuing a Wind Tunnel Testing standard and anticipates opening it for public comment. With respect to Recommendation #9, ASCE/SEI has been working with the Society of Fire Protection Engineers, and has already prepared a draft to update ASCE/SEI/SFPE 29–99 (Standard Calculation Methods for Structural Fire Protection), by incorporating performance-based fire resistant design. With regard to Recommendation #27, we look forward to engaging ASCE's professional practices committee for comment and guidance, though our initial reaction is that it may not be necessary or beneficial to all parties for the Engineer of Record to retain all documents for all time; our preliminary view on document retention is that the owner should retain the drawings.

ASCE/SEI favors the development of tools to assist engineers in addressing the issue of progressive collapse (Recommendation #1). The development of a consensus document providing multiple approaches to mitigating progressive collapse would benefit the profession by providing concepts and techniques upon which to build. It is worth noting that GSA requirements have already advanced technology for evaluating progressive collapse. In general, ASCE/SEI prefers a building-specific and/or owner-specific approach to mitigating progressive collapse rather than a code-mandated requirement.

However, also with respect to Recommendation #1, the ASCE/SEI reserves judgment on whether and how to develop standardized software to evaluate the susceptibility of a particular structural system to progressive collapse. Not all buildings are at risk of being exposed to the type of events commonly associated with initiating progressive collapse. This NIST recommendation needs study of its application and its effect upon the profession because of the various design thresholds involved.

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[1] ASCE, founded in 1852, is the country's oldest national civil engineering organization. It represents more than 139,000 civil engineers in private practice, government, industry, and academia who are dedicated to the advancement of the science and profession of civil engineering. ASCE carried out Building Performance Assessments of the World Trade Center, the Pentagon and the Murrah Federal Building, and its technical assessments following earthquakes, hurricanes, and other natural disasters. The New Orleans levee technical group includes representatives appointed by the ASCE Geo-Institute and ASCE Coasts, Oceans, Ports, and Rivers Institute. ASCE is a 501(c) (3) non-profit educational and professional society.

When considering possible causation events, other, non-structural, solutions are sometimes effective. Having said that, we look forward to discussing who would develop and maintain the potential software, who would distribute it and who would take responsibility for training the profession in its use.

ASCE/SEI agrees that designing for fire performance of structures (Recommendations #4–7) needs to be discussed within the broad engineering profession, and is interested in taking an active role in supporting studies examining these recommendations. A draft has been prepared and we would welcome NIST's input in furthering the development of this standard. The concept embedded in Recommendation #8 of treating fire as a load case for structural design will necessitate assumption concerning fire protection systems. Their historical performance will need to be included in the discussions along with the technical and economic impact.

ASCE/SEI feels that some of the NIST recommendations need further clarification and discussion. ASCE/SEI would like a clearer description of the rationale and motivation for developing limit state criteria in Recommendation #3. It is possible that serviceability, perception of motion issues, and existing seismic criteria on drift may satisfy this recommendation. While much of Recommendation #25 appears to ASCE/SEI to be reasonable, the concept of certification of "as-designed or as-built" safety needs additional discussion and understanding. Without further understanding of the envisioned intent of this recommendation, its implementation may face numerous technical, economic, and authoritative hurdles. Improving safety in existing buildings, as directed in Recommendation #26, is certainly a laudable goal and one that ASCE/SEI supports. While the existence of as-built drawings would assist in the rehabilitation of existing structures as specified in Recommendation #26, a requirement for the retention of a broad range of documents would not improve the safety or performance of structures. Lastly, the roles of various professionals within a project will change and vary from project to project. The assignment of roles and responsibilities is an issue best handled by the contract documents rather than codes and standards, as proposed in Recommendation #28.

ASCE also supports Recommendations #29 and #30 which call for increased continuing professional development for engineers and the curriculum be expanded strengthen the base of available technical capabilities and human resources. It is essential that practicing civil engineers remain current with issues and advancements in technology. ASCE supports the attainment of a Body of Knowledge for entry into the practice of civil engineering at the professional level. The Body of Knowledge prescribes the necessary depth and breadth of knowledge, skills, and attitudes required of an individual entering the practice of civil engineering at the professional level in the 21st Century. Establishing innovative solutions to protect public health and safety requires coordination, training and sustained research and development.

We are particularly encouraged by the recommendations pertaining to education and we enthusiastically support continuing education of the profession. However, specific issues, such as cross-training of fire and structural engineering professionals, need to be clarified in further discussions.

Our profession is responsible for protecting the public to the best of our abilities and to seek new technologies to help us meet that charge. In order to do that, we feel it is important to draw a distinction between advancing the technology through the development of various tools, such as consensus documents on progressive collapse and fire-structure interaction, and potentially adversely affecting the profession by imposing regulations and restricting the engineers' freedom to develop the best solution for each individual building and the embedding of mandatory provisions in building codes.

While not every NIST recommendation may be ready for enactment as is, ASCE/SEI is moving forward with discussion of the issues and their implications for structural engineering practice, and looks forward to working closely with NIST to clarify the application of these recommendations.

NIST Recommendations Referenced:

Recommendation 1. NIST recommends that: (1) progressive collapse should be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice; and (2) a standard methodology should be developed—supported by analytical design tools and practical design guidance—to reliably predict the potential for complex failures in structural systems subjected to multiple hazards.

Recommendation 2. NIST recommends that nationally accepted performance standards be developed for: (1) conducting wind tunnel testing of prototype struc-

tures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.

Recommendation 3. NIST recommends that an appropriate criterion should be developed and implemented to enhance the performance of tall buildings by limiting how much they sway under lateral load design conditions (e.g., winds and earthquakes).

Recommendation 4. NIST recommends evaluating, and where needed improving, the technical basis for determining appropriate construction classification and fire rating requirements (especially for tall buildings greater than 20 stories in height)—and making related code changes now as much as possible—by explicitly considering factors including:

- timely access by emergency responders and full evacuation of occupants, or the time required for burnout without local collapse;
- the extent to which redundancy in active fire protection (sprinkler and standpipe, fire alarm, and smoke management) systems should be credited for occupant life safety;
- the need for redundancy in fire protection systems that are critical to structural integrity;
- the ability of the structure and local floor systems to withstand a maximum credible fire scenario without collapse, recognizing that sprinklers could be compromised, not operational, or non-existent;
- compartmentation requirements (e.g., 12,000 ft^2) to protect the structure, including fire rated doors and automatic enclosures, and limiting air supply (e.g., thermally resistant window assemblies) to retard fire spread in buildings with large, open floor plans;
- the impact of spaces containing unusually large fuel concentrations for the expected occupancy of the building; and
- the extent to which fire control systems, including suppression by automatic or manual means, should be credited as part of the prevention of fire spread.

Recommendation 5. NIST recommends that the technical basis for the century-old standard for fire resistance testing of components, assemblies, and systems should be improved through a national effort. Necessary guidance also should be developed for extrapolating the results of tested assemblies to prototypical building systems.

Recommendation 6. NIST recommends the development of criteria, test methods, and standards: (1) for the in-service performance of spray-applied fire resistive materials (SFRM, also commonly referred to as fireproofing or insulation) used to protect structural components; and (2) to ensure that these materials, as-installed, conform to conditions in tests used to establish the fire resistance rating of components, assemblies, and systems.

Recommendation 7. NIST recommends the nationwide adoption and use of the "structural frame" approach to fire resistance ratings.

Recommendation 8. NIST recommends that the fire resistance of structures should be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without local or global collapse.

Recommendation 9. NIST recommends the development of: (1) performance-based standards and code provisions, as an alternative to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse: and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the structure as a whole system.

Recommendation 25. Non-governmental and quasi-governmental entities that own or lease buildings and are not subject to building and fire safety code requirements of any governmental jurisdiction are nevertheless concerned about the safety of the building occupants and the responding emergency personnel. NIST recommends that such entities should be encouraged to provide a level of safety that equals or exceeds the level of safety that would be provided by strict compliance with the code requirements of an appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends

that it is important that as-designed and as-built safety be certified by a qualified third party, independent of the building owner(s). The process should not use self-approval for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the life of the buildings.

Recommendation 26. NIST recommends that State and local jurisdictions should adopt and aggressively enforce available provisions in building codes to ensure that egress and sprinkler requirements are met by existing buildings. Further, occupancy requirements should be modified where needed (such as when there are assembly use spaces within an office building) to meet the requirements in model building codes.

Recommendation 27. NIST recommends that building codes should incorporate a provision that requires building owners to retain documents, including supporting calculations and test data, related to building design, construction, maintenance and modifications over the entire life of the building. Means should be developed for off-site storage and maintenance of the documents. In addition, NIST recommends that relevant building information should be made available in suitably designed hard copy or electronic format for use by emergency responders. Such information should be easily accessible by responders during emergencies.

Recommendation 28. NIST recommend that the role of the "Design Professional in Responsible Charge" should be clarified to ensure that: (1) all appropriate design professionals (including, e.g., the fire protection engineer) are part of the design team providing the standard of care when designing buildings employing innovative or unusual fire safety systems, and (2) all appropriate design professionals (including, e.g., the structural engineer and the fire protection engineer) are part of the design team providing the standard of care when designing the structure to resist fires, in buildings that employ innovative or unusual structural and fire safety systems.

Recommendation 29. NIST recommends that continuing education curricula should be developed and programs should be implemented for training fire protection engineers and architects in structural engineering principles and design, and training structural engineers, architects, and fire protection engineers in modern fire protection principles and technologies, including fire-resistance design of structures.

Recommendation 30. NIST recommends that academic, professional short-course, and web-based training materials in the use of computational fire dynamics and thermostructural analysis tools should be developed and delivered to strengthen the base of available technical capabilities and human resources.

BIOGRAPHY FOR JAMES R. HARRIS

Experience

Jim is well versed in structural engineering practice and research. He has designed or evaluated hundreds of structures ranging from dwellings to high-rise buildings including industrial facilities, long spans, buildings in the highest seismic zones, excavation bracing, pile and pier foundations, vibration issues, and renovations of historic buildings. This background spans nearly all types of construction and structural materials and includes responsibility for management of all design disciplines. His experience includes six years of full-time research. His research has focused on the loading and response of structures, particularly earthquake and snow loadings. A second focus is on improving the formulation and use of engineering standards. He has written over 30 reports and journal articles on the results of his research and practice. He is an active member of several committees that produce national standards for structural engineering practice.

Education

Ph.D., University of Illinois, 1980, Structures and Foundations

MSCE, University of Illinois, 1975, Structures

BSCE, University of Colorado, 1968, Structures

Registration

Colorado: Professional Engineer #11118

California: Civil Engineer #34192; Structural Engineer #2640

Idaho: Professional Engineer #10309

Missouri: Professional Engineer #E–22713
Ohio: Professional Engineer #52667
National Council of Engineering Examiners Record #8449 (currently inactive)

Professional Employment

1984–	J.R. Harris & Company, Principal, Denver
1981–84	Structural Consultants, Inc., Principal, Denver
1975–81	National Bureau of Standards, Center for Building Technology, Research Structural Engineer, Gaithersburg, MD
1973–75	University of Illinois, Graduate Research and Teaching Assistant
1969–73	Zeiler and Gray, Engineer and Associate, Denver
1968–69	Ken R. White Company, Engineer, Denver

Awards

- Structural Engineering Institute of the American Society of Civil Engineers, Walter P. Moore, Jr., Award, 2002.
- Building Seismic Safety Council of the National Institute of Building Sciences, BSSC Honor Award, 1997.
- Colorado Engineering Council, Certificate of Honor, 1997.
- U.S. Federal Emergency Management Agency Outstanding Public Service Award, 1986.
- U.S. Department of Commerce Bronze Metal Award for Superior Federal Service, 1981.
- District of Columbia Council of Engineering and Architectural Societies National Capital Award for Special Achievement, 1981.
- University of Colorado Department of Civil Engineering Ketchum Award for outstanding graduating senior, 1968.

Professional Society Membership

- American Concrete Institute; Fellow
- American Consulting Engineers Council
- American Institute of Steel Construction
- American Society of Civil Engineers
- American Society for Testing and Materials
- American Welding Society
- Coalition of American Structural Engineers
- Earthquake Engineering Research Institute
- International Association for Bridge and Structural Engineering
- International Conference of Building Officials
- The Masonry Society
- National Society of Professional Engineers
- National Trust for Historic Preservation
- The Post Tensioning Institute
- Structural Engineers Association of Colorado

Professional Committees and Activities (current)

- American Concrete Institute: Member, Committee 318, Standard Building Code, and subcommittees on Seismic Provisions and on Safety, Serviceability, and Analysis
- American Institute of Steel Construction: Member of Task Committees on Seismic Provisions, Emeritus Member of Specification Committee; Former Chair, Committee for the Design for Blast Resistant Steel Buildings
- American Society of Civil Engineers: Chairman, Committee for Minimum Design Loads for Buildings and Other Structures (ASCE 7); formerly Chairman, Task Committee on Earthquake Loads
- American Society of Civil Engineers: Member, Executive Committee for Codes and Standards Activities Division of the Structural Engineering Institute

- American Society of Civil Engineers: Member, core team for the Pentagon to study building performance in the wake of the September 11, 2001, attacks
- Applied Technology Council: Member, Board of Directors
- Building Seismic Safety Council: Member, Provisions Update Committee, Technical Subcommittee on Structural Design; Code Resource Support Committee; formerly chair of committee that produced 1985 edition of *NEHRP Recommended Provisions* (first edition), plus activity on several other technical subcommittees
- International Standards Organization, Chair of U. S. Technical Advisory Group for TC 98, Bases for the Design of Structures
- Mid-American Earthquake Engineering Research Center: Member, Executive Advisory Board (Chair 2002–3)
- Portland Cement Association: Member, Concrete Technology Advisory Council
- Structural Engineering Institute of ASCE: member of Board of Governors
- Structural Engineers Association of Colorado: Chairman, Committee on Seismic Standards and Member, Committee on Snow Loads; President, 1990
- The Masonry Society: Member, Board of Directors

Chairman BOEHLERT. Thank you very much. Mr. Corbett.

STATEMENT OF PROF. GLENN P. CORBETT, ASSISTANT PROFESSOR OF FIRE SCIENCE, JOHN JAY COLLEGE OF CRIMINAL JUSTICE

Mr. CORBETT. Thank you, Chairman Boehlert. Chairman Boehlert and Members of the House Committee on Science, my name is Glenn Corbett. I want to thank you for the opportunity to testify again before you concerning NIST and the World Trade Center disaster investigation. Before I discuss the investigation, I would first like to extend my thanks to you, Chairman Boehlert, and the House Science Committee, for initiating the creation of the *National Construction Safety Team Act,* and shepherding it through Congress to final approval by President Bush. The American public is the beneficiary of this critical legislation, and will reap the benefits of your labors through the savings of lives and the construction of safer buildings.

Additionally, I must also note that although I am a Member of the Federal Advisory Committee to the National Construction Safety Team, I do not speak on their behalf. My testimony represents only my own opinions. I recommend that the House Committee on Science review the annual reports of the NCST Advisory Committee for details on their perspective.

Over three years have passed since NIST began its investigation into the World Trade Center disaster. We now have come to the conclusion of this $16 million effort of a search for answers about what happened in the twin towers. The investigation has taken much longer than anticipated, including the fact that the World Trade Center Building Number 7 investigation will likely not be completed until next summer.

Although NIST has done quite a bit of work and has amassed many thousands of pages of useful research, I feel that the investigation has fallen far short of what is needed. From the beginning, I had hoped for a true investigation with a tight set of specific recommendations at the conclusion, that could be immediately passed to our national code writing groups and trade associations. Instead of passing a blazing torch of detailed recommendations, this lengthy marathon race has resulted in NIST giving our model code

writing groups only a handful of flickering embers that, although generally good in principle, are entirely too vague. The model code writing groups now have to wait even longer while NIST hires an outside organization to prepare a set of recommendations that actually can be assimilated into our construction codes.

During the course of the WTC investigation, I have had serious concerns about some of the findings and conclusions that NIST has drawn. Other individuals, including some people on the Federal Advisory Committee, have also had concerns. While this hearing is not the appropriate place to debate technical issues, I would suggest that a more formal mechanism be developed to officially address comments from the public. Such a protocol should include the technical basis for which NIST rejects or accepts the content of a public comment.

Overall, I have been disappointed by the lack of aggressiveness that has characterized not only the World Trade Center investigation, but the Rhode Island Station Nightclub investigation as well. Instead of a gumshoe inquiry that has left no stone unturned, I believe the investigations were treated more like research projects, in which they waited for information to flow to them. In both investigations, they were reluctant to use the subpoena given to them under the NCST Act. To some extent, this lack of assertiveness was likely the result of legal opinions given to NIST by staff attorneys.

Recently, this situation was greatly amplified by NIST's reluctance to respond to Hurricanes Katrina and Rita under the banner of the NCST Act. I suggested to NIST that they assemble an NCST team for Katrina before it struck the Gulf Coast. They actually sent a handful of people a week after Katrina hit, and only recently sending a much larger group of researchers to the area. Curiously, they have decided not to respond under the NCST Act.

To their credit, NIST has brought many talented people to the WTC investigation. They have expended a tremendous amount of effort, compiled a great deal of technical data, pushed the technical limits of computer models, and identified the general areas of concern where improvements in safety regulation and practice are called for. They are to be commended for their extraordinary research efforts, given the immensity of the project.

With respect to the 30 recommendations that NIST has developed, despite being vague, they are areas of significant importance. I feel the following particular ones deserve greater attention. These recommendations concern enhanced structural fire resistance, redundancy for fire protection systems in tall buildings, enhanced egress capabilities, including dealing with stairwell counterflow, remoteness of exits, and full building evacuation capacity, hardened elevators for egress, as well as robust communication capabilities for emergency responders.

Where do we go from here with regard to the World Trade Center? The ball is in NIST's court, and it is up to them, with their contractor, to quickly whittle the desirable but too general recommendations into well-defined code language that can be quickly moved through the model code review process. I strongly encourage them to be bold, use their best engineering judgment, and come up with clear and concise code language. High rise fire safety and safety in general is held in the balance.

When I look to the future of the NCST Act, sadly, I find it necessary to recommend that serious consideration be given to finding a new agency to implement the Act. I don't think that NIST is the right place for the NCST. Their nonaggressiveness, their absence of investigative instinct, and the palatable lack of interest they have shown in the Act has brought me to this conclusion. NIST is an organization of exceptional scientists and engineers, not detectives.

Short of creating an entirely new Construction Safety Team Board, I would recommend that serious consideration be given to moving the NCST to the U.S. Chemical Safety and Hazard Investigation Board. They are a close fit. They investigate explosions and chemical disasters in and around structures. They deal with many of the same code writing bodies that NIST deals with, including some of the organizations represented on this panel today. More importantly, they are solely an investigative agency that issues recommendations. Perhaps their purview could be expanded to include the NCST Act.

In conclusion, I want to again thank you, Chairman Boehlert, and the House Committee on Science, for taking the leadership role in creating the NCST Act. The fact that it has drawn the attention of many people sitting here today, and the organizations included on this panel today from the safety and construction fields, is a testament to its importance.

Thank you.

[The prepared statement of Mr. Corbett follows:]

PREPARED STATEMENT OF GLENN P. CORBETT

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BIOGRAPHY FOR GLENN P. CORBETT

Glenn P. Corbett is an Assistant Professor of Fire Science at John Jay College of Criminal Justice in New York City, an Assistant Chief of the Waldwick, New Jersey Fire Department, and a Technical Editor of *Fire Engineering* magazine. He also serves as a member of the Federal Advisory Committee to the National Construction Safety Team at NIST.

He was formerly the Administrator of Engineering Services for the San Antonio, Texas Fire Department.

Chairman BOEHLERT. Thank you very much, Mr. Corbett. Mr. Green.

STATEMENT OF HENRY L. GREEN, PRESIDENT, INTERNATIONAL CODE COUNCIL (ICC)

Mr. GREEN. Thank you, Mr. Chairman, and good morning to you and the distinguished Members of this committee. It is indeed a pleasure to be here today to discuss the role of building codes and standards in the protection of the public through enhanced measures in building safety. I am Henry Green, President of the International Code Council, and immediate past chair of the National Institute of Building Sciences Board of Directors.

Through my testimony today, I hope to not only discuss how the NIST recommendations can be employed in improving building safety across the country, but also to leave you with a broader understanding of the International Code Council and its role in protecting the public health, safety, and welfare by creating better codes and standards to make for better buildings and safer communities.

ICC, as you may be aware, is the product of a consolidation of three regional code organizations, who came together at the urging of public and private sector interests seeking a single set of nationally uniform model codes for use in this country. As a result, the ICC now provides states and local government with a single set of codes upon which to base commercial and residential building standards for the safety of the public. It has also given the federal sector a platform upon which to transition from the government developed standards to voluntary standards, as directed by OMB Circular A–119 and the *National Technology Transfer and Advancement Act of 1995.*

Today, virtually all states and localities using a model code adopt codes developed and maintained through a governmental consensus process facilitated by the International Code Council. The codes bind together hundreds of building standards developed by voluntary sector standard developers, including many of those on this panel, and NFPA, ASTM, ASCE, ASHRAE, and others. The codes provide the administrative and technical language necessary for meaningful and consistent adoption and code enforcement and results in the protection of the public's health, safety, and welfare.

Because we are all focused on disaster response, I would like to take a moment, if I may, to address concerns regarding the construction codes and standards as they relate to the recent disaster resulting from Hurricanes Katrina and Rita and now, Wilma. As demonstrated in the hurricane that struck Florida over a year ago, and from earlier high wind events that have caused devastation in the United States, we have learned that compliance with codes and standards provide benefits in securing the safety of the public in the built environment, as well as reducing mitigation costs in recovery following these events.

ICC has worked with both federal and State agencies in assisting in the recovery and rebuilding efforts in the Gulf region, and is establishing a resource office in the Gulf region to assist in the rebuilding efforts. When codes and standards are used effectively, we know that for every dollar spent in prevention, we gain a residual of $3 to $5 in savings in recovery efforts.

The Committee requested a brief discussion or understanding of the process of ICC, of how ICC facilitates all interests, interested

parties in the preparation and the development of the international codes. While I would enjoy today to give you an exhaustive explanation of that process, I am sure you wouldn't sit through it, so we will forego that. My extended testimony does, however, speak to, more to the point, for your reference. My oral remarks, may it suffice to say that our processes both predate and is consistent with the principles embodied in NTTAA and the OMB A–119, as well as internationally accepted practices, or principles in consensus development. As with any democratic process, like that which guides this body, it is deliberative, exhaustive in examination, time-consuming, and requires much more care and attention. The result is an abiding respect for both the process and the resulting quality and confidence the codes, in the codes that our members produce.

I would like to proceed to the questions that have actually been posed by this panel, and respond to those. Does ICC support the recommendations of the NIST study? Events such as the structural failure of the World Trade Center shake to our core our faith in science, engineering standards, and means of ensuring building safety that we use to protect our lives, our property, and our economy. The ICC has worked with NIST in examining the collapse of the World Trade Center and the development of recommendations for reform of the Nation's building and fire codes and standards.

We have acted in support of the NIST recommendations by empanelling technical committees of member experts to prioritize the recommendations and prepare specific proposals that will be addressed by our code development process. Also in support of the recommendations, ICC responded to NIST requests for review of the document, the draft report, earlier with extensive comments directed at assessing NIST, assisting NIST in the clarity of its discussion and findings.

The majority of NIST recommendations on the subject of codes and standards do apply to the international building code. Again, I would reference you to my pre-filed remarks for a summary of our specific remarks on the NIST report. It should be noted that the questions posed by the committee is focused on new construction and significant renovation of existing buildings. As we focus on code reform, we should not ignore the needs to address the safety of ongoing use of our massive base of existing building stock.

What specific steps will ICC be undertaking to determine whether and how to incorporate the NIST recommendations into the codes? Some of the steps associated with the NIST recommendations, we have already begun. As a result of the World Trade Center attacks, the ICC formed an ad hoc committee on terrorist resistant buildings. The committee, made up of code officials, engineers, architects, and other building professionals, is looking at the NIST work and other research in response to new threats that we know now have to perpetually address.

In addition, we have charged our permanent Code Technology Committee to specifically prioritize the NIST recommendations, and to prepare them as code change proposals. In the two days just before this hearing, our Code Technology Committee has been meeting with the National Institute of Building Sciences to coordinate the work in developing and preparing proposals based upon the NIST recommendations.

As to timing, the next code development cycle begins with a deadline of March 24, 2006, for any interested party to submit code changes. Through a multi-stage process of technical committee examination, two public hearings, and two stages of public notice and comment, final action on those proposals in the fall of 2007 will yield the 2007 supplement to the 2006 international building code. This process is repeated every 18 months, resulting in a new edition of the code every three years, and a new supplement in each interim.

The most significant barrier to adoption, as with any code change proposal, is having technical documentation for the membership to review the consideration of specific code changes and the advanced use of formal and informal processes of discussion and review, to fully vet and analyze each proposal.

What specific actions will NIST be taking to help organizations incorporate its recommendations? It is our view that NIST and other federal agencies already do participate in the code development processes through submission of and advocacy of code changes. This participation both adds to the quality of the review of all proposed changes, and helps the agencies to achieve their program goals, as directed by both executive and legislative branches of the government. This sort of federal interagency coordination is precisely what is necessary for NIST to advance the recommendations of the WTC report.

The NIST recommendations do not need to be reframed in a manner that is consistent with the statutory construction of the ICC codes. In the simplest terms, the probability of a code change being accepted or eventually incorporated is dependent on the degree to which the existing code is changed, first, and life-cycle cost impact associated with the change, availability of any required new technology, and support infrastructure for the technology, impacts on various trade, labor, and manufacturing interests, and product—and impacts on the interests of advocacy groups. This process is quite similar to what you use here in this legislative body to develop law and/or other regulations.

ICC has recommended to NIST that it further partner with interested and affected parties in the development of codes and standard proposals, as opposed to taking up the effort alone, and assuming others will take the lead. In addition, ICC has also stressed to NIST that without their involvement and leadership in this process, there are two probable outcomes: either nothing can be done to implement the WTC findings in codes and standards; or multiple and varied interests will each use the findings to their own advantage, resulting in multiple and varied non-uniform code and standards proposals, that will be much more difficult and time-consuming.

With that said, there are some certainties associated with the process. Changes that are not enforceable, and require specific products or materials by name, are not likely to be accepted, nor are the changes that reference codes and standards that have not been fully completed. We at ICC applaud the work of Congress and support of Congress in this matter, such that was conducted by NIST. We encourage continued support for such work by Congress,

and increased collaboration by the public and private sectors in enhancing public performance and safety.

Finally, I would like to quote one section out of the NIST report that I think is really focused on the issue of codes and standards. "Rigorous enforcement of building codes and standards by State and local agencies, well-trained and managed, is critical in order for standards and codes to ensure the effective level of safety. Unless they are complied with, the best codes and standards cannot protect occupants and emergency responders or buildings."

Thank you again for the opportunity to speak today, and I would be pleased to answer any questions that you might have.

[The prepared statement of Mr. Green follows:]

PREPARED STATEMENT OF HENRY L. GREEN

Good morning Mr. Chairman and distinguished Members of the Committee. It is a pleasure to be here today to discuss the role of building codes and standards in protecting the public through enhanced measures in building safety.

I am Henry Green, President of the International Code Council (ICC). Through my testimony I hope to discuss how the NIST recommendations can be employed in improving building safety across the country, as well as leave you with a broader understanding of how ICC is protecting health, safety and welfare by creating better buildings and safer communities. Certainly the subject of today's hearing and the ICC's mission is well-aligned. Aside from my elected position with ICC, I also serve as the Director of The Bureau of Construction Codes and Fire Safety for the State of Michigan.

I am participating in today's hearing to specifically address the implementation of the lessons learned from the world trade center (WTC) collapse. In more general terms my comments also apply to and stress the need for increased collaboration between Federal, State and local government in the development, adoption and implementation of codes and standards to enhance the safety and performance of new and existing buildings.

As a matter of background, I have been involved with building codes and standards development, adoption, implementation and enforcement issues at the international, national, State and local level for almost 30 years, serving not only ICC but such organizations as the National Institute of Building Sciences (NIBS), of which I serve as Past President. Briefly, before I speak to the questions the Committee has asked me to address, I will lay a foundation for a better understanding of ICC's responses to those three specific questions.

State and local government have relied on nationally recognized model codes, and the standards referenced in those codes, as a basis for their building construction regulations for almost 100 years. Initially many State and local government agencies wrote their own "home grown" provisions but over time they began to rely more and more on one of four regional model codes (the BOCA National Code, the ICBO Uniform Code and SBCCI Standard Code and the National Building Code of the American Insurance Association). The AIA ceased maintenance of its model code almost 30 years ago and just recently the three other model code organizations merged to form the International Code Council (ICC). The merger of the three regional organizations came at the urging of public and private sector interests seeking a single nationally uniform model building code developed through a voluntary consensus process. The development of one family of model codes by the ICC, which in turn reference standards from hundreds of building standards developers such as ASCE, ASME, and ASTM, has provided State and local government with a single national consolidated family of model codes upon which to base commercial and residential building construction and fire safety regulations. It has also given the federal sector a platform upon which to transition from government developed standards to voluntary standards, as directed by OMB Circular A–119 and the *National Technology Transfer and Advancement Act of 1995.*

Today the majority of State and local agencies adopt building and fire codes developed and maintained through the governmental consensus process facilitated by the ICC. Think of these model codes as a coordinated set of provisions that bind separate and distinct building component standards so they can fully address the technical and administrative aspects of building safety and performance. In most states I-Code based building codes are required and enforced as a function of State-level authority. In others, such as Tennessee, Maryland, Colorado and Illinois, the au-

thority to adopt and enforce codes primarily resides with local government, and in those states most all local governments adopt ICC model codes to guide residential and commercial construction.

In parallel to the events leading up to the formation of the ICC and development of the ICC codes, the federal executive and legislative branches of government established the groundwork for the federal sector to increasingly base their building regulations on nationally recognized model building codes as opposed to writing their own unique provisions. As a matter of national policy, established through OMB Circular A–119 and the NTTAA, all federal agencies are encouraged to use codes and standards developed in the voluntary sector and, equally important, to participate in the voluntary sector code and standards development processes. This policy eliminates the duplication of effort and conflict in application that occurred when federal agencies developed and maintained unique government standards. This policy also enhances voluntary sector standards development by infusing those processes with the experience and resources of federal agencies such as NIST.

This federal policy also saves time and money and ensures consistency between public and private sector construction. Such consistency is important to designers, contractors, manufacturers, and other entities doing business with both the private and public sectors. Consistency is also imperative where the structure in question is a private sector facility that is leased to a federal agency. Such a facility must concurrently satisfy federal as well as State and local building requirements. Most importantly, federal sector use of voluntary sector codes and standards allows for public-private partnerships that can bring the result of building research and experience to bear on revision and enhancement to those codes and standards. Such is the case with the NIST investigations associated with the WTC.

In summary, what not too long ago was a "crazy quilt" of differing federal, State and local requirements, each supported by separate and distinct educational and other programs, has become a tapestry with a singular foundation that involves public and private sector interests and allows for unique federal, State and local threads without compromising the quality of the fabric of the tapestry.

As we are all focused on disaster response I would also like to take a moment to address concerns regarding construction codes and standards as they relate to the recent disasters resulting from Hurricanes Katrina and Rita. As demonstrated in the hurricane that struck Florida last year and from earlier high wind events that have caused devastation in the U.S., we have learned that compliance with codes and standards provides benefits in securing the safety of the public in the built environment, as well as reducing mitigation costs in recovery following these events.

ICC has pledged to work with both federal and State agencies in assisting in the recovery and rebuilding efforts in the Gulf region. We believe our effort will assist in providing a higher level of safety not only from such devastating events as hurricanes but in prevention of fires and other situations that plague our built environment. When codes and standards are used effectively, we know that for every dollar spent in prevention we gain a residual of three dollars in savings in recovery cost.

We will be providing a resource office in the Gulf Region to assist in the rebuilding efforts by furnishing local governmental and code officials with the resources they need to assure the reconstruction is completed to a standard that will assist in minimizing damage and recovery cost.

Given our experience and the working relationship we maintain with federal agencies, we would like to expand our relationship and further develop safety provisions for the protection of America's citizens.

In addition to responding to the questions regarding the NIST WTC report that the committee put to the ICC it was asked that in my testimony I provide the committee with a brief description of the code development process used by the membership of the ICC to build and maintain each of the 14 model codes, and with an understanding of how and where the model codes are adopted by authorities having jurisdiction over the adoption and enforcement of regulations impacting building design, construction and maintenance.

The widespread national application of the IBC and other ICC codes is due in large part to the recognition of respect for the voluntary consensus process by which the codes are developed. They are developed in a democratic process with input and advocacy from both private and public sector building and fire safety interests and any other interested or affected party. ICC's governmental consensus process adheres to the guiding principles at the national and international level for development of consensus documents. These principles—openness, transparency, balance of interest, due process, consensus and process of appeals are embodied in the governmental consensus process. The uniquely notable quality of the governmental consensus process is that it leaves final determinations on code provisions in the hands

of public safety officials, who, like myself, are charged with representing the public interest and have no commercial interest associated with the outcome the process.

In this process any interested party can submit a change to the codes or request that a new code be developed. All submittals are published and made available for public review. All submittals are then published and made available for written comment and discussed at nationally noticed public hearings. At the first public hearing a committee of balanced interests listens to all testimony, reviews all information submitted on each proposal, then votes to recommend approval, rejection or approval with modification. If any party at the hearing disagrees with the committee recommendation the process provides for action by those at the hearing to make and democratically act on a proposal for a substitute motion.

The results of the first hearing, both the committee recommendation and any substitute assembly action are published and disseminated in print and electronic form. Anyone can then submit a public comment on those results and provide documentation supporting a different outcome. The committee recommendation and additional public comment is again published and becomes the basis for the agenda of a final action hearing at which time the proposed changes and public comment are considered. At the final action hearing the final vote on code content is made by public safety officials, which, not unlike the legislative and regulatory processes used to establish federal law and regulations, is made by Federal, State and local government representatives who represent the public-at-large.

The IBC and other ICC codes are used by Federal, State and local government to ensure building safety through the adoption, implementation and enforcement of these codes. Nearly every federal, State and local agency that enacts building codes has adopted the IBC as the basis for jurisdictionally controlled building laws and regulations. Jurisdictional adoption occurs through legislative or regulatory action that cites or directly incorporates the IBC and may also include amendments that specifically tailor the code to the needs of the adopting agency or jurisdiction. For instance, the U.S. Department of State adopts the IBC as a basis for U.S. Embassy construction worldwide but then adds provisions to address security needs unique to a U.S. diplomatic facility.

States such as Michigan, Minnesota, Maryland, Washington, New York, Oregon, North Carolina and Utah have authority in the executive branch of government to develop and adopt a state-wide building code and do so, again with amendments that tailor the IBC to address unique geographic and climatic issues and differing legal and administrative environments. In states without authority to adopt statewide codes, or where local governments are not required to adopt the state code, the state adopts codes for state-owned buildings and leaves regulation of private sector construction to local government. This is the case in states such as Tennessee, Colorado and Illinois with local government having the authority to adopt codes and Maryland that has a state code but does not have preemptive authority to mandate local government action to adopt and enforce the code. Just as is the case with state adoption, local adoption is effected through local elected bodies or regulatory agencies.

Subsequent to adoption, the IBC is used to ensure building safety through a number of mechanisms, each of which are focused on ensuring that the requirements of the code are actually adhered to in the construction of the building. Adoption of the code can be viewed as establishing a speed limit for highway travel. Though the limit is set, it is meaningless unless the limit is posted and enforced to ensure traffic safety. So too, federal, State and local agencies have ways to ensure code compliance and, as a result, building safety. Note that the IBC not only contains design and construction requirements but also a number of administrative criteria associated with inspection to ensure compliance in the field.

In the case of an agency that adopts the IBC and is also the building owner—such again as the U.S. Department of State, or State or local government agency responsible for State or local owned construction—the adopting agency enforces the code and typically does so as a function of the contracting process that governs the building design and construction. The contractor is responsible for compliance and may be subject to inspection from the authorizing governmental agency, may be subject to inspection by other third parties or may be allowed to self-certify compliance with penalties assessed in the future if non-compliance is verified.

For private sector construction, building safety is ensured through a review of the building plans and specifications for code compliance by the applicable State or local agency, inspection of the building for code compliance during construction, a final occupancy inspection and continued monitoring and evaluation of selected issues during the life of the building.

Now, to the questions the Committee asked that I address.

Does ICC support the recommendations of the NIST study? Why or why not?

Events such as the structural failure of the World Trade Centers shake to our core our faith in the science, engineering, standards and means of ensuring building safety that we use to protect our lives, our property and our economy. The ICC, from the beginning of this investigation, has supported the work of NIST in examining the collapse of the WTC and the development of recommendations for reform of our nation's building and fire codes and standards. The NIST investigation, even as it was in process, began providing the building industry with information which has been used to develop and implement new criteria in building codes and standards. Last year, as the membership of the ICC began the process of evaluating code change proposals for publication in the 2006 edition of the codes, a proposal emanating from early understandings of the collapse was put forward, thoroughly evaluated, discussed and approved. The IBC now requires buildings of 420 feet and higher to be constructed with structural components having at least a three-hour fire resistance rating; the previous requirement was a two-hour fire resistance rating for structural components. These increased requirements match the changing conditions we face in providing for building and fire safety and address the public will to afford higher levels of security and protection. In making these changes it is also important to protect the integrity of the public deliberation inherent in maintaining the democratic development of voluntary consensus. We have begun to infuse post-WTC concerns into the code, and, as I will speak to in addressing the committee's other questions, the ICC has acted in support of the NIST recommendations by empanelled technical committees of member-experts to prioritize the recommendations and form them into specific proposals that can be addressed by our code development process. In addition, we are working with other groups, such as the National Institute of Building Sciences in efforts to assess the WTC findings and to effectively develop proposals for change to the code.

Also in support of the recommendations ICC responded to NIST's request for review of its draft report earlier with extensive comments directed at assisting NIST with the clarity of its discussion and findings. The majority of NIST recommendations on the subject of codes and standards do apply to the IBC. These are noted below with a brief indication of how ICC gauges their potential applicability.

- NIST calls for more rigorous enforcement of codes. ICC believes a more appropriate term than enforcement is compliance. Enforcement is a means to achieve the goal of safe buildings, something embodied in compliance. There are other ways to secure compliance such as incentives or labeling that not only ensures the goal is reached but can secure results above and beyond simple enforcement of minimum codes and standards.
- NIST calls for well trained and managed staff and educational programs. ICC agrees and feels that NIST and other federal agencies can and should become more active in working with the private sector to develop and deploy programs that would strengthen the resources that support code compliance.
- NIST suggests an increased focus in structural issues from a design, construction, and operations and maintenance standpoint. The IBC, and referenced standards therein such as those from ASCE, provide a basis for measuring and expressing structural performance and ensuring some agreed minimum level of structural integrity in buildings.
- NIST suggests an increased focus in the fire resistance of structures and methods to evaluate and determine their performance with respect to fire. The IBC, and referenced standards therein such as those from ASTM, provide a basis for measuring and expressing building performance from the standpoint of fire resistance and ensuring some agreed minimum level of performance.
- NIST suggests increased consideration of performance based criteria as an alternate to prescriptive criteria. The IBC addresses this in two ways. In establishing minimum prescriptive criteria the IBC establishes a basis to evaluate alternative approaches to performance equivalency. The IBC also references the ICC building performance code, a stand-alone code that is completely performance-basis oriented. It is notable that NIST staff has been involved in the development of this performance-based code.
- NIST suggests development and use of new materials, coatings, barriers and other technology. The IBC addresses this by allowing acceptance of alternative materials and methods of construction when they are certified to perform at least as well as items specifically allowed in the IBC. Equivalency is based on evaluation reports developed through engineering analysis prepared

by entities approved by the authority enforcing the code. As new certified materials become more commonplace standards are proposed and adopted to specifically address criteria for their application and use.

- NIST recommends improvements in active fire protection systems. The IBC and referenced standards therein, such as those by NFPA, provides a basis for review and incorporation of such improvements.
- NIST recommends improvements in building egress and evaluation. As I have discussed, the IBC provides a basis for review and incorporation of such improvements.
- NIST recommends improvements to emergency response, building access, communications and central controls. The IBC provides a basis for review and incorporation of such improvements.

On the basis of the WTC investigation NIST has made a number of recommendations to improve building safety. The IBC provides a basis to address and take action on proposals for these recommendations and, through adoption as previously noted, ensure their widespread implementation throughout the U.S. In this manner the NIST work on the WTC report can have a significant impact on future building design and construction.

It should be noted that the question posed by the committee is focused on the IBC, which is used to guide new construction and significant renovations to existing buildings. There is also a need to address the safety of the on-going use of our massive base of existing buildings. Through the ICC, safety requirements for these buildings are addressed through documents such as the ICC International Existing Buildings Code (IEBC) and ICC International Fire Code (IFC). Through the NFPA these issues are addressed in the Life Safety Code and the National Fire Code. Jurisdictional use of these codes, coupled with incentive programs to foster enhancement to existing buildings, can address building safety where it may not be possible to legislate renovation.

What specific steps will ICC be undertaking to determine whether and how to incorporate the NIST recommendations into its codes? How long should that process take? What will be the greatest barriers in the process?

Some of the steps associated with taking action on the NIST recommendations, as I have discussed, we have already begun. As a result of the WTC attacks and the need to consider code changes to address terrorism-related issues in the built environment, the ICC formed an Ad Hoc Committee on Terrorism Resistant Buildings. The committee—made up of code officials, engineers, architects and other building professionals—is looking at the NIST recommendations as well as other research related to responding to new threats that we now have to perpetually address. In addition, at the annual assembly of our membership last month, the ICC charged our permanent Code Technology Committee with a corresponding assignment to specifically prioritize the NIST recommendations and to prepare those recommendations as proposals for the deliberate review of our code development process. In the two days just before this hearing our Code Technology Committee has been meeting with the National Institute for Building Sciences to coordinate work in developing and preparing proposals based on the NIST recommendations.

For the next code development cycle any recommendations to revise the IBC and other ICC codes can be submitted by any party, including NIST staff or parties with whom NIST participates, on or before March 24, 2006. The recommended changes, as discussed, need to provide specific language and citations to amend the code and need to be accompanied by supporting documentation. It is our view that the information gathered and analysis conducted by NIST on the WTC collapse would prove instrumental in development of changes and supporting documentation.

As to the standards referenced in the IBC, NIST would have to take similar action with each standards developer based on individual procedures and deadlines.

The timeframe associated with the next cycle of the ICC code development process is from March 24, 2006, at which time proposed changes are due as noted above, to October 4, 2007 with the completion of the final action hearing. The result of this process will yield the 2007 supplements to the 2006 editions of each code. This process is repeated every 18 months, resulting in a new edition of the codes each three years and a new supplement each interim.

More details on this process are covered in a PowerPoint presentation presented and discussed with NIST staff earlier this year. The objective of ICC's initiative with NIST staff, in advance of release of the WTC report, was to advise NIST of the full extent of the public process or code amendment so that NIST could begin to develop a strategy for implementing the WTC report recommendations in parallel to completion of the report. In this way it was hoped NIST could develop specific

codes and standards proposals prior to the March 2006 deadline. One such suggestion was for NIST to not only take the lead in development of proposed changes to the IBC and other ICC codes but also to parallel that activity by submitting those changes to federal agencies and key State and local government for early consideration for action.

The most significant barrier, as with any code change proposal, is having technical documentation for the membership to review in consideration of specific code change proposals, and the advance use of formal and informal processes of discussion and review to fully vet and analyze each proposal.

What specific actions should NIST be taking to help code organizations incorporate its recommendations? Are the recommendations framed in a way that facilitates their adoption by code organizations or are they too general or too specific?

NIST, as well as a number of other federal agencies, do already participate in the code development process through submission of and advocacy for code changes. This participation both adds to the quality of the review of all proposed code changes and helps the agencies to achieve their program goals as directed by both executive and legislative branches of government. For instance the U.S. Department of Energy has submitted changes to the IBC in the past to more fully address the structural and fire resistance aspects of buildings associated with certain radiation-related processes. This will specifically help address DOE interests as a building owner as well as the general public. This sort of federal interagency coordination is precisely what is necessary for NIST to advance the recommendations of the WTC report through ICC's code development process, as well as the code and standards development of other providers of voluntary consensus standards. Another example is participation by the Consumer Product Safety Commission in realization that the ICC codes are effective vehicles to achieve CPSC's public safety goals where they may not have otherwise have rule-making authority.

As I've discussed, the recommendations are not written in a way that facilitates direct adoption and do need to be reframed in a manner that is specific to the desired result, consistent with the statutory construction of the ICC codes, and presented in a manner that provides citation to each section and subsection of the code that is directly or collaterally impacted by the proposal; not too much unlike the manner in which legislation this panel reviews must be framed to be consistent with the standing body of our U.S. Code. The prospects of the adoption of any recommended change to the IBC or other ICC codes cannot be addressed without seeing the details of the particular change. The nature of the process to develop codes and standards within the voluntary sector, in allowing for participation by all interested and affected parties, ensures full due consideration with respect to all views and variables.

In the simplest terms, the probability of a code change being accepted and eventually incorporated into the IBC or other ICC codes and maintained in federal, State and local adoption of those codes is dependent on the degree to which the existing code is changed, first and life cycle cost impacts associated with the change, availability of any required new technology and support infrastructure for that technology, impacts on various trade, labor and manufacturing interests, and impacts on the interests of advocacy groups, among other factors. In this manner the effects on the process are quite similar to what the legislative or executive branches go through in considering laws or regulations that impact U.S. industry, public interests, the economy and the environment.

The ICC has recommended to NIST that, as the degree of revision associated with changes to the codes and standards increases, NIST should consider partnering with interested and affected parties in the development of codes and standards proposals as opposed to taking up the effort alone or assuming others will take the lead. In addition ICC has also stressed to NIST that without their involvement and leadership in this process there are two probably outcomes; either nothing will be done to implement the WTC findings codes and standards, or multiple and varied interests will each use the findings to their own advantage resulting in multiple, varied and non-uniform codes and standards proposals that will be much more difficult and time consuming to sort out, address and eventually agree upon.

With that said, there are some certainties associated with the process. Changes that are not enforceable or require specific products or materials by name are not likely to be accepted, nor are changes that reference standards that have not been fully completed.

As an association comprised building regulatory and construction industry professionals who come together to establish model codes for use by the public and private sectors, the ICC is focused on building and fire safety. The ICC codes provide a plat-

form and foundation for achieving improved building safety. The process for their revision and enhancement is open to all and affords NIST and all others the opportunity to take the results of research, investigations and studies and have them, through the wide adoption of the ICC codes, put into practice.

We at ICC applaud all the work supported by Congress, such as that conducted by NIST. We encourage continued support for such work by Congress and increasing collaboration by the public and private sectors in enhancing building performance and safety.

Thank you again for the opportunity to speak with you today. I will be pleased to answer any questions you have or provide additional information you may need.

BIOGRAPHY FOR HENRY L. GREEN

In 1989 Henry L. Green was appointed Executive Director of the Bureau of Construction Codes and Fire Safety. Henry has worked in the Bureau for more than twenty years serving as a building inspector, Chief of the Barrier Free Design Division, Chief Building Inspector and as Deputy Director before assuming his current role.

As Executive Director, Henry provides management and oversight for construction and fire safety programs in the state of Michigan. These program responsibilities include the development and implementation of construction codes and standards, fire fighter training, building, and fire inspection programs, public fire safety education, and the state fire marshal.

Additionally, Henry serves as Project Director for the Michigan Timely Applications and Permit Service (MiTAPS), an on-line processing system for permits and licenses issued by the State of Michigan, and serves as President of the International Code Council Board of Directors, an organization of which he is a founding member.

Henry has also served on the Building Officials and Code Administrators (BOCA) Board of Directors for ten years, serving as President in 1997. He also serves as a member of the Board of Directors of the National Institute of Building Sciences, recently completing a term as Chairman of the Board of Directors in 2004.

Over the years, Henry has been recognized nationally and internationally as a proponent for developing and implementing building and fire safety initiatives and codes. In 1990, the Automatic Fire Alarm Association (AFFA) named Henry "Man of the Year" for his contributions to life safety as Chairman of the BOCA Ad Hoc Committee for Fire Protection. AFFA acknowledged, "under his fine leadership, the committee developed numerous code changes to the BOCA National Building and Fire Prevention Codes. . .and significantly improved life safety in both new and existing construction."

In 1998, Henry received the "Distinguished Service to Government" award from the Building Industry Association of Southeastern Michigan and was awarded the Walker S. Lee Award in recognition of outstanding service to BOCA International in 1999.

In addition to serving the state of Michigan, Henry has participated in national and international code forums representing building code officials at World Organization of Building Officials conferences in Hong Kong and Australia.

A life-long resident of Lansing, Michigan, Henry serves as a member of the Trustee Ministry and Building Construction Committee at his church, Union Missionary Baptist Church. He is a former President of the Woodcreek Parent Teacher Association and served on the Waverly High School Parents Advisory Committee.

He, and his wife Angela, are the parents of two grown sons, William and Jason.

DISCUSSION

Chairman BOEHLERT. Thank you very much, Mr. Green. As all of you have observed, we have been rudely interrupted by a call of the House. The Speaker doesn't check first with the Science Committee to see how we are doing in our proceedings before determining whether or not we are going to be voting. So, we are going to have to take a recess for about 20 minutes, while we answer the call of the House. It is my understanding that there will be two votes, and on this vote, there are exactly six minutes and 41 seconds left for us to get over to the Capitol.

I will just leave you with a couple of thoughts before we come back and begin the questioning in earnest. I think, Mr. Corbett, you asked the most profound question of the moment. Where do we go from here? And that is our determined effort, to determine where we go from here, and how we get there. I would point out that Dr. Jeffrey didn't direct the study or conceive it. He inherited it, and he is the new guy on the block, and we have got to deal with that fact of life.

Secondly, I would point out that if you look at the report, some observers might say it is bold and comprehensive. Others might charge that it is vague. I think it is a little bit of both, and where it is bold and comprehensive, we have to seize upon the direction and guidance given us. Where it is vague, we have to flesh out some of the details, and get a little more specificity. And that is what we are going to direct our questioning to, as we return from this rude interruption.

And I will let the Speaker know that you all share my view that he rudely interrupted this proceeding. With that, let us adjourn for 20 minutes.

[Recess.]

Chairman BOEHLERT. We will start again. Members will be drifting back from the floor activity. Understandably, our focus will be on the report, and particularly, Dr. Jeffrey, your commentary will be welcome. Doctor, several of the witnesses have implied, and Mr. Green and Mr. Corbett have stated quite explicitly, that NIST recommendations are not presented in a specific enough form to fully inform the code writing process. This is obviously a very serious matter, and we recognize that. I am sure you do, too.

Let me ask you a series of questions, and then, I will shut up and listen to your response. Why did NIST choose to present its recommendations in this fashion, and why have you only now contacted NIBS, the National Institute of Building Sciences, and when will NIBS' document be completed, and to what extent will NIST review the document, and finally, and very importantly, will NIST be making specific recommendations to the ICC prior to March, because if they don't come prior to March, well, that just adds more time to the whole process?

So, I know it is a tall order. I have asked those questions, and I see you furiously taking notes. And let me, once again, acknowledge the fact that I recognize that you didn't direct this study. You inherited it. But you are the guy on the block now, and you are the point man, and we have a high regard for you, and we want to work cooperatively with you, but we want to do as much as we can to eliminate vagueness and concentrate on specificity.

The floor is yours.

Mr. JEFFREY. Thank you, Mr. Chairman.

I did inherit this, but I am very proud of what I inherited. I think the NIST team, and working with the outside experts, have done a phenomenal job on this.

In terms of the first question, why were they couched in this fashion, this level of specificity? The actual detailed recommendations are in the end of the summary report, Chapter 9, and so I hope everybody takes a look at that. That is where there is a little bit more detail on them. But the real trade-off is we aimed for per-

formance-based. As I am fairly new to the codes and standard setting organizations, I have learned to appreciate the process as they go forward. And this is very much of a give and take. It is a consensus-building. It is a very open, consensus-built process, and the point is to try to put forward the guidance as to what needs to get done. And I believe that the NIST recommendations do a very, very good job of defining the what in terms of the recommendations.

The specifics of the how is where you now need to do the tradeoffs between different organizations, different vested interests, and the whole process of how the standard setting organizations and the code model organizations define this is this give and take between the different vested interests from the builders, developers, engineers, public safety——

Chairman BOEHLERT. I am going to interrupt you here, and——

Mr. JEFFREY. Sure.

Chairman BOEHLERT. But just let me, I mean, do you disagree with what Mr. Green said, specifically, the recommendations are not written in a way that facilitates direct adoption. And how can you have give and take on vagueness?

Mr. JEFFREY. I believe that the recommendations are specific in terms of the performance, but we now need to go through this consensus process of turning those into the specific language that the code developers can use in their national model codes. And this is that step of, now, using the National Institute of Building Sciences, and working with these organizations to address those very concerns. That is the next step, and we are working with them. In the process of being very open, I was very pleased to hear several of the witnesses talk about actually starting this process during the investigation itself, as some of the recommendations started to become apparent.

And so, I think that it is at the appropriate level of detail now, as I believe Mr. Green also stated, that if we over-specified them, they would also have a higher risk of rejection. So, it is that delicate balance of trying to do the consensus. In terms of the timeline, we are very much committed to meeting the requirements as appropriate. For example, right now, what we are going through is all of the recommendations, with NIBS and with others, to identify those codes where we can get the language in place to meet the March 2006 deadline.

Chairman BOEHLERT. So, you are personally committed to that March deadline.

Mr. JEFFREY. Absolutely. Some of the recommendations, as has been pointed out in the documents and by some of the witnesses, require more work in terms of some of the research and development, and so, what we are trying to do is separate those with NIBS, to identify those that can go forward very quickly, those that require a little bit more detail, in terms of the research.

Chairman BOEHLERT. So, when is NIBS going to be ready, and you are going to have their report, you are going to evaluate? What is the timeline there?

Mr. JEFFREY. It is going to be actually more of an ongoing process where we would expect that as a lot of the language becomes available, they are going to be submitting these. As I said, there is going to be a set by March 2006. I will actually defer to the ex-

pert here, Shyam Sunder, who ran the investigation, and is running the NIBS contract, on is there a specific final deliverable and a date. I am not trying to put you on the spot, Shyam.

Chairman BOEHLERT. Well, come on up and identify yourself for the purposes of the record.

Mr. SUNDER. I am Shyam Sunder. I am Deputy Director of the Building and Fire Research Laboratory, and lead investigator of the——

Chairman BOEHLERT. We will provide seats, if you would like to have a seat. You know, we don't want you——

Mr. JEFFREY. You are more generous than I am, so——

Mr. SUNDER. Thank you.

There are—we will prioritize the recommendations, so that those that are ready for the March deadline will go to the March deadline, and those that are ready for the next three year cycle, which would be a deadline six to eighteen months after that, we would go for that. But the people on our committee, the NIBS committee, do represent the organizations around this table. So, we have official representatives from those organizations.

Chairman BOEHLERT. All right. Let me ask some of the other witnesses. Mr. Green, Mr. Corbett, let us go down the line. What is your reaction to what he said? Is that good enough?

Mr. GREEN. Well, we are committed to working with them and NIST to make sure that they have in line for March code changes that are appropriate, to the degree that we can get through after we prioritize. I think that once that is accomplished, getting it in the context of submission for code language is somewhat easy, because we will have the experts working with them at NIBS to put it in that context. That is what we need to do.

The language that is used in the report is not here is how you would put it in the code body, and that is why we have the people sitting at the people with them. So, I am confident that we can get through this process, albeit we may not get through all of the recommendations, but those that we can get through, we will have them ready for March.

Chairman BOEHLERT. Mr. Corbett, what do you say?

Mr. CORBETT. I am glad to hear that they are committed to March. I think everyone recognizes that the code development process is a long one to begin with, and if we could have truncated this somehow, and got that process of recommendation, preparation, started during the investigation itself. Because some of these, I think, are kind of no-brainers. I mean, there are things that we could have been doing perhaps a year and a half ago.

Chairman BOEHLERT. Yeah, but as you said so eloquently, where do we go from here? So, we can't re-create what——

Mr. CORBETT. Right, right.

Chairman BOEHLERT.—is already——

Mr. CORBETT. Well, I think——

Chairman BOEHLERT.—behind us.

Mr. CORBETT. I think, you know, from my perspective, if they are committed to a March timetable, I mean, that is a pretty quick turnaround, I would think. I mean, from my perspective. As far as having so many people involved here. I mean, NIBS is bringing 15 or 20 people into this process here, so——

Chairman BOEHLERT. But—let me ask you—and I will get to Dr. Harris and Ms. McNabb.

Mr. CORBETT. Yeah.

Chairman BOEHLERT. My red light is on, so I will go to Mr. Miller in a second, but are you comforted by what Dr. Jeffrey is saying in his testimony now, in his response to these questions? Do you feel that we are on-course and we are going to be timely with specific recommendations, and there is enough time before March to have that so-called give and take he is referring to, and that we are going to produce something worthy of note?

Mr. CORBETT. Yeah. As I said, I think I had hoped that it would have been a lot sooner, but I mean, this is a commitment they have made, and I appreciate that. I think it is telling, also, that the NFPA and ICC both have made changes years ago, on some of these things we are talking about today. I mean, the fact is that this investigation has gone beyond what even the code groups themselves have done on their own. So, I think that is—we have got to shorten this process for the future.

Chairman BOEHLERT. Dr. Harris or Ms. McNabb, do you have any comment? Microphone.

Mr. HARRIS. Sorry. I am comforted by what Dr. Jeffrey says, and if you recall, the last thing I said was, this process is going to take a long time. And let me tell you why I said that. In February of 1970 or '71, there was a significant earthquake in the San Fernando Valley of Southern California, and it demonstrated that buildings built according to the then most current building codes and standards would not perform well in what could only be considered a moderate earthquake at the time. That got the attention of several federal agencies. They commissioned some studies to essentially realize that finding, and make recommendations that building codes and standards needed to be brought up to the state of knowledge, if you will, that existed in the research community. That process took about a quarter of a century.

The knowledge base wasn't intended to be expanded, per se, just get that knowledge base into mandatory requirements and codes and standards. It happened in several stages. There were things that did occur within three years of that event in interim updates to some building codes. About six years later, there was an act of Congress that was passed, the Earthquake Hazard Reduction Program. That took some time. Even following that, there was another major milestone in about 1988 in the building codes, and another one in 1997. It takes a long time to incorporate some of these changes. Now, some of the ones are very narrow scope detailed, and I think you may see action on them beginning in March. That is fine.

Some of them, like the one I happen to be the most concerned with, number one, increasing the structural integrity in buildings, and providing resistance to progressive collapse. That is not an easy nut to crack. In fact, there, we probably even need more basic knowledge. And so, it is going to take a long time before everything that NIST has uncovered and recommended is addressed, and it will not all happen in one fell swoop.

Chairman BOEHLERT. Ms. McNabb.

Ms. MCNABB. Yes. NFPA has already made a number of changes to our codes and standards, as a result of the NIST investigation. We don't really need the NIBS process, because our process is a consensus one. We bring together all the stakeholders in our process, so it is not just the enforcers who are making the final decision. It is, you know, the users of the buildings, the laborers, the insurers, the design professionals. We have nine categories of stakeholders that participate in our process. We have the technical expertise.

And after the NIST investigation began, we set up a High Rise Safety Advisory Committee to look at high rise safety, and to be ready for the NIST report, because we recognized that it is really society's role to take the recommendations, the science, and set the thresholds, and determine which buildings should these recommendations apply to, and to weigh that and balance the risk and the safety as it is.

Were we frustrated that the recommendations were not more specific? In some cases, yes, because the other investigation that we were familiar with was the Station Nightclub investigation, and that investigation done by NIST was much more specific than that World Trade Center investigation. So, we feel that they could have been more specific in some cases, but again, you know, just by its very nature, the investigation, the largest building failure investigation, I think, is going to come up with some science that needs to be studied and thought about, and all the viewpoints need to be brought in. And that is what we are doing.

Chairman BOEHLERT. Well, it is good to know that we are moving forward on several fronts, but we are impatient, understandably. A lot of people are impatient, understandably, and a lot of people want action as quickly as possible. And I am reminded of another issue, acid rain, which is one of my pet concerns, and people kept calling for more studies, more studies, more conversation, more give and take. And I remember Governor Kean, at the time, who ironically headed the 9/11 Commission, Governor Kean saying if all we do is continue to study the problem, we will end up with the best documented environmental disaster in history.

So, I think we are all very anxious to get going with some degree of specificity, with something that is tangible, that we can get a hold of, and we appreciate the fact that some of these things are going to be time-consuming, but time is a wasting. With that, Mr. Miller.

Mr. MILLER. Thank you.

I understand that building codes are designed to be a balance between risk and cost. If something is a serious risk, we will expect people to pay money to provide against that risk, to incur expense to provide against that risk. But if something is a real remote possibility, we will be less inclined to do that.

Dr. Jeffrey, I was struck by your testimony and by Ms. McNabb's about whether NIST recommendations for building codes should apply to every building, every commercial building the same. Most of the discussions about our terrorism risk have assumed that there is some possibility that there would be truly a random attack on any garden variety commercial building in America, but the most likely targets are what homeland security has called iconic

buildings, buildings of high symbolic value. The World Trade Center. The Pentagon, obviously both of those. The John Hancock Center. The Empire State Building. Dr. Jeffrey, I have practiced law for a while, in a garden variety six story office building in the North Hills area of Raleigh called the Landmark Center. It was Class B space. That was fine. I had kind of a Class B law practice. Why on Earth would you expect the Landmark Center on Six Forks Road in Raleigh to have the same standards of preparation against terrorist attack that the John Hancock Center would have?

Mr. JEFFREY. Thank you, Mr. Miller. Actually, the actual building codes that get adopted are at the State and local level. First, you know, that is part of the political process within the State and local governments as to what is appropriate for that specific setting.

Secondly, in the report, NIST does recommend that the owners of the iconic buildings, much like the ones you have mentioned, may want to view a higher level of preparedness than the average—the report specifically does not try to recommend that every building in the Nation be able to survive an attack with a fully loaded 747. And so, it does try to make that distinction, and calls out the iconic buildings separately.

Mr. MILLER. Should that be something dealt with by—that sliver of commercial properties, that are the most likely terrorism targets, should those be dealt with by Congress, rather than leaving that to local building codes?

Mr. JEFFREY. I am not sure that I am actually qualified to respond to where the State and local versus federal roles should plan.

Mr. MILLER. All right. Well, Ms. McNabb, what is your thought on this? Do you think that the Landmark Center ought to have essentially the same standards applied to it that apply to the John Hancock Center?

Chairman BOEHLERT. Let me interrupt here. Now, I won't take this from your time, but you know, this is not just about terrorist attack. It is about wind, it is about fire, it is about a whole bunch of other things that may not involve any terrorist activity, but we know we don't know enough, and I am not quite certain we know what we don't know, but we know we don't know a hell of a lot, and with that, Dr. Jeffrey——

Mr. MILLER. Mr. Chairman, could you diagram that sentence for me? Ms. McNabb. Dr. Jeffrey, did you want to respond now?

Mr. JEFFREY. No, I will wait.

Mr. MILLER. Okay. Ms. McNabb.

Ms. MCNABB. I don't think you can make a building terror-proof, and I don't think that you can have a code that, you know, sets forth terror-proof regulations, because by definition, terror is finding out what people have planned for, and then doing something above and beyond that to scare them or hurt them. So, I don't think that that is reasonable. I do think that there—that after 9/11, we see that it is important to set the threshold for some buildings differently. And even, I will say, high rise construction has progressed so much that, you know, what we used to think of as a high rise now is, has gone very, very high. And so, maybe it is time to think about different thresholds for tall buildings.

That, I think, is part of what we want to do when we bring all of the players. Perhaps, it is not just a threshold for how high the building it is or how iconic the building is, but where it is located in terms of the urban fabric, that is, that surrounds it. So, those are all things that we need to take into consideration, and unfortunately, catastrophes are what we respond to, rather than common sense. I mean, we could be moving forward on this on a regular basis, but people's attention isn't on it regularly, even though the science progresses, and we learn more about how to provide elevators for tall buildings, and we learn more about different technologies that can help us construct buildings. We don't move along on the safety as quickly, I think.

Mr. MILLER. Okay. It is striking to me that there does not appear to be a sense of urgency in the private sector about agreeing upon a standard for private sector preparedness, of what is expected of them. The 9/11 Commission devoted all of about a page and a quarter to private sector preparedness, but essentially said it should be the law of civil liability, negligence, and insurance considerations, and underwriting. It should be financial incentives that moves American business to take steps, care, that are appropriate to the risks they face. And suggest further industry standards, which it seems NIST might very well be part of.

The initial estimate of the insurance loss from 9/11 was $40 billion. It turned out to be $32 billion. The difference was all liability claims, that Congress' compensation for victims made compensation contingent upon waiving liability claims. So, everyone except the passengers on the airplanes, of their families, waived the liability claims, because those were very uncertain claims, given how stunned the Nation was by 9/11 and the very idea that we should have anticipated that and provided against it, something that seemed beyond our imagination. It won't be beyond our imagination the next time.

I would think American business, that commercial real estate, would be pushing hard for an industry standard, some standard that makes very clear what should be expected of them, not just so they can do the right thing, and so that they will not go to bed thinking that people died when people could have lived if they had something different. But for the simple, pragmatic reason that they will have a defense to a negligence claim to show that they met the standard of care that was expected of them, that there was an honest standard. But in this hearing, and in other discussions in other committees, there seems to be no such urgency. Do any of you have any, do you sense that there is an urgency, and if not, why not?

Ms. McNabb.

Ms. MCNABB. We have a standard, NFPA 1600, on emergency preparedness, that encourages the public and private sector to come together and ask themselves a series of questions. And I think that is the kind of thing that works, because you and your facility, if it is located, and I believe it is being used in New York City, you look at what the hazards are in your building, what the population is, what the context is, and you answer a series of questions, and then you plan for those. You provide, you know, your employees with what they need, the information they need, places to go if it is a biochemical event. Places to go if it is fire, if it is,

you know, and if follows through and allows them to plan for different kinds of emergencies. So, it is out there, and it is being used and adopted.

Mr. MILLER. Mr. Corbett.

Mr. CORBETT. I will just add that I testified before the 9/11 Commission on this specific issue, and I think, unfortunately, they missed the mark as far as the other piece of it. We have talked—she just mentioned NFPA 1600, which deals with the people side of preparedness for issues of terrorism, things like that. But what, really, they missed was the need for some kind of document, some kind of ruler to measure the level of protection provided for iconic buildings, with specific regard to terrorism, because the code groups have up until this point not developed anything, and I applaud the ICC, because they actually did create a committee to address those issues. ASCE has a committee on blast-resistant design, but you are right. There has been no rush to have at least, again, not a requirement, but at least a set of guidelines or a ruler that you can measure a building against to say yes, this building is well prepared for a terrorist attack, versus one that perhaps is not. Thank you.

Chairman BOEHLERT. Thank you. Dr. Jeffrey, does NIST have any estimates of the costs of implementing the recommendations, and were costs a factor in making their recommendations, and do you think cost should be a factor in determining whether to adopt the recommendations?

Mr. JEFFREY. Thank you. Cost was not a factor in making the recommendations. These were, again, performance-based. Part of the process of having all of the different groups represented, including the building operators, the engineers, the architects, the standard setting organizations, is for us not to specify that specific solution, but for those trade-offs to be made, and to try to find the best approach. And then, depending upon the situation, some of the expenses may be more justified than others. It is much along the lines of the sentence that was trying to be parsed. There has got to be a risk-based approach to this, and for some situations, some of the requirements may make more sense than others. But that is part of what this next step is.

Chairman BOEHLERT. Ms. Regenhard made some recommendations about making a lot of the information more available to the public at large relating to the investigation.

One, do you think she is on to something, and two, why aren't more of the deliberations available for public consumption, and three, I would be anxious to hear what the other witnesses on the panel would say about if she thinks that recommendation about making publicly more information available?

Mr. JEFFREY. Thank you. We are actually committed to make publicly available as much of the evidence from the investigation as we can. A portion of the evidence we received from third parties is protected under nondisclosure agreements, and we are actually going back to those parties to try to figure out exactly how much of that we can release legally.

In addition, a lot of the photographers have material that is copyrighted, and so, we are working with them to try to make sure that we have the proper, appropriate copyright protections in place,

as that data gets released. And also, a lot of the interviews that were taken, we are going through all of that information to redact out any of the information that might be able to identify the individual, to protect their personal privacy. But as we go through that process, we are going to be releasing a vast amount of that data.

Chairman BOEHLERT. Let me ask the other panel members. What do you think about that? I mean, should we have more information publicly available for review and examination and comment and response? Mr. Corbett.

Mr. CORBETT. Definitely. The answer is yes to that. That has been one of my concerns on the advisory committee, is that for example, all the information dealing with the first person accounts, the interviews that NIST had conducted, at one point, there was discussion about destroying that information. No decision had been made, but that was a possibility at one point, and I think now, NIST has basically said at this point, it won't be destroyed, but we are still not sure how it is going to be disclosed. And I think for the benefit of myself and other people that are, weren't part of the investigation, that we are kind of on the outside looking in. This is critical information for them for other research they are doing also. But also, to verify the conclusions, the findings, and of course, the recommendations that were, that come about. So, critically important to get that information, as much of it that can be given.

Unfortunately, I think this is an issue with the Act that NIST ended up in a position of having to sign agreements with various entities to not disclose this information, but again, this is diametrically opposed to that whole open process that we have talked about so many times here today, and also three years ago.

Chairman BOEHLERT. Well, you know, proprietary information, I suppose I can understand that, but if the information is subpoenaed, if you ask for information, saying "please come forward and give us all the information you have," and they say, "well, we will sign this nondisclosure agreement." Why would anybody sign a nondisclosure agreement unless there are instances, clearly, where you can understand the need for that.

Mr. CORBETT. Totally understandable, and I think this is a critical, critical issue that you have brought up, because this was certainly an issue for the World Trade Center investigation, was certainly an issue for the Rhode Island Nightclub investigation, because the Rhode Island Nightclub investigation, in my opinion, was effectively shut down because they had access to virtually information in the first place, the witnesses that were there that day, because the Rhode Island Attorney General told them they couldn't have it, and NIST really from, I would imagine from their legal staff, decided that it wasn't possible for them to have open hearings, to solicit information, to issue subpoenas for that information, and that is critical. It is critical to this Act, and it was critical to what happened with these investigations, and——

Chairman BOEHLERT. Well, yeah. There is always a balancing, delicate balance in there——

Mr. CORBETT. There is, and I have no qualms about proprietary information and personal information. That is not at issue here. But it affected, especially, that Rhode Island investigation, because a lot of the accounts that are recorded in the investigation report

are from the Providence, Rhode Island *Journal,* the newspaper. They are newspaper accounts. So, why didn't we have access to people that actually were there, like the Rhode Island Attorney General, and I think that these whole legal clouds that have been over these investigations are particularly troubling.

Chairman BOEHLERT. Anybody else care to comment? Ms. Jackson Lee.

Ms. MCNABB. I think the more——

Chairman BOEHLERT. Or excuse me, Ms.——

Ms. MCNABB. I think the more sunshine on the process, the better it is. I think that in general, in America, there is sort of a disconnect between the science and the application of the science, and knowing information, and then, knowing then what should be done with that information.

In Katrina, for example, I mean the last NOAA reports that we had when they were talking about wind speeds, and what was going to happen. It was hard to get people to understand the implications of the science, and they started saying things like dogs and cats will be living together and it is going to shake buildings. The more science that NIST can give us, and the more information that we have, I think the better off it will be for the public, because they will understand that building regulations don't just come out of a vacuum and from the building police, that there is a reason for, perhaps, raising the cost of construction, or perhaps making some trade-offs, or doing things differently.

Chairman BOEHLERT. In almost all cases, more information, rather than less, is desirable if you are reviewing and serious about making recommendations to prevent something in the future from happening.

Did you want to add something?

Mr. JEFFREY. Just a short statement, that we are absolutely committed to that. We agree with that. I think the entire process that we have tried to follow has been as open as possible, as described. The number of open meetings, the number of comments received. And we are committed to trying to release as much of the data as we legally can, and so, we know, we approve and agree with the statements.

Chairman BOEHLERT. Ms. Jackson Lee.

Ms. JACKSON LEE. I have been on this committee a sufficient number of years to remember the hearings that we had immediately after 9/11 to discuss a number of elements, including the question of the building safety and security, but also, a number of other issues dealing with interoperability and science, that could have been affected, particularly in the area dealing with fire protection. So, I am gratified that we are now here for a hearing that has to do with a report that has been rendered.

I am interested in the testimony of Ms. Regenhard. Are you able to come to the table, or answer any questions? I would be delighted to have you—let me. And let me thank you, first of all, for your testimony, and accept my tardiness because I was flying in on a late flight. But I thought this hearing was important enough for me to be able to come and to assess the testimony, and to hear from you as well.

You made, I think, a very potent point, which is that there was a sensitivity that the NIST study was not detailed enough, that it seemed to have some political ramifications. They may not have been on the ground, and many of us have been to Ground Zero. I serve on the Homeland Security Committee, as many of the Members of this Science Committee does, and we have a very visual sense of the need.

Can you share with us what more you would want, would have wanted NIST to do, or where were the political correctness issues that you think really didn't do the appropriate, or did not give the appropriate response?, particularly as you have faced a personal loss in the loss of your son, and you have my deepest sympathy?

Ms. REGENHARD. Thank you very much.

First of all, I just want to preface my comments with saying I often introduce myself in the way that I am basically just a little mother from the Bronx, and really, that is what I am, and I am not a technical person. However, I do have, over the last four years, you know, the input from my wonderful technical advisory panel, which represents some excellent, excellent people in the academic fields, and certainly, you know, in structural engineering, fire protection, architecture, and evacuation specialists.

So—but to get back to your question, you know, political correctness. I have seen, and the other families of the victims have seen the aftermath of 9/11 to be somewhat definitely flavored by political correctness in many, many ways, in so many ways. But certainly, with the NIST investigation, I mean, I understand that it is a wonderful organization of scientists, and scientists are not trained to be like NYPD detectives. There is a professional and academic way that these kinds of organizations deal with one and with other entities. And you have other professional people in that investigation that should have been really interrogated, such as the Port Authority, such as their building plans. You know, the Port Authority never turned over their building plans until there was an article about it in the front page of the *New York Times* condemning them, or not condemning them, but accusing them of really not coming forward. That is one of the examples. People like the chief structural engineer for the first World Trade Center, you know, his work should have been investigated, because after all, he was responsible for the design of that building, and the subsequent, and yet, instead of that, he was sort of dealt with in a friendly basis, and he was actually put on the payroll to explain his plans and all that.

So, there were these very, you know, maybe because I am a layperson, I can't understand why these entities that should have been scrutinized and investigated were sort of taken in and became part of the investigation. You know, that is just one of the examples of where the families were really, really deeply concerned about that. And also, the avoidance of certain things that were not politically correct, like the avoidance of blaming anyone for anything. I mean, we all teach our children to obey the law, and to respect authority, and not to break any laws, but yet, when we have this investigation of the, I would say the needless deaths of nearly 3,000 people, no one is to be blamed. It is handled so gingerly. I mean, there is a reason why nearly 3,000 people are dead, and I

feel the majority of them needlessly, but yet, the approach of these investigations is very, very tentative, and no one wants to put anyone on the line, and no one wants to look into what was the effect of the Port Authority immunities from building and fire codes?

If someone said to me what are the two major grievous examples of what went wrong on 9/11 in those buildings? I would say the two things are the Port Authority exemptions and immunities from New York City building and fire codes, and the wholesale failure of the FDNY radio communications, and the wholesale failure of the Emergency Management System of the City of New York and the Port Authority. And these are the crux of the matter. This is the bottom line. Yet, these are the issues that were, you know, skirted around and, you know, tiptoeing through the tulips, instead of—and still, today, I have to fault both the 9/11 Commission and the NIST investigation for not taking a stand, for not saying that in our country, no building should be above the law, especially the Port Authority buildings that were the tallest and largest buildings in the world, that at that time, was built to contain the largest number of people in the world, and yet, those buildings were allowed to be exempt and immune from building and fire codes, essentially above the law, and now, we are allowing the Port Authority to do the same thing all over again.

The new World Trade Center and the memorial, and every single building down there on that property will be just as exempt and immune from every single New York City building and fire code as the first one. That is an abomination. That is a sin. That is an outrage against humanity. And you know, I am sorry to get emotional. I expected the NIST investigation and the 9/11 Commission to take a stand on that, but you know what, it is only the average Joe Q. Citizen. When we break the law, we have to pay the consequences, but when we have these huge organizations breaking the law, I feel they are not held to the same standard as an average citizen, and that hurts.

Chairman BOEHLERT. Thank you very much.

Ms. REGENHARD. Thank you. I am sorry. I am talking too much. I am sorry.

Ms. JACKSON LEE. Thank you very much for giving us that testimony. Mr. Chairman, I would hope that in the course of this review, that Dr. Jeffrey of NIST and others who are representing the fire protection community, Mr. Green, who has several ideas about being able to self-code or self-improve your buildings against wind and others, the Katrina story that I understand that you shared with us, can respond to her inquiry about building codes and immunity. That seems to be an indictment of the report from the very start, and I hope we will have an opportunity to review that, and I hope Mr. Jeffrey will have an opportunity to respond to that indictment.

Chairman BOEHLERT. Thank you. The——

Ms. JACKSON LEE. Thank you.

Chairman BOEHLERT.—gentlelady's time has expired.

I would report that we anticipated, in developing the legislation that authorized the report and everything, we anticipated that there would be a reluctance on the part of some to provide information. There would be inertia. And that is why we gave subpoena

power to NIST, to go in and get the information, and it was not NIST's role to assign blame. It is NIST's role to investigate, to determine what went wrong, to make recommendations on how to go forward, and that is what we are determined to work cooperatively with Dr. Jeffrey and the NIST people, to make certain it happens the way we want it to happen, and that we don't drag our feet, or we don't issue a report, and sort of say gee, we did a great job. We have this report, and have it not as specific as we would like, or there be a lack of follow through.

And quite frankly, Congress has a responsibility, too. We have got to conduct more meaningful oversight hearings. It is all well and good for Congress to pass legislation, and then put out our press releases, and say boy, we passed this legislation dealing with an important problem facing the people of the Nation we are privileged to represent, and then go on to the next thing. We have got to pause now and then, and look back and say, is it working as intended? How can we make sure it works more effectively?

And that is why we are having this hearing today. This isn't the first hearing or the second hearing, it is the third hearing, and we are going to have more. And we are not ignoring Ms. Regenhard and her group. They are very valuable resources for this committee, and we listen to them, and we want to work cooperatively with them, but we want to work cooperatively with everybody.

So, let me ask you, talking about our responsibility, Dr. Jeffrey. In your testimony, you haven't discussed what actions should be taken by the Federal Government in response to your recommendations. It seems there are a number of steps, not only relating to the General Services Administration, but to the agencies that run R&D and education programs, including FEMA and NSF, and NIST itself. What should the Federal Government be doing? Is NIST going to put out any formal document on this, and how are you going to work with the other federal agencies on these matters?

Mr. JEFFREY. Thank you, sir.

There are a number of actions that need to be taken. As I mentioned earlier, there are a number of research and development programs, for example, that are sure to come out in this report. In fact, the report actually highlights where some of those R&D efforts are. And you know, a lot of them fall under NIST to try to execute. We have made a plug for the last—probably the last couple of days I can make this plug, we have got a program in the FY '06 President's budget to try to address some of those R&D programs, and I am hoping Congress looks kindly on that, so we can start to address some of those.

Chairman BOEHLERT. No, continue. But how about some of the other agencies?

Mr. JEFFREY. On the other agencies, we need to get together. We have not done that yet. There are some of the recommendations that involve, especially some of the education programs. We have been working a lot with the private sector on that. We need to bring in some of the other parts of the Federal Government that we have not yet done.

Chairman BOEHLERT. Because you know what happens. You know, you all march down the, you develop your budget, and then, you march down to OMB, and say this is what we want. This is

what we can justify. Here is the documentation. And then, the cuts start happening, particularly in the R&D area, and because that is longer range, and we have got to deal with the issue of the moment.

So, we are going to be helpful to you, with respect to NIST's particular budget, and quite frankly, what an embarrassment the way Congress treated you last round. This round, we are going to treat you better, and we are determined to see that. You got all friends here, but some of these other people, we have got to convince, or don't even know what the hell NIST stands for. But you have got to talk to some of the other agencies, and have some specific recommendations on what they should be doing, and we want to follow through with you on that, to make sure we keep on their tails, so to speak.

Mr. JEFFREY. Absolutely, and I would be very happy to follow up with you and your staff on that.

Chairman BOEHLERT. All right. Now, I think it is fair to say that NIST is making some pretty far-reaching, perhaps even revolutionary suggestions here, particularly with regard to full building evacuation. All of you, perhaps understandably, are hedging your bets at best, in your testimony as to whether the recommendations would find their way into code. Is your general sense that NIST's approach makes sense? Do these recommendations have applicability beyond terrorism, to more—and I think they should and do—to more routine problems encountered in the field, including natural disasters?

Let me go down the panel, and ask who wants to respond first to that? Dr. Harris.

Mr. HARRIS.—able to make these recommendations. The solution to the terrorism problem is not to really make buildings stronger. It is to keep airplanes and things like that out of buildings. This event has created a tragic misconception, I think, in the minds of the public, that buildings actually perform better than typical buildings really will perform. The public believes that when a big airplane flies into a building, what happens is what happened at the World Trade Center and at the Pentagon, that is, the plane disappears into the building, and there is a hole. Smoke begins to come out, and after a while, some portion, or maybe all of the building collapses. That is not what happens when you fly a big airplane into most buildings. What happens is——

Chairman BOEHLERT. They do know that the building was structurally sound. It was the insulation, the foam that was blown off, and——

Mr. HARRIS. That is correct. What happens with most buildings is, in fact, a portion or maybe all of the building collapses immediately. Their recommendation number one addresses that. But the addressing it is not to make it safe for an airplane. It is to make it safe for a satchel bomb, or perhaps, a car bomb outside. There are completely different issues, all right.

But that is—the real value of the study is we do need to think about that. When we get into this question of iconic buildings, there is not just going to be one dividing line, I do not believe. We are going to have something for the next World Trade Center, cer-

tainly. There will be something for the City Hall in Denver, Colorado, for example. I had——

Chairman BOEHLERT. Well, how about Mr. Miller's six story building in Raleigh, because——

Mr. HARRIS. And Mr. Miller's six story building probably will not be affected by that recommendation, at least in my own opinion, it probably would not. And that is not because I invest in real estate or construction. It is just I don't think it will be. But there will be a gradation, and that is what is going to take time to come to, as well as, on that particular issue, the technical substance of how you do it is going to have to take some time, too. There is no one magic recipe there. I would want to get on the record something I had meant to say earlier, and commend the General Services Administration for the leadership they have been taking on that issue of progressive collapse, with the construction of new federal courthouses, where they are taking that issue very seriously.

And I would like to make one other comment, while I have the mike. And that is I saw that recommendation number 25 actually does respond to the issue raised by Ms. Regenhard of the Port Authority having an exemption. It is an important recommendation here that needs to be carefully considered. There are all sorts of legal ramifications about how you implement this, so it is not going to come quickly, either. But I think the pressure of your bully pulpit, and Congress in general, bringing to light the issue of various entities having these exemptions, and how you go about fulfilling the promise that I am trying to build something as good as the code would require. How do you go about that? That is something for, I think, all of us to focus. It is——

Chairman BOEHLERT. Just let me read into the record. It won't take me long. The recommendation number 25, because it is very pertinent. "Nongovernmental and quasi-governmental entities that own or lease buildings, and are not subject to building and fire safety code requirements of any governmental jurisdiction should provide a level of safety that equals or exceeds the level of safety that would be provided by strict compliance with the code requirements of the appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends that as designed and as built, safety be certified by a qualified third party, independent of the building owner or owners. The process should not use self-approval for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the list of the buildings." That is a pretty good recommendation, I think.

Mr. Corbett, Mr. Green, do you want to comment on this?

Mr. GREEN. Well, from my perspective, I think that we should encourage, if not more strongly encourage, states to establish standards for buildings in their areas where they may not have code enforcement.

Chairman BOEHLERT. But does this approach make sense to you?

Mr. GREEN. It does make sense, but the value of having a governmental entity have that oversight, I think, adds value to the safety in the building. I am not so sure I am sold on this third party element. I would rather see that the third party would be a

governmental entity that has some enforcement responsibility, to assure that the building does comply. I don't want to suggest before this committee that it is not appropriate to have third party involvement, but you are assured at a greater level when you have governmental involvement for oversight to compliance.

Chairman BOEHLERT. What do you say, Mr. Corbett?

Mr. CORBETT. I agree totally. I might also make a couple notes, that the word governmental is missing from recommendation number 25. The Federal Government, State government, local government. The word government isn't in there. So, that is a whole group of buildings out there that are not, obviously, subject as we stand today, with local and State regulations, and I would point out, it is ironic that you mentioned GSA before, because I know GSA actually has participated in the code development process, and actually, to my understanding, was stating an opposition of proposals for wider stairs in high rise buildings. So, it is kind of ironic that on one hand, you know, we are not—they do not have to comply with the code, but on the other hand, are able to participate in the process that affects other buildings. So——

Chairman BOEHLERT. Government has a way of doing that.

Mr. CORBETT. But I do, I agree totally with Mr. Green that my own opinion that I would have, I would prefer that recommendation 25 not look for a third party, but look for that, again, that local government or State government, whatever it is, to review and to inspect and to oversee the nongovernmental and quasi-governmental entities.

Chairman BOEHLERT. I don't think we have legal authority. But government is in the habit of saying don't do as I do, do as I say. Any other comment on that, before I go to Dr. Ehlers? Ms. McNabb, did you have something?

Ms. MCNABB. Yes. In terms of the recommendation 25, I think it is a good recommendation. We support it. In fact, the NFPA comments were to include government, but understanding that that is a matter of Constitutional law, and perhaps, that is why NIST recommended the third party, is that is an easy way of dealing with that issue, related to the Constitution.

In terms of full building evacuation, to go back to your earlier question, I think that it is inevitable that after 9/11, even though it is not required, that building occupants may want to do a full building evacuation or drills in the event of an emergency. NFPA has a pamphlet on this, but we think that it should be looked at, because full building evacuation could result from things like a bomb threat, from things like a power failure, not necessarily terrorism. So, it is something that I think needs to be studied, and it is a good recommendation.

Chairman BOEHLERT. Thank you very much. Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman. I apologize for missing much of the hearing, but we still have one of my markups going on, and I will have to dash over there shortly.

On the issue of evacuation, I was amused in thinking about this and the relationship with NIST, but when I spent a year at JILA in Boulder, Colorado, as you know, there are a lot of mountaineers in that area, including in JILA. I went into one of my colleague's offices one day, and he is up on the ninth floor of JILA, and saw

this 150-foot coil of rope there, and I said oh, going climbing later? He says no, no. That is my emergency escape route. And he was dead serious. If anything happened down below, he was going to just rappel out the window, and go on down.

Dr. Jeffrey, I have a question for you, that there apparently has been some controversy or criticism of NIST that they did not invoke the NCST, and did not send their NCST team down, as part of investigative team, to the Gulf Coast after Hurricanes Katrina and Rita, but instead, used your standard authority for that. And the criticism has been that you haven't exercised your leadership role in the federal investigation of the damage to—hurricane-related damage to the buildings in that area. And I would just like to get on the record a response to this. Why did NIST choose not to invoke the *National Construction Safety Team Act* when deploying these teams? And how has NIST interacted with other federal agencies that are on the ground in the Gulf Coast states? And why are you not leading the effort on building safety investigations?

Mr. JEFFREY. Thank you, sir. The authorities that NIST has to do investigation are essentially the tools in our toolbox. And we are going to use the best tool, the most appropriate tool, for whatever investigation we need to do. And for the Hurricane Katrina and Gulf Coast areas, we have got authorities that are actually broader than the NCST, and more appropriate for the kinds of investigations that we need to do.

For example, we had a reconnaissance team go down there, and a lot of the things that were identified, in terms of further investigation, includes not just buildings, but includes other components of the infrastructure, for example, water, and sewage plants. It includes bridges, tunnels, et cetera, that are not covered under the NCST. In addition, we are going to learn a lot from buildings that have not just failed, but buildings that were damaged, which again, is not covered under the NCST. So, we are applying exactly the authorities that we think we need to to try to get the job done.

In terms of leadership, from day one, we have been working with FEMA as part of their emergency response, as part of the National Response Plan. Within the first week, we had a person go there, a roofing expert go down with a group of 23 volunteers to Mobile, Alabama, to look at roofing. We sent out a team, as I mentioned just a second ago, in terms of reconnaissance, to try to look through the Gulf region, and we have now got three teams that are under NIST coordination that are made up of 16 different private and government organizations of experts, that are going around the Gulf region, doing detailed assessments now.

So, we believe that we have been very aggressive in the teams that we have sent down there, and using the appropriate authorities to get as broad a view of the situation as possible.

Mr. EHLERS. Thank you. Does anyone else wish to comment on that issue? Mr. Corbett.

Mr. CORBETT. Yes, thank you. I commented on this during my testimony, and I still believe the NCST would have been useful down there, especially given the fact that the problems we have had with the World Trade Center investigation, you know, securing evidence, getting evidence early on. I mean, we were very heavily reliant on computer models to tell us what happened to the Twin

Towers, because we lacked that physical evidence, because there wasn't an Act when the Trade Center was hit.

And I really believe that I would have preferred to have a much more aggressive paratrooper type response from this, with reconnaissance teams to figure out what are the buildings we have got to study, you know. The Act, I believe, does include provisions for investigating building disasters that had the potential for a large life loss. It doesn't have to be, my understanding that it has to have lives lost in the building. So, I just—I would have hoped that we could have done under the Act. I understand that they have other authorities to do that work, but I had always hoped that NCST would skip to that same level as the NTSB, in terms of public recognition, public understanding of what, you know, what we are looking for.

Mr. EHLERS. Dr. Jeffrey, let me just ask, couldn't you have done both? Couldn't you have sent down an NCST team to investigate those areas where they needed that type of authority, and used the standard teams in other areas, where they needed their authority?

Mr. JEFFREY. They are the same people. I mean, we have got the same technical experts, and it is actually transparent. As long as they have the authorities to do the job, and at any time that they need additional authorities, we will find those additional authorities within our legal limits, to provide them that. But it is the same people. It is the same technical experts.

Mr. EHLERS. And did you at all invoke the authorities under the NCST?

Mr. JEFFREY. Not for Hurricane Katrina. As the broad scope of what the investigation is actually fits better under other existing NIST authorities.

Mr. EHLERS. But weren't there some instances, as Mr. Corbett is mentioning, where you should have used the authority of the NCST?

Mr. JEFFREY. The authorities that we have got would cover a lot of the situations. The unique authority that the NCST would provide us is essentially the ability to legally require a release of documentation. We have not reached a situation where that has been an issue for the Hurricane Katrina situation.

If, at some point, we need subpoena authority, and it fits under the legal guidelines of the NCST, we will, without hesitation, use that authority.

Chairman BOEHLERT. Thank you. The gentleman's time has expired. I thank all of you for being resources for this committee. I will end, Mr. Corbett, by answering your question. Where do we go from here? We are going to—eternal vigilance. We are going to keep on top of this. We developed the whole legislation to make possible this investigation. We are going to keep on it.

Dr. Jeffrey, we fully expect you and your team at NIST, we compliment you for all the good work you have done. You have got a lot more to do, and we want to follow very closely your interaction with NIBS, and we want to make sure you get recommendations with specificity to the ICC before March. There are a lot of things we want to make sure of, and so, this is not the end of the process. We are somewhere in the middle of the process. We are going to go forward.

And Ms. Regenhard and the people on your committee, we thank you for all that you have done. We are sorry that this work was necessary, but it is, and we are going to do it to the best of our ability.

Thank you all very much. This hearing is adjourned.

[Whereupon, at 1:45 p.m., the Committee was adjourned.]

Appendix 1:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by William Jeffrey, Director, National Institute of Standards and Technology (NIST)

Questions submitted by the Majority

Q1. In your testimony you described how a staff member at NIST had been assigned to each of NIST's recommendations to ensure that they are carried out. Please provide the Committee with a list of the recommendations that call for an explicit code or standard change, a brief description of the steps in the process of changing these codes and standards, where NIST is in this process, and the code and standards groups with whom NIST is working on each recommendation.

A1. Please see attachment A which identifies the affected codes and standards by each of the WTC recommendations. NIST is currently pursuing action on each of the WTC recommendations with an emphasis on meeting the March 24 deadline for the International Building Code.

Q2. In her testimony, Ms. McNabb said that the recommendation related to elevators may be one of the most important. Do you agree? How difficult would that be to codify and implement? Can you give the Committee a sense of what specific next steps you would take to evaluate that recommendation and what additional information you would need and from whom?

A2. NIST agrees that improved building evacuation overall should be a priority. Buildings should be improved to include system designs that facilitate safe and rapid egress, methods for ensuring clear and timely emergency communications to occupants, better occupant preparedness for evacuation during emergencies, and incorporation of appropriate egress technologies. Recommendations 16, 17, 18, 19, and 21 address these. The use of occupant evacuation and fire service elevators in emergencies is a key element of these recommendations. Further, Recommendation 20 recommends that the full range of current and *next generation evacuation technologies* should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell descent devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access. As part of the implementation process for the WTC report recommendations, the American Society of Mechanical Engineers is addressing the use of elevators for occupant evacuation and fire service use.

Q3. How many people does NIST have working on WTC investigation-related projects now that the main part of the investigation is wrapping up? Will the Hurricane Katrina investigation take resources away from WTC follow-up?

A3. NIST has over 20 members of its staff continuing to work on WTC investigation-related projects as part of its overall WTC response plan, which includes a research and development program and a dissemination and technical assistance program. A key part of this effort is promoting implementation of the WTC recommendations. NIST staff continue to work vigorously with the building and fire safety communities to assure that there is a complete understanding of the WTC recommendations and to provide needed technical assistance in getting them implemented. The Hurricane Katrina assessment will not take resources from the WTC investigation follow-up.

Q4. In your testimony, you said that NIST's recommendations are achievable within "a reasonable period of time." How long will that be? Will NIST set some benchmarks to guide its activities to promote implementation?

A4. NIST is committed, working through the various building code organizations, to meeting the March deadline of the next code development cycle of the International Code Council with as many of the recommendations as appropriate and possible. I have assigned top priority for NIST staff to work vigorously with the building and fire safety communities to assure that there is a complete understanding of the recommendations and to provide needed technical assistance in getting them implemented. We have identified specific codes, standards, and practices affected by each of the recommendations in the summary report for the WTC towers and already begun to reach out to the responsible organizations to pave the way for a timely, expedited consideration of the recommendations. We also have awarded a contract to the National Institute of Building Sciences (NIBS) to convene a panel of building code experts to turn appropriate recommendations into code language

suitable for submission of code change proposals to the two national model code developers.

The timeline for achieving the recommendations is governed by the established development cycle for each of the impacted national standards, codes, practice guidelines or regulations. For example, the model codes follow a three-year development cycle with the next edition due in 2009. The IBC also will issue a supplement in 2007 based on code change proposals submitted by March 2006. The next edition of ASCE 7, a key standard, is due in 2010. Many other standards have an ad hoc development cycle.

Working in partnership with NIBS, NIST will target the IBC's 2007 supplement as well as the 2009 editions of the model codes. In addition, NIST will work with ASCE and the other standards developers to target their appropriate next edition.

In carrying out this work, NIST recognizes that not all of the recommendations will have an impact on model building codes. Many will impact standards that are referenced in model codes. Others will impact stand alone standards used in practice but not referenced in model codes. A few will impact practices, including education and training, that don't have any impact on codes and standards. In many cases, a standard will need to be developed before the recommendation can be implemented in the model codes.

In addition, we will implement a web-based system so that the public can track progress on implementing the recommendations. The web site, which is already operational, will list each of the recommendations, the specific organization or organizations (e.g., standards and code developers, professional groups, State and local authorities) responsible for its implementation, the status of its implementation by organization, and the plans or work in progress to implement the recommendations. The web site is available at *http://wtc.nist.gov/recommendations/* and includes detailed information on the work with NIBS. The web site will be updated with information on plans and status by the end of January 2006.

Q5. In terms of how a building safety investigation should be conducted, what are the three most important lessons derived from NIST's experience with World Trade Center buildings?

A5. The experience gained from the WTC investigation will help NIST to better plan and execute future investigations. Examples of the challenges include:

- The need to identify, collect, index, review, and analyze massive amounts of data from external sources.
- The need to model and validate extraordinarily complex and multi-step physical and failure processes in large-scale systems that required advancements in the state-of-the-art and tested the limits of current commercial software.
- The need to design first person interview protocols, based on rigorous social science methods, which could be used to draw definitive results and be generalized to make well founded recommendations for improving evacuation and emergency response procedures.

Q6. You testified that more data and research are needed to implement some of NIST's recommendations. In your statement you said "there is a number of research and development programs, for example, that come out in this report. In fact, the report actually highlights where some of the R&D efforts are. . .a lot of them fall under NIST to try to execute." Please summarize NIST's research plan based on the WTC report recommendations.

A6. NIST has a number of on-going research and development projects as part of its WTC response plan which address needs set forth in the WTC report. These projects include:

- Prevention of Progressive Collapse
- Fire Resistance Design and Retrofit of Structures
- Fire Resistive Coatings for Structural Steel
- Fire Resistance of Uncoated Structural Steel with Improved Thermal Properties
- Fire Resistance of Building Partitions
- Occupant Behavior and Egress
- Emergency Use of Elevators
- Equipment Standards for First Responders
- Standard Building Information Models for Vulnerability Assessment
- Technologies for Building Operations in CBR Attacks

- Cost-effective Risk Management Tools

In addition, NIST has on-going research in areas relevant to building and fire safety. These include:

- *High Performance Construction Materials and Systems:* Enable scientific and technology-based innovation to modernize and enhance the performance of construction materials and systems.
- *Fire Loss Reduction:* Enable engineered fire safety for people, products, facilities; and enhanced firefighter effectiveness with 50 percent reduction in fatalities.
- *Enhanced Building Performance:* Provide the means to assure buildings work better throughout their useful lives.

Q7. In written testimony submitted to the Committee, the American Institute of Architects points to the lack of afire test facility in United States—a facility large enough to test components of a tall building—as a major shortcoming in the Nation's ability to improve skyscraper safety. Is the maintenance and operation of large-scale fire testing capability a NIST responsibility, or does it lie elsewhere in the Federal Government or the private sector? How do you respond to the AIA's comments?

A7. NIST agrees with AIA that fire testing of large building components under load conditions is a vital need that is not available in the United States at this time. Recommendation #5 recognizes this need by stating "A key step in fulfilling this recommendation is to establish a capability for studying and testing the components, assemblies, and systems under realistic fire and load conditions."

As the Federal Government's principal fire research laboratory, NIST maintains some of the country's best and most extensive fire testing facilities. More than 400 fire experiments are performed each year in the specially equipped, 27m (90 ft.) x 37m (120 ft.), Large Fire Research Facility. However, this facility is not capable of conducting fire tests under load conditions currently.

NIST has held discussions with the major fire testing laboratories and the academic community to help define the requirements for such a fire testing capability in the United States. In addition, NIST is considering how its Large Fire Research Facility could be modified to meet this national need.

Q8. Some critics argue that, since most fires that result in fatalities occur in residential buildings, particularly homes, the focus on skyscraper safety is a distraction from more common threats to life and property. How do you respond to this criticism?

A8. We do not believe the focus of the NIST investigation into the collapse of the buildings at the World Trade Center is a distraction from the impact of or need to address the losses from residential fires. NIST has an assigned responsibility to enable better fire safety for people, products, and facilities; and to enhance fire fighter effectiveness and continue to place a high priority on programs and activities that impact the threats from residential fires. The U.S. annual losses attributable to fire are nearly 3600 lives, 22,000 serious injuries, $10 billion in direct property loss, and $128 billion total cost. NIST's fire research programs work to: enable safer and more effective fire service operations through new technology, measurement standards, and training tools; develop effective strategies for cost-effectively reducing the Nation's fire losses (both human and financial) by limiting fire growth and spread in and to residences; provide the fundamental knowledge, algorithms, and measurement techniques necessary for advancing engineered fire safety for people, products, facilities, and first responders; and provide the infrastructure necessary to facilitate the transfer of NIST-developed technology into practice through participation with codes and standards organizations, maintenance of the premier international research bibliography and electronic data for the fire community, and the development of laboratory facilities with a premium on accurate, innovative and safe large-scale fire experiments.

Q9. Testimony submitted to the Science Committee by the Building Owners and Managers Association (BOMA) calls for the development of cost-benefit analyses on the implementation of NIST's recommendations. Do believe this is a good idea? Why or why not? If so, what would NIST do to develop these analyses?

A9. The NIST recommendations do not prescribe specific systems, materials, or technologies. Instead, NIST encourages competition among alternatives that can meet performance requirements. The recommendations also do not prescribe specific threshold levels; NIST believes that this responsibility properly falls within the pur-

view of the public policy setting process, in which the standards and codes development process plays a key role. Cost-to-benefit would be an inherent part of this process.

Only a few of the recommendations call for new requirements in standards and codes. Most of the recommendations deal with improving an existing standard or code requirement, establishing a standard for an existing practice without one, establishing the technical basis for an existing requirement, making a current requirement risk-consistent, adopting or enforcing a current requirement, or establishing a performance-based alternative to a current prescriptive requirement.

Q10. Attached is testimony submitted to the Committee from the Building Owners and Managers Association (BOMA). Please review this testimony and provide the Committee with comments on the issues that BOMA raises on the recommendations.

A10. The review of the WTC recommendations contained in BOMA's testimony was received and reviewed by NIST during the public comment period for the draft WTC reports. Based on the comments, it appears BOMA concurs with or is in general agreement with 11 of the 30 recommendations, did not have a comment on seven recommendations, was concerned with six of the recommendations (e.g., due to cost or risk justification), considered two recommendations to be vague, and requested clarification or did not adequately understand four of the recommendations.

In a few cases, BOMA cited a lack of history to suggest that tall buildings face increased risk. First, the excellent safety record of tall buildings that is cited by critics is based mostly on data from roughly the past 30 years. Such historical statistics, however, do not adequately capture rare design events due to a lack of data at the tails of probability distributions. For example, buildings which have useful lives of as much as 100 years are often designed for a 500-year hurricane or a 2,500-year earthquake. Statistical data over, for example, a 30- to 50-year period would not be able to adequately capture the rare events that should be considered in design. Second, the aim of design is to anticipate rare design events in a rational manner. Unanticipated events have surprised the design community in the past, most notably after the 1994 Northridge earthquake when safety concerns were identified in a widely used type of steel building and the industry had to improve building codes and standards for such buildings. Third, for a given threat, the risks increase with building height since the *consequences* of the threat become more severe with height.

Some of the WTC recommendations were considered by BOMA not to be adequately specific. The NIST recommendations do not prescribe specific systems, materials, or technologies. Instead, NIST encourages competition among alternatives that can meet performance requirements. The recommendations also do not prescribe specific threshold levels; NIST believes that this responsibility properly falls within the purview of the public policy setting process, in which the standards and codes development process plays a key role. The issue of specificity will be resolved as part of NIST's ongoing efforts with NIBS in support of model code changes (one of the NIBS building code experts is a BOMA representative) and with standards organizations.

The basis for some of the WTC recommendations was not adequately understood by BOMA. NIST is working actively with the standards, codes, and industry organizations, including BOMA, to develop a shared understanding of the basis for the recommendations and to provide needed clarification and justification. The private sector inputs will lead to requirements that are appropriate for adoption in standards and codes.

In a few instances, BOMA suggests an incremental approach to adopting the recommendations. NIST believes that strong industry commitment to working such issues will lead to early implementation of acceptable solutions.

Please see the answer to Question 9 that address cost concerns with a few of the recommendations.

Questions submitted by the Minority

Q1. Dr. Jeffrey, what interactions and information has NIST shared with the General Services Administration (GSA) about the findings of its World Trade Center investigation. Could this information be useful for the development of standards for federal buildings at risk such as embassies?

A1. NIST has had several interactions with GSA on its WTC response plan, including the WTC investigation. Most recently, six members of the GSA staff attended the WTC Technical Conference held at NIST September 13–15, 2005. GSA also is

co-funding a multi-year research and development project at NIST on emergency use of elevators. NIST has an agreement with GSA to implement a demonstration project in a federal building where protected occupant evacuation and fire service elevators will be installed, meeting all of the proposed standards and code requirements based on the WTC investigation. In addition, NIST is working with GSA to collect occupant behavior data during evacuation drills within GSA buildings. NIST has working relationships with GSA and State Department staff on its research and development program to prevent progressive collapse in buildings. Staff from these agencies have participated in NIST workshops and provided reviews of draft guidance documents.

Q2. Dr. Jeffrey, NIST believes that its recommendations are achievable within a reasonable period of time. In your view, what is the shortest time period that the NIST recommendations could be implemented?

A2. NIST is committed, working through the various building code organizations, to meeting the March deadline of the next code development cycle of the International Code Council with as many of the recommendations as possible. I have assigned top priority for NIST staff to work vigorously with the building and fire safety communities to assure that there is a complete understanding of the recommendations and to provide needed technical assistance in getting them implemented. We have identified specific codes, standards, and practices affected by each of the recommendations in its summary report for the WTC towers and already begun to reach out to the responsible organizations to pave the way for a timely, expedited consideration of the recommendations. We have also has awarded a contract to the National Institute of Building Sciences (NIBS) to convene a panel of building code experts to turn appropriate recommendations into code language suitable for submission of code change proposals to the two national model code developers.

The timeline for achieving the recommendations is governed by the established development cycle for each of the impacted national standards, codes, practice guidelines or regulations. For example, the model codes follow a three-year development cycle with the next edition due in 2009. The IBC also will issue a supplement in 2007 based on code change proposals submitted by March 2006. The next edition of ASCE 7, a key standard, is due in 2010. Many other standards have an ad hoc development cycle.

Working in partnership with NIBS, NIST will target the IBC's 2007 supplement as well as the 2009 editions of the model codes. In addition, NIST will work with ASCE and the other standards developers to target their appropriate next edition.

In carrying out this work, NIST recognizes that not all of the recommendations will have an impact on model building codes. Many will impact standards that are referenced in model codes. Others will impact stand alone standards used in practice but not referenced in model codes. A few will impact practices, including education and training, that don't have any impact on codes and standards. In many cases, a standard will need to be developed before the recommendation can be implemented in the model codes.

In addition, we will implement a web-based system so that the public can track progress on implementing the recommendations. The web site, which is already operational, will list each of the recommendations, the specific organization or organizations (e.g., standards and code developers, professional groups, state and local authorities) responsible for its implementation, the status of its implementation by organization, and the plans or work in progress to implement the recommendations. The web site is available at *http://wtc.nist.gov/recommendations/* and includes detailed information on the work with NIBS. The web site will be updated with information on plans and status by the end of January 2006.

Q3. What specific plans does NIST have to inform local officials about the safety implications of it recommendations?

A3. NIST has been and is reaching out to all communities involved in building and fire safety. We have strongly urged that immediate and serious consideration be given to these recommendations by the building and fire safety communities in order to achieve appropriate improvements in the way buildings are designed, constructed, maintained, and used and in evacuation and emergency response procedures—with the goal of making buildings, occupants, and first responders safer in future emergencies.

We are also strongly urging building owners and public officials to (1) evaluate the safety implications of these recommendations to their existing inventory of buildings and (2) take the steps necessary to mitigate any unwarranted risks without waiting for changes to occur in codes, standards, and practices. We are urging

State and local agencies to rigorously enforce building codes and standards since such enforcement is critical to ensure the expected level of safety. Unless they are complied with, the best codes and standards cannot protect occupants, emergency responders, or buildings.

NIST experts have been meeting with state and local officials over the past year providing them with information on NIST's investigation. In September, NIST held a conference attended by over 200 experts from standards developing organization, state and local officials, fire fighting organizations and builders. Throughout the course of our investigation, NIST's work has received major media coverage—including by media outlets followed closely by building, fire, and other emergency preparedness and response officials.

Q4. Dr. Jeffrey, what will be the impediments to translating the NIST recommendations to improvements to building codes and emergency response and evacuation procedures?

A4. There are a number of features intrinsic to the building and fire safety regulatory system in the United States that affect the speed and outcome of the change process for codes, standards, and practices.

- First, building and fire safety regulations, promulgated and enforced by State and local jurisdictions, are based on national model codes developed by private sector organizations.
- Second, the model codes adopt by reference standards that are developed by a large number of private sector standards development organizations.
- Third, the process and schedule for consideration of changes differ for each code or standard.
- Fourth, changes to codes and standards are based on the review and consensus approval of committees comprising a spectrum of interests and perspectives.

The above process accommodates the inputs and concerns of a wide range of groups—including architects, engineers, developers, owners, operators, users, emergency responders, State and local regulatory officials, policy-makers, and concerned citizens. Incorporating these inputs into regulations is complex, but the system has evolved into one that balances the sometimes contradictory desires of the various groups while providing for public safety and welfare.

NIST has identified 37 specific national model codes, standards, practice guidelines, or regulations impacted by its recommendations. We have called on the various organizations for a timely consideration of these recommendations. We have hosted a conference where every major standards and code developer was represented, we have hired NIBS to assist in converting the appropriate recommendations into draft code language, and we are working with organizations representing local and State authorities to assist in their adoption and enforcement.

Q5. Dr. Jeffrey, how much funding will NIST require to carry out its follow-on duties in the area of research during the next three years?

A5. The President's Fiscal Year 2006 budget requested $2M for NIST to carry out research to enable development and adoption of cost-effective technical solutions to enhance safety and avoid major disasters through improved first responder equipment, better evacuation and emergency response procedures, and risk-sensitive national practices for building safety. The *FY 2006 Commerce, Justice, State and Science Appropriations Act* does not contain funding for this request.

Q6. Dr. Jeffrey, for two years the National Construction Safety Team Advisory Committee has reiterated that successful implementation of the National Construction Safety Team (NCST) Act *is dependent upon the creation of a NCST office funded at $2 million and the establishment of a $2 million reserve fund. Why hasn't NIST acted upon these recommendations in its budget request?*

A6. NIST believes that it has responded appropriately to all significant disaster events worthy of investigation. The President's Fiscal Year 2006 budget requested $2M for NIST to carry out research to enable development and adoption of cost-effective technical solutions to enhance safety and avoid major disasters through improved first responder equipment, better evacuation and emergency response procedures, and risk-sensitive national practices for building safety. The *FY 2006 Commerce, Justice, State and Science Appropriations Act* does not contain funding for this request.

Q7. Dr. Jeffrey, the National Construction Safety Team (NCST) Advisory Committee has recommended that the Act be invoked after any natural disaster such as

earthquakes, hurricanes and other windstorms, floods and wildfires. Why didn't you invoke the Act after Hurricanes Katrina, Rita and now Wilma? In their reports to Congress the Advisory Committee has generally been critical that NIST has not invoked the Act more often. Why do you disagree with the recommendations of the Advisory Committee?

A7. NIST authorities are "tools" by which we can conduct an investigation. We will always pick the best tool to get the job done. In response to Hurricane Katrina, NIST is using authorities that are broader than under the NCST Act and better fit the specific situation.

In addition to major buildings and residential structures, the current effort involves key infrastructure facilities (electric power, water and wastewater, oil and gas, and communication) and transportation (ports, pipelines, bridges, roads, and airports) which are not covered by the NCST Act.

Moreover, NIST is interested in assessing the performance not only of facilities that "failed" but also those that sustained "damage"—and hence not covered by the NCST.

In addition, NIST is assessing the damage not only to structures but also other building systems (e.g., the roofing system, fire safety, and HVAC) which are not specified in the Act.

Q8. Dr. Jeffrey, some of Ms. Regenhard's and Dr. Corbett's criticisms of NIST's reluctance to use the full authority of the National Construction Safety Team (NCST) Act *are echoed by the NCST Advisory Board. What is your response?*

A8. NIST believes that it has used appropriately the authority of the *National Construction Safety Team Act.* NIST has obtained all available documents and evidence essential to carrying out a thorough and credible technical investigation. NIST believes the findings from its investigation are well justified on the basis of those documents and evidence.

A large number of individuals and organizations provided materials and documents, including the Port Authority of New York and New Jersey, Silverstein Properties, the City of New York and its departments, the manufacturers and fabricators of the building components, the companies that insured the WTC towers, the building tenants, the aircraft manufacturers, the airlines, the public (including survivors and family members), and the media. NIST officials reviewed tens of thousands of pages of documents, conducted interviews with over a thousand people; and analyzed 236 pieces of steel that were obtained from the wreckage. At no time was NIST reluctant to use the full authority of the NCST.

Attachment A
Final Reports of the Federal Building and Fire Investigation of the World Trade Center Disaster – Recommendations and Affected Standards and Codes

Recommendation	Affected Standards and Codes
Recommendation 1. NIST recommends that: (1) progressive collapse be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice; and (2) a standard methodology be developed—supported by analytical design tools and practical design.	*Affected Standards:* ASCE-7, AISC Specifications, and ACI 318. These standards and other relevant committees should draw on expertise from ASCE/SFPE 29 for issues concerning progressive collapse under fire conditions. *Model Building Codes:* The consensus standards should be adopted in model building codes (i.e., the *International Building Code* and NFPA 5000) by mandatory reference to, or incorporation of, the latest edition of the standard. State and local jurisdictions should adopt and enforce the improved model building codes and national standards based on all 30 WTC recommendations. The codes and standards may vary from the WTC recommendations, but satisfy their intent.
Recommendation 2. NIST recommends that nationally accepted performance standards be developed for: (1) conducting wind tunnel testing of prototype structures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.	*Affected National Standard:* ASCE-7. *Model Building Codes:* The standard should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 3. NIST recommends that an appropriate criterion be developed and implemented to enhance the performance of tall buildings by limiting how much they sway under lateral load design conditions (e.g., winds and earthquakes).	*Affected National Standards:* ASCE-7, AISC Specifications, and ACI 318. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 4. NIST recommends evaluating, and where needed improving, the technical basis for determining appropriate construction classification and	*Model Building Codes:* A comprehensive review of current construction classification and fire rating requirements and the establishment of a uniform set of revised

fire rating requirements (especially for tall buildings)—and making related code changes now as much as possible—by explicitly considering factors including: • timely access by emergency responders and full evacuation of occupants, or the time required for burnout without partial collapse; • the extent to which redundancy in active fire protection (sprinkler and standpipe, fire alarm, and smoke management) systems should be credited for occupant life safety;24 • the need for redundancy in fire protection systems that are critical to structural integrity;25 • the ability of the structure and local floor systems to withstand a maximum credible fire scenario26 without collapse, recognizing that sprinklers could be compromised, not operational, or non-existent; • compartmentation requirements (e.g., 12,000 ft2 (27)) to protect the structure, including fire rated doors and automatic enclosures, and limiting air supply (e.g., thermally resistant window assemblies) to retard fire spread in buildings with large, open floor plans; • the effect of spaces containing unusually large fuel concentrations for the expected occupancy of the building; and • the extent to which fire control systems, including suppression by automatic or manual means, should be credited as part of the prevention of fire spread.	thresholds with a firm technical basis that considers the factors identified above should be undertaken.
Recommendation 5. NIST recommends that the technical basis for the century-old standard for fire resistance testing of components, assemblies, and systems be improved through a national effort.	*Affected National and International Standards:* ASTM E 119, NFPA 251, UL 263, and ISO 834. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or

Necessary guidance also should be developed for extrapolating the results of tested assemblies to prototypical building systems. A key step in fulfilling this recommendation is to establish a capability for studying and testing the components, assemblies, and systems under realistic fire and load conditions.	incorporation of, the latest edition of the standard.
Recommendation 6. NIST recommends the development of criteria, test methods, and standards: (1) for the in-service performance of sprayed fire-resistive materials (SFRM, also commonly referred to as fireproofing or insulation) used to protect structural components; and (2) to ensure that these materials, as-installed, conform to conditions in tests used to establish the fire resistance rating of components, assemblies, and systems.	*Affected Standards:* AIA MasterSpec and AWCI Standard 12 for field inspection and conformance criteria; ASTM standards for SFRM performance criteria and test methods. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard. (See Recommendation 10 for more on this issue.)
Recommendation 7. NIST recommends the adoption and use of the "structural frame" approach to fire resistance ratings.	This approach is currently required by the *International Building Code (IBC)*, one of the model codes, and is in the process of adoption by NFPA 5000, the other *model code*. This requirement ensures consistency in the fire protection provided to all of the structural elements that contribute to overall structural stability. State and local jurisdictions should adopt and enforce this requirement.
Recommendation 8. NIST recommends that the fire resistance of structures be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without partial or global (total) collapse.	*Model Building Codes:* This recommendation should be included into the national model codes as an objective and adopted as an integral part of fire resistance design for structures. The issue of non-operational sprinklers could be addressed using the existing concept of Design Scenario 8 of NFPA 5000, where such compromise is assumed and the result is required to be acceptable to the Authority Having Jurisdiction. *Affected Standards:* ASCE-7, AISC Specifications, ACI 318, and ASCE/SFPE 29.
Recommendation 9. NIST recommends the development of: (1) performance-based standards and code provisions, as an alternative to current prescriptive design	*Affected National and International Standards:* ASCE-7, AISC Specifications, ACI 318, and ASCE/SFPE 29 for fire resistance design and retrofit of structures;

methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse: and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the structure as a whole system.	NFPA, SFPE, ASCE, and ISO TC92 SC4 for building-specific multi-compartment, multi-floor design basis fire scenarios; and ASTM, NFPA, UL, and ISO for new test methods. *Model Building Codes:* The performance standards should be adopted as an alternate method in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 10. NIST recommends the development and evaluation of new fire-resistive coating materials, systems, and technologies with significantly enhanced performance and durability to provide protection following major events.	*Affected Standards:* Technical barriers, if any, to the introduction of new structural fire resistance materials, systems, and technologies should be identified and eliminated in the AIA MasterSpec, AWCI Standard 12 and ASTM standards for field inspection, conformance criteria, and test methods. *Model Building Codes:* Technical barriers, if any, to the introduction of new structural fire resistance materials, systems, and technologies should be eliminated from the model building codes.
Recommendation 11. NIST recommends that the performance and suitability of advanced structural steel, reinforced and pre-stressed concrete, and other high-performance material systems be evaluated for use under conditions expected in building fires.	*Affected Standards:* AISC Specifications and ACI 318. Technical barriers, if any, to the introduction of these advanced systems should be eliminated in ASTM E 119, NFPA 251, UL 263, ISO 834. *Model Building Codes:* Technical barriers, if any, to the introduction of these advanced systems should be eliminated from the model building codes.
Recommendation 12. NIST recommends that the performance and possibly the redundancy of active fire protection systems (sprinklers, standpipes/hoses, fire alarms, and smoke management systems) in buildings be enhanced to accommodate the greater risks associated with increasing building height and population, increased use of open spaces, high-risk building activities, fire department response limits, transient fuel loads, and higher threat profile.	*Affected Standards:* NFPA 13, NFPA 14, NFPA 20, NFPA 72, NFPA 90A, NFPA 92A, NFPA 92B, and NFPA 101. *Model Building Codes:* The performance standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 13. NIST recommends that fire alarm and communications systems in buildings be developed to provide continuous, reliable, and accurate	*Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by

information on the status of life safety conditions at a level of detail sufficient to manage the evacuation process in building fire emergencies; all communication and control paths in buildings need to be designed and installed to have the same resistance to failure and increased survivability above that specified in present standards.	mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 14. NIST recommends that control panels at fire/emergency command stations in buildings be adapted to accept and interpret a larger quantity of more reliable information from the active fire protection systems that provide tactical decision aids to fireground commanders, including water flow rates from pressure and flow measurement devices, and that standards for their performance be developed.	*Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 15. NIST recommends that systems be developed and implemented for: (1) real-time off-site secure transmission of valuable information from fire alarm and other monitored building systems for use by emergency responders, at any location, to enhance situational awareness and response decisions and maintain safe and efficient operations;35 and (2) preservation of that information either off-site or in a black box that will survive a fire or other building failure for purposes of subsequent investigations and analysis. Standards for the performance of such systems should be developed, and their use should be required.	*Affected Standards:* NFPA 1, NFPA 72, and NFPA 101. *Model Building and Fire Codes:* The performance standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 16. NIST recommends that public agencies, non-profit organizations concerned with building and fire safety, and building owners and managers develop and carry out public education and training campaigns, jointly and on a nationwide scale, to improve building occupants' preparedness for evacuation in case of building	*Affected Standard:* ICC/ANSI A117-1. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard. *Affected Organizations:* NFPA, NIBS, NCSBCS, BOMA, and CTBUH.

emergencies.	
Recommendation 17. NIST recommends that tall buildings be designed to accommodate timely full building evacuation of occupants when required in building-specific or large-scale emergencies such as widespread power outages, major earthquakes, tornadoes, hurricanes without sufficient advanced warning, fires, explosions, and terrorist attack. Building size, population, function, and iconic status should be taken into account in designing the egress system. Stairwell capacity and stair discharge door width38 should be adequate to accommodate counterflow due to emergency access by responders.	*Affected Standards:* NFPA 101, ASME A 17. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 18. NIST recommends that egress systems be designed: (1) to maximize remoteness of egress components (i.e., stairs, elevators, exits) without negatively impacting the average travel distance; (2) to maintain their functional integrity and survivability under foreseeable building-specific or large-scale emergencies; and (3) with consistent layouts, standard signage, and guidance so that systems become intuitive and obvious to building occupants during evacuations.	*Affected Standard:* NFPA 101. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 19. NIST recommends that building owners, managers, and emergency responders develop a joint plan and take steps to ensure that accurate emergency information is communicated in a timely manner to enhance the situational awareness of building occupants and emergency responders affected by an event. This should be accomplished through better coordination of information among different emergency responder groups, efficient sharing of that information among building occupants and emergency responders, more robust design of emergency public address systems, improved emergency responder communication systems, and use of the	*Affected Standard:* NFPA 101 and/or a new standard. *Model Building and Fire Codes:* The standard should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard to the extent it is within the scope of building and fire codes.

Emergency Broadcast System (now known as the Integrated Public Alert and Warning System) and Community Emergency Alert Networks.	
Recommendation 20. NIST recommends that the full range of current and next generation evacuation technologies should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell descent devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access.	*Affected Standards:* NFPA 101, ASME A 17, ASTM E 06, ANSI A117.1. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 21. NIST recommends the installation of fire-protected and structurally hardened elevators to improve emergency response activities in tall buildings by providing timely emergency access to responders and allowing evacuation of mobility-impaired building occupants.	*Affected Standards:* ASME A 17, ANSI 117.1, NFPA 70, NFPA 101, NFPA 1221, NFPA 1500, NFPA 1561, NFPA 1620, and NFPA 1710. *Model Building and Fire Codes:* The standards should be adopted in model building and fire codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 22. NIST recommends the installation, inspection, and testing of emergency communications systems, radio communications, and associated operating protocols to ensure that the systems and protocols: (1) are effective for large-scale emergencies in buildings with challenging radio frequency propagation environments; and (2) can be used to identify, locate, and track emergency responders within indoor building environments and in the field.	*Affected Standards:* FCC, SAFECOM, NFPA Standards on Electronic Safety Equipment, NFPA 70, NFPA 297, and NFPA 1221. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 23. NIST recommends the establishment and implementation of detailed procedures and methods for gathering, processing, and delivering critical information through integration of relevant voice, video, graphical, and written data to enhance the situational awareness of all emergency responders. An information intelligence sector45 should be established to coordinate the effort for each incident.	*Affected Standards:* National Incident Management System (NIMS), NRP, SAFECOM, FCC, NFPA Standards on Electronic Safety Equipment, NFPA 1500, NFPA 1561, NFPA 1620, NFPA 1710, and NFPA 1221. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 24. NIST recommends	*Affected Standards:* NIMS, NRP,

the establishment and implementation of codes and protocols for ensuring effective and uninterrupted operation of the command and control system for large-scale building emergencies.	SAFECOM, FCC, NFPA Standards on Electronic Safety Equipment, NFPA 1221, NFPA 1500, NFPA 1561, NFPA 1620, and NFPA 1710. *Model Building Codes:* The standards should be adopted in model building codes by mandatory reference to, or incorporation of, the latest edition of the standard.
Recommendation 25. Nongovernmental and quasi-governmental entities that own or lease buildings and are not subject to building and fire safety code requirements of any governmental jurisdiction are nevertheless concerned about the safety of the building occupants and the responding emergency personnel. NIST recommends that such entities be encouraged to provide a level of safety that equals or exceeds the level of safety that would be provided by strict compliance with the code requirements of an appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends that asdesigned and as-built safety be certified by a qualified third party, independent of the building owner(s). The process should not use self-approval for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the life of the buildings.	
Recommendation 26. NIST recommends that state and local jurisdictions adopt and aggressively enforce available provisions in building codes to ensure that egress and sprinkler requirements are met by existing buildings.47 Further, occupancy requirements should be modified where needed (such as when there are assembly use spaces within an office building) to meet the requirements in model building codes.	Provisions related to egress and sprinkler requirements in existing buildings are available in such codes as the *International Existing Building Code (IEBC)*, International Fire Code, NFPA 1, NFPA 101, and ASME A 17.3.
Recommendation 27. NIST recommends that building codes incorporate a provision	*Model Building Codes:* Model building codes should incorporate this

that requires building owners to retain documents, including supporting calculations and test data, related to building design, construction, maintenance and modifications over the entire life of the building. Means should be developed for offsite storage and maintenance of the documents. In addition, NIST recommends that relevant building information be made available in suitably designed hard copy or electronic format for use by emergency responders. Such information should be easily accessible by responders during emergencies.	recommendation. State and local jurisdictions should adopt and enforce these requirements.
Recommendation 28. NIST recommends that the role of the "Design Professional in Responsible Charge" be clarified to ensure that: (1) all appropriate design professionals (including, e.g., the fire protection engineer) are part of the design team providing the standard of care when designing buildings employing innovative or unusual fire safety systems, and (2) all appropriate design professionals (including, e.g., the structural engineer and the fire protection engineer) are part of the design team providing the standard of care when designing the structure to resist fires, in buildings that employ innovative or unusual structural and fire safety systems.	*Affected Standards:* AIA Practice Guidelines. Model Building Codes: The IBC, which already defines the "Design Professional in Responsible Charge," be clarified to address this recommendation. The NFPA 5000 should incorporate the "Design Professional in Responsible Charge" concept and address this recommendation.
Recommendation 29. NIST recommends that continuing education curricula be developed and programs be implemented for (1) training fire protection engineers and architects in structural engineering principles and design, and (2) training structural engineers, architects, fire protection engineers, and code enforcement officials in modern fire protection principles and technologies, including fire-resistance design of structures, and (3) training building regulatory and fire service personnel to upgrade their understanding and skills to conduct the review, inspection, and approval tasks for which they are	*Affected Organizations:* AIA, SFPE, ASCE, ASME, AISC, ACI, and state licensing boards. *Model Building Codes:* Detailed criteria and requirements should be incorporated into the model building codes under the topic "Design Professional in Responsible Charge."

responsible.	
Recommendation 30. NIST recommends that academic, professional short-course, and webbased training materials in the use of computational fire dynamics and thermostructural analysis tools be developed and delivered to strengthen the base of available technical capabilities and human resources.	*Affected Organizations:* AIA, SFPE, ASCE, ASME, AISC, and ACI, ICC, NFPA.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Nancy McNabb, Director, Government Affairs, National Fire Protection Association

Questions submitted by the Majority

Q1. In your testimony, you said that NIST takes some positions on "controversial and sometimes unpopular subjects." What do you have in mind? What should NIST do to make sure that controversy doesn't block progress?

A1. I would point to subjects such as progressive collapse design, wind tunnel testing and the recommendation to include fire protection engineers on the design team. NIST has set an agenda for codes and standards organizations and the private sector to determine how best to manage change (if any) in all 30 areas. NIST can best serve as an advisor to those groups and when necessary, fund research in the private sector to establish additional information and possible solutions.

Q2. In your testimony you stated that "the need to conduct more research in numerous areas is clear." What are the top three priority areas where additional research and data are needed? Which specific entities should be doing this research? Which recommendations are most hampered by lack of data?

A2. **Elevator Use:** These criteria are very close to being finalized. The reality is that elevator use is the only practical way to ensure timely building evacuation in very tall (40-story) buildings. Additional research may also benefit disabled occupants by providing equal access to self evacuation capability in many types of multistory buildings. The current ASME/NIST research project, in which NFPA has been a significant participant, has been underway since 2003.

Coordinated communication capabilities: This is an Achilles heel in most major events including many high rise fires. Major natural disasters also present communication challenges between the various responding entities. Research groups: NFPA and IEEE.

Fire test procedures/materials: Reliability of the test procedures, materials and field applications are all interrelated. Innovative materials have potential use, but progress on all of these issues may be stymied absent additional data demonstrating clear cost effective advantages associated with such new materials or deficiencies with the current materials and test methods. Research groups: FPRF/ASTM/UL

Q3. Building trade associations have raised concerns that the implementation of some of the recommendations will be expensive. Which of the recommendations do you believe will be most costly? Would these costs be justified in terms of their expected outcomes?

A3. Building trade associations and building associations such as BOMA are likely concerned that any change to building safety requirements will increase cost. Short-term costs associated with building safety should not be the prime concern. BOMA's tenants and the public at large are a good barometer of how safe our buildings need to be and they do not generally object to initial costs for providing long-term building and life safety.

Q4. In written testimony submitted to the Committee, the American Institute of Architects points to the lack of a fire test facility in United States—a facility large enough to test components of a tall building—as a major shortcoming in the Nation's ability to improve skyscraper safety. Is the maintenance and operation of large-scale fire testing capability a NIST responsibility, or does it lie elsewhere in the Federal Government or the private sector? How do you respond to the AIA's comments?

A4. The private sector should retain control and operation of the largest fire test facilities. NIST may best work in a private/public sector partnership role to assist with funding of expanded test facilities at Underwriters Laboratories (UL) or Factory Mutual (FM) or preferably both.

Q5. Testimony submitted to the Science Committee by the Building Owners and Managers Association (BOMA) calls for cost-benefit analyses to be developed on the implementation of NIST's recommendations. Do you believe this is a good idea? Why or why not? If so, who should develop these analyses?

A5. Cost-benefit forecasts for safety related issues are a no win approach to changing codes, standards and protocols. As repeatedly expressed by BOMA at federal,

State and local hearings, their primary concern seems to be initial construction costs rather than long tern sustainability or safety of their tenants. Cost-benefit can almost always be used to argue a change in any direction. It is NFPA's view that cost benefit analyses should not be a primary consideration in the debate for implementation of these potential changes.

Q6. Which recommendations do you think most require action by the Federal Government, particularly with respect to research, and which agencies should be responsible?

A6. At this point, it is NFPA's view that the private sector, with funding from federal agencies (including NIST) are in the best position to pursue the level of detail needed to move towards change. Competition to develop better materials, methods and designs can be driven by code-related change and social awareness; no one entity should have a sole source advantage for building research.

Questions submitted by Democratic Members

Q1. Ms. McNabb, your organization has moved forward on a number of the NIST recommendations. How have the NFPA code changes been greeted by the user community—for example, states and localities and the building industry?

A1. NFPA code changes have been met with mixed reaction by various interest groups. For example, various groups, including the U.S. General Services Administration (GSA) filed appeals against some of the new changes such as the provisions to increase the stair width for certain buildings. NFPA's Building Code has been met with resistance by a number of jurisdictions and trade associations representing the economic building owner interests. Many of these groups are designated as "Code Partners" of the ICC thus they align themselves with technical provisions that are more traditional and in many cases, several years behind what the NFPA codes require. First responders and tenant representatives have embraced NFPA code provisions as they reflect the state of the art. The NFPA code development process ensures broad representation for all of the construction community stakeholders including first responders, tenant representatives and those designated as "code partners."

Q2. Ms. McNabb, you mention that "it is likely, that after a through and detailed analysis of the final recommendations, there may not be sufficient data, detail or compelling evidence to promulgate a change to a particular safety code or standard." What is the timeframe for this analysis? Also, which of the NIST recommendations do you think most likely to fail this analysis?

A2. Some of the analyses will be complex such as Recommendation 1 concerning progressive collapse criteria. We believe that work will take several years because it requires the development of a design approach (supported by analytical tools and practical guidance) to determine how much of a building's structural support system will be lost and an expectation of how long the structure must remain standing.

The recommendations concerning fire test protocols will require approximately two years of review. At present, the main concern seems to be that "the test procedures have been used for 90 years," the implication being that we should be doing something different. There is no obvious reason to change the fire test protocols; after thorough study and review, we may determine that the status quo is acceptable.

Q3. Ms. McNabb, could you give us an idea of the follow-on work required before we can arrive at an appropriate "best practices" for the built environment?

A3. Best practices are always moving forward. In the last few years, changes to the NFPA codes such as increases to hourly fire resistance ratings for structural systems in high rise buildings, wider stairs and provisions that have been in our codes for a longer time such as requirements for automatic sprinkler retrofits in high rise buildings, are all examples of best practices for the built environment that were initially determined by NFPA technical committees.

Code changes such as greater use of elevators for building evacuations by occupants and first responders will likely be ready for consideration in the code change cycle within the next year. One issue that must be addressed is that of liability. After decades of indoctrinating building occupants that use of the elevator in a fire emergency is prohibited, there will naturally be concerns about reversing that message. Likewise, concerns related to elevator equipment malfunction during emergency conditions must be overcome.

Mass notification systems discussed in Recommendations 22 and 23 will be a reality in 2006 when the technical provisions for these systems have been proposed to be incorporated in the next edition of NFPA 72, National Fire Alarm Code.

The largest obstacle to establishing best practices will be the extent, if any, to which such code changes will affect the existing building stock. Such implementations are often initially expensive or technically infeasible. The U.S. General Services Administration (GSA) could provide an example for the commercial building industry by embracing this opportunity to include new building safety enhancements in their construction plans and leasing agreements.

ANSWERS TO POST-HEARING QUESTIONS

Responses by James R. Harris, President, J.R. Harris and Company; Member, American Society of Civil Engineers

Please note that these responses are, in general, confined to the subject of structural engineering. Some of the recommendations made by NIST concern subjects outside the expertise of civil and structural engineers.

Questions submitted by the Majority

Q1. In her testimony, Ms. McNabb said that the recommendation related to elevators may be one of the most important. Do you agree? How difficult would that be to codify and implement? Can you give the Committee a sense of what specific next steps you would take to evaluate that recommendation and what additional information you would need and from whom?

A1. Most of the issues surrounding this recommendation do not concern structural engineering. The primary structural issue here is the provision of strong shaft walls, and that is not particularly difficult. Ms. McNabb may have been referring to protection of the elevator and its controls from fire where it would be intended to use the elevator to pass through stories with uncontrolled fire. This is a phenomenon that should be tested to verify potential solutions before any code requirement is implemented, but it is not, fundamentally, a structural issue.

Q2. In your testimony, you suggested that codes are not necessarily the best way to promote changes in practice. What is the problem with using codes? What are the alternatives? What NIST recommendations should be implemented through means other than codes?

A2. Codes are a useful and effective mechanism to assure a minimum level of protection where proven technologies exist. However, they are not particularly effective where the issue requires development of new technology. I will use performance-based design for fire resistance as an example. Here the codes can be used as an incentive, by allowing the possibility for performance-based design, but the method will not be an effective tool until several things happen: an extension of present knowledge through targeted research, a critical mass of the profession becomes properly educated and trained to implement the methods, and a change in the legal climate to remove disincentives to this expansion of professional practice. This will require changes in the basic curriculum to educate engineers of the future as well as a broad continuing education program to train practicing professionals.

The interaction of professional practice and tort law is a matter of public policy that requires careful consideration before the potential benefits of performance based fire design can be realized. Prescriptive codes effectively shield structural engineers and architects from tort, and the prescriptive codes for fire resistance do deliver buildings with successful fire resistance in the vast majority of cases. There is no incentive for engineers to become responsible for fire safety and there is a major disincentive in the form of potential liability for fire damage and injury in a building designed to a performance standard. These obstacles need to be removed.

Q3. You testified that data and research are needed to implement some of NIST's recommendations. What are the top three priority areas where additional research and data are needed? Which specific entities should be doing this research? Which recommendations are most hampered by lack of data?

A3. From the structural engineering point of view three areas do stand out: improving the general structural integrity of building (improve the resistance to progressive collapse), improving the design of structures to resist wind loads, and performance-based design for structural response to fire. The research in the first area is likely to be a long-term effort before tools are developed that will be usable in routine design practice, but it is highly likely to bear fruit. Structural connection details that are faster, better, cheaper can readily be developed in a program of academic research, large scale testing, and support of the creation of technical provisions in codes and standards. The steel connection details for improved seismic resistance that emerged from FEMA's SAC project are an example of what can be done for a relatively small outlay (overall, this research program will likely be larger, owing to the many different types of construction that must be considered). Progressive collapse resistance also needs a component of social science research in order to better define the needs and our objectives. The second area will be enhanced if funds are appropriated for the already authorized National Windstorm Mitigation Program. Wind effects on buildings are a complex topic that has long

been shorted in the federal research budget. NIST's findings and the hurricanes of the past two years should persuade the Federal Government to be proactive in supporting wind research. The third area requires close coordination between specialists in fire and structural engineering in order to assure that the two professions are communicating meaningfully, and the disincentives described in the answer to Question 2 should be addressed before large research programs here are funded.

Q4. You expressed a concern about the "unreasonable acceleration" of the codes process. What's your concern? Do you see any indication of that happening?

A4. The concern is that premature attempts to change building codes without thorough vetting in the voluntary standards communities and without compelling substantiation could create somewhat of a backlash or stigma around these recommendations, which could ultimately delay widespread implementation. Realize that the model building codes, and the standards upon which they rely, are not developed by elected governmental bodies operating on a simple majority vote. They are developed in voluntary bodies that operate with a formal consensus building procedure, which is necessary to generate the support in industry for successful implementation of change, and significant change requires significant time. In my opinion the objectives of the NIBS panel should be to coordinate efforts among the many standards developing organizations and to provide a forum for discussion of issues across technical disciplines. For most of the issues of concern in the structural engineering community it is premature to prepare changes to model building codes.

Q5. Building trade associations have raised concerns that the implementation of some of the recommendations will be expensive. Which of the recommendations do you believe will be most costly? Would these costs be justified in terms of their expected outcomes?

A5. In the long run those costs associated with construction, maintenance, and economic use of facilities will far overrun the initial costs of educating and training engineers, architects, and building officials, although in the short run the latter costs will be significant and will likely slow implementation. Reasonable resistance to progressive collapse will not cost much for some structural systems, while in others it will be very costly, which will change the relative market share among competing products and systems for those structures for which resistance to progressive collapse is deemed necessary. Such changes are usually slow to come to fruition. The imposition of a limit on lateral drift under wind (Recommendation Number 3) will increase the cost of structural framing. Changes that affect the economic use of space, such as the provision of larger egress paths (stairwells) can impose very real costs. Some changes hold the potential for cost savings, such as improved understanding of wind effects on buildings and the use of a performance approach for design for fire resistance. It is likely that the impact on construction cost for those items that do increase the cost will be limited to a few percent of construction cost. Where these kinds of change are applied equally to all competing products in a market, the change may not be as slow.

Q6. In written testimony submitted to the Committee, the American Institute of Architects points to the lack of a fire test facility in United States—a facility large enough to test components of a tall building—as a major shortcoming in the Nation's ability to improve skyscraper safety. Is the maintenance and operation of large-scale fire testing capability a NIST responsibility, or does it lie elsewhere in the Federal Government or the private sector? How do you respond to the AIA's comments?

A6. The lack of a facility large enough to test structural components of practical size is not limited to tall buildings. Common components of low-rise buildings suffer the same problem. Some private sector furnaces in this country have closed due to a lack of economic demand. Canada and Japan are examples of countries with larger facilities, and those facilities are government facilities. That does not mean that a government test facility is the only possible solution here, but at the very least there will be a need for government support and incentives. International cooperation should be explored.

Q7. Testimony submitted to the Science Committee by the Building Owners and Managers Association (BOMA) calls for cost-benefit analyses to be developed on the implementation of NIST's recommendations. Do you believe this is a good idea? Why or why not? If so, who should develop these analyses?

A7. Some aspects of limited cost analysis is commonly necessary to persuade members of standards bodies to implement changes, however, such analyses are rarely

a rigorous economic study, especially on the benefit side. It is not easy to assess the true cost of new technology before implementation. Benefits are particularly difficult to predict. The normal approach is to rely on the judgment of informed professionals developed in a consensus building process. FEMA funded one moderately large cost study in the early 1980's as the Nation was considering the adoption of a new generation of provisions for seismic safety in construction. A cost-benefit analysis on the same topic has recently been completed at the request of the Congress. Requiring formal cost-benefit analysis for every change is not typical in the field of building codes and design standards, and it would probably unduly slow implementation.

Q8. Which recommendations do you think most require action by the Federal Government, particularly with respect to research, and which agencies should be responsible?

A8. The bulk of the research described in the answer to Question 3 will require federal funding. Among the agencies that I would expect to fund such research are NSF, NIST, and FEMA. NIST has historically not been able to fund significant external research in the building sciences area, and FEMA's future role is not well defined as it adapts to its incorporation inside DHS. Perhaps most importantly, the funding for structural engineering research in the CMS (Civil and Mechanical Systems) area of NSF is projected to be reduced by a mere pittance compared to past levels. This situation must be reversed to see real progress in developing the improvements recommended by NIST.

Q9. In your testimony regarding Recommendation #1 on progressive collapse, you said that the recommendation needed further study of its application and its effects upon the profession because of the various design thresholds involved. Please explain what you mean by this, what the major points of the study would be, and who should carry out this work.

A9. NIST has tentatively proposed a definition of high-rise buildings at 420 feet, which is apparently related to common limitations on pumping water for fire suppression. There has been discussion of using this same threshold for application of a requirement for resistance to progressive collapse. It is not clear why the two topics need to be correlated. There are many lower buildings that should probably have such resistance. The General Services Administration has been requiring a measure of resistance to terrorism attack and progressive collapse for most federal courthouses built in the past several years, and the Department of State has been doing the same for most of our new overseas embassies, yet none of these buildings would be more than 420 feet tall. Considerations beyond occupancy and size, including location, will likely be involved. A careful, and probably long, public discussion is needed to achieve a comprehensive classification of buildings for which this resistance is going to be required by law (as opposed to being implemented by option of the owner). This discussion should be supported by research in the social science, economic policy, and insurance areas. Congress should lead at least some of this public discussion, because the Federal Government is obviously spending heavily in response to the September 11 attack, and improving our resistance to other terrorist attacks should be guided in part by intelligent approaches to limiting such outlays in the future.

Questions submitted by Democratic Members

Q1. Dr. Harris, what is the timeframe for your organization to act upon the NIST recommendations? How long will it take for any ASCE code revisions to occur?

A1. These recommendations will be a focus of our activities for several years to come. We are in the process of collecting public comment on our new standard for the use of wind tunnel testing in determining design wind loads on buildings, which is responsive in part to a NIST recommendation. In that process we have formed an ad hoc committee to give specific consideration to making our new standard even more responsive to that recommendation. We expect the standard to be formally issued in 2006. We have just issued the 2005 edition of our standard *Minimum Design Loads for Buildings and Other Structures.* This standard defines basic wind loads, among other actions on structures, and contains guidance for resistance to progressive collapse. The committee will be reformed in 2006 as we prepare to issue anew edition in 2010, and plans are already underway to focus specific task groups on the NIST recommendations. Should specific items gather the necessary consensus in time, we will be prepared to issue a supplement to our 2005 edition. While it is reasonable to predict that the 2010 edition will have changes stimulated by the NIST recommendations, it is also true that there will probably be continuing ad-

vancements in knowledge and therefore in our standards for many years after that. We will also plan to update our standard *Structural Design for Fire Conditions* as more information about performance-based design is developed. We also have a large number of technical committees that operate to advance the state of knowledge in a many areas of interest to structural engineers, and we will be encouraging such committees with a focus on structural integrity and on wind loads to carefully review the research needs implicit in the NIST recommendations.

Q2. Dr. Harris, ASCE believes that some of the NIST recommendations need further clarification and discussion. What interaction did your organization have with NIST during the course of its investigation and while it was drafting this report? For example, did ASCE participate in the public sessions that NIST held in the course of its investigations? Since the report has been made public have you had any follow-up conversation with NIST? Do you feel that NIST has been un-responsive to your concerns?

A2. Recall that our *World Trade Center Building Performance Study* issued in September 2002 as FEMA report 403 identified many issues needing further study and served as a starting point for the NIST study. Key members of our team behind FEMA 403 provided input as the NIST program was being defined, and many ASCE/SEI members have been involved with review of the NIST work at many stages. During this year a select group from our Board of Governors had a day-long briefing from the NIST leadership team in the spring, then an electronic update shortly before the draft was issued as the conclusions were firmed. We submitted comments on the draft during the summer, and we have had one additional briefing as NIST has prepared strawman proposals for changes to the *International Building Code.* It is worth repeating that we believe NIST's study is well done and provides much to advance the cause of public safety. NIST actively solicited our comments and has listened carefully and respectfully.

Q3. Dr. Harris, one of the recommendations that ASCE strongly endorses is continuing education. This seems an important recommendation as structural materials and techniques have changed so dramatically over the past twenty years. Currently, what type of courses does ASCE sponsor for the continuing education of its members? I also noticed from your biography that you are a certified Professional Engineer, what does the National Society of Professional Engineers do in the area of continuing education for its members? What sort of continuing education courses do you think are needed?

A3. ASCE has an active continuing education program. Among the popular courses for structural engineers currently being offered are:

- Analysis and Preservation of Historic Bridges
- Bridge Inspection
- Bridge Rehabilitation
- Cable-Stayed Bridges: Key Design, Construction, and Management Issues
- Connection Design for Steel Structures
- Dam Safety and Rehabilitation
- Design and Renovation of Wood Structures
- Design and Strengthening of Shallow Foundations for Conventional and Pre-Engineered Buildings
- Design of Foundations for Dynamic Loads
- Design of Metal Buildings: Avoid Pitfalls in Specifying and Procuring
- Design, Construction, and Renovation of Masonry Structures
- Designing Aluminum Structures
- Earth Retaining Structures Selection, Design, Construction and Inspection
- Earthquake Induced Ground Motions
- Fundamentals of Earthquake Engineering
- Highway Bridge Design, Evaluation and Strengthening Using LRFD
- Joints, Bearings and Devices (JBDs)
- Post Tensioning Construction and Design
- Probabilistic Design
- Progressive Collapse Mitigation: Practical Analysis Methods & Proven Solutions

- Security Risk Management Procedures: Countering Terrorism and Other Threats
- Seismic Design and Performance of Building Structures
- Seismic Design of Highway Bridges
- Structural Condition Assessment of Existing Structures
- Structural Design of Buildings and Industrial Facilities for Bomb Blast Loads and Accidental Explosions
- Structural Design of Industrial Facilities
- Structural Design of Residential Buildings Using the 2003 International Residential Code
- Structural Renovation of Buildings
- Structural Vibration Analysis, Design and Troubleshooting
- Wind Loads for Buildings and Other Structures

We also have several popular Webinars, and we are planning a new series of courses illustrating the new edition of ASCE 7 that we plan to take to a large number of cities. I am not as familiar with the continuing education program of NSPE, but it is my impression that their continuing education can be divided into two general categories: technical information for young engineers who are preparing for licensing exams and less technical information for licensed professionals, where the emphasis tends to be on ethics, professional practice, and similar topics. I would be happy to forward a request for information to NSPE so that you get more accurate information about their programs, if you desire. With respect to changes in continuing education for the future as influenced by the NIST recommendations, I believe that analytical prediction of structural performance under fire conditions is a subject that will be in great demand. More detail about this subject is in our answer to the general questions for the record.

I would also like to point out that I am registered, not certified, as a professional engineer by the State of Colorado, among others, and registered as a structural engineer by the State of California. Our profession encourages State governments to recognize that structural engineering is a profession essential to protecting public safety, that it requires highly trained specialists with substantial experience for success in the endeavor to protect the public, and that these facts justify separate licensure of structural engineers.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Glenn Corbett, Assistant Professor of Fire Science, John Jay College of Criminal Justice; Member, NIST National Construction Safety Team Advisory Board

Questions submitted by the Majority

Q1. In her testimony, Ms. McNabb said that the recommendation related to elevators may be one of the most important. Do you agree? How difficult would that be to codify and implement? Can you give the Committee a sense of what specific next steps you would take to evaluate that recommendation and what additional information you would need and from whom?

A1. Yes, I agree that the use of elevators for egress *in very tall high-rise buildings* is an important recommendation. Several industry meetings have been held and research has already been conducted on this topic (some of it prior to September 11th, 2001). 1 would suggest that NIST convene a summit to establish what, if any, "research holes" still exist and quickly fill them. I believe we could swiftly move forward with a model code recommendation if NIST takes this proactive stance.

Q2. If NIST had taken more of a "detective" approach to its work, how might that have affected its recommendations?

A2. If NIST had taken a more "detective" approach, we may have obtained more facts that are critical for gaining support for the code recommendations. In addition, other code-related issues may have surfaced.

Q3. In terms of how a building safety investigation should be conducted, what are the three most important lessons derived from NIST's experience with World Trade Center buildings?

A3. The NCST lessons of the WTC investigation (and the Station Nightclub) are: quickly get to the scene of the incident, quickly secure evidence (critical steel was lost at the WTC prior to enactment of the NCST), swiftly establish an investigation plan, utilize a "can-do" legal staff that aggressively gains access to information and physical evidence, and move forward to the ultimate goal of the investigation: specific recommendations to changes in codes and practices.

Q4. The WTC report concludes that some recommendations require more data and research to be implemented. What are the top three priority areas where additional research and data are needed? Which specific entities should be doing this research? Which recommendations are most hampered by lack of data?

A4. In my opinion, the three priority areas are: 1). the development of a new fire resistance protocol to replace the ASTM E–119 test standard, 2) the development of more robust fire-resistive coatings for steel members, 3) the development of a reliable radio communications system for emergency responders in high-rise and other "problem" locations. While NIST could be a coordinator for such research, there are other governmental and private sector organizations that should be involved. In my opinion, the first two priority areas that I have identified (fire resistance testing and fire resistive coatings) are the recommendations most hampered by lack of data.

Q5. Building trade associations have raised concerns that the implementation of some of the recommendations will be expensive. Which of the recommendations do you believe will be most costly? Would these costs be justified in terms of their expected outcomes?

A5. More often than not, new code provisions have a cost associated with implementation. Some of the recommendations will likely be expensive. Although I am not a structural engineer, it is my understanding that the "progressive collapse" recommendation is one of the most costly. Although that may be the case, the loss in terms of lives of another progressive collapse like the WTC disaster or the recent Madrid high-rise fire is totally unacceptable.

Q6. In written testimony submitted to the Committee, the American Institute of Architects points to the lack of a fire test facility in United States-a facility large enough to test components of a tall building—as a major shortcoming in the Nation's ability to improve skyscraper safety. Is the maintenance and operation of large-scale fire testing capability a NIST responsibility, or does it lie elsewhere in the Federal Government or the private sector? How do you respond to the AIA's comments?

A6. I agree that a test facility that tests all components as a group (similar to a facility in Great Britain) is desperately needed. Then current ASTM E–119 test standard is not realistic and needs to be replaced. Unfortunately, there is no incentive for the private sector to develop such an expensive facility. Despite the fact that building safety is a local government function, it would be inappropriate and fiscally impossible for cities and states to fund such a facility. It is only logical that the Federal Government assume such a responsibility and locate the facility within NIST.

Q7. Testimony submitted to the Science Committee by the Building Owners and Managers Association (BOMA) calls for cost-benefit analyses to be developed on the implementation of NIST's recommendations. Do you believe this is a good idea? Why or why not? If so, who should develop these analyses?

A7. The use of a cost-benefit analysis is not currently utilized (to any great extent) when preparing the hundreds of codes and standards developed by the NFPA, ICC, and other groups. While I agree that such a process *could* be desirable for all codes and standards, I do not believe we should start with the WTC investigation. The use of a cost-benefit analysis must first be debated on a national level, ensuring that the public (typically left out of the current code development process) has input into the decision of what is "too costly."

Q8. Which recommendations do you think most require action by the Federal Government, particularly with respect to research, and which agencies should be responsible?

A8. I believe that my response to Question 4 above answers this question. I would add, however, that the radio communications issue is one of great importance to emergency responders and crosses over several lines of jurisdiction within the Federal Government. An serious attempt must be made to take control of this issue and move it forward to resolution.

Questions submitted by Democratic Members

Q1. What is your assessment of how well NIST has carried out its duties under the National Construction Safety Team (NCST) Act? *Do you feel that NIST should invoke the ACT more often, for example should NIST have invokes the Act to investigate Hurricane Katrina-related infrastructure failures? Does NIST have clear criteria for when it should invoke the* National Construction Safety Team (NCST) Act? *When reading the comments of the NCST Advisory Committee I have the impression that they are frustrated that NIST is not doing enough under the authorities provided by the Act.*

A1. I feel that NIST has not made a substantial effort to implement the NCST and have shown little interest in it. While NIST has worked to develop response criteria to establish when teams will be organized, they have done little else. For example, they have not established an NCST office within NIST and have not developed a detailed investigation protocol manual for actual investigations. To my knowledge, they have not published a list of actual potential team members (including individuals from the private sector).

NIST should have responded to the Chicago E2 nightclub disaster of 2003, the Florida hurricanes and California wildfires of 2004, and most certainly hurricane Katrina in 2005. These were all substantial incidents where the NCST should have been deployed. All of them fall within their own "when to respond" criteria.

It is critical that NIST respond to such disasters, and they use the NCST to do it. The NCST provides two critical elements not contained under other NIST authorities: the ability to investigate without having to have local officials ask NIST to do it and requires NIST to prepare code recommendations.

Q2. Mr. Corbett, you feel that NIST took to long to complete its investigation. What do you think would have been a more reasonable timeframe? Why do you think it took so long to complete the investigation?

A2. NIST frequently moved their target completion dates further and further back (the World Trade Center building 7 investigation is still not complete). While this is somewhat understandable because of the complexity of the investigation, a completion target of two and a half years would have been more reasonable. From my perspective, it seems that it took too long to get out of the starting gate, too long to get to the actual investigation initiated. It also seems to be due to legal problems as well. For example, some of the delay in the evacuation investigation was due to problems in obtaining Institutional Review Board (IRB) approval for the oral interviews.

Q3. Mr. Corbett, you are critical of the NIST recommendations for being too vague. Would you give us some examples of where you see problems? What should have been done differently?

A3. NIST should have begun developing code recommendations months ago. The fact that they are now only hiring the National Institute of Building Sciences to prepare them is inexcusable. I consistently advocated for development of recommendations in "tight" code language well over a year ago. For example, NIST should have easily been able to come up with specific language for increasing minimum high-rise stairwell widths and providing secondary water supplies for sprinkler/standpipe systems *in acceptable code text.*

Q4. Mr. Corbett, you believe that NIST was not assertive enough in its investigation and you lay the blame at NIST staff attorneys. How should have NIST been more assertive? What leads you to believe it was bad counsel by staff attorneys?

A4. NIST legal staff should have exhibited a more "can-do" attitude to the WTC and Station Nightclub investigations. Instead of spending time identifying all the roadblocks to getting information, NIST legal staff should have spent more time establishing ways of legally getting the information NIST needed. In addition, NIST should have used its subpoena power, especially in the case of the Station Nightclub. NIST relied almost exclusively on newspaper accounts of club survivors for its "investigation" rather than actual interviews—totally unacceptable.

Q5. Mr. Corbett, the NIST recommendations are just the first step in the process. They have to be implemented by building code organizations and adopted by states and localities. How do you see the process moving forward? I understand that New York City is currently revising its building codes, are they using the NIST report and recommendations in this process?

A5. The process will move forward ever so slowly. The model code groups and local jurisdictions (like NYC) need tight code language for consideration, not material that they have to further refine. The model code development process itself takes a long time as does the adoption process by local governments. The fact NIST took so long to complete the investigation (and continues to in the case of WTC 7) only extends this timeline. The National Air Disaster Alliance has said: "safety delayed is safety denied." I think this statement is appropriate in the case of the NCST WTC investigation.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Henry L. Green, President, International Code Council

Questions submitted by the Majority

Q1. When is your committee that is prioritizing the NIST recommendations going to complete its work? Will that committee then be putting any of the recommendations into play for the upcoming ICC review process? How is it determining priorities?

A1. The ICC has two committees at work on NIST/WTC related issues, the ad-hoc committee on Terror Resistant Buildings (TRB) and the permanent Code Technology Committee (CTC). These committees met together in early December to continue coordination of activities in advance of the March 24, 2006 deadline for submission of code change proposals for the 2007 supplements to the 2006 editions of the I–Codes. Each of the two committees will continue the process of preparing independent proposals based on each committee's unique charter and in review of the NIST/WTC recommendations. In early February the CTC will meet to formally receive the recommendations of the TRB, and has scheduled to issue a report on the consolidated work of the two committees in advance of the March 24 deadline. As is addressed more fully in responses to questions below, some of the NIST/WTC recommendations require preparation of additional technological and economic assessments. In immediate prioritization the committees are focused on those measures for which documented supporting evidence is available by the March 24, 2006 deadline for the next code cycle.

Q2. In her testimony, Ms. McNabb said that the recommendation related to elevators may be one of the most important. Do you agree? How difficult would that be to codify and implement? Can you give the Committee a sense of what specific next steps you would take to evaluate that recommendation and what additional information you would need and from whom?

A2. Full exploration of the technological feasibility and costs and benefits of this recommendation are a priority. At this time, however, it should be observed that it appears unlikely that cost/benefit findings based on this recommendation will be available in advance of the deadline for the next code development cycle. At present the CTC awaits reporting from the American Society of Mechanical Engineers (ASME) regarding the technological and economic issues associated with this recommendation. Upon availability of findings from ASME, ICC's CTC will be able to issue advice regarding the potential timing of a code change proposal related to the use of elevators in occupant evacuation and emergency response access.

Q3. In your testimony, you suggested that codes are not necessarily the best way to promote changes in practice. What is the problem with using codes? What are the alternatives? What NIST recommendations should be implemented through means other than codes?

A3. My view in this respect is this, that the quality and value of building codes is meaningless unless the enactment of these codes is followed up by local and State code officials with the proper training, equipment and action by these officials. Building codes, as uniformly enforced, both ensure the public of an adequate minimum standard of safety in any building they or their family may visit, and also provide a level economic playing field for the construction and maintenance of our personal and public facilities.

As I closed my testimony before the Committee, I share the emphasis of the NIST/WTC report on recommendations on building regulations:

> Rigorous enforcement of building codes and standards by State and local agencies, well trained and managed, is critical in order for standards and codes to ensure the expected level of safety. Unless they are complied with, the best codes and standards cannot protect occupants, emergency responders, or buildings. *NIST NCSTAR 1, Section 9.1, p. 202*

Q4. How did the ICC determine that a three-hour fire rating was appropriate in light of the NIST recommendations?

A4. The increase of the fire rating on structural systems for buildings greater than 420 feet in height was adopted in final form by ICC's membership at its final code action hearings held in September 2003, and first became a requirement in the 2004 Supplement to the 2003 International Building Code. This action was taken in the early stages of the NIST/WTC review, well before issuance of recommendations.

This significant change in the fire rating of structural systems of high-rise structures was made with the understanding that it will impose considerable additional expenses to the construction of new high-rise buildings. In my view this change is not a product of new scientific understanding; it is a result of our society's profound new realization of the attractiveness of such structures to terrorist attack.

Q5. You say that recommendations related to specific products will have trouble getting through. Have any been made?

A5. That observation I shared from generalized experience with ICC's code process, but I am not aware of any WTC event inspired code change proposals related to specific products. It should be noted that because the NIST/WTC final report was issued well after the August 2004 deadline for code change proposals in the cycle just completed, we have not yet received or acted upon code change proposals based on the issuance of the final NIST/WTC report.

Q6. You testified that we need more data and research to implement some of NIST's recommendations. What are the top three priority areas where additional research and data are needed? Which specific entities should be doing this research? Which recommendations are most hampered by lack of data?

A6. In my view the top three areas of need for scientific research relative to code regulations in conjunction with the recommendations of the NIST report are:

1) A comprehensive scientific analysis of egress, fire ratings and fire proofing for high-rise structures.
2) Specific technical and cost/benefit analysis, in conjunction with ASTM International, of the serviceability of elevator systems for fire event occupant egress and fire services access for high-rise buildings.
3) Specific scientific investigation, in conjunction with the American Society of Civil Engineers, of the cost and benefit of enhanced structural provisions necessary to address structural stability and progressive collapse.

Those questions most hampered by lack of data relate to fire event egress; especially the technological potential and the cost/benefit calculations of developing elevator systems designed to operate during fire evacuation and fire suppression events.

Q7. Building trade associations have raised concerns that the implementation of some of the recommendations will be expensive. Which of the recommendations do you believe will be most costly? Would these costs be justified in terms of their expected outcomes?

A7. It is clear that implementation of many of the recommendations would significantly increase the cost of construction and operation of new buildings, as well as reduce the percentage of leasable space in new construction. It seems that the most expensive of the recommendations relate to enhanced egress measures, especially provisions for refuge floors and the construction and operation of elevator systems that could be relied upon for occupant egress and fire services access during fire events. Considerable additional construction costs would also come with providing secondary water systems for fire suppression and the additional complexity of constructing enhanced structural systems to mitigate potential for progressive collapse. Without new data presenting technical feasibility and cost/benefit analysis, it is not possible to suggest the likely outcome of a code change recommendation based on any of these measures.

Q8. In written testimony submitted to the Committee, the American Institute of Architects points to the lack of a fire test facility in the United States—a facility large enough to test components of a tall building—as a major shortcoming in the Nation's ability to improve skyscraper safety. Is the maintenance and operation of large-scale fire testing capability a NIST responsibility, or does it lie elsewhere in the Federal Government or the private sector? How do you respond to the AIA's comments?

A8. It is important to observe, in context of this question, that the NIST report conveys a clear understanding that the structural failures of Tower 1 and Tower 2 were a result of the profoundly unique and unprecedented conditions associated with terrorist attacks of September 11, 2001. In this respect the NIST report (page xli) summarizes:

> The tragic consequences of the September 11, 2001 attacks were directly attributable to the fact that terrorists flew large jet-fuel laden commercial airliners into the WTC towers. Buildings for use by the general population are not de-

signed to withstand attacks of such severity; building regulations do not require building designs to consider aircraft impact. In our cities, there has been no experience with a disaster of such magnitude, nor has there been any in which the total collapse of a high-rise building occurred so rapidly and with little warning.

The AIA states in its testimony that:

> The NIST report and recommendations raise powerful issues about how best to achieve building safety and security. The AIA encourages NIST to further investigate areas such as actual building occupant loads and develop data on actual building performance through additional testing of full-sized components. NIST provides an ideal platform to investigate and report fairly these issues. However, it will be necessary to gather much more data to verify any change in the direction of model building codes. *The AIA continues to believe that the best way to ensure that building codes protect the public is to ensure that model codes are developed through an open consensus based process. (AIA testimony, page 7)*

The ICC concurs with the AIA that any NIST recommendation that leads to a code change proposal should be considered through a voluntary consensus based code and standards process and be accompanied with data from a thorough scientific evaluation of the change in materials, technology, building design or fire-resistance testing and rating processes that are proposed. In assessing questions regarding the responsibility for and the value of increased scaling of fire-testing, as well as the capacity of present public and private sector testing facilities to do such, it is imperative to frame the NIST recommendations as specific proposals for change to present codes and standards. At this writing the ICC is in receipt of a concept, or "Strawman" proposal prepared by NIST which suggests additional consideration of scaling on fire resistance standards when test specimens are less than ½ actual scale. In conducting real fire testing for the WTC examination NIST found that the largest facility in North America provided testing up to 30 feet; one-half of the size that would have been necessary for full-scale testing. NIST has observed that, worldwide, there may be only one or two facilities with furnaces capable of testing connected structural elements, at designed load, with up to 60 foot spans. Given our present understanding of the unique character of the conditions under which such full-scale testing would enhance the safety of high-rise buildings it may, as the AIA suggests, be incumbent on the Federal Government to undertake to construct and operate such a unique facility.

Q9. Testimony submitted to the Science Committee by the Building Owners and Managers Association (BOMA) calls for cost-benefit analyses to be developed on the implementation of NIST's recommendations. Do you believe this is a good idea? Why or why not? If so, who should develop these analyses?

A9. As a first measure the public safety benefit of any recommendation must be clearly evidenced and supported, and the ICC welcomes the results of the NIST/WTC report as significant science in the consideration of improving the defensibility of our public structures. At the same time it is necessary, in putting forward building code changes based on those recommendations, to clearly understand the economic consequences of each specific proposal. It is ICC's view that NIST, along with all federal agencies with responsibilities impacting the built environment, should be active participants in offering building code amendment proposals, whether based on the NIST/WTC report, or through the general course of involvement in operating in or regulating the built environment. As with any code change participant or advocate, this includes participation in the development of both the scientific evidence supporting a change, and analyses of the economic cost and public policy justification for the change.

Q10. Which recommendations do you think most require action by the Federal Government, particularly with respect to research, and which agencies should be responsible?

A10. As suggested in my testimony to the Committee, and my observations regarding other follow-up questions, the ICC believes that federal agency involvement in ICC's Governmental Consensus process is critical in providing a full range of interests in the proposal of code change recommendations, and in providing scientific and economic evidence that allows for a fully considered debate on those recommendations. In this manner the federal agency representatives participate, consistent with federal policy guidance in OMB A–119 and the NTTAA, as colleagues in the voluntary sector model code development and amendment process. This participation should reach as well to all standards developing organizations (SDOs) that maintain

standards which have been identified by NIST as addressed by the NIST/WTC report. These developers include the American Concrete Institute, the American Institute of Architects, the American Institute of Steel Construction, the American Society of Civil Engineers, the American Society of Mechanical Engineers, The Association of the Wall and Ceiling Industry, ASTM International, the International Organization for Standardization, the National Fire Protection Association, and Underwriters Laboratories. The work of each of these SDOs is, as well, referenced in the International Codes. This being said, recommendations 22, 23 and 24 of group 6 "Improved Emergency Response" have direct and unique impact on the regulatory responsibilities of the Department of Homeland Security and the Federal Communications Commission, and would require consideration in federal rule-making processes.

Questions submitted by Democratic Members

Q1. Mr. Green, the ICC recommends closer collaboration between Federal, State and local governments on building code issues. What needs to be improved?

A1. Consistent with the spirit and purpose of OMB Circular A–119 and the *National Technology and Transfer Act of 1995,* U.S. federal agencies need not only to look to the private sector for standards to utilize in governmental application, but also to participate in these standards development processes. Federal Government agencies do have a history of participation in the Governmental Consensus Process utilized by ICC. That participation should continue to grow along with the agencies' growing reliance on ICC's model building codes both to guide federal agency construction, as well as in facilitation of federal rule-makings. Together with expanded participation in proposing and advocating independent amendments to the model codes, the agencies should actively coordinate the federal perspective on code changes that will be considered in ICC's code development process, regardless of the source of the proposal.

Q2. The ICC agrees with NIST's recommendations for continuing education for building industry professionals. Currently what professional development activities does ICC sponsor? What new activities do you envision being developed in cooperation with NIST and other federal agencies?

A2. Below is ICC's published training schedule for the coming year. These programs are routinely attended by local, State and federal officials with responsibilities in facilities construction or in regulating the building environment.

Beyond putting forward these professional training programs conducted by ICC's training professionals, and assistance to agencies directly utilizing I–Codes in facilities construction, ICC's on-going work with NIST and other federal agencies includes policy development coordination with ICC's Federal Government relations staff.

A short list of ICC's collaborative work includes initiatives with the Departments of Justice and Housing and Urban Development in addressing elimination of barriers to building access and egress, and providing HUD's Partnership for Advancing Technology in Housing (PATH) with technical support on building regulations. ICC initiatives with the Department of Commerce include work with the International Trade Administration in hosting foreign delegations researching U.S. standards, and similarly with NIST's Office of Standards Services. ICC is working with the U.S. Chemical Safety Board in dissemination of results from investigations of dust explosions, and in presentation of CBC findings to codes and standards amendment processes. Collaboration with the Department of Health and Human Services includes work with the Centers for Disease Control on a program related to CDC's objective of elimination of residential fire deaths by 2020.

ICC'S 2006 Training Schedule

IC06-154	**Cosponsored by the South Carolina Building Codes Council** 2003 IFC® Fundamentals	Jan. 09, 2006	Columbia	SC
IC06-155	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Solving Means of Egress Issues in Commercial Buildings	Jan. 10, 2006	Columbia	SC
IC06-230	TELEPHONE SEMINAR 2006 International Code Update: IBC	Jan. 11, 2006	TELEPHONE SEMINAR	
IC06-156	**Cosponsored by the South Carolina Building Codes Council** 2003 IFC® Fire Protection Systems	Jan. 11, 2006	Columbia	SC
IC06-157	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Hazardous Materials	Jan. 12, 2006	Columbia	SC
IC06-158	**Cosponsored by the South Carolina Building Codes Council** Creating a Hazard Mitigation and Emergency Management Plan	Jan. 13, 2006	Columbia	SC
COI	Code Official Institute	Jan. 23-26, 2006	Phoenix	AZ
CO06-111	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	Jan. 24, 2006	Chicago	IL
CO06-112	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals	Jan. 26, 2006	Huntley	IL

	Supp. Edition			
IC06-091	**The Code Administrators Association of Kentucky encourages members and other building safety professionals to attend this training** 2003 IMC® Performing Commercial Mechanical Inspections	Feb. 06-08, 2006	Lexington	KY
AMBO	**Sponsored by the Association of Minnesota Building Officials (AMBO)** AMBO Educational Institute	Feb. 06-10, 2006	Brooklyn Park	MN
IC06-092	**The Code Administrators Association of Kentucky encourages members and other building safety professionals to attend this training** 2003 IFGC® Fundamentals	Feb. 09, 2006	Lexington	KY
IC06-093	**The Code Administrators Association of Kentucky encourages members and other building safety professionals to attend this training** Customer Service for Code Administration	Feb. 10, 2006	Lexington	KY
CO06-113	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	Feb. 16, 2006	Macomb	IL
CO06-114	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	Feb. 23, 2006	Salem	IL
EduCode	EduCode International	Feb. 27-Mar. 03, 2006	Las Vegas	NV
IC06-231	TELEPHONE SEMINAR 2006 International Code Update: IRC	Feb. 28, 2006	TELEPHONE SEMINAR	
RII	**Cosponsored by the Texas Residential Construction Commission (TRCC)** Residential Inspection Institute	Mar. 13-17, 2006	Austin	TX
CO06-115	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	March 9, 2006	Bloomington/ Normal	IL
CO06-116	Sponsored by the Illinois Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	March 14, 2006	Rockford	IL
CO0	Sponsored by the Illinois	March	Springfiel	IL

6-117	Clean Energy Community Foundation 2004 IECC Fundamentals Supp. Edition	15, 2006	d	
CF	2006 Codes Forum—An Educational Program	Mar. 20-22, 2006	Sacramento	CA
DPI	Design Professional Institute	Mar. 21-22, 2006	Sacramento	CA
IC06-251	2003 IBC Concrete Quality & Field Practices	Mar. 23, 2006	Los Angeles	CA
IC06-258	2003 IBC Prestressed Concrete Quality & Field Practices	Mar. 24, 2006	Los Angeles	CA
IC06-232	TELEPHONE SEMINAR 2006 International Code Update: IPC	Mar. 28, 2006	TELEPHONE SEMINAR	
SWDS	ICC Education Provider Seminar Structural Welding: Design and Specification	Mar. 28, 2006	Philadelphia	PA
SSI	ICC Education Provider Seminar Structural Steel Inspection	Mar. 29-30, 2006	Philadelphia	PA
IC06-324	Overview of the Chicago Energy Conservation Code	March 30, 2006	Chicago	IL
IC06-159	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC Performing Commercial Building Inspections	April 03-05, 2006	Columbia	SC
IC06-060	**Co-Sponsored by the Metropolitan Kansas City Chapter of ICC** 2003 IMC® Performing Commercial Mechanical Inspections	April 03-05, 2006	Kansas City	MO
SWDS	ICC Education Provider Seminar Structural Welding: Design and Specification	April 4, 2006	New York (midtown)	NY
SSI	ICC Education Provider Seminar Structural Steel Inspection	April 5-6, 2006	New York (midtown)	PA
IC06-160	**Cosponsored by the South Carolina Building Codes Council** 2003 IRC® Performing Residential Building Inspections	April 06-07, 2006	Columbia	SC
IC06-233	TELEPHONE SEMINAR 2006 International Code Update: IFC	April 19, 2006	TELEPHONE SEMINAR	
IC06-243	2003 IBC® Special Inspector Certification Renewal	April 22, 2006	Los Angeles	CA
COI	Code Official Institute	April 24-27, 2006	Portland	OR

IC06-244	2003 IBC® Special Inspector Certification Renewal	April 29, 2006	Oakland	CA
SCSA	ICC Education Provider Seminar Steel Connections: Seismic Applications	May 2, 2006	Buena Park	CA
SSI	ICC Education Provider Seminar Structural Steel Inspection	May 03-04, 2006	Buena Park	CA
SCSA	ICC Education Provider Seminar Steel Connections: Seismic Applications	May 9, 2006	Fremont	CA
SSI	ICC Education Provider Seminar Structural Steel Inspection	May 10-11, 2006	Fremont	CA
IC06-325	Overview of the Chicago Energy Conservation Code	May 19, 2006	Chicago	IL
IC06-012	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IBC® Fundamentals - Nonstructural	June 19, 2006	Reno	NV
IC06-010	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2003 IBC Performing Commercial Building Inspections	June 19-21, 2006	Reno	NV
IC06-013	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IBC® Fundamentals - Structural	June 20, 2006	Reno	NV
IC06-014	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IRC® Fundamentals	June 21, 2006	Reno	NV
IC06-015	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IFC® Fundamentals	June 22, 2006	Reno	NV
IC06-011	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2003 IBC Fire Resistance and Egress for Building Inspectors	June 22-23, 2006	Reno	NV
IC06-016	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IEBC® Fundamentals	June 23, 2006	Reno	NV
IC06-161	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Nonstructural Fire and Life Safety Principles	June 26-27, 2006	Myrtle Beach	SC
IC06-162	**Cosponsored by the South Carolina Building Codes Council**	June 28, 2006	Myrtle Beach	SC

	2003 IBC® Special Uses and Mixed Occupancies			
IC06-163	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Solving Means of Egress Issues in Commercial Buildings	June 29, 2006	Myrtle Beach	SC
IC06-164	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Accessibility and Usability	June 30, 2006	Myrtle Beach	SC
IC06-165	**Cosponsored by the South Carolina Building Codes Council** 2003 IPC® Performing Commercial Plumbing Inspections	July 10-12, 2006	Columbia	SC
IC06-166	**Cosponsored by the South Carolina Building Codes Council** Increasing the Credibility of the Code Official	July 13, 2006	Columbia	SC
IC06-167	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Hazardous Materials	July 14, 2006	Columbia	SC
IC06-080	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2003 IRC® Performing Residential Electrical Inspections	Aug. 07-09, 2006	Kansas City	MO
IC06-081	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2003 IBC® Performing Commercial Electrical Inspections	Aug. 10-11, 2006	Kansas City	MO
IC06-247	2003 IBC® Special Inspector Certification Renewal	Sept. 16, 2006	Los Angeles	CA
IC06-254	2003 IBC Concrete Quality & Field Practices	Sept. 11, 2006	Oakland	CA
IC06-261	2003 IBC Prestressed Concrete Quality & Field Practices	Sept. 12, 2006	Oakland	CA
IC06-248	2003 IBC® Special Inspector Certification Renewal	Sept. 23, 2006	Oakland	CA
IC06-255	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this**	Oct. 05, 2006	Kansas City	MO

	training 2003 IBC Concrete Quality & Field Practices			
IC06-262	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2003 IBC Prestressed Concrete Quality & Field Practices	Oct. 06, 2006	Kansas City	MO
IC06-017	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IBC® Fundamentals - Nonstructural	Oct. 16, 2006	Las Vegas	NV
IC06-018	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IBC® Fundamentals - Structural	Oct. 17, 2006	Las Vegas	NV
IC06-019	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IRC® Fundamentals	Oct. 18, 2006	Las Vegas	NV
IC06-020	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IFC® Fundamentals	Oct. 19, 2006	Las Vegas	NV
IC06-021	**Cosponsored by the Northern and Southern Nevada Chapters of ICC** 2006 IEBC® Fundamentals	Oct. 20, 2006	Las Vegas	NV
FPI	Fire Prevention Institute	Oct. 23-26, 2006	Las Vegas	NV
IC06-104	**The Code Administrators Association of Kentucky encourages members and other building safety professionals to attend this training** 2006 IPMC Fundamentals	Nov. 13, 2006	Lexington	KY
IC06-086	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2006 IBC® Fundamentals - Nonstructural	Nov. 13, 2006	St. Louis	MO
IC06-168	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC Performing Commercial Building Inspections	Nov. 13-15, 2006	Columbia	SC
IC06-087	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety**	Nov. 14, 2006	St. Louis	MO

	professionals to attend this training 2006 IBC® Fundamentals - Structural			
IC06-105	**The Code Administrators Association of Kentucky encourages members and other building safety professionals to attend this training** 2006 IFGC Fundamentals	Nov. 14, 2006	Lexington	KY
IC06-088	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2006 IRC® Fundamentals	Nov. 15, 2006	St. Louis	MO
IC06-089	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2006 IFC® Fundamentals	Nov. 16, 2006	St. Louis	MO
IC06-169	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC Fire Resistance and Egress for Building Inspectors	Nov. 16-17, 2006	Columbia	SC
IC06-090	**The Metropolitan Kansas City Chapter of ICC encourages members and other building safety professionals to attend this training** 2006 IEBC® Fundamentals	Nov. 17, 2006	St. Louis	MO
PRI	**Cosponsored by the South Carolina Building Codes Council** Plan Review Institute	Nov. 27-30, 2006	Myrtle Beach	SC
IC06-170	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Performing Nonstructural Plan Reviews	Dec. 11-12, 2006	Myrtle Beach	SC
IC06-171	**Cosponsored by the South Carolina Building Codes Council** 2003 IBC® Performing Structural Plan Reviews	Dec. 13-14, 2006	Myrtle Beach	SC
IC06-172	**Cosponsored by the South Carolina Building Codes Council** Communication for Code Officials	Dec. 15, 2006	Myrtle Beach	SC

Q3. Mr. Green, I understand that your organization just included a general meeting. What were the general reactions to the NIST report by your membership?

A3. It should be noted that the main focus of ICC's meeting in Detroit in September, 2005 was the final action hearings on code change proposals that were submitted in August 2004—well before the release of either the draft or final NIST reports. As such no review of the report was undertaken by the body at-large. I would observe, however, that the membership welcomes the NIST/WTC report and recognizes that some of its most significant recommendations, such as those addressed in my responses to the other questions from the committee, will require additional review, evaluation and findings from standards developers in order to have complete information on technological feasibility and in order to fully evaluate the cost/benefit balance of specific proposals. As I discussed in my testimony, affirmative action was taken by the Board of Directors in directing the ICC Code Technology Committee to work with NIST and parties in order to prioritize the recommendations and prepare specific code change proposals in advance of the March 24, 2006 deadline for submission to our next 18 month code change cycle.

Q4. Mr. Green, why do you feel that without NIST involvement and leadership that either nothing will be done to implement their recommendations or that they may be misinterpreted?

A4. It is my view that NIST has and continues to carry forward its responsibilities effectively. NIST will have a critical role in elaborating the intent and substantiation of its WTC recommendations during discussion of code change proposals stimulated by the WTC report. NIST's role will be crucial in ensuring that ICC's technical committees and the membership at-large receive a full and accurate interpretation and basis for the NIST recommendations. With the public circulation of the NIST/WTC report, we do expect that a number of additional interested and affected parties will use the report as the foundation for specific code changes proposals. To further stimulate this process NIST has already demonstrated leadership through the issuance, in late November, of a set of "Strawman" model building code change proposals which present the NIST/WTC recommendations in a manner consistent with submissions for actual code change proposals. The Strawman document is already being evaluated by ICC's TRB and CTC committees in preparation of their report on the development of code change proposals based on the NIST/WTC report.

Appendix 2:

Additional Material for the Record

STATEMENT OF THE AMERICAN INSTITUTE OF ARCHITECTS

The American Institute of Architects is pleased to provide written testimony for the House Science Committee's hearing on "NIST's Investigation of the World Trade Center Collapse."

The AIA represents more than 76,000 licensed architects, emerging professionals, and allied partners who are fully committed to the highest professional standards in the design of the Nation's built environment. As the AIA's public policies state, "Architecture profoundly affects people. The work of architects is essential to human well being, and architects must embrace their ethical obligation to uphold this public trust."

This testimony is based on the AIA's public comments on NIST's *Final Report of the National Construction Safety Team on the Collapses of the World Trade Center Towers.* When NIST released its report last June, the AIA invited its members to provide input to the Institute about the draft report and recommendations. These comments reflect the views expressed by the AIA's members.

The AIA cannot overstate the accomplishments of the NIST investigating team and the substantial body of information they gathered and organized in response to one of the worst catastrophes in American history. The results are a definitive historical record of the largest and most devastating building disaster ever. The AIA was honored to participate in this process by having one of its members serve on the National Construction Safety Team Advisory Committee.

Recognizing the superior design and performance of the twin towers during an unprecedented terrorist attack, the data that the investigating team compiled should not only help identify deficiencies but also serve as a testament to the buildings' ability to stand long enough after the attack to allow thousands of occupants to evacuate.

We owe it to the victims of the September 11 attacks, and to the millions of Americans who use buildings every day, to ensure that our built environment is safe, and that any changes to how we design and construct buildings come about as the result of an open, deliberative and rational building code and regulation development process.

The Investigation: Demonstrating the Robustness of the Towers

On September 11, 2001, the World Trade Center towers were subjected to an almost unimaginable attack from hijacked, fuel-laden 767s flying at such high speeds that one of the jets nearly broke apart in mid-air. Following its Congressional authorization to investigate the circumstances that contributed to the towers' collapse, NIST lauds the success of the design, construction and materials for their exceptional performance. The report finds that the buildings would have survived the catastrophic event were it not for the fact that the aircraft caused extensive damage to the buildings and their fire protective systems (both passive and active), and ignited extensive fires that were limited only by the amount of combustible material they could reach.

The report presents, in its Executive Summary, the following findings regarding the design, construction and materials of the towers:

1. *. . .the towers withstood the impacts and would have remained standing were it not for the dislodged insulation (fireproofing) and the subsequent multi-floor fires. The robustness of the perimeter frame-tube system and the large size of the buildings helped the towers withstand the impact. The structural system redistributed loads without collapsing in places of aircraft impact, avoiding larger scale damage upon impact.*
2. *The WTC towers likely would not have collapsed under the combined effects of aircraft impact damage and the extensive, multi-floor fires if the thermal insulation had not been widely dislodged or had been only minimally dislodged by aircraft impact.*
3. *Since the flow of people from the building had slowed considerably 20 min.* [sic] *before the tower* [WTC 1] *collapsed, the stairwell capacity was adequate to evacuate the occupants on that morning.*
4. *As in WTC 1, shortly before collapse, the flow of people from the building* [WTC 2] *had slowed considerably, indicating that the stairwell capacity was adequate that morning.*
5. *The fire safety systems (sprinklers, smoke purge, and fire alarms,) were designed to meet or exceed current practice.*
6. *For the approximately 1,000 emergency responders on the scene, this was the largest disaster they had even seen. Despite attempts by the responding agencies*

to work together and perform their own tasks, the extent of the incident was well beyond their capabilities.

7. *. . .the actual design and approval process produced two buildings that generally were consistent with nearly all of the provisions of the New York City Building Code and other building codes of the time. The loads for which the buildings were designed exceeded the code requirements. The quality of the structural steels was consistent with the building specifications. The departures from the building codes and standards did not have a significant effect on the outcome of September 11.*
8. *On September 11, 2001, the minimum specified thickness of the insulation was adequate to delay heating of the trusses; the amount of insulation dislodged by the aircraft impact, however, was sufficient to cause the structural steel to be heated to critical levels.*
9. *. . .in all cases* [during NIST's testing of fire rated assemblies], *the floors continued to support the full design load without collapse for over two hours.*
10. *The wind loads used for the WTC towers, which governed the structural design of the external columns and provided the baseline capacity of the structures to withstand abnormal events such as major fires or impact damage, significantly exceeded the requirements of the New York City Building Code and selected other building codes of the day.*

The North Tower. The first account of the performance of World Trade Center 1 (the north tower) is found in Chapter 2 of NIST's final report. Following a detailed description of the extent of damage, the report states, "Even with all this damage, the building still stood." Ignition of the building contents by the explosion of 10,000 gallons of jet fuel is addressed in the account of WTC 1, which finds that the ignition of the contents of the building and airplane caused a fuel-controlled fire, creating an exposure that is not typical of any condition that is considered when designing buildings.

The report finds that the aircraft impact virtually destroyed the fire protection systems. The report states that the system was designed to supply water to about eight sprinkler heads at one time, enough to control the flames from as much as 1,500 square feet of burning material. The water supply was likely sufficient to control fires up to triple that size. However, the fires caused by the aircraft impact were far larger than those envisioned by any imaginable fire protection system.

The South Tower. World Trade Center 2 (the south tower) was subjected to a similar event, but faced a number of factors that were distinct from WTC 1. Those factors resulted in a larger overall fraction of the occupants surviving, despite the fact that WTC 2 collapsed in a shorter period of time. According to the report, within five minutes of the impact on WTC 1, half of the occupants of WTC 2 had left their floors, and the number of evacuees subsequently increased rapidly. Based on their perception of events occurring in WTC 1, approximately 3,000 people in WTC 2 escaped in the 16 minutes between the aircraft impact on WTC 1 and the impact on WTC 2.

The report goes on to state that WTC 2 "swayed more than one foot back and forth in each direction on the impact floors, about one-third the sway under the high winds for which the building was designed." Nonetheless, just like WTC 1, WTC 2 absorbed the aircraft strike and remained standing for nearly an hour. Similar to the circumstances of WTC 1, jet fuel played a critical role in providing an extraordinary ignition source to the fuel load in WTC 2, contributing to the ultimate failure of the structural system.

The World Trade Center collapse provided the design and construction industry with an opportunity to evaluate and reexamine its processes and practices. Based upon the outstanding success of these buildings under extraordinary circumstances, it is clear that the design community can be trusted to create redundancies for typical building emergency situations, that codes are developed in a manner that provides sufficient input from all quarters to ensure adequate life safety for typical emergency situations, and that no upgrading of code requirements is warranted given the performance of these buildings.

The Recommendations: Missed Opportunities

Although the report provides significant information regarding the performance of the buildings, their occupants and the extraordinary efforts of the responding emergency personnel, the AIA believes that a number of the recommendations in the report are not supported by the findings of the investigation. Other recommendations suggest reforms that have already been addressed by the design and construction

industry or the model code organizations. The Appendix to this testimony provides a detailed analysis of NIST's recommendations and the AIA's responses.

At the same time, the AIA believes that the report misses opportunities to make recommendations that would improve the understanding of how buildings perform in extreme events. Developing that understanding in order to protect building occupants must be a fundamental mission of all organizations that work to create a better built environment.

One such area is fire testing. NIST developed advanced fire modeling techniques to evaluate the complex circumstances at the World Trade Center, examining the spread of fire and its impact on structural members. This may become an important tool for designing safer buildings, although their ability to integrate known conditions into the modeling currently used in the marketplace was a major problem even for NIST when it evaluated the 2003 fire at the Station nightclub in Rhode Island.

The AIA believes that improved fire testing is a vital need, and opportunity, that must not be ignored. The Institute is therefore troubled by the fact that there are no test facilities in the United States that can accommodate the larger lengths or sizes of elements such as those found in the twin towers. If the Federal Government is truly committed to understanding the effects of such fire hazards on the built environment, it is critical that it provide for adequate testing facilities at home.

The AIA strongly encourages this committee to consider authorizing funding to construct new testing facilities or retrofit existing facilities that can address the full range of building conditions present in the United States.

In addition, NIST should be encouraged to take advantage of its position as the preeminent research facility in the United States to examine innovative materials and processes and assure that they meet the most rigorous of standards appropriate for their use. Performance codes, which the AIA believes are the future direction for building codes and regulations, are sorely in need of supporting information on the actual performance of buildings and building systems. Without this data, designers are left to make assumptions based on limited resources.

Furthermore, the AIA believes that NIST should facilitate opportunities to develop "smart" building systems that would better advise first responders of actual building conditions and situations. The current efforts to improve the use of elevators in an emergency are an example of the dramatic changes that will take place to the guidance provided to building occupants.

Building Codes: An Accountable and Comprehensive System

The major finding of the NIST report is that the design and construction materials of the World Trade Center did not contribute to the disaster; they performed exceptionally well. Despite this fact, the report offers several recommendations that are not supported by the investigation, nor are they backed by substantive research. In fact, the premises of some of the statements appear to be in error.

For example, in section 9.1 ("Building Standards and Codes: Who is in Charge?"), the report states, "Very few members of the general public and building occupants participate in [the code development] process." Although this is true of most standards development groups, including NFPA and IAPMO, it is not true for the International Code Council's family of codes. State and local code enforcement officials (building, fire, plumbing, electrical, etc.) are a driving force behind code changes and have the controlling votes on all changes to ICC's codes. These officials are public officials who represent their states, counties and cities, and do not fall within any of the categories that NIST lists as "influencing the practices used in the design, construction, operation, and maintenance of buildings in the United States."

The code enforcement community has been extraordinarily aggressive in pursuing education and certification for their members. Many states and local jurisdictions have worked diligently to assure the credibility of their enforcement programs by requiring certification of training obtained by their code enforcement officials.

The question of "who is in charge" regarding the development and application of codes and standards is well established and recognized by 45 states as the code official using the *International Building Code,* and in 36 states as the code official using the *International Fire Code.*

The AIA believes that State and local governments must retain the authority to determine appropriate building regulations. The AIA does not agree that the Federal Government is in a position to supplant the voice or the rights of local and state jurisdictions by presuming to speak for the public that is given the constitutional authority through police powers to determine what is appropriate for building regulation in their communities.

The fundamental challenge regarding codes and life safety today is the lack of an understanding or an appreciation by users of the safety features designed and built into modern buildings. This includes building owners, managers, tenants and serv-

ice providers who often unintentionally subvert life safety features out of ignorance about how they work. This was most evident in the Rhode Island nightclub tragedy, where modifications that were made to the interior of the building and the use of pyrophoric materials in the facility were both major violations of the applicable codes. Had the owner or the user of the space been more knowledgeable about the potential hazards associated with such actions, that disaster would likely have been averted.

Conclusion

NIST has undertaken an extraordinary effort to investigate and understand the consequences of the most devastating terrorist attack in our nation's history. It should be reassuring to the public that the report concludes that the World Trade Center towers were well within the contemporary norms of design and construction, and that the buildings were able to stand long enough to allow thousands of people to escape.

But the terrible loss of life that day demands that we study the results of this investigation closely to learn what the design and construction professions have done right, and where improvements can be made to better protect people in buildings.

The recommendations in the NIST report are useful guidelines towards that end. However, the AIA believes that at times the recommendations overlook measures and technologies that are already in practice, or go in directions that are not supported by either the investigation or scientific research.

The need to protect the health, safety and welfare of people who use buildings is not a subject of debate. This is why the AIA requires its members to adhere to the highest professional standards and take at least eight hours of health, safety and welfare continuing education classes each and every year throughout their careers in order to remain members in good standing.

The NIST report and recommendations raise powerful issues about how best to achieve building safety and security. The AIA encourages NIST to further investigate areas such as actual building occupant loads and develop data on actual building performance through additional testing of full-sized components. NIST provides an ideal platform to investigate and report fairly these issues. However, it will be necessary to gather much more data to verify any change in the direction of model building codes. *The AIA continues to believe that the best way to ensure that building codes protect the public is to ensure that model codes are developed through an open, consensus based process.*

The AIA commends NIST for making education a focus of its efforts. The AIA encourages the design and construction industry, and everyone who uses buildings, to take advantage of opportunities to gain a greater understanding of how buildings affect our lives and our communities.

Appendix: Recommendations and Responses

The report states that NIST's recommendations (Section 9.2) are based on:

1. Findings related to building performance, evacuation and emergency response, and to procedures and practices used in the design, construction, operation, and maintenance of the buildings;
2. Whether these findings relate to the unique circumstances surrounding the terrorist attacks of September 11, 2001, or to normal building and fire safety considerations (including evacuation and emergency response);
3. Technical solutions that are needed to address potential risks to buildings, occupants, and emergency responders, considering both identifiable hazards and the consequences of those hazards; and
4. Whether the risks apply to all buildings or are limited to certain building types (e.g., buildings that exceed a certain height and floor area or that employ a specific type of structural system), buildings that contain specific design features, iconic/signature buildings, or buildings that house critical functions.

NIST's recommendations are broken down into eight groups. The AIA's comments follow each recommendation.

Group 1: Increased Structural Integrity

Group 1 (Increased Structural Integrity) calls for improved standards to enhance structural integrity for estimating load effects of progressive collapse and wind.

Recommendation 1. *NIST recommends that: (1) progressive collapse should be prevented in buildings through the development and nationwide adoption of consensus standards and code provisions, along with the tools and guidelines needed for their use in practice; and (2) a standard methodology should be developed—supported by analytical design tools and practical design guidance—to reliably predict the potential for complex failures in structural systems subjected to multiple hazards.*

Recommendation 2. *NIST recommends that nationally accepted performance standards be developed for: (1) conducting wind tunnel testing of prototype structures based on sound technical methods that result in repeatable and reproducible results among testing laboratories; and (2) estimating wind loads and their effects on tall buildings for use in design, based on wind tunnel testing data and directional wind speed data.*

Recommendation 3. *NIST recommends that an appropriate criterion should be developed and implemented to enhance the performance of tall buildings by limiting how much they sway under lateral load design conditions (e.g., winds and earthquakes).*

AIA Response

It should be noted that nothing in the NIST report criticizes nor questions the structural integrity of the World Trade Center towers and their design. In fact, the report finds that the buildings were more robust than would have been required by any code in force at the time they were designed and constructed. NIST's report focuses on the varying results they received when different consultants examined the buildings' wind design. It is the lack of a consensus method for evaluating buildings that NIST's recommendations address, not providing additional requirements for the design of structures.

A recent article by Jesse Beitel and Nestor Iwankiw, Ph.D., P.E., from Hughes Associates, Inc., in SFPE's *Fire Protection Engineering* (Summer 2005) documents a "Historical Survey of Multistory Building Collapses Due to Fire." The data in the article was taken from a NIST survey performed in 2002 that focused on buildings four or more stories tall. The survey covered the time period between 1970 and 2002 and discovered a total of 22 buildings that had either full or partial collapse. The article states, "While the number of fire events may appear low (average of one per year), these fire events are high-consequence occurrences with respect to loss of life, injuries, and economic costs." When examining those statistics, five of the fire events were the result of the September 11 attacks, and 13 of the buildings were four to eight stories tall. There were only three "high-rise" buildings that involved any collapse scenario.

The Beitel/Iwankiw article states:

> Almost 60 percent (13/22) of the cases are in the 4–8 stories range, with the remainder affecting much taller buildings. Six collapses occurred in buildings over 20 stories, and three of these were the WTC steel-framed buildings (1, 2,

and 7). At least four of these fire collapses had occurred during construction or renovations of some kind, when the usual expected architectural, structural and fire protection functions were still incomplete or temporarily disrupted.

It is common knowledge that a construction site is an unsafe and dangerous environment. Additionally, the research for this study does not include any information determining whether the buildings conformed to any code or standard. Based on NIST's own study, it appears that the recommendation to increase structural integrity is due to fire events in a total of four collapsed structures four stories or taller over a 32-year period. Assuming that one of the collapses is the Murrah Federal Building in Oklahoma City, Oklahoma, in which the collapse was the result of a vehicle-borne explosive, this leaves a total of three such fire events worldwide that resulted in collapse or partial collapse of a high-rise building.

Group 2: Enhanced Fire Resistance of Structures

Group 2 (Enhanced Fire Resistance of Structures) recommends that the procedures and practices used to ensure that the basis for classification of fire resistance in buildings should be enhanced.

Recommendation 4. *NIST recommends evaluating, and where needed improving, the technical basis for determining appropriate construction classification and fire rating requirements (especially for tall buildings greater than 20 stories in height)—and making related code changes now as much as possible—by explicitly considering factors including:*

- *timely access by emergency responders and full evacuation of occupants, or the time required for burnout without local collapse;*
- *the extent to which redundancy in active fire protection (sprinkler and standpipe, fire alarm, and smoke management) systems should be credited for occupant life safety;*
- *the need for redundancy in fire protection systems that are critical to structural integrity;*
- *the ability of the structure and local floor systems to withstand a maximum credible fire scenario without collapse, recognizing that sprinklers could be compromised, not operational, or non-existent;*
- *compartmentation requirements (e.g., 12,000 ft2) to protect the structure, including fire rated doors and automatic enclosures, and limiting air supply (e.g., thermally resistant window assemblies) to retard fire spread in buildings with large, open floor plans;*
- *the impact of spaces containing unusually large fuel concentrations for the expected occupancy of the building; and*
- *the extent to which fire control systems, including suppression by automatic or manual means, should be credited as part of the prevention of fire spread.*

Recommendation 5. *NIST recommends that the technical basis for the century-old standard for fire resistance testing of components, assemblies, and systems should be improved through a national effort. Necessary guidance also should be developed for extrapolating the results of tested assemblies to prototypical building systems.*

Recommendation 6. *NIST recommends the development of criteria, test methods, and standards: (1) for the in-service performance of spray-applied fire resistive materials (SFRM, also commonly referred to as fireproofing or insulation) used to protect structural components; and (2) to ensure that these materials, as-installed, conform to conditions in tests used to establish the fire resistance rating of components, assemblies, and systems.*

Recommendation 7. *NIST recommends the nationwide adoption and use of the "structural frame" approach to fire resistance ratings.*

AIA Response

Enhanced fire resistance was not an issue in the World Trade Center collapse, as the buildings would have survived even the massive fires caused by the aircraft had the planes not dislodged fire proofing materials.

Recommendation 4 implies that structures should be designed for an aircraft impact, which does not comport with NIST's findings. In fact, the lead investigator for NIST has stated that it is far easier to ensure that airplanes are not used as weapons against buildings than to design for such an event. As noted earlier, the instances of structural failure due to fire are extremely rare and, in a fully

sprinklered building, even rarer. These facts do not indicate a need for enhanced levels of fire resistance in building design.

One of the concerns expressed with regard to construction methods involves the application of spray-on fireproofing. This debate is not new and has been well documented. It is of concern that, with such a large focus in the report on the fire resistance of materials used in the buildings, there is no mention of the appropriateness of test standards such as **ASTM E605–00** *(Test Method for Thickness and Density of Sprayed Fire-resistive Material (SFRM) Applied to Structural Members)* and **ASTM E736** *(Cohesion/Adhesion of Sprayed Fire-Resistive Materials Applied to Structural Members),* both of which are referenced in the *International Building Code,* and thus presumably "required by code" and enforced.

Similarly lacking is reference to, or a measure of the appropriateness of, **ASTM E759** *(Effect of Deflection on Sprayed Fire-Resistive Materials Applied to Structural Members),* **ASTM E760** *(Effect of Impact on Bonding of Sprayed Fire-Resistive Materials Applied to Structural Members),* **ASTM E761** *(Compressive Strength of Sprayed Fire-Resistive Materials Applied to Structural Members),* **ASTM E859** *(Air Erosion of Sprayed Fire-Resistive Materials Applied to Structural Members),* or **ASTM E937** *(Corrosion of Steel by Sprayed Fire-Resistive Materials Applied to Structural Members).*

In recommendation 5, NIST suggests reevaluation of the ASTM E119 procedure. The AIA believes that a better approach would be to take the research performed by NIST using recognized testing procedures to explore how the large-scale testing compares with results obtained using small-scale tests. The fact that the unrestrained assembly outperformed the restrained assembly is still unexplained. It appears that design is still taking place under the assumption that a restrained assembly will outperform an unrestrained assembly.

NIST specifically refers to the AIA in recommendation 6, suggesting that it is important "to develop criteria, test methods and standards for the 'in-service' performance of spray-applied fire resistive materials." NIST suggests that MasterSpec is the appropriate forum for such activity. Architects in general, and MasterSpec in particular, do not have that sole responsibility establishing such standards. Other agencies or organizations develop standards, which are then included in MasterSpec where appropriate as requirements for the construction of buildings. Architects and specifiers often participate in the development of standards, which is appropriate to assure the applicability of the resulting standards. But it is the *collaborative* development of standards that should be encouraged. With the lack of specific direction on the use of the standards that even now are found in building codes, it is unclear what NIST is recommending be done.

Lastly, recommendation 6 suggests adoption of a structural frame approach to design throughout the United States. However, the requirement for design of a structural frame has already been accomplished by the adoption of the *International Building Code* in 45 states.

Group 3: New Methods for Fire Resistance Design of Structures

Group 3 (New Methods for Fire Resistance Design of Structures) recommends that procedures used to design the fire resistance should be enhanced by considering uncontrolled fires to burnout. This recommendation suggests that new coatings and technology for evaluating them be developed to enhance conventional and high-performance structural materials.

Recommendation 8. *NIST recommends that the fire resistance of structures should be enhanced by requiring a performance objective that uncontrolled building fires result in burnout without local or global collapse.*

Recommendation 9. *NIST recommends the development of: (1) performance-based standards and code provisions, as an alternative to current prescriptive design methods, to enable the design and retrofit of structures to resist real building fire conditions, including their ability to achieve the performance objective of burnout without structural or local floor collapse: and (2) the tools, guidelines, and test methods necessary to evaluate the fire performance of the structure as a whole system.*

Recommendation 10. *NIST recommends the development and evaluation of new fire resistive coating materials, systems, and technologies with significantly enhanced performance and durability to provide protection following major events.*

Recommendation 11. *NIST recommends that the performance and suitability of advanced structural steel, reinforced and pre-stressed concrete, and other high-performance material systems should be evaluated for use under conditions expected in building fires.*

AIA Response

Recommendation 8 suggests consideration of designing to allow "uncontrolled fires to burnout." Such circumstances may be a consideration, but are not appropriate in most circumstances. Even where there have been uncontrolled fires that caused a "burnout," there is no evidence that current procedures are inadequate. In the article by Beitel and Iwankiw, which uses NIST data, the rationale is not present to warrant such a major change in building code requirements.

Recommendation 9 reflects actions taken by both the ICC and the NFPA in the development of performance code criteria. What is currently lacking are the tools and background information on responses of buildings and the performance of the elements within them for any given event. The AIA believes that NIST could provide a significant resource to the industry by examining actual fire scenarios more closely and developing guidelines for understanding such events. With that kind of data available, designers would be able to utilize a performance approach to building safety that is informed by real world evidence.

The AIA questions the logic behind recommendations 10 and 11. The report frequently expresses doubt about "innovative" design materials and methods in its evaluation of the floor truss systems in the World Trade Center. Yet those innovative floor framing systems performed as anticipated and were proven to be adequate based on the tests that NIST performed. Industry will continuously develop innovative materials and systems, and the AIA believes that NIST can and should play a vital role in encouraging them by facilitating more realistic testing that would replicate actual construction.

Group 4: Improved Active Fire Protection

Group 4 (Improved Active Fire Protection) calls for enhancements to sprinklers, standpipes, hoses, fire alarms and smoke management systems, including redundancy.

Recommendation 12. *NIST recommends that the performance and redundancy of active fire protection systems (sprinklers, standpipes/hoses, fire alarms, and smoke management systems) in buildings should be enhanced to accommodate the greater risks associated with increasing building height and population, increased use of open spaces, available compartmentation, high-risk building activities, fire department response limits, transient fuel loads, and higher threat profile.*

Recommendation 13. *NIST recommends that fire alarm and communications systems in buildings should be developed to provide continuous, reliable, and accurate information on the status of life safety conditions at a level of detail sufficient to manage the evacuation process in building fire emergencies, and that standards for their performance be developed.*

Recommendation 14. *NIST recommends that control panels at fire/emergency command stations in buildings should be adapted to accept and interpret a larger quantity of more reliable information from the active fire protection systems that provide tactical decision aids to fireground commanders, including water flow rates from pressure and flow measurement devices, and that standards for their performance be developed.*

Recommendation 15. *NIST recommends that systems should be developed and implemented for: (1) real-time off-site secure transmission of valuable information from fire alarm and other monitored building systems for use by emergency responders, at any location, to enhance situational awareness and response decisions and maintain safe and efficient operations; and (2) preservation of that information either off-site or in a black box that will survive a fire or other building failure for purposes of subsequent investigations and analysis. Standards for the performance of such systems should be developed, and their use should be required.*

AIA Response

NIST's concerns about the redundancy of active and passive fire protective systems are valid in circumstances where *all* such systems may be rendered ineffective or inoperative. However, such circumstances are extremely rare, as was the case in the unprecedented aircraft attack on the World Trade Center. The *ICC Performance Code for Buildings and Facilities,* NFPA's 101 *Life Safety Code* and 5000 *Building Code* already include this approach to fire protection design in their performance guidelines. Although the World Trade Center was not designed for such complex circumstances, it nevertheless performed remarkably well.

Recommendations 13, 14, and 15 include opportunities for significant improvement in the performance of fire protection systems by installing smart building devices. Where there is a reasonable risk of natural or manmade hazards to a par-

ticular structure, every effort should be taken to ensure the security of the facilities and protection of the occupants.

Group 5: Improved Building Evacuation

Group 5 (Improved Building Evacuation) addresses communications systems and the design of means of egress.

Recommendation 16. *NIST recommends that public agencies, non-profit organizations concerned with building and fire safety, and building owners and managers should develop and carry out public education campaigns, jointly and on a nationwide scale, to improve building occupants' preparedness for evacuation in case of building emergencies.*

Recommendation 17. *NIST recommends that tall buildings should be designed to accommodate timely full building evacuation of occupants due to building-specific or large-scale emergencies such as widespread power outages, major earthquakes, tornadoes, hurricanes without sufficient advanced warning, fires, accidental explosions, and terrorist attack. Building size, population, function, and iconic status should be taken into account in designing the egress system. Stairwell and exit capacity should be adequate to accommodate counterflow due to emergency access by responders.*

Recommendation 18. *NIST recommends that egress systems should be designed: (1) to maximize remoteness of egress components (i.e., stairs, elevators, exits) without negatively impacting the average travel distance; (2) to maintain their functional integrity and survivability under foreseeable building-specific or large-scale emergencies; and (3) with consistent layouts, standard signage, and guidance so that systems become intuitive and obvious to building occupants during evacuations.*

Recommendation 19. *NIST recommends that building owners, managers, and emergency responders develop a joint plan and take steps to ensure that accurate emergency information is communicated in a timely manner to enhance the situational awareness of building occupants and emergency responders affected by an event. This should be accomplished through better coordination of information among different emergency responder groups, efficient sharing of that information among building occupants and emergency responders, more robust design of emergency public address systems, improved emergency responder communication systems, and use of the Emergency Broadcast System (now known as the Integrated Public Alert and Warning System) and Community Emergency Alert Networks.*

Recommendation 20. *NIST recommends that the full range of current and next generation evacuation technologies should be evaluated for future use, including protected/hardened elevators, exterior escape devices, and stairwell navigation devices, which may allow all occupants an equal opportunity for evacuation and facilitate emergency response access.*

AIA Response

Recommendation 16, though well intentioned, misses a key element of building safety. While ensuring proper egress during an emergency is important, too many building owners, managers and occupiers fail to prepare for emergencies before the fact. Examples of malfunctioning or failed systems (such as burned out exit sign lights or fire doors that are blocked by furniture or boxes) are routine, leaving occupants in jeopardy. It is therefore just as important to educate users about maintaining the many life safety elements in a building so that they are functioning as designed when an emergency happens.

Recommendation 17 suggests wider stairwells and greater exit capacity to accommodate regarding counter-flow from first responders. This raises a concern about orderly and controlled egress. No research is cited regarding the effect wider stairs may have, or the possibility that evacuating occupants will simply fill the larger stairwell. Faster-moving individuals will tend to pass slower people descending the stairs, potentially leading to conflict and disruption of an orderly egress process.

Regarding the distribution of exits, the current model codes address the minimum remoteness issue. Had the stairs been more remote from each other at the World Trade Center there is no guarantee that even hardened stair enclosures would not have been totally incapacitated had the aircraft impacted the buildings at or near the more remote stair. Placing stairs further outside the core of buildings reduces their level of hardening and leaves them more vulnerable to abuse by the occupants of the building.

Recommendation 20 calls for hardening of elevators and stairway enclosures as well as additional devices that aid egress. Unfortunately, the hardening issue can be a catch-22. Although hardening may help in maintaining an element's viability

in certain emergency situations, the hardened features may be difficult for occupants to manage if they are damaged. Reports have emerged about individuals caught inside elevators at the twin towers who used various devices to escape by cutting their way through the drywall shaft. Would that have been possible in a hardened shaft? Furthermore, the occupants who discovered the single stair that remained partially open to the upper floors in WTC 2 would not have been able to remove "hardened" debris and egress those stairs.

Technology for aids to egress are encouraged. However the most promising development to assist egress in a tall building is a functioning elevator system, as proven in WTC 2.

Group 6: Improved Emergency Response

Group 6 (Improved Emergency Response) recommends technical and procedural changes to gain access to buildings and maintain effective communications and command and control in large-scale emergencies

Recommendation 21. *NIST recommends the installation of fire-protected and structurally hardened elevators to improve emergency response activities in tall buildings by providing timely emergency access to responders and allowing evacuation of mobility-impaired building occupants. Such elevators should be installed for exclusive use by emergency responders during emergencies. In tall buildings, consideration also should be given to installing such elevators for use by all occupants.*

Recommendation 22. *NIST recommends the installation, inspection, and testing of emergency communications systems, radio communications, and associated operating protocols to ensure that the systems and protocols: (1) are effective for large-scale emergencies in buildings with challenging radio frequency propagation environments; and (2) can be used to identify, locate, and track emergency responders within indoor building environments and in the field.*

Recommendation 23. *NIST recommends the establishment and implementation of detailed procedures and methods for gathering, processing, and delivering critical information through integration of relevant voice, video, graphical, and written data to enhance the situational awareness of all emergency responders. An information intelligence sector should be established to coordinate the effort for each incident.*

Recommendation 24. *NIST recommends the establishment and implementation of codes and protocols for ensuring effective and uninterrupted operation of the command and control system for large-scale building emergencies.*

AIA Response

Recommendation 21 largely duplicates recommendation 20. Existing elevator technology recalls all elevators for emergency use. Whether hardening is appropriate is a serious question; it has not been proven to be appropriate or even desirable in those locations where it has been attempted.

Group 7: Improved Procedures and Practices

Group 7 (Improved Procedures and Practices) addresses code compliance by non-governmental agencies, adoption of egress and sprinkler requirements in codes for existing buildings and maintenance of building documents over the life of the structure.

Recommendation 25. *Non-governmental and quasi-governmental entities that own or lease buildings and are not subject to building and fire safety code requirements of any governmental jurisdiction are nevertheless concerned about the safety of the building occupants and the responding emergency personnel. NIST recommends that such entities should be encouraged to provide a level of safety that equals or exceeds the level of safety that would be provided by strict compliance with the code requirements of an appropriate governmental jurisdiction. To gain broad public confidence in the safety of such buildings, NIST further recommends that it is important that as-designed and as-built safety be certified by a qualified third party, independent of the building owner(s). The process should not use self-approval for code enforcement in areas including interpretation of code provisions, design approval, product acceptance, certification of the final construction, and post-occupancy inspections over the life of the buildings.*

Recommendation 26. *NIST recommends that state and local jurisdictions should adopt and aggressively enforce available provisions in building codes to ensure that egress and sprinkler requirements are met by existing buildings. Further, occupancy*

requirements should be modified where needed (such as when there are assembly use spaces within an office building) to meet the requirements in model building codes.

Recommendation 27. *NIST recommends that building codes should incorporate a provision that requires building owners to retain documents, including supporting calculations and test data, related to building design, construction, maintenance and modifications over the entire life of the building. Means should be developed for off-site storage and maintenance of the documents. In addition, NIST recommends that relevant building information should be made available in suitably designed hard copy or electronic format for use by emergency responders. Such information should be easily accessible by responders during emergencies.*

Recommendation 28. *NIST recommend that the role of the "Design Professional in Responsible Charge" should be clarified to ensure that: (1) all appropriate design professionals (including, e.g., the fire protection engineer) are part of the design team providing the standard of care when designing buildings employing innovative or unusual fire safety systems, and (2) all appropriate design professionals (including, e.g., the structural engineer and the fire protection engineer) are part of the design team providing the standard of care when designing the structure to resist fires, in buildings that employ innovative or unusual structural and fire safety systems.*

AIA Response

Recommendations 25 and 26 call for the adoption and use of codes. *The AIA has long advocated that every jurisdiction in the Nation, at all levels of government, to use a modern building code that is comprehensive, coordinated and contemporary.* The AIA believes that the ICC family of codes, in conjunction with the NFPA electrical code, provide the "bookshelf" of codes that should be endorsed by all legislative and quasi-legislative agencies for application on all projects. Adoption of a single "bookshelf" of codes utilized by all designers, builders and operators of buildings across the Nation has been a long sought goal of the AIA to avoid confusion in the creation of the built environment.

Recommendation 28 calls for the "design professional in responsible charge" to assure that the appropriate professionals are included on each design team. This is, and has been for a long time, standard practice in this country and is demanded by the licensing criteria in all states. There appears to be a presumption that fire protection engineers and structural engineers are somehow excluded from "innovative or unusual fire safety systems." It is most likely that these designers are the ones who are proposing innovative solutions to innovative designs. It would be unethical and unprofessional to fail to include a fire protection engineer or structural engineer in such projects.

Group 8: Education and Training

Group 8 (Education and Training) calls for the skills of building and fire professionals to be upgraded through education and training of fire protection engineers, structural engineers, and architects.

Recommendation 29. *NIST recommends that continuing education curricula should be developed and programs should be implemented for training fire protection engineers and architects in structural engineering principles and design, and training structural engineers, architects, and fire protection engineers in modern fire protection principles and technologies, including fire-resistance design of structures.*

Recommendation 30. *NIST recommends that academic, professional short-course, and web-based training materials in the use of computational fire dynamics and thermostructural analysis tools should be developed and delivered to strengthen the base of available technical capabilities and human resources.*

AIA Response

Recommendations 29 and 30 call for education of members of the design and construction industry. As the only professional organization in the industry that holds its members to a standard of education (accredited degrees) and continuing education (18 hours of continuing education per year, of which at least eight must be related to health, safety and welfare), the AIA applauds NIST's call to others in the field to gain additional education.

However, education is only valuable if the information is readily understood and can be incorporated into every-day practice. While computational fire dynamics and thermostructural analysis tools may be helpful in certain circumstances, they must be of use to those that will make the decisions associated with fire resistance and fire protection and design.

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January 11, 2006

The Honorable Sherwood Boehlert
Chairman, House Committee on Science
2325 Rayburn House Office Building
Washington, DC, 20515

Dear Chairman Boehlert:

ASTM International is pleased for this opportunity to submit our comments regarding the Science Committee's hearing entitled "The Investigation of the World Trade Center Collapse: Findings, Recommendations and Next Steps."

ASTM International committees have been developing voluntary consensus standards for over 100 years. Formed in 1904, Committee E05 on Fire Standards has been providing valuable evaluation tools to advance the cause of fire safety. Today, ASTM E05 has over 500 dedicated volunteers and jurisdiction of 55 standards that help to foster a deeper understanding of fire safety issues amongst the construction, building, and public safety communities.

As you know, the National Institute of Standards and Technology (NIST) conducted a three-year building and safety investigation to study the factors contributing to the collapse of the World Trade Center buildings in New York on September 11, 2001. NIST published these findings in a series of reports. Chapter 9 of the report entitled *Final Report of the National Construction Safety Team on the Collapse of the World Trade Center Towers* contained 30 recommendations pertaining to building codes and standards.

In anticipation that the NIST recommendations would provide the technical basis for improved building and fire standards and practices, ASTM Committee E05 on Fires Standards formed an Advisory Group in 2005 for the review and implementation of those recommendations which relate to the work of ASTM Committees. Recognizing the significance that the NIST recommendations may have on some ASTM standards, and that the scope and urgency of this effort may exceed what would ordinarily be accomplished solely through voluntary efforts, the ASTM Board of Directors sought the expertise of an independent organization knowledgeable of ASTM. In June of 2005, ASTM commissioned Fires Science and Technology, Inc. to analyze the NIST reports.

In December 2005, Fires Science and Technology, Inc, produced and delivered to ASTM the attached report entitled, *An Analysis of the NIST Report on the Collapse of the World Trade Center Towers for Potential Recommendations and Impacts on ASTM Standards*. This report was reviewed by an E05 Advisory Group which included a representative from NIST as a member to ensure that this analysis was consistent with the objectives of NIST reports.

Provided in this analysis are recommendations that effect standards under the jurisdiction of eleven ASTM technical committees. The analysis provides a commentary on each of the recommendations that

are grouped by both functional topics and also indexed by the effected ASTM committees. Early in the analysis it was revealed that the series of NIST reports contained more standards and code related suggestions and recommendations than the official 30 NIST recommendations outlined in Chapter 9 of the final report, therefore the analysis was expanded to include all NIST reports in the series.

We note that the independent analysis of the NIST reports performed by Fires Science and Technology, Inc., concluded that NIST did not find any technical flaws in ASTM standards. Rather, the analysis and recommendations focused on further extensions of ASTM standards and additional applications of those standards.

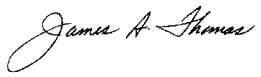
An ASTM workshop was held at the December 2005 Committee E05 meeting on "Improving the Technical Basis for Structural Design for Fire". The workshop included presentations on the NIST Report and the subsequent analysis performed by Fires Science and Technology, Inc.

In their analysis, NIST and Fires Science and Technology, Inc. provided comments on ASTM E119 Standard Test Methods for Fire Tests of Building Construction and Materials. ASTM Subcommittee E05.11 on Fire Resistance, the subcommittee of E05 responsible for standard E119, has already developed a matrix of each of the 22 recommendations resulting from the analysis concerning that standard. Some recommendations are currently in the early stages of ballot and may be approved and incorporated into E119 over the next year.

ASTM staff will coordinate the activities of all effected committees and will maintain an action plan for each recommendation in the analysis report. Each committee and its volunteer members will deliberate on its proposed work items following ASTM's established procedures to ensure that any resulting standards are developed on a full consensus basis, that all dissenting parties receive due process.

The NIST investigation has provided a unique examination of engineering practices and test methods that is expected to significantly impact future codes and standards. ASTM International wishes to continue to work with NIST and Congress to contribute to the development of safer building standards. I thank you and the members of the Science Committee for its leadership in this important area of fire safety. Please feel free to contact Jeff Grove at ASTM International's office in Washington, DC, at (202) 223-8505 if you or your staff would like addition information.

Sincerely,



James A. Thomas

An Analysis of the NIST Report on the Collapse of the World Trade Center Towers for potential recommendations and impacts on ASTM standards

Prepared on behalf of

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

By *Vytenis Babrauskas, Ph.D.*
Fire Science and Technology Inc., 9000 – 300th Place SE, Issaquah WA 98027

15 December 2005

Final report

Executive summary

The National Institute of Standards and Technology (NIST) recently completed its investigation of the World Trade Center disaster and published its final report on the investigation. This was the most extensive investigation ever of a disaster occurring in a U.S. building. The investigation had the primary purpose of determining the sequence of events that transpired and the factors that could have influenced the outcome. It had a further, educational mission with objectives (a) to determine if there was anything to be learned from any avoidable deficiencies involved in the processes of design, construction, or management of the buildings and (b) to make recommendations for U.S. building codes, standards organizations, engineering societies, and other entities involved with determining building design and construction practices for possible improvements to their processes.

Since ASTM International (ASTM) is the organization providing the largest fraction of engineering standards for use by the building industry, it had a strong interest (1) to determine if, in the course of this investigation there were any problems found with ASTM standards that should be fixed; and (2) provide its Committees with recommendations on new directions that NIST might be urging the construction industry to explore. Issues identified under the first category will receive immediate standards-making attention, while issues under the second category will involve the participation of ASTM Committee members in the longer-term process of liaison with the proposed new research activities and prompt Committee action at the time when each such item reaches the stage that it is ready for standardization action. It should be noted that ASTM is not a research organization, thus, ASTM itself will not be performing the research needed to advance the NIST proposals sufficiently so that they reach the stage where there are items ready to be standardized. Instead, it will be closely cooperating with the institutions that do carry out the research and offer them early guidance on strategies that can lead to successful standards development.

Having performed a detailed analysis of the NIST report and its recommendations, it is a pleasure to report that, generally, NIST did not identify in ASTM standards any errors, nor procedures that could be improved without mounting pertinent research programs. Of items that are within the scope of ASTM standards and do not require further research, a number of the NIST recommendations suggest that the standards could be extended or broadened in their applicability. They are discussed in detail in this Analysis and these items will directly become new business items for the pertinent Committees. By far the larger fraction of NIST recommendations involve issues where substantive technical research is required. These are also individually identified and will be brought before each of the pertinent Committees. The ASTM role will then be to maintain liaison with the organizations doing this research and to offer them guidance on preparing results in such form as to be suitable for eventual development into new ASTM standards. The majority of the items in the latter category are associated with performance-based or risk-based engineering design. The test and data requirements for these new types of engineering methods are significantly different from the requirements of traditional, prescriptive building codes and engineering approaches. Thus, ASTM welcomes NIST's explicit championing of these new approaches and looks forward to working with NIST and other research organizations that will be advancing these alternatives for the building industry.

Introduction

The attack on the World Trade Center (WTC) on September 11, 2001 was—by far—the most severe terrorist attack ever on American soil. The U.S. Federal Government responded, among other things, with the most extensive investigation in U.S. history of a building fire or collapse. It should be noted, however, that the event was primarily a ballistic attack (i.e., by airplanes), with an ensuing (and intended) fire. Thus, the investigation perforce was much more complex than would be the case for an event that was solely a fire.

The remit for the investigation conducted by the National Institute of Standards and Technology (NIST) included offering recommendations pertinent to U.S. building codes and standards, not solely establishing the mode of collapse of the buildings. ASTM International (ASTM) is the organization whose standards are the most integrally incorporated into the building codes, thus ASTM management wished to make available to ASTM technical Committees the relevant recommendations emerging from the NIST study. Since the NIST report comprised over 11,000 pages, your analyst was asked to prepare a study which would specifically identify each recommendation emerging from the NIST report that has relevance to ASTM Committees. The present Analysis constitutes this documentation.

In addition to analyzing the NIST report, your analyst also attended the *Technical Conference on the Federal Building and Fire Safety Investigation of the World Trade Center Disaster* that NIST sponsored on September 13-15, 2005. At that conference, NIST researchers presented for the first time the technical details of the entire study. They also invited a number of private-sector speakers to participate and to present their views (or the views of their organization). Private-sector recommendations made in the course of these presentations are also included in the material presented below, if these were found pertinent to ASTM standards. Some of these public comments raised issues not addressed by NIST, or helped to indicate the diversity of opinions existing on some of the issues that proved controversial. It can also be noted that, while not included in the Report proper, NIST have published all of the comments delivered at the Conference on their web site[1], making these part of the official record. Similarly, some additional clarifications offered by NIST staff during this conference (or obtained by personal communication to your analyst) are also included where they are relevant to the material discussed below.

Some preliminary comments

The present document will be referred to as "this analysis," rather than being called a "report" in order to make clear the distinction between it and the NIST report. Conversely, in the absence of specific, contrary information, "report" will be used as the term to refer to the NIST report. Furthermore, although there is one "main" report and 42 supplementary reports, "report" will generally be used to designate this work product rather than using the plural "reports." It is somewhat confusing that the main NIST report lacks a specific, distinct number[2]. Thus, in this analysis it will be referred to as "Main." In addition to the 43 reports on the collapse of the towers, NIST intends to publish a separate report on the collapse of the WTC Building 7. Since NIST have stated that this report will not appear before May 2006, its findings are not included in the present analysis. Your analyst has been informally informed by NIST that they do not anticipate introducing any significant number of new issues in that report which would affect ASTM and which have not already been covered in the report on the WTC Towers.

For simplicity, the following form of reference to the NIST report has been used: ("Report No." "Page No."; "Report No." "Page No."; ...). Thus, for example, (Main 33; 6 51; 6B 72) would refer to a

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[1] Apart from those speakers who did not supply the text of their comments.

[2] The main report carries the designation "NIST NCSTAR 1," which is the same designation that appears as the initial segment of the report number on each and every supplementary report.

recommendation which is described on p. 33 of report NIST NCSTAR 1, and on p. 51 of report NIST NCSTAR 1-6, and on p. 72 of report NIST NCSTAR 1-6B.

The page number in this Analysis have all been numbered with a prefix "A" in order to more clearly distinguish the pagination of this analysis, versus the NIST Report.

With very limited exceptions, the analysis is based solely on the NIST report. Initially, the draft issued on 23 June 2005 was reviewed, then when it became available on 26 October 2005, the Final report was reviewed. The author did not have (nor did he seek) NIST file materials that would go beyond their published report.

At the start, it should be noted that the NIST staff conducting the investigation did not ask the question "*Whether* changes to standards should be made"; instead, the stated goals [Main xxi] included developing "Recommended revisions to current codes, standards, and practices." Another goal was explicitly stated as "Improvements in the way buildings are designed, constructed, maintained, and used." Because the investigation was a direct, Congressionally-mandated response to an extremely tragic disaster, a stance of this kind is to be expected. Nonetheless, presumably ASTM, not being part of this Congressionally-mandated activity, may wish to start with the question "Are changes to ASTM standards required"? Because a multitude of ASTM standards are affected, including ones which do not presently exist but would be within the scope of ASTM operations to develop, it will almost certainly be concluded that changes to ASTM standards are desirable. But these decisions will be made by each affected Committee and the author of this analysis endeavored to maintain a neutral stance in this regard.

It should be noted that, despite the Congressional assignment to NIST, the issue of whether the overall level of safety in high-rise buildings is inadequate and needing of upgrading has been contentious. For example, a fire protection engineer, Richard Schulte, who writes a widely-read magazine column ("Fire Protection" in *Plumbing Engineer*) has described[3] the "NIST recommendations that address building fire safety represent what can only be described as a radical agenda of change in the way we protect high-rise buildings (exceeding 20 stories in height) from fire." He then argued that there has already been a "better-than-excellent fire safety record of high-rise buildings since special provisions for high-rise buildings were introduced in the model building codes used in the United States 30 years ago," that NIST has not done a cost-benefit analysis for the proposed changes (see below), and that such a cost-benefit analysis would turn out to be highly unfavorable, if it were to be done. Conversely, there have also been various advocacy groups which have argued that buildings should be built that can withstand any terrorist attack.

This analysis endeavors to present all of the report issues seen as having an impact on ASTM committees. Furthermore, to provide adequate context for this, the analysis also treats other, closely-related issues which pertain to building design even when no ASTM committees have a role in the particular subject (e.g., exit stairway width requirements). Technical recommendations which are obviously far from ASTM's scope of operation (e.g., fire department command and control activities), however, are excluded from this analysis.

In the present analysis, the concept of "recommendation" is broadly interpreted. The NIST report identifies a number of items by specifically labeling them to be "recommendations." But additional statements are contained in many instances in the report which indicate that the NIST authors believe that something should have been done, even though they do not attach the word "recommendation" to these statements. Such material was also fully included in the present analysis. Furthermore, in order to avoid making the analysis cumbersome and legalistic, the present author generally has not quoted the exact

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[3] Schulte, R., The NIST Investigation Recommendations for Changes to Building Codes, *Plumbing Engineer* 14, 16, 18, 21 (Sep. 2005).

wording of the NIST report but rather attempted to condense the meaning into a concise, clear explanation of the issue.

A difference was made by your analyst in the treatment of explicit NIST recommendations versus indirect statements, as concerns the scope of ASTM Committees. For items which are within the scope of ASTM Committees, the NIST reports were carefully searched for statements which imply that certain changes should be made, even when the formal NIST recommendations do not mention the particular issue. But for items which are not within the scope of any ASTM Committees, mention in this Analysis is generally made only of formal Recommendations and not of other issues which are only alluded to.

Generally, it can be summarized that NIST recommendations do not find technical flaws in ASTM standards. (Technical flaws would be issues such as insufficient data recording, lack of reproducibility, lack of clarity, ambiguousness of procedures, etc.). Instead, the recommendations typically focus on further extensions of ASTM standards or additional applications for them.

In order to make this analysis the most readily usable by ASTM Committees, the analysis is presented twice, first organized according to functional topics, then organized according to the affected ASTM standard, or the ASTM Committee (and Subcommittee) scope of operation. In the second section (analysis according to affected standard) recommendations and issues which are obviously far removed from the sphere of operations of ASTM Committees have generally been omitted, even though many such items were included in the first section.

In the case of many fires and other disasters, tragic outcomes have been at least partly attributed to violations of codes and standards. However, in the case of the World Trade Center disaster, NIST specifically concluded that any "departures from the building codes and standards did not have a significant effect on the outcome of September 11." However, NIST concluded that while a number of factors that it identified in their study would have had no beneficial outcome on the 9/11 disaster, these findings still should be considered because they may make a crucial impact on life safety in the future.

NIST did not order or categorize their Recommendations according priority. Thus, in this Analysis there is also no rank-ordering used for NIST recommendations. Your analyst assumes that establishing priorities will be done individually within each relevant ASTM Subcommittee.

NIST correctly point out (Main 179) that there had never been previously an incident "in which the total collapse of a high-rise building occurred so rapidly and with little warning." Thus, ASTM committees will need to consider that any changes they make to ASTM standards should have some generality, as opposed to responding to the parameters of a unique event.

The Main report is obviously intended as a summary of the whole NIST project, with technical details being given in the 42 supplementary documents. In a number of cases, however, a recommendation is found only in the Main report and its underlying basis is not described elsewhere in the project documents. In several such cases, there are difficulties in understanding the exact implication of the recommendation (and the basis for the recommendation), since background material was not supplied.

Your analyst would like to emphasize that he was *not* requested to offer personal opinions on the merits of the various NIST recommendations. His task was to prepare a document summarizing the NIST recommendations and organizing this material according to the ASTM Committee or Subcommittee affected, and this constitutes the entire scope of this Analysis.

A note on costs

The scope of the NIST project did not include assessment of costs of any proposed changes to the building design or regulation process. This is appropriate, since NIST is not a regulatory agency. In the case of ASTM, however, the standards discussed here are all standards developed primarily—or exclusively—for the building codes. Building code bodies must, of necessity, evaluate proposals giving due consideration not just to the technical merit but also to the costs associated. Thus, the Committees in charge of the ASTM standards discussed here, in order not to defeat the utility of these standards to the building codes, will also have to consider whether such revisions are likely to be acceptable to the building codes from the economic viewpoint.

Listing of the documents reviewed (only the initial portion of long titles)

No.	Pages	Title
Main	**298**	**Final Report on the Collapse of the World Trade Center Towers**
1	280	**Report on project 1: Design, Construction, and Maintenance of Structural and**
1A	554	Design and Construction of Structural Systems
1B	272	Comparison of Building Code Structural Requirements
1C	392	Maintenance and Modifications to Structural Systems
1D	202	Fire Protection and Life Safety Provisions Applied to the Design and Construction of
1E	100	Comparison of Codes, Standards, and Practices in Use at the Time of Design and
1F	92	Comparison of 1968 and Current (2003) New York City Building Code Provisions
1G	64	Amendments to the Fire Protection and Life Safety Provisions of the New York City
1H	142	Post-Construction Modifications to Fire Protection and Life Safety Systems of the
1I	46	Post-Construction Modifications to Fire Protection, Life Safety, and Structural
IJ	84	Documentation of the Fuel System for Emergency Power in World Trade Center 7
2	462	**Report on project 2: Baseline Structural Performance and Aircraft Impact**
2A	230	Reference Structural Models and Baseline Performance Analysis of the World Trade
2B	508	Analysis of Aircraft Impacts into the World Trade Center Towers
3	184	**Report on project 3: Mechanical and Metallurgical Analysis of Structural Steel**
3A	86	Contemporaneous Structural Steel Specifications
3B	112	Steel Inventory and Identification
3C	594	Damage and Failure Modes of Structural Steel Components
3D	322	Mechanical Properties of Structural Steels
3E	162	Physical Properties of Structural Steels
4	138	**Report on project 4: Active Fire Protection Systems**
4A	140	Post-Construction Fires prior to September 11, 2001
4B	278	Fire Suppression Systems
4C	148	Fire Alarm Systems
4D	248	Smoke Management Systems
5	240	**Report on project 5: Reconstruction of the Fires in the World Trade Center**
5A	1122	Visual Evidence, Damage Estimates, and Timeline Analysis
5B	352	Experiments and Modeling of Structural Steel Elements Exposed to Fire
5C	130	Fire Tests of Single Office Workstations
5D	146	Reaction of Ceiling Tile Systems to Shocks
5E	158	Experiments and Modeling of Multiple Workstations Burning in a Compartment
5F	164	Computer Simulation of the Fires in the World Trade Center Towers
5G	338	Fire Structure Interface and Thermal Response of the World Trade Center Towers
6	470	**Report on project 6: Structural Fire Response and Probable Collapse**
6A	326	Passive Fire Protection
6B	202	Fire Resistance Tests of the Floor Truss Systems
6C	252	Component, Connection, and Subsystem Structural Analysis
6D	480	Global Structural Analysis of the Response of the World Trade Center Towers to
7	298	**Report on project 7: Occupant Behavior, Egress, and Emergency**
7A	70	Analysis of Published Accounts of the World Trade Center Evacuation (230 pgs.)
7B	79	Technical Documentation for Survey Administration: Questionnaires, Interviews, and
8	808	**Report on project 8: The Emergency Response Operations**
Total	11,773	

Analysis according to functional topics

In this Section, the recommendations are presented and the affected ASTM work is identified. For recommendations that pertain to existing ASTM standards, the format used is "Affected: ASTM X XXXX," where "X XXXX" is the alphanumeric designation of the standard. For recommendations that fall within ASTM scope of operation, but where a standard does not currently exist, the format used is: "Affected: ASTM A99.99," where "A99.99" denotes the identification of the Subcommittee. In cases where the recommendation affects the entire Committee, the decimal modifier is omitted. Other affected organizations are designated by their customary acronyms[4]. The abbreviations for the other organizations are:

ACI – American Concrete Institute
AISC – American Institute of Steel Construction
ASCE – American Society of Civil Engineers
ASHRAE – American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME – American Society of Mechanical Engineers
GA – Gypsum Association
ICC – International Code Council
NFPA – National Fire Protection Association
SEI – Structural Engineering Institute
SFPE – Society of Fire Protection Engineers
UL – Underwriters Laboratories.

While not specifically identified here, it should be noted that a number of the recommendations that are directed at ASTM, NFPA, and other organizations identified herein will also be pertinent to ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission).

General provisions

NIST recommends that members of the public and representatives of building occupants play a more active role in the development of codes and standards (Main 201). *Affected: ASTM management.*

NIST recommends that jurisdictions aggressively adopt and enforce code provisions for existing buildings to ensure that they have adequate egress and sprinkler functionality (Main 221). *Affected: local authorities.*

NIST recommends that performance-based standards and code provisions be established as an alternative to prescriptive requirements (Main 211). Furthermore, NIST believes that this should include at least four aspects: (a) development of design methodologies and performance criteria; (b) development of appropriate multifloor fire scenarios; (c) development of publicly-available thermostructural design software; and (d) development of test methods needed to support performance-based design methods. For (d), NIST specifically point out that they view that design fires will have to be developed which are specifically tailored to represent the full burnout of fires. *Affected: ASTM management, NFPA, SFPE.*

NIST recommends that entities which have the authority to build and operate buildings outside the purview of established building codes be urged to provide levels of safety equivalent to code-complying structures and that this be based on third-party review, not on self-certification (Main 221). *Affected: governmental and quasi-governmental agencies.*

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[4] The focus of this Analysis is on ASTM activities; other organizations are mentioned only for clarity and context, thus, lack of mention of such additional organizations is not to be interpreted as a comment that their role or potential involvement is being minimized.

NIST recommends that fire protection engineers and structural engineers be required to be a part of the design team for buildings involving innovative or unusual fire safety systems (Main 222). *Affected: ASCE, ICC, NFPA, SEI, SFPE, local authorities, and other institutions.*

NIST recommends that education curricula for architects, fire protection engineers, and structural engineers be improved, specifically in offering instruction on modern fire-protection technologies and fire-resistance design of structures (Main 222). *Affected: AIA, ASCE, SEI, SFPE, and other institutions.*

NIST recommends that training materials on use of computational fire dynamics and thermostructural analysis be developed and delivered (Main 223). *Affected: ASTM E05.33, ASCE, SFPE.*

Some portions of the NIST report contain a Glossary (e.g., 1G xv). This glossary contains some terms which either do not occur in ASTM E 176 or have a different definition. Since presumably NIST concluded that their definitions have some advantages, ASTM should consider these items. *Affected: ASTM E 176.*

Enforcement of safety provisions for existing buildings; building operations of existing buildings

NIST recommends that building codes and standards be rigorously enforced and that entities doing this enforcement be well-trained and managed (Main xliii). *Affected: local authorities.*

NIST recommends that building plans and building design documents be retained for the life of the building at an off-site location and also that means be developed to deliver this information rapidly to emergency responders (Main 194, 221-222; 1 184). *Affected: ASTM E06, ICC, NFPA.*

NIST recommends that existing buildings be surveyed to determine if their safety is adequate in light of the NIST findings and to upgrade their safety if it is determined that it is not (Main xliii). *Affected: ICC, NFPA.*

NIST recommends that field inspections be conducted to make sure that spray-on fireproofing conforms to the requirements laid down for it (Main 198). *Affected: ASTM E06.21, ICC, local authorities, NFPA.*

Movement facilities for occupants and emergency personnel

NIST recommends that education campaigns be mounted to enhance the preparedness of building occupants to evacuate in the case of emergency (Main 214-215). *Affected: fire departments.*

NIST recommends that tall buildings be designed to permit the timely, full evacuation of occupants (Main 215; 1 155; 1 158). In other words, the WTC disaster demonstrated that the concept of refuge shelters or a "defend-in-place" strategy may not be workable. The NIST recommendations indirectly imply that occupant loadings used in building codes should be reexamined, since the issue is provoked partly because of the classification of restaurants by building codes as "public assembly," even where the nature of the establishment is such that dense crowds do not occur there (1 156). *Affected: ICC, NFPA.*

NIST recommends that fire drills be mandatory and not optional (Main xxxix). *Affected: local authorities.*

NIST recommends that that, in cases where several similar buildings exist on one site, clear signs be posted in each building allowing emergency responders to unambiguously ascertain the identity of building that they are in (Main 171). *Affected: local authorities, NFPA.*

NIST recommends that improved egress analysis models and design methodologies should be developed (Main 215). *Affected: ASTM E05.33, SFPE.*

NIST recommends that new technologies for improving evacuation be considered, including protected and hardened elevators, exterior escape devices, and stairwell navigation devices (Main 218). *Affected: ASTM E06.77, ASME A17.1, ICC, NFPA, SFPE.*

NIST recommends that mobility-challenged occupants be provided means for self-evacuation (Main 216). This is understood to most likely consist of fire-resistive and structurally-hardened elevators. *Affected: ASTM E05.11, ASME A17.1, ICC, NFPA.*

NIST recommends that fire-protected elevators be developed as one available means for emergency egress and firefighter access and that building code provisions containing an across-the-board prohibition of such use of elevators be abrogated (1 161; 1 191). *Affected: ASME A17.1, ICC, NFPA, ASTM E05.11.*

NIST recommends (Main xxxix) that building code egress provisions (specifically, stairway width) be re-examined, even though they proved sufficient for the light occupant that was present at WTC, since they would have been inadequate for a normal occupant load in the WTC towers. Consequently, NIST recommends that these be upgraded to provide for successful exiting of the entire occupant load of a building. *Affected: ICC, NFPA.*

NIST recommends that egress facilities be intuitive and obvious during an evacuation (Main 216). This includes use of consistent layouts, standard signage, and avoidance of confusing geometries. NIST found that evacuation routes requiring the use of transfer hallways (i.e., a scheme whereby an evacuee has to exit one stairway, go down a corridor, then enter another stairway in order to continue the downward progress) are confusing to use during an emergency (Main xxxix; 7 168) and slow down the evacuation (7 28). NIST explains (1 152) that such digressions were arranged not because of necessity but because evidently mechanical equipment layouts were made prior to arranging for occupant exit facilities. The recommendation evidently considers that the priorities should be reversed. *Affected: ICC, local authorities, NFPA.*

NIST implies that building codes should consider making explicit provisions, where suitable, that roofs be accessible for emergency evacuation or rescue (Main 26). *Affected: ICC, local authorities, NFPA.*

NIST recommends that evacuation facilities be designed so that occupants and emergency personnel do not counterflow on the same staircase or that the capacity be provided for this movement (Main 31, 190, 215). *Affected: ASTM E06.77, ICC, NFPA.*

NIST recommends that the height of the building be considered in establishing the requirements for egress stairways (Main 58). *Affected: ICC, NFPA.*

NIST recommends that stairwells be widely spaced, not clustered together closely (Main 58; Main 216; 1 168). In addition, in his comments Jake Pauls presented the view that staircases which are separated by less than ½ the diagonal distance of the building should not be considered as widely-spaced. *Affected: ICC, NFPA.*

NIST recommends that stairway shafts be designed to resist mechanical forces such as earthquakes, gas explosions, impacts, or hurricanes (Main 216). *Affected: E05.11, ICC, NFPA, SFPE.*

NIST recommends that stairway evacuation times not be based on results from non-emergency drills, since real-incident speeds were shown to be only half those recorded during drills (Main 190). *Affected: ICC, NFPA.*

NIST recommends that smoke-proof stairways be used where appropriate (Main 196). *Affected: ICC, NFPA.*

In his comments, Kevin Doherty recommended that photoluminescent materials be adopted for marking the exit routes and their requirements be similar to those in ISO 16069. *Affected: ICC, NFPA.*

Two individuals offering comments, Roberto Catalan and Jonathan Shimshoni, offered the recommendation that external escape devices be specifically utilized for high-rise buildings. *Affected: ASTM E06.77, ICC, NFPA.*

Fire alarm and communication systems

NIST recommends that performance and redundancy of active fire protection systems be enhanced in tall buildings (Main 213). Fire alarm systems are included among "active fire protection systems." *Affected: ICC, NFPA, UL.*

NIST recommends that better inspection and testing be conducted in order to ensure that communications systems will be functional when needed (Main 219). *Affected: ICC, local authorities, NFPA.*

NIST recommends that consideration be given to making fire alarm systems provide information at the fire department command station location which is more fully descriptive of fire conditions in various areas of a building on fire (Main 187; Main 213). They also urge the adoption of systems to provide real-time indication of water flows from suppression systems and indicate that standards should be developed for this purpose. *Affected: ICC, NFPA, UL.*

NIST recommends that provisions be made for alarm systems to provide feedback information to the fire command station as to whether announcements that are intended to be delivered are actually being transmitted (Main 187). *Affected: ICC, NFPA, UL.*

NIST recommends that provisions be made for transmitting critical, real-time information to an additional location that is not within the building, along with means of storing this information for subsequent analysis (Main 187, 214). In addition, during his conference presentation, NIST's Dr. Grosshandler recommended that this include the alternative (or supplement) of an on-site, fire resistive "black box." The latter recommendation was also made in his presentation by John P. Couch (Kori Technology). *Affected: ASTM E05.33, ICC, NFPA.*

NIST recommends that improved systems be developed for reliably communicating information to building occupants in times of emergency (Main 217). This includes more robust design of public address systems and better utilization of radio communications (the Integrated Public Alert and Warning System, formerly called Emergency Broadcast System; and also Community Emergency Alert Networks). *Affected: ICC, NFPA, UL.*

NIST points out that off-site alarm monitoring was not mandated for the WTC (1 169), implying that this should be a requirement for important buildings. *Affected: ICC, NFPA.*

NIST recommends that alarm signaling and communications equipment be made less vulnerable and specifically that consideration be given to avoiding centralizing equipment and wiring at a locale that could be incapacitated during a fire or a bombing (1 169). *Affected: ICC, NFPA, UL.*

Fire suppression systems

NIST recommends that performance and redundancy of active fire protection systems be enhanced in tall buildings (Main 213). Automatic sprinklers and standpipes are included among "active fire protection systems." *Affected: ICC, NFPA.*

NIST recommends that authorities "require installation of sprinklers in existing buildings" but it is not clear what types of buildings this is intended to encompass (1 190). *Affected: ICC, NFPA.*

NIST recommends that "sprinkler tradeoff" provisions be reviewed, with the implication that they should be tightened or eliminated (1 190-191). In his conference presentation, Robert Polk (National Assn. of State Fire Marshals) made the same recommendation. Similarly, in his presentation, Stephen Szoke (Portland Cement Assn.) recommended that fire resistance requirements not be reduced and that economic considerations not enter into consideration. Conversely, Ron Burton (BOMA) argued in favor of keeping tradeoff provisions. Even further, Richard Schulte (Schulte & Associates) made extensive recommendations that fire resistance provisions do not need to be made tougher and could be relaxed, since sprinkler protection can be relied upon in office occupancies that are not undergoing an airplane attack. This was based on NFPA statistics showing nearly-zero life loss due to fire in U.S. office buildings which are not being attacked by airplanes. *Affected: ICC, NFPA.*

NIST recommends that the sprinkler system of a building not rely on a single supply pipe (Main xl). *Affected: ICC, NFPA.*

NIST recommends that design requirements for automatic sprinkler systems take into account the height, size, and threat level for the building (Main 186). *Affected: ICC, NFPA.*

NIST notes that, in the WTC, the design areas for the sprinkler systems were greatly smaller than the undivided space present on that particular floor, implying that either the design area for a sprinkler system should be made equal to the undivided area present, or else that such spaces be subdivided by fire-resistive partitions into areas no bigger than the sprinkler design area (Main 187-188). *Affected: ICC, NFPA.*

NIST recommends that that, where multiple or secondary sprinkler water supply systems are provided, there be automatic (rather than manual) means for engaging the alternate source in the case of non-delivery from the primary source (Main 188). *Affected: ICC, NFPA.*

NIST points out that NYC, in contrast to other jurisdictions, never abandoned Code requirements for occupant hoselines, to be substituted by fire extinguisher provisions (1 151). Your analyst adds the historical comment that most building codes dropped occupant hoseline requirements due to publicity given to a circa-1970 GSA study. The latter deprecated occupant hoselines since it concluded that they were often not properly maintained and that occupants were often not tutored in their proper use. However, the consequence of this policy is that medium-capacity extinguishing devices were replaced by ones of very small capacity. *Affected: ICC, NFPA.*

NIST recommends that maximum spacings for standpipes be established and not violated due to design convenience (1 154). *Affected: ICC, NFPA.*

During his conference presentation, Mark Hopkins (Hughes Associates) pointed out that more reliable sprinkler systems could be designed if NFPA 13 were changed to require that a single-point failure would not disable the sprinkler system of an entire floor. *Affected: NFPA 13.*

Smoke management systems

NIST recommends that performance and redundancy of active fire protection systems be enhanced in tall buildings (Main 213). Smoke management systems are included among "active fire protection systems." *Affected: ASHRAE, ICC, NFPA.*

NIST recommends that active smoke management systems be mandated for complex buildings (Main 199). *Affected: ASHRAE, ICC, NFPA.*

NIST recommends that smoke venting systems use automatic controls and not rely on manual activation (Main 188). *Affected: ASHRAE, ICC, NFPA.*

Fire resistance

NIST make a generalized recommendation that the fire resistance testing standards are based largely on research that is roughly a century-old and should be upgraded (Main 209). *Affected: ASTM E 119, E 814, E 1529, E 1725, E 1966, E 2010, E 2074, E 2226, E 2336; AIC, AISC, ASCE, SFPE.*

NIST noted (6 13) that nomenclature of E 119 is inconsistent and that the same concept is variously referred to as "period of fire resistance," "performance," "exposure," or "classification." NIST also implies that the term should preferably be "fire resistance rating." *Affected: ASTM E 176, ASTM E05.11.*

NIST recommends that fire resistance requirements be re-formulated on a risk basis[5] (Main 208; 1 187). Specifically, they recommend that the following factors be included in establishing the risk level: time required for full evacuation of occupants; time required for burnout of the fuel content; appropriate credits for active fire protection systems, while still maintaining redundancy; explicit provisions for redundancy; spaces with unusual fuel concentrations. NIST specifically points out that evacuation (and fire department access) to extremely tall buildings is difficult and that present Code requirements do not consider the time that may be required for doing this (1 187). *Affected: ASTM E05.11, ASTM E05.33, ACI, AISC, ASCE, ICC, NFPA, SFPE.*

NIST testing results (6 49) indicate that failure to support load may not be realistically expressed by the temperatures prescribed in ASTM E 119 as defining failure of load-carrying ability (593°C average, 704°C max). While they do not explicitly offer a recommendation on this point, the test results they present show that load was actually being carried roughly 2× longer than obtained by temperature end-point criteria (6B 94-96). Thus, the implicit recommendation is that the scheme contained in ASTM E 119 wherein collapse times are imputed on the basis of a certain prescribed steel temperature must be re-examined, and that such a temperature may be dependent on a number of factors and not simply constitute a fixed constant characteristic of ASTM A 36 (or similar) steel. In any case, floor/beam ratings based on steel beam temperatures should not be termed "unrestrained ratings", as the current ASTM E119 suggests, because it misleads the users to associate these ratings with unrestrained tests. Ratings based on steel beam temperatures should be appropriately termed (e.g. "beam temperature rating") in ASTM E119. *Affected: ASTM E 119.*

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[5] It is relevant to cite that there has been very recent progress on this topic. The Japanese Society of Steel Construction, in cooperation with The Council on Tall Buildings and Urban Habitat (CTBUH), produced two relevant publications: Guidelines for Collapse Control Design, Volume I – Design and Volume II – Research. (September 2005).

NIST recommends that tall buildings be able to resist uncontrolled, full burnout without local or global collapse even with failure of the sprinkler system (if present) and unavailability of manual firefighting (Main 211; 1 189-190). Note that "collapse" only is being discussed, not flame or heat transmission. In ISO jargon pertinent to fire resistance tests, this means that here only R is to be considered of the three fire resistance criteria: R (stability), E (integrity), and I (insulation). In his conference presentation, Roger Plank (University of Sheffield) discussed studies he had performed which indicated that, while global collapse should be prevented, local collapse may be permitted because, in some situations, such collapse will not have negative effects, e.g., will not produce cascading destruction. This same point was made by Barbara Lane (Arup), who pointed to the fact that her firm had done modeling which also indicated that local collapse is not necessarily to be prohibited. In his conference presentation, Stephen Szoke (Portland Cement Assn.) argued that even provisions against total collapse are not necessary and that, instead, it should be sufficient to have building code provisions that control the impact of a falling building, if it does undergo total collapse, e.g., that open space adjacent to the building may be acceptable. *Affected: ASTM E05.11, ICC, NFPA.*

NIST recommends that thermostructural design methodologies be developed (1 188). In her conference presentation, Barbara Lane (Arup) emphasized that this should not be taken to mean that prescriptive designs should be discontinued, but, rather, that thermostructural design will only be done for large projects that are risk-based. In his conference presentation, Michael Faber (ETH Zurich) discussed his research which indicated that risk-based design methodologies must be formulated to include an assessment of costs and that cost-conscious designs be produced. *Affected: ASTM E05.11, ASTM E05.32, ASTM E05.33, ACI, AISC, ASCE, ICC, NFPA.*

NIST recommends that design fires be developed to support "performance-based" design (1 188) since NIST considers that the standard time-temperature curve is not appropriate for this. In addition, the NIST report specifically notes (5G 91; 5G 118) that time/temperature curves produced by their computer simulations "do not resemble 'standard' time temperature curves used in furnace tests of structural elements." The latter statement is understood not as a criticism of the ASTM E 119 time/temperature curve for use in traditional, prescriptive applications, but, rather, that a different concept of design fires will be needed for "performance-based" designs. In her conference presentation, Barbara Lane (Arup) argued in favor of carefully-crafted, realistic design fires, while Roger Plank (University of Sheffield) pointed out that design fires which do not include a decay (burnout) portion are never realistic. *Affected: ASTM E 119, ASTM E05.32, ASTM E05.33, SFPE.*

NIST recommends that the relationship between performance in real fires and fire resistance ratings of assemblies be studied (Main 209). *Affected: ASTM E05.11, ASTM E05.32, ASTM E05.33, ACI, AISC, ASCE, GA, SFPE.*

NIST recommends that repeatability and reproducibility of fire resistance tests be further studied, especially in view of the fact that furnace tests are normally not run in replicate (Main 209). *Affected: ASTM E05.11, ASTM E05.32, ASTM E05.33.*

In his presentation, Stephen Szoke (Portland Cement Assn.) recommended that furnace designs for conducting fire resistance tests be standardized, in order to improve test reproducibility. *Affected: ASTM E 119.*

NIST recommends that studies should be done to ensure that realistic fire-test ratings are being produced for assemblies containing materials that have improved elevated-temperature properties (Main 209). *Affected: E05.11, E05.32, E05.33, A01, C09, C11, ACI, AISC, GA.*

NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming. *Affected: ASTM E06.21, ASTM E05.11, ASTM E05.32, ASTM A01, ASTM C09, ASTM C11.*

NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 213). *Affected: ASTM E05.11, ASTM E05.32, ASTM E05.33, ASTM A01, ASTM C09, ASTM C11, ACI 318, AISC.*

NIST recommends that guidance be developed for extrapolating fire resistance test data to real-life assemblies which are larger than the furnace test specimen (Main 209). Specifically, NIST noted that shorter specimens gave longer ASTM E 119 fire resistance ratings (6B 102), also noted that the specimens normally tested in standard ASTM E 119 furnaces are much shorter than in real-life buildings, that even the "longer" NIST specimens were shorter than in real life, and consequently recommend that the means be developed to realistically apply ASTM E 119 fire resistance ratings to structures where specimen length is greater than in the test furnace (6B 106). *Affected: ASTM E 119, E 2032, ACI, AISC, ASCE, SFPE,UL.*

NIST recommends that fire resistance tests be improved to refine the definition of structural limit states and the means used to measure them (Main 209). *Affected: ASTM E05.11, ACI, AISC.*

NIST recommends that ASTM E 119 tests be continued until failure to carry load occurs, and not be stopped because some different criterion (e.g., transmission of heat or flame) has been exceeded (6B xxxiii). This is because, in a real building, the opportunity to fail via thermal transmission may never occur, and it would be valuable to have data on how long a particular assembly can actually support load. In his conference presentation, Roger Plank (University of Sheffield) also spoke to the importance of this recommendation. *Affected: ASTM E05.11.*

NIST describes the calculations performed by their consultant to produce the "maximum load condition" according to ASTM E 119 (6B 43-45). These resulted in the 17-ft tests being run with a 293 psf uniform superimposed load, plus an 86 psf concentrated superimposed load. A surprisingly-short fire resistance rating was reported for one of the 17-ft tests (Test 4), and this was possibly, in part, due to excessive loading requirements contained in ASTM E 119. NIST presented these facts without making a recommendation, but your analyst concludes that a recommendation to ASTM is implied: Reexamine the superimposed-load requirements in ASTM E 119. *Affected: ASTM E 119.*

NIST recommends that improved procedures be developed for extension of data (Main 209). Your analyst notes here that NIST does not reference ASTM E 2032 and is possibly unaware that ASTM already has provided guidance on this topic. *Affected: ASTM E 2032.*

NIST recommends that the effect of restraint be further studied, especially for the case of longer, more flexible members (Main 209). *Affected: ASTM E 119, ACI, AISC, ASCE.*

NIST recommends that, irrespective of the presence of sprinklers, compartmentation be used to limit the open area to a size consistent with feasible firefighting, which they suggest may be approximately 12,000 ft^2 (Main 208). *Affected: ICC, NFPA.*

NIST recommends that provisions for fire sprinklers should not automatically allow elimination of compartmentation requirements (Main 53). *Affected: ICC, NFPA.*

NIST recommends that structural integrity of stairway shaft enclosures include improved provisions to resist non-fire caused mechanical loadings (Main xxxix; 1 166; 1 185). This implies that fire resistance classifications might usefully include a fourth category beyond the traditional three: R (stability), E (integrity), and I (insulation). The fourth category would presumably involve some sort of lateral mechanical loading which is more severe than the lateral loading already provided during hose stream testing. *Affected: ASTM E05.11, AIC, AISC, ASCE, ICC, NFPA.*

NIST recommends that enclosure walls for stairway be designed as load-bearing elements, not as partition walls, in order to better withstand accidental mechanical loadings (Main 195). *Affected: ICC, NFPA.*

NIST recommends that testing be mandated in cases where adequate data do not exist to allow an assembly to be qualified on the basis of past tests (Main 197; 1 187). *Affected: ICC, local authorities, NFPA.*

NIST recommends that more conservative fire resistance provisions be applied to the elements of a building identified as the structural frame (Main 198). Specifically, NIST suggests that the "structural frame approach" be used in determining the required fire resistance ratings (Main 198, 211). NIST further explains that they are referring to the following statement in the IBC: "The structural frame shall be considered to be the columns and the girders, beams, trusses and spandrels having direct connections to the columns and bracing members designed to carry gravity loads." [footnote to Table 601]. In his conference presentation, however, Roger Plank (University of Sheffield) pointed out that this should be carefully considered, because there are some practical problems with this approach. Instead, he pointed out that a more viable design option can comprise using a strong "meta-grid" with a weaker subgrid as the repeating element in the building frame. *Affected: ICC, NFPA.*

NIST recommends that clear provisions be established for rating of connections or connecting elements, especially ones that join members having two different fire-resistance rating requirements (Main 198, 209). *Affected: ASTM E05.11, ICC, NFPA.*

NIST recommends that connections or connecting elements joining two members of disparate fire ratings be rated for the more severe of these (1 189). *Affected: ASTM E05.11, ICC, NFPA.*

NIST recommends that windows be required to resist breakage in order to reduce the potential to supply oxygen to the fire (Main 200). *Affected: ASTM E05.11, ICC, NFPA.*

NIST recommends that elevators for both occupant evacuation and responder access be designed and constructed to have appropriate fire resistance and resistance to accidental mechanical loadings (Main 200). *Affected: ASTM E05.11, ASME A17.1, ICC, NFPA.*

NIST recommends that a study should be made of "effect of the combination of loading and exposure (time-temperature profile) required to adequately represent expected conditions" (Main 209). Your analyst did not understand the meaning of this statement and queried NIST's Dr. Grosshandler, who explained that NIST meant that, in performing a thermostructural design, a realistic, time-varying fire temperature curve should be used. *Affected: AIC, AISC, ASCE, SFPE.*

NIST notes that actual fire-resistance ratings required will be dependent on the 'Type' of building selected by the designer and points out the illogical consequence that the tallest buildings in New York City were assigned a Type lower than the maximum i.e., 1B and not 1A (1 164, 186). The implied recommendation is that code provisions requiring a minimum 'Type' need to be tightened up and the choice should not be left up to the designer. *Affected: ICC, local authorities, NFPA.*

NIST recommends that, for fire resistance ratings of walls to be meaningful, it must be mandated that walls be carried up to the floor slab above, not stopped at the ceiling (1 168; 1 190). *Affected: ICC, local authorities, NFPA.*

In their tests, NIST documented that the unexposed-face temperature criterion can sometimes be exceeded at a time greatly less than the time of the structural failure (6B 96). In such cases, it is essential that the temperature criterion not be unreasonably over-conservative, since it will be the governing classification criterion. A review of the literature by your analyst (provided separately to ASTM) indicates that the present values are over-conservative, and should be changed. *Affected: ASTM E 119.*

In his conference presentation, NIST's Dr. Sunder recommended that use should be considered of "sacrificial" truss-column connections, so that a floor truss might fall off its seat rather than buckling the column to which it is attached. *Affected: ASTM E 119, AISC, ASCE.*

NIST's Dr. Gross informed your analyst that the reason that cotton-waste ignition times were not recorded among the test results is that UL does not perform the cotton-waste target test when conducting floor tests, because they do not consider that they can practically and safely reach the needed portions of the specimen with a cotton-waste target. Since Sec. 31.1.1 of ASTM E 119 requires this target testing, ASTM should consider whether the requirement should be changed. *Affected: ASTM E 119.*

In his presentation, Joseph Treadway (UL) pointed out that floor tests sometimes have to be prematurely discontinued because the specimen sags sufficiently to come into contact with the furnace thermocouples. The implied recommendation is that the ASTM E 119 provisions be changed to either increase the thermocouple-to-specimen distance, or that a means be developed for adjusting thermocouple spacing during the course of the test. *Affected: ASTM E 119.*

ASTM should consider developing a standard for exposing floor systems from both sides, for exceptional structures which require utmost levels of protection. This recommendation was offered by NIST's Dr. Prasad in his conference presentation. In addition, in her comments, Barbara Lane (Arup) explicitly considered the need to model such fires. *Affected: ASTM E05.11, ACI, AIA, AISC, ASCE, SFPE.*

In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that no fire resistance tests be so configured that the end supports are outside the heated zone, because such tests produce misleadingly positive results. *Affected: ASTM E 119.*

In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that tests be run where beam-column connections are tested in furnaces specifically designed for this type. He explained that two such furnaces have been built in Taiwan. In his presentation, Roger Plank (University of Sheffield) reaffirmed the importance of accurately assessing the role of beam-column connections, but pointed out that successful finite-element modeling is already being done on such connections. In his presentation, Stephen Szoke (Portland Cement Assn.) pointed out that it can be economically unaffordable to test beam-column connections, since this would multiply enormously the number of tests needed. *Affected: ASTM E 119.*

In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that loading of columns in ASTM E 119 tests be required to have a realistic amount of axial eccentricity. This recommendation was made in view of his having noted that column tests sometimes give spuriously favorable results due to an unrealistically small eccentricity imposed by the loading rig. *Affected: ASTM E 119.*

Structural design requirements

NIST recommends that code provisions against progressive collapse be considered (Main 54; Main 195; Main 205). *Affected: ASTM E06, ACI, AISC, ASCE, ICC, NFPA, SFPE.*

NIST effectively suggests that important buildings be required to have a periodic inspection program of the structural members of the building (1 117-133; 1C whole report). Fire resistance features comprise one, but small, portion of this; mainly the intention is to ensure that the entire load-carrying system is still functioning as designed. *Affected: ASTM E06, ICC, local authorities, NFPA.*

NIST recommends that drift of the top of the building under strong wind conditions be considered in design (Main 94; Main 207). *Affected: ASCE 7, ACI 318, AISC, ASCE, ICC, NFPA, SFPE.*

NIST notes that wind tunnel testing is superior to simple code-sanctioned formulas for assessing the effect of wind (1 185) and recommends that design methods be evolved for estimating wind loads and their effects on tall buildings based on using wind tunnel testing data and directional wind speed data (Main 207). *Affected: ASTM E 1300, ASCE 7, ICC, NFPA, SFPE.*

NIST recommends that standards be developed for wind tunnel testing of prototype structures for resistance to wind load (Main 207). The need for standards is motivated by the fact that NIST found major (40%) discrepancies when two firms conducted such retrospective WTC tests independently (Main 179). *Affected: ASTM E 1300, ASCE, ICC, NFPA.*

Protection against aircraft

NIST specifically points out that buildings for use by the general population are normally not designed to withstand the impact of large jetliners and they do *not* recommend that this philosophy be changed (Main xli). *Affected: ICC, NFPA.*

Spray-on fireproofing (sprayed fire-resistive materials, SFRM)

NIST recommends that means be established to ascertain the spray-on fireproofing retains its required properties throughout the lifetime of the building and withstands the effects of shock, impact, vibration, and abrasion (Main 198; Main 210; 1 188). *Affected: ASTM E06.21; UL 2431 (draft).*

NIST recommends that the effects of elevated temperatures on the thermal properties and the bond strength of these materials be studied (Main 210). *Affected: ASTM E06.21.*

NIST recommends that standardized procedures be established for field inspection of spray-on fireproofing, including determination that a sufficient thickness has been applied (Main 210; 1 188). *Affected: ASTM E06.21, AWCI (Association of Wall and Ceiling Industries) 12.*

NIST found that adhesive strength is greatly reduced when SFRMs are sprayed onto primed steel surfaces (Main 186; 6 330). They also presented data (6A 101) that the adhesion strength depends strongly on the type of the primer that is used, when a primer is used. Thus, the recommendation is that either SFRMs be applied onto bare steel, or that ASTM E 736 testing be done solely with the primer type that will actually be used. *Affected: ASTM E 736, ASTM D01.*

NIST recommends that methods be developed for "predicting the effectiveness of spray-on fireproofing as a function of its properties, the application characteristic and the duration and intensity of the fire" (Main 211). Your analyst did not understand the meaning of this recommendation, and, upon querying NIST's Dr. Grosshandler, was told that it meant that NIST was urging that a systematic engineering

methodology be developed for predicting the performance of SFRMs. *Affected: ASTM E06.21; SFRM manufacturers.*

NIST documented that procedures were sometimes followed at the WTC whereby sample portions of SFRMs in existing buildings were cut out and an inspection was made whether steel corrosion would have nullified the efficacy of fireproofing; while not stating so explicitly, there is a connotation that this may be a generally desirable practice (1H 35). *Affected: ASTM E06.21.*

NIST recommends that ASTM E 736 be revised to provide unambiguous values of cohesive and adhesive strengths and that it provide values of in-plane cohesive tensile strength (6 34; 6A 87-94). They also noted that the concepts used in ASTM C 1583 could be usefully introduced into ASTM E 736. *Affected: ASTM E 736.*

NIST recommends that ASTM test methods used to characterize thermophysical properties be updated or expanded to explicitly encompass spray-on fireproofing materials (Main 132; 6 30). *Affected: ASTM E06.21, ASTM E37.05, ASTM E37.01, ASTM D02.11.*

NIST noted that impact of aircraft failed to dislodge SFRM in certain places where these were protected by a protective coating (3 55; 3 100-101; 3 131), while adjacent, non-coated SFRM material was dislodged. A recommendation is implied—but not explicitly stated—that ASTM might wish to develop a test standard or a specification for such over-coated products. *Affected: ASTM E06.21.*

Other fireproofing materials

In his conference presentation, Bill Allen (Leigh's Firetex Paints) recommended that ASTM develop tests to fully characterize intumescent materials that provide fire resistance, including tests for mechanical robustness. *Affected: ASTM E05.11, ASTM E06, ICC, NFPA.*

Steel

NIST recommends that "fire-resistant" steels be more widely used in high-rise buildings (3 134) and that steels with improved high-temperature creep properties be utilized (Main 200). In addition, in his presentation, NIST's Dr. Gayle specifically recommended that ASTM develop standards for the assessment of high-temperature properties of such steels for structural applications. *Affected: ASTM A01.*

NIST examined at length the question of what instrumental methods might be used to determine the maximum temperature to which a piece of structural steel had been exposed to. They concluded that the presence of spheroidizing of iron carbide can be used to determine if the steel had undergone heating to 625°C or more for at least 15 minutes (3C 224) and that a microscopic examination of the paint coating (3C 437) could be used to indicate if a certain lower temperature was exceeded (250°C, for the case of the paint studied in the report). It appears that ASTM standards were not available for either procedure, so a recommendation that ASTM develop such standards is inferred. *Affected: ASTM A01, ASTM A04, ASTM A08.*

It should be noted that Report No. 3A contains an appendix (Appendix B) which provides an extensive discussion of ASTM standards pertinent to structural steels. However, this Appendix does not make—nor imply—any recommendations that would involve revising ASTM standards. Similarly, ASTM standards pertinent to steel are discussed in several other places (e.g., Report No. 3E) and, again, no recommendations are made there that any revisions are needed.

Thermal conductivity measurements

NIST experienced problems in using ASTM C 1113 due to excessive shrinkage of some specimens (6A 67). Presumably this indicates the standard should be reexamined from the point of view of whether procedures need to be implemented to explicitly give directions to the user on this issue. *Affected: ASTM C 1113.*

Mechanical equipment

NIST recommends that pressurized piping systems for ignitable liquids not be arranged so that a leak will result in the emptying of the entire fuel tank contents into the space where the leak has occurred (1 181. *Affected: ASME, ICC, NFPA.*

Analysis grouped by the Subcommittee that is affected

The NIST recommendations listed in the preceding Section in thematic order are here collected and presented according to the ASTM Subcommittee that is affected. A number of organizations other than ASTM were listed above, in order that a comprehensive context would be established. Organizations apart from ASTM are not listed in the cross-listing below, since this cross-listing has been developed solely for ASTM's operating guidance.

The column "Now" (Y/N) indicates whether this is an item potentially ready for use a new business item by the relevant Subcommittee; "N" indicates that liaison and monitoring is indicated for the present, with a new business item being needed only at the conclusion of needed research.

The notation "--" indicates that the item is inapplicable. The notation "??" indicates that there may be an applicable entity, but your analyst has not been able to identify it.

Com.	SC	Std.	Now	Agenda item
ASTM mgt.	--	--	Y	NIST recommends that members of the public and representative of building occupants play a more active role in the development of codes and standards (Main 201)
ASTM mgt.	--	--	N	NIST recommends that performance-based standards and code provisions be established as an alternative to prescriptive requirements (Main 211). Furthermore, NIST believes that this should include at least four aspects: (a) development of design methodologies and performance criteria; (b) development of appropriate multifloor fire scenarios; (c) development of publicly-available thermostructural design software; and (d) development of test methods needed to support performance-based design methods. For (d), NIST specifically point out that they view that design fires will have to be developed which are specifically tailored to represent the full burnout of fires.
A01	??	??	Y	NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming.
A01	A01.13	--	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 213).
A01	??	--	Y	NIST recommends that "fire-resistant" steels be more widely used in high-rise buildings (3 134) and that steels with improved high-temperature creep properties be utilized (Main 200). In addition, in his presentation, NIST's Dr. Gayle specifically recommended that ASTM develop standards for the assessment of high-temperature properties of such steels for structural applications.

- A21 -

Com.	SC	Std.	Now	Agenda item
A01	??	--	Y	NIST examined at length the question of what instrumental methods might be used to determine the maximum temperature to which a piece of structural steel had been exposed to. They concluded that the presence of spheroidizing of iron carbide can be used to determine if the steel had undergone heating to 625°C or more for at least 15 minutes (3C 224) and that a microscopic examination of the paint coating (3C 437) could be used to indicate if a certain lower temperature was exceeded (250°C, for the case of the paint studied in the report). It appears that ASTM standards were not available for either procedure, so a recommendation that ASTM develop such standards is inferred.
C08	C08.02	C 1113	Y	NIST experienced problems in using ASTM C 1113 due to excessive shrinkage of some specimens (6A 67). Presumably this indicates the standard should be reexamined from the point of view of whether procedures need to be implemented to explicitly give directions to the user on this issue.
C09	??	??	Y	NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming.
C09	??	??	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 213).
C11	??	??	Y	NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming.
C11	??	??	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 213).
D01	??		Y	NIST found that adhesive strength is greatly reduced when SFRMs are sprayed onto primed steel surfaces (Main 186; 6 330). They also presented data (6A 101) that the adhesion strength depends strongly on the type of the primer that is used, when a primer is used. Thus, the recommendation is that either SFRMs be applied onto bare steel, or that ASTM E 736 testing be done solely with the primer type that will actually be used.
D02	D02.11	??	Y	NIST recommends that ASTM test methods used to characterize thermophysical properties be updated or expanded to explicitly encompass spray-on fireproofing materials (Main 132; 6 30).

Com.	SC	Std.	Now	Agenda item
E04	??	??	Y	NIST examined at length the question of what instrumental methods might be used to determine the maximum temperature to which a piece of structural steel had been exposed to. They concluded that the presence of spheroidizing of iron carbide can be used to determine if the steel had undergone heating to 625°C or more for at least 15 minutes (3C 224) and that a microscopic examination of the paint coating (3C 437) could be used to indicate if a certain lower temperature was exceeded (250°C, for the case of the paint studied in the report). It appears that ASTM standards were not available for either procedure, so a recommendation that ASTM develop such standards is inferred.
E05	E05.11	--	Y	NIST recommends that mobility-challenged occupants be provided means for self-evacuation (Main 216). This is understood to most likely consist of fire-resistive and structurally-hardened elevators.
E05	E05.11	--	Y	NIST recommends that stairway shafts be designed to resist mechanical forces such as earthquakes, gas explosions, impacts, or hurricanes (Main 216).
E05	E05.11	E 119 E 814 E 1529 E 1725 E 1966 E 2010 E 2074 E 2226 E 2336	N	NIST make a generalized recommendation that the fire resistance testing standards are based largely on research that is roughly a century-old and should be upgraded (Main 209).
E05	E05.11	E 119; poss. others	Y	NIST noted (6 13) that nomenclature of E 119 is inconsistent and that the same concept is variously referred to as "period of fire resistance," "performance," "exposure," or "classification." NIST also implies that the term should preferably be "fire resistance rating."
E05	E05.11	--	N	NIST recommends that fire resistance requirements be re-formulated on a risk basis (Main 208; 1 187). Specifically, they recommend that the following factors be included in establishing the risk level: time required for full evacuation of occupants; time required for burnout of the fuel content; appropriate credits for active fire protection systems, while still maintaining redundancy; explicit provisions for redundancy; spaces with unusual fuel concentrations. NIST specifically points out that evacuation (and fire department access) to extremely tall buildings is difficult and that present Code requirements do not consider the time that may be required for doing this (1 187).

Com.	SC	Std.	Now	Agenda item
E05	E05.11	E 119	Y	NIST testing results (6 49) indicate that failure to support load may not be realistically expressed by the temperatures prescribed in ASTM E 119 as defining failure of load-carrying ability (593°C average, 704°C max). While they do not explicitly offer a recommendation on this point, the test results they present show that load was actually being carried roughly 2× longer than obtained by temperature end-point criteria (6B 94-96). Thus, the implicit recommendation is that the scheme contained in ASTM E 119 wherein collapse times are imputed on the basis of a certain prescribed steel temperature must be re-examined, and that such a temperature may be dependent on a number of factors and not simply constitute a fixed constant characteristic of ASTM A 36 (or similar) steel. In any case, floor/beam ratings based on steel beam temperatures should not be termed "unrestrained ratings", as the current ASTM E119 suggests, because it misleads the users to associate these ratings with unrestrained tests. Ratings based on steel beam temperatures should be appropriately termed (e.g. "beam temperature rating") in ASTM E119.
E05	E05.11	E 119	Y	NIST recommends that tall buildings be able to resist uncontrolled, full burnout without local or global collapse even with failure of the sprinkler system (if present) and unavailability of manual firefighting (Main 211; 1 189-190). Note that "collapse" only is being discussed, not flame or heat transmission. In ISO jargon pertinent to fire resistance tests, this means that here only R is to be considered of the three fire resistance criteria: R (stability), E (integrity), and I (insulation). In his conference presentation, Roger Plank (University of Sheffield) discussed studies he had performed which indicated that, while global collapse should be prevented, local collapse may be permitted because, in some situations, such collapse will not have negative effects, e.g., will not produce cascading destruction. This same point was made by Barbara Lane (Arup), who pointed to the fact that her firm had done modeling which also indicated that local collapse is not necessarily to be prohibited. In his conference presentation, Stephen Szoke (Portland Cement Assn.) argued that even provisions against total collapse are not necessary and that, instead, it should be sufficient to have building code provisions that control the impact of a falling building, if it does undergo total collapse, e.g., that open space adjacent to the building may be acceptable.
E05	E05.11	--	N	NIST recommends that thermostructural design methodologies be developed (1 188). In her conference presentation, Barbara Lane (Arup) emphasized that this should not be taken to mean that prescriptive designs should be discontinued, but, rather, that thermostructural design will only be done for large projects that are risk-based. In his conference presentation, Michael Faber (ETH Zurich) discussed his research which indicated that risk-based design methodologies must be formulated to include an assessment of costs and that cost-conscious designs be produced.

Com.	SC	Std.	Now	Agenda item
E05	E05.11	E 119 new stds.	N	NIST recommends that design fires be developed to support "performance-based" design (1 188) since NIST considers that the standard time-temperature curve is not appropriate for this. In addition, the NIST report specifically notes (5G 91; 5G 118) that time/temperature curves produced by their computer simulations "do not resemble 'standard' time temperature curves used in furnace tests of structural elements." The latter statement is understood not as a criticism of the ASTM E 119 time/ temperature curve for use in traditional, prescriptive applications, but, rather, that a different concept of design fires will be needed for "performance-based" designs. In her conference presentation, Barbara Lane (Arup) argued in favor of carefully-crafted, realistic design fires, while Roger Plank (University of Sheffield) pointed out that design fires which do not include a decay (burnout) portion are never realistic.
E05	E05.11	--	N	NIST recommends that the relationship between performance in real fires and fire resistance ratings of assemblies be studied (Main 209).
E05	E05.11	E 119	Y	NIST recommends that repeatability and reproducibility of fire resistance tests be further studied, especially in view of the fact that furnace tests are normally not run in replicate (Main 209).
E05	E05.11	E 119	Y	In his presentation, Stephen Szoke (Portland Cement Assn.) recommended that furnace designs for conducting fire resistance tests be standardized, in order to improve test reproducibility.
E05	E05.11	E 119	Y	NIST recommends that studies should be done to ensure that realistic fire-test ratings are being produced for assemblies containing materials that have improved elevated-temperature properties (Main 209).
E05	E05.11	--	Y	NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming.
E05	E05.11	--	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 209).
E05	E05.11	E 119 E 2032	Y	NIST recommends that guidance be developed for extrapolating fire resistance test data to real-life assemblies which are larger than the furnace test specimen (Main 209). Specifically, NIST noted that shorter specimens gave longer ASTM E 119 fire resistance ratings (6B 102), also noted that the specimens normally tested in standard ASTM E 119 furnaces are much shorter than in real-life buildings, that even the "longer" NIST specimens were shorter than in real life, and consequently recommend that the means be developed to realistically apply ASTM E 119 fire resistance ratings to structures where specimen length is greater than in the test furnace (6B 106).

Com.	SC	Std.	Now	Agenda item
E05	E05.11	E 119	N	NIST recommends that fire resistance tests be improved to refine the definition of structural limit states and the means used to measure them (Main 209).
E05	E05.11	E 119	Y	NIST recommends that ASTM E 119 tests be continued until failure to carry load occurs, and not be stopped because some different criterion (e.g., transmission of heat or flame) has been exceeded (6B xxxiii). This is because, in a real building, the opportunity to fail via thermal transmission may never occur, and it would be valuable to have data on how long a particular assembly can actually support load. In his conference presentation, Roger Plank (University of Sheffield) also spoke to the importance of this recommendation.
E05	E05.11	E 110	Y	NIST describes the calculations performed by their consultant to produce the "maximum load condition" according to ASTM E 119 (6B 43-45). These resulted in the 17-ft tests being run with a 293 psf uniform superimposed load, plus an 86 psf concentrated superimposed load. A surprisingly-short fire resistance rating was reported for one of the 17-ft tests (Test 4), and this was possibly, in part, due to excessive loading requirements contained in ASTM E 119. NIST presented these facts without making a recommendation, but your analyst concludes that a recommendation to ASTM is implied: Reexamine the superimposed-load requirements in ASTM E 119.
E05	E05.11	E 2032	Y	NIST recommends that improved procedures be developed for extension of data (Main 209). Your analyst notes here that NIST does not reference ASTM E 2032 and is possibly unaware that ASTM already has provided guidance on this topic.
E05	E05.11	E 119	N	NIST recommends that the effect of restraint be further studied, especially for the case of longer, more flexible members (Main 209).
E05	E05.11	--	N	NIST recommends that structural integrity of stairway shaft enclosures include improved provisions to resist non-fire caused mechanical loadings (Main xxxix; 1 166; 1 185). This implies that fire resistance classifications might usefully include a fourth category beyond the traditional three: R (stability), E (integrity), and I (insulation). The fourth category would presumably involve some sort of lateral mechanical loading which is more severe than the lateral loading already provided during hose stream testing.
E05	E05.11	E 119	Y	NIST recommends that clear provisions be established for rating of connections or connecting elements, especially ones that join members having two different fire-resistance rating requirements (Main 198, 209).
E05	E05.11	E 119	Y	NIST recommends that connections or connecting elements joining two members of disparate fire ratings be rated for the more severe of these (1 189).
E05	E05.11	E 2010	N	NIST recommends that windows be required to resist breakage in order to reduce the potential to supply oxygen to the fire (Main 200).

Com.	SC	Std.	Now	Agenda item
E05	E05.11	--	N	NIST recommends that elevators for both occupant evacuation and responder access be designed and constructed to have appropriate fire resistance and resistance to accidental mechanical loadings (Main 200).
E05	E05.11	E 119	Y	In their tests, NIST documented that the unexposed-face temperature criterion can sometimes be exceeded at a time greatly less than the time of the structural failure (6B 96). In such cases, it is essential that the temperature criterion not be unreasonably over-conservative, since it will be the governing classification criterion. A review of the literature by your analyst (provided separately to ASTM) indicates that the present values are over-conservative, and should be changed.
E05	E05.11	E 119	Y	In his conference presentation, NIST's Dr. Sunder recommended that use should be considered of "sacrificial" truss-column connections, so that a floor truss might fall off its seat rather than buckling the column to which it is attached.
E05	E05.11	E 119	Y	NIST's Dr. Gross informed your analyst that the reason that cotton-waste ignition times were not recorded among the test results is that UL does not perform the cotton-waste target test when conducting floor tests, because they do not consider that they can practically and safely reach the needed portions of the specimen with a cotton-waste target. Since Sec. 31.1.1 of ASTM E 119 requires this target testing, ASTM should consider whether the requirement should be changed.
E05	E05.11	E 119	Y	In his presentation, Joseph Treadway (UL) pointed out that floor tests sometimes have to be prematurely discontinued because the specimen sags sufficiently to come into contact with the furnace thermocouples. The implied recommendation is that the ASTM E 119 provisions be changed to either increase the thermocouple-to-specimen distance, or that a means be developed for adjusting thermocouple spacing during the course of the test.
E05	E05.11	E 119	N	ASTM should consider developing a standard for exposing floor systems from both sides, for exceptional structures which require utmost levels of protection. This recommendation was offered by NIST's Dr. Prasad in his conference presentation. In addition, in her comments, Barbara Lane (Arup) explicitly considered the need to model such fires.
E05	E05.11	E 119	Y	In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that no fire resistance tests be so configured that the end supports are outside the heated zone, because such tests produce misleadingly positive results.

Com.	SC	Std.	Now	Agenda item
E05	E05.11	E 119	N	In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that tests be run where beam-column connections are tested in furnaces specifically designed for this type. He explained that two such furnaces have been built in Taiwan. In his presentation, Roger Plank (University of Sheffield) reaffirmed the importance of accurately assessing the role of beam-column connections, but pointed out that successful finite-element modeling is already being done on such connections. In his presentation, Stephen Szoke (Portland Cement Assn.) pointed out that it can be economically unaffordable to test beam-column connections, since this would multiply enormously the number of tests needed.
E05	E05.11	E 119	Y	In his conference presentation, T.-D. Lin (National Cheng Kung University) recommended that loading of columns in ASTM E 119 tests be required to have a realistic amount of axial eccentricity. This recommendation was made in view of his having noted that column tests sometimes give spuriously favorable results due to an unrealistically small eccentricity imposed by the loading rig.
E05	E05.11	--	N	In his conference presentation, Bill Allen (Leigh's Firetex Paints) recommended that ASTM develop tests to fully characterize intumescent materials that provide fire resistance, including tests for mechanical robustness.
E05	E05.31	E 176	Y	Some portions of the NIST report contain a Glossary (e.g., 1G xv). This glossary contains some terms which either do not occur in ASTM E 176 or have a different definition. Since presumably NIST concluded that their definitions have some advantages, ASTM should consider these items.
E05	E05.32	--	N	NIST recommends that thermostructural design methodologies be developed (1 188). In her conference presentation, Barbara Lane (Arup) emphasized that this should not be taken to mean that prescriptive designs should be discontinued, but, rather, that thermostructural design will only be done for large projects that are risk-based. In his conference presentation, Michael Faber (ETH Zurich) discussed his research which indicated that risk-based design methodologies must be formulated to include an assessment of costs and that cost-conscious designs be produced.

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E05	E05.32	--	N	NIST recommends that design fires be developed to support "performance-based" design (1 188) since NIST considers that the standard time-temperature curve is not appropriate for this. In addition, the NIST report specifically notes (5G 93; 5G 118) that time/temperature curves produced by their computer simulations "do not resemble 'standard' time temperature curves used in furnace tests of structural elements." The latter statement is understood not as a criticism of the ASTM E 119 time/ temperature curve for use in traditional, prescriptive applications, but, rather, that a different concept of design fires will be needed for "performance-based" designs. In her conference presentation, Barbara Lane (Arup) argued in favor of carefully-crafted, realistic design fires, while Roger Plank (University of Sheffield) pointed out that design fires which do not include a decay (burnout) portion are never realistic.
E05	E05.32	--	N	NIST recommends that the relationship between performance in real fires and fire resistance ratings of assemblies be studied (Main 209).
E05	E05.32	--	Y	NIST recommends that repeatability and reproducibility of fire resistance tests be further studied, especially in view of the fact that furnace tests are normally not run in replicate (Main 209).
E05	E05.32	--	Y	NIST recommends that studies should be done to ensure that realistic fire-test ratings are being produced for assemblies containing materials that have improved elevated-temperature properties (Main 209).
E05	E05.32	--	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 209).
E05	E05.33	--	N	NIST recommends that fire resistance requirements be re-formulated on a risk basis (Main 208; 1 187). Specifically, they recommend that the following factors be included in establishing the risk level: time required for full evacuation of occupants; time required for burnout of the fuel content; appropriate credits for active fire protection systems, while still maintaining redundancy; explicit provisions for redundancy; spaces with unusual fuel concentrations. NIST specifically points out that evacuation (and fire department access) to extremely tall buildings is difficult and that present Code requirements do not consider the time that may be required for doing this (1 187).
E05	E05.33	--	N	NIST recommends that thermostructural design methodologies be developed (1 188). In her conference presentation, Barbara Lane (Arup) emphasized that this should not be taken to mean that prescriptive designs should be discontinued, but, rather, that thermostructural design will only be done for large projects that are risk-based. In his conference presentation, Michael Faber (ETH Zurich) discussed his research which indicated that risk-based design methodologies must be formulated to include an assessment of costs and that cost-conscious designs be produced.

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E05	E05.33	--	Y	NIST recommends that repeatability and reproducibility of fire resistance tests be further studied, especially in view of the fact that furnace tests are normally not run in replicate (Main 209).
E05	E05.33	--	Y	NIST recommends that studies should be done to ensure that realistic fire-test ratings are being produced for assemblies containing materials that have improved elevated-temperature properties (Main 209).
E05	E05.33	--	Y	NIST recommends that high-temperature-resistant steel, reinforced concrete, and prestressed concrete materials be evaluated for use as fire-resistive elements in buildings (Main 209).
E05	E05.33	--	N	NIST recommends that training materials on use of computational fire dynamics and thermostructural analysis be developed and delivered (Main 223).
E05	E05.33	--	N	NIST recommends that improved egress analysis models and design methodologies should be developed (Main 215).
E05	E05.33	--	Y	NIST recommends that provisions be made for transmitting critical, real-time information to an additional location that is not within the building, along with means of storing this information for subsequent analysis (Main 187, 214). In addition, during his conference presentation, NIST's Dr. Grosshandler recommended that this include the alternative (or supplement) of an on-site, fire resistive "black box." The latter recommendation was also made in his presentation by John P. Couch (Kori Technology).
E06	??	??	Y	NIST recommends that code provisions against progressive collapse be considered (Main 54; Main 195; Main 205).
E06	??	??	Y	NIST effectively suggests that important buildings be required to have a periodic inspection program of the structural members of the building (1 117-133; 1C whole report). Fire resistance features comprise one, but small, portion of this; mainly the intention is to ensure that the entire load-carrying system is still functioning as designed.

Com.	SC	Std.	Now	Agenda item
E06	??	??	Y	NIST recommends that building plans and building design documents be retained for the life of the building at an off-site location and also that means be developed to deliver this information rapidly to emergency responders (Main 189, 221-222; 1 184).
E06	E06.21	??	Y	NIST recommends that development of new, improved materials for providing fire resistance should be encouraged (Main 212). One technology they specifically identify is the possibility of providing factory-applied fireproofing materials onto steel, since their research indicated that adhesion is significantly better when these materials are applied directly to steel, without priming.
E06	E06.21	--	N	NIST recommends that means be established to ascertain the spray-on fireproofing retains its required properties throughout the lifetime of the building and withstands the effects of shock, impact, vibration, and abrasion (Main 198; Main 210; 1 188).
E06	E06.21	--	N	NIST recommends that the effects of elevated temperatures on the thermal properties and the bond strength of these materials be studied (Main 210).
E06	E06.21	--	N	NIST recommends that standardized procedures be established for field inspection of spray-on fireproofing, including determination that a sufficient thickness has been applied (Main 210; 1 188).
E06	E06.21	E 736	Y	NIST found that adhesive strength is greatly reduced when SFRMs are sprayed onto primed steel surfaces (Main 186; 6 314). They also presented data (6A 95) that the adhesion strength depends strongly on the type of the primer that is used, when a primer is used. Thus, the recommendation is that either SFRMs be applied onto bare steel, or that ASTM E 736 testing be done solely with the primer type that will actually be used.
E06	E06.21	--	N	NIST recommends that methods be developed for "predicting the effectiveness of spray-on fireproofing as a function of its properties, the application characteristic and the duration and intensity of the fire" (Main 211). Your analyst did not understand the meaning of this recommendation, and, upon querying NIST's Dr. Grosshandler, was told that it meant that NIST was urging that a systematic engineering methodology be developed for predicting the performance of SFRMs.
E06	E06.21	--	N	NIST documented that procedures were sometimes followed at the WTC whereby sample portions of SFRMs in existing buildings were cut out and an inspection was made whether steel corrosion would have nullified the efficacy of fireproofing; while not stating so explicitly, there is a connotation that this may be a generally desirable practice (1H 35).
E06	E06.21	E 736	Y	NIST recommends that ASTM E 736 be revised to provide unambiguous values of cohesive and adhesive strengths and that it provide values of in-plane cohesive tensile strength (6 34; 6A 87-94). They also noted that the concepts used in ASTM C 1583 could be usefully introduced into ASTM E 736.

Com.	SC	Std.	Now	Agenda item
E06	E06.21	--	Y	NIST recommends that ASTM test methods used to characterize thermophysical properties be updated or expanded to explicitly encompass spray-on fireproofing materials (Main 132; 6 30).
E06	E06.21	--	N	NIST noted that impact of aircraft failed to dislodge SFRM in certain places where these were protected by a protective coating (3 55; 3 100-101; 3 131), while adjacent, non-coated SFRM material was dislodged. A recommendation is implied—but not explicitly stated—that ASTM might wish to develop a test standard or a specification for such over-coated products.
E06	E06.21	--	N	In his conference presentation, Bill Allen (Leigh's Firetex Paints) recommended that ASTM develop tests to fully characterize intumescent materials that provide fire resistance, including tests for mechanical robustness.
E06	E06.21	--	Y	NIST recommends that field inspections be conducted to make sure that spray-on fireproofing conforms to the requirements laid down for it (Main 193).
E06	E06.51	E 1300	Y	NIST notes that wind tunnel testing is superior to simple code-sanctioned formulas for assessing the effect of wind (1 185) and recommends that design methods be evolved for estimating wind loads and their effects on tall buildings based on using wind tunnel testing data and directional wind speed data (Main 207).
E06	E06.51	E 1300	Y	NIST recommends that standards be developed for wind tunnel testing of prototype structures for resistance to wind load (Main 207). The need for standards is motivated by the fact that NIST found major (40%) discrepancies when two firms conducted such retrospective WTC tests independently (Main 179).
E06	E06.77	--	Y	NIST recommends that new technologies for improving evacuation be considered, including protected and hardened elevators, exterior escape devices, and stairwell navigation devices (Main 218).
E06	E06.77	--	Y	NIST recommends that evacuation facilities be designed so that occupants and emergency personnel do not counterflow on the same staircase or that the capacity be provided for this movement (Main 31, 190, 215).
E06	E06.77	--	Y	Two individuals offering comments, Roberto Catalan and Jonathan Shimshoni, offered the recommendation that external escape devices be specifically utilized for high-rise buildings.
E08	??	??	Y	NIST examined at length the question of what instrumental methods might be used to determine the maximum temperature to which a piece of structural steel had been exposed to. They concluded that the presence of spheroidizing of iron carbide can be used to determine if the steel had undergone heating to 625°C or more for at least 15 minutes (3C 224) and that a microscopic examination of the paint coating (3C 437) could be used to indicate if a certain lower temperature was exceeded (250°C, for the case of the paint studied in the report). It appears that ASTM standards were not available for either procedure, so a recommendation that ASTM develop such standards is inferred.

Com.	SC	Std.	Now	Agenda item
E37	E37.01	??	Y	NIST recommends that ASTM test methods used to characterize thermophysical properties be updated or expanded to explicitly encompass spray-on fireproofing materials (Main 132; 6 30).
E37	E37.05	??	Y	NIST recommends that ASTM test methods used to characterize thermophysical properties be updated or expanded to explicitly encompass spray-on fireproofing materials (Main 132; 6 30).

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October 26, 2005

The Honorable Sherwood L. Boehlert
Chairman, Committee on Science
U.S. House of Representatives
Washington, DC 20515

Dear Chairman Boehlert:

The Building Owners and Managers Association (BOMA) International respectfully requests that the following comments be included in the record of the Committee on Science's October 26, 2005 hearing on *The Investigation of the World Trade Center Collapse: Findings, Recommendations and Next Steps*. Along with the following comment, attached are comments that BOMA International submitted on the draft report on the World Trade Center Disaster developed by the National Construction Safety Team.

BOMA was founded in 1907 and is a dynamic international federation of over 100 local associations. BOMA's 19,000-plus members own or manage more than 9 billion square feet of downtown and suburban commercial properties and facilities in North America and abroad. The mission of BOMA is to advance the performance of commercial real estate through advocacy, professional competency, standards and research.

The National Institute of Standards and Technology issued its draft Report on the Collapse of the World Trade Center Buildings on June 23, 2005. The report is comprised of several technical reports on various aspects of the September 11 disaster and includes 30 recommendations on building and fire codes and standards as well as on construction and building operation practices. The recommendations are based upon NIST research and analysis of the World Trade Center disaster and apply to buildings of 20 or more stories or to iconic or other critical structures.

In addition to commenting on the recommendations and their impact on BOMA members, BOMA also urged NIST to consider the fact that safety in the built environment has made tremendous strides over the past several decades. Improvements in structures, fire protection systems, and building components and materials have made for a safer place for building occupants that ever before. Also, BOMA noted that through the private consensus code development process, further improvements will be made and that these improvements will be incremental, carefully considered, fair to occupants and owners, and cost-effective

BOMA's comments focused on two areas of the report: 1) occupant egress and emergency response and 2) the analysis of active fire

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protection systems, and building and fire codes and practices. Some of the issues that BOMA International raised included:

- BOMA supports the NIST research into the WTC collapse and seeks to work with NIST to facilitate a discussion of the findings among professionals in the commercial real estate industry.
- Statistics show that high-rise and commercial office buildings have performed very well in a variety of fire and other emergency situations. BOMA urges NIST to ensure against possible unintended consequences with unnecessarily restrictive recommendations.
- Sensitivity to the concerns of the commercial real estate industry is essential as these recommendations are debated in the public codes and standards development arena.
- BOMA believes the national private codes and standards development arena is the proper forum for consideration of regulatory changes such as the NIST recommendations.
- BOMA urges NIST to develop cost/benefit studies for these recommendations as part of their due diligence obligation. Cost/benefit analyses must accompany the recommendations as they are presented in the regulatory arena.
- BOMA urges more study to determine the extent to which buildings should be required to be designed to a) withstand terrorist attacks or acts of war or b) require redundant or alternative systems. The issue of the existence of a specific terrorist threat to buildings in general as well as the level of that specific threat also needs additional study.
- NIST should emphasize that there are vast differences between existing buildings and new buildings, and the recommendations for one will not necessarily fit the other. There are also differences in emergency egress and other considerations between smaller (20 story) and larger (100 story) buildings.
- BOMA seeks to pursue joint NIST/BOMA educational and informational initiatives to assist BOMA members in accommodating some of the recommendations of the report.

Building safety is an issue that BOMA International and its membership take very seriously. BOMA International will work with any organization that has the improvement of building safety in mind. BOMA reminds NIST that improvement in building safety is a gradual process built upon past experience and the advances of new technology.

Again, we express our appreciation for the opportunity to submit a statement for the record of this hearing.

Respectfully submitted,

Ron Burton
Vice President for Advocacy and Research

BOMA Comments on
NIST Recommendations Contained in the
Report on the WTC Disaster

Recommendation 1:

Progressive Collapse: The big issue here would be to what extent it would be required to 'prevent' progressive collapse. How many column failures (specific number, a percentage of a floor; etc) would need to be able to be withstood? "Progressive collapse should be prevented" is a pretty vague 'goal', without better explanation of what factors must be considered.

Recommendation 2:

No Comment.

Recommendation 3:

No Comment.

Recommendation 4:

BOMA believes that any code change recommended by NIST must be considered by national bodies and not on a community-by-community basis.

The record of sprinklered building performance is outstanding, no matter what their size. There is no need to increase redundancy with enhanced passive fire protection systems or passive fire protection systems in general. (This should be one of our major, recurring, points. Where is the basis to claim that sprinklers need to be assumed to fail completely? Especially while not noting that 'passive' solutions (or redundancies) also include active components (doors, dampers) that may fail, and that if not adequately maintained, the passive solutions may not work as advertised. In sum, BOMA points to the inspection, maintenance, and testing requirements for sprinkler systems and their excellent performance record. Re: the 12,000 compartment limitation: it would have significant impact, and again, cannot be justified in a sprinklered building.

How many situations could compromise any fire protection system? The number of specific perils needs to be assessed by the national building code community.

Recommendation 5:

No comment.

Recommendation 6:

No comment.

Recommendation 7:

No comment

Recommendation 8:

This recommendation is a bit unrealistic and unwarranted. NIST assumes the complete loss of the sprinkler system, and no intervention by fire department. This has two parts: how much compartmentation would be required (to keep the uncontrolled fire from spreading), and how the burnout could occur and not lead to collapse (progressive collapse issue).

Recommendation 9:

The effort to 'retrofit' on a large building-wide scale is an enormous task. This recommendation should, at least initially, be focused on new buildings.

Recommendation 10:

BOMA International concurs, but to achieve it is going to take some time.

Recommendation 11:

BOMA International concurs. However, it must be noted that this is a state-of-the-art type of recommendation. Certainly the buildings being designed now are better than the buildings designed10 years ago, and the building 10 years from now will be even better.

Recommendation 12:

Greater risks associated with greater heights? BOMA International will question what criteria and facts NIST is using to justify 'gold-plated' over-engineered fire protection requirements. Some questions that BOMA poses to NIST: How can building population be determined at any given time? What is 'higher threat profile'? NIST again says we must enhance the systems/design of what we now have. Where is data that shows that sprinklers fail? There is a lack of history to prove NIST's claim of 'increased risk' in taller buildings.

Recommendation 13:

This is more a communications issue. As long as this stays a general "more communication is better", the recommendation is hard to argue against. A modern zoned voice-alarm system would provide most, if not all, of what NIST is asking for here. Also, the NIST recommendation is against hardwired fire-department communication systems, which seems to be the direction building design is going. Communications providers are producing better and more reliable radio systems (sometimes requiring repeaters or antennas in buildings).

Recommendation 14:

Early detection is a big part of minimizing a fire. Many buildings just don't require this type of fire command center. Incremental improvements in the information provided will continue as the industry evolves, and major mandated advances are not warranted....a 'modern' system provides a good deal of information already (water flow location, fire alarm zones, etc.) Security and other building management systems controls also already can provide extensive info....video, doors open/closed, temperature, etc.

Recommendation 15:

This recommendation is just too costly to implement. BOMA International asks NIST exactly how many building collapses have there been.....ever? Again, this may be an incremental change that will occur as building management systems continue to evolve. Mandating off-site transmission doesn't appear warranted, and raises many questions.....off-site to whom? (fire department? property management company?)

Recommendation 16:

Drills are good. BOMA International encourages the inclusion of fire drills in any building emergency management plan. A large amount of assistance is going to be required from the United States Fire Administration to advance this awareness.

Recommendation 17:

Certainly, fire protection system that extend building performance and that extend the time for building evacuation should be taken into account. Trade offs between the various systems are going to be important as the building community goes forward in making buildings safer.

BOMA International is concerned about paragraph (b) in the recommendations, which focuses on persons with disabilities, specifically about the 'provide them means of self-evacuation' recommendation. BOMA International believes that it's more appropriate to stay with current Americans with Disabilities Act provisions.....evacuation planning is just another policy/procedure...and it should include provisions for how to accommodate persons with disabilities.

Recommendation 18:

Although this recommendation is more common sense than anything else, NIST needs to look at why it is making this recommendation. BOMA International recommends that buildings should be designed to provide safety to building occupants until the occupants can evacuate them.

If NIST starts to tie elevator locations to 'travel distance', which is a big leap towards starting to treat elevators as 'means of egress' components, this is a huge leap. Opening the door toward considering elevators as a way to move people in some situations is satisfactory; however the initiation of considering them parts of the means of egress, or as exits, is another matter entirely that BOMA questions.

Recommendation 19:

BOMA agrees with this recommendation and has publications to accommodate it. BOMA International currently works with the Department of Homeland Security on real estate alerts that notify building owners and managers of specific threats that are considered such by DHS.

BOMA International as well makes available emergency planning information to buildings owner and managers. This is accomplished through standard publications that BOMA makes available through it publications catalogue and through the offering of courses, seminars, and committee meetings.

Recommendation 20:

This is a pretty vague recommendation. I would assume that NIST would hope that the model codes would consider ALL the recommendations, not just these.

Recommendation 21:

Yes, building elevator protocols should be reviewed by code groups. This recommendation proposes separate, dedicated, hardened elevators for fire department use. It isn't clear how NIST justifies adding elevators that will ONLY be used in major emergencies. Why isn't use of general building elevators (which are used all the time, and therefore possibly more likely to be maintained), with whatever 'enhancements' might be found to be needed, acceptable?

Recommendation 22:

This recommendation is really not a matter for building owners. However, it may come into play for building owners if building owners need to provide signal repeaters or antenna. BOMA will comment on a specific proposal if it is advanced.

Recommendation 23:

BOMA International sees this recommendation as very expensive to implement. BOMA encourages NIST to accomplish a cost-benefit study prior to urging the adoption of this recommendation.

Recommendation 24:

This recommendation is directed more at the emergency response teams than for building owners and managers.

Recommendation 25:

BOMA International questions whether state and local governments would be receptive to this recommendation. A mandate to always have a third party review done, both of the design and the as-built condition, may be an intrusion on local government authority.

Recommendation 26:

BOMA International is unsure whether NIST is encouraging the sprinklering of existing buildings to the extent required in the codes for existing building (retroactive requirements), or to the extent required for new buildings. Even if only sprinklering buildings to meet retroactive code requirements, this picks up most high-rise buildings under NFPA 101 (unless an approved 'life safety plan' is done). Typically, retroactive sprinkler regulations have been a local/state issue.

Recommendation 27:

In an ideal world the idea of document retention is a good one. However, in reality, many buildings are older and, in some, if not many, their records are missing, inaccurate, or unusable for any number of reasons. Information for buildings of a certain size, if available, should be provided to emergency responders. If this recommendation does advance, it MUST focus on new buildings and maybe alteration work. An entire industry could otherwise be created to document existing buildings for which the original and/or as-built information is not available.

Recommendation 28:

BOMA International does not have an issue with this recommendation.

Recommendation 29:

The design professions are already stretched close to the maximum with so many knowledge requirements placed on them. There is very little, if any, room in curriculums currently for additional coursework on any topic. Possibly, there could be one designated profession to assume responsibility for complete knowledge on this topic. Architects, as the team leader, can collaborate with structural engineers, fire protection engineers, and as a team, they all can pull the project together. A solution to this maybe the institution of a certificate stating that "we, as a team, have looked at the risks related to fire damage and agree that we have employed the greatest technology presently available to mitigate those risks."

Recommendation 30:

BOMA International asks NIST the specific audience this recommendation is directed toward.

STATEMENT BY JAMES G. QUINTIERE
PROFESSOR, DEPARTMENT OF FIRE PROTECTION ENGINEERING
UNIVERSITY OF MARYLAND

In my opinion, the WTC investigation by NIST falls short of expectations by not definitively finding cause, by not sufficiently linking recommendations of specificity to cause, by not fully invoking all of their authority to seek facts in the investigation, and by the guidance of government lawyers to deter rather than develop fact finding.

I have over 35 years of fire research in my experience. I worked in the fire program at NIST for 19 years, leaving as a division chief. I have been at the University of Maryland since. I am a founding member and past-Chair of the International Association for Fire Safety Science—the principal world forum for fire research. I have followed the investigation from onset of the incident, as I was about to teach fire investigators at the ATF Academy (FLETC) in Georgia on the morning of 9/11. I joined the SSC team of Sally and Monica after we mutually discovered each other by speaking our concerns on the WTC collapse. I have published in the area of the WTC incident, our students built a scale-model of the fire on a floor of the North Tower, and I have followed the NIST activities from before their special funding. I assisted NIST early in 2002 in viewing photographs and video held by the NY Times. I had wished for clear and complete analyses and evidence to determine the full cause of the factors behind and the reasons for the collapse of the WTC buildings, as they bear on the fire safety design of current and future buildings. I am also concerned about the lack of sufficient government support for fire research and its implementation in fire safety design, codes and standards.

Concerns about the NIST Investigation

Scientists at NIST should be commended for their individual efforts in rising to the occasion of the WTC investigation. NIST should be commended for organizing an activity of this scale for the first time. However, there are some issues of concern that I will summarize. All of these have been submitted to NIST, but never acknowledged or answered. I will list some of these.

1. Why is not the design process of assigning fire protection to the WTC towers fully called out for fault? The insulation thickness of the truss members varied from 0.5 inches at its construction, changed to a specification of 1.5 inches in 1995, and was taken on its face as 2.5 inches for the North tower fire floors based on a PA report. This extraordinary range of thicknesses bears an in depth investigation. Why were no hearings held or witness testimonies heard on this critical design process?
2. Why were not alternative collapse hypotheses investigated and discussed as NIST had stated repeatedly that they would do? Their current explanation for the collapse of the towers is critically based on an assumption that the insulation was removed from the steel in the path of the aircraft, particularly the core columns. NIST does not show calculations or experiments to satisfactorily confirm that the insulation was removed in the core. As some large aircraft components went directly through the buildings, and NIST indicates the others were splintered on impact, can they explain why these small splinters could still denude the steel?
3. Spoliation of a fire scene is a basis for destroying a legal case in an investigation. Most of the steel was discarded, although the key elements of the core steel were demographically labeled. A careful reading of the NIST report shows that they have no evidence that the temperatures they predict as necessary for failure are corroborated by findings of the little steel debris they have. Why hasn't NIST declared that this spoliation of the steel was a gross error?
4. NIST used computer models that they said have never been used in such an application before and are the state of the art. For this they should be commended for their skill. But the validation of these modeling results is in question. Others have computed aspects with different conclusions on the cause mechanism of the collapse. Moreover, it is common in fire investigation to compute a time-line and compare it to known events. NIST has not done that.
5. Testing by NIST has been inconclusive. Although they have done fire tests of the scale of several work stations, a replicate test of at least ¼ of a WTC floor would have been of considerable value. Why was this not done? Especially, as we have pointed out to NIST that they may have underestimated

the weight of the furnishings in the North Tower by a factor of 3. As fire effects on structure depend on temperature and time, this likely longer burning time is significant in the NIST analyses. Other tests of the trusses in the UL furnaces show that the steel attains critical temperatures in short times, and these temperatures correspond to NIST's own computation of truss failure for a single truss. Why have these findings seemingly been ignored in the NIST analyses?

6. The critical collapse of WTC 7 is relegated to a secondary role, as its findings will not be complete for yet another year. It was clear at the last NIST Advisory Panel meeting in September that this date may not be realistic, as NIST has not demonstrated progress here. Why has NIST dragged on this important investigation?

On the Recommendations

The eight group-headings of the NIST recommendations are not specific, as they cannot connect directly to their findings. Instead they speak to developing, improving or advancing technology for safety from fire. Hence, they really cry out for more research, technology adaptation, and education with respect to fire. This is understandable as the NIST role has been to be a leader in research, and a source of new knowledge for codes and standards. The Science Committee and the Congress should take note of the needs underlying the nature of these recommendations. They are more *a need for research to assist standards.*

NFPA testified at the Hearing that the implementation of new performance-based codes requires tools that have not yet been developed and nor are there sufficient people to understand how to use them. Congressman Boehlert pointed out to Sally Regenhard *many* are "do-gooders" that serve on the standard committees, but few come to the table with technical information that is needed for a full discussion. This transfer of technical information for standards in fire safety is only a role that government can effectively support. The Science Committee should thoughtfully consider how that support could be implemented.

I point out some alarming facts. The fire program at NIST received a boost in the 1970's under the confluence of several forces: NSF advancing $2 million per year for fire research, consumer product safety legislation (CPSC), and the funding advanced by industry and government agencies for fire research (about $ 2–3 million per year). This funding has considerably dropped in real dollars. The NIST fire program continues to survive by taking contracts from government and the private sector that could otherwise support academic or private industry. The extramural research program of NIST, inherited from NSF, has shrunk from effectively $2 million to about $500k in 1970 dollars. The NSF has defaulted a fire program to NIST so investigators in academia have no program to turn to at NSF. The NASA microgravity program had taken up the slack in fire research beginning about 1985, but its current fire research budget has been decimated in a shift from space station needed research to a Mars human flight program. The Science Committee has oversight over NSF, NASA, and NIST. It should investigate how it can best support the needed fire research.

NIST speaks to the need for education. I left NIST to contribute to that goal. The U.S. produces about 50 fire protection engineers per year when about 500 are really needed. If the fire service would incorporate fire engineers this number would double. There is a big lack of knowledge here, and it contributes to an infrastructure of fire safety that is currently fraught with good intentions, special interests, and ignorance. The Science Committee should recognize this deficiency.

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Submission by Jake Pauls, CPE, to House Science Committee Supporting Testimony by Sally Regenhard

October 26, 2005

My professional opinion is that NIST's work on the evacuation, other occupant behavior and related first responder activities in the WTC exit stairs is neither a reasonably complete, balanced investigation nor acceptable research. This has significant implications for codes/standards applications of NIST's work as well as for NIST's role as leading federal science and technology organization for buildings.

Background to comments: I have over 38 years of professional experience in the field of human factors and building safety including 20 years with NIST's Canadian counterpart, the National Research Council of Canada, where my earliest work—dating to the 1960s—dealt with evacuation of tall office buildings. I am the most published individual internationally on matters of evacuation, use of stairways, human factors in building safety and related issues of codes/standards development, adoption and enforcement. My work includes being an advisor to the largest public inquiry held on high-rise safety, the Webber Commission in Ontario in the 1980s. Currently, I am a member—mostly representing the American Public Health Association (as a consumer representative)—of about a dozen national committees of NFPA and ICC responsible for leading national model building codes, other model codes and ANSI safety standards. Membership includes being one of ten on NFPA's High-Rise Building Safety Advisory Committee. NIST also knows me as the best informed, most involved public critic of its work on the WTC, providing public comment at all of its public hearings in NYC and Gaithersburg and at all of its meetings of the National Construction Safety Team Advisory Committee. Beyond this, no forum is available in the US to ***thoroughly*** discuss all WTC-related egress and occupant behavior studies. Ironically, the UK government is funding an international meeting on this topic Nov. 17-18 in London where I am invited to present "A Perspective on the NIST World Trade Center Study." Generally, my criticisms of NIST efforts in human factors in building safety, especially evacuation issues, date back to July of 1974—***over 31 years of closely monitoring its work and pointing out the need for change.***

NIST's team failed badly to properly investigate/research egress activity in the WTC stairwells. There were major failings in Projects 7 and 8 of NIST's work. For example, about ten times the occupant survey effort was devoted to less significant issues of pre-evacuation activity of occupants than was given to the roughly 90 percent of activity occurring in the exit stairways. Thus NIST's findings and recommendations about the crucial occupant and first responder activities in the exits are few and highly questionable scientifically. More tragic, they are deficient and of dubious merit on technical grounds as bases for code changes. The related code changes include one of the most debated issues over the last four years in model code development—minimum exit stairway width and related egress performance.

Regarding the crucial issue of exit stair remoteness, NIST has improperly played down the compliance of the WTC stairs with code requirements in the 1970s and later. Remoteness—a critical factor in exit redundancy—did not meet code requirements, in letter or spirit, in my opinion (as one working on technical and regulatory aspects of this specific issue over the last 35 years).

Generally, NIST appears averse to doing an investigation, using for example its subpoena power and assigning blame where it is warranted. Too often, NIST staff and contracted advisors appear to be like "the kid in the candy store" as money finally was available to do personally favored studies as opposed to those essential for a ***full, balanced*** WTC investigation. **Too often a laggard in the building evacuation field, NIST needs to shape up or have some of its assignment given to others.**

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Fireproofing Blown Off Twin Towers

REPORT DETAILS 9/11 COLLAPSE IN N.Y.
BY MICHELLE GARCIA
SPECIAL TO *The Washington Post*

WEDNESDAY, APRIL 6, 2005; PAGE A03

NEW YORK, April 5—The hijacked airplanes that struck the World Trade Center hit with such force that the resulting explosions blew the fireproofing off the steel columns, accelerating heat buildup and weakening the structural core—contributing to the towers' eventual collapse, according to a report issued Tuesday.

The process was hastened by fires outside that consumed the buildings' face and caused the exterior columns to bow in, according to the report.

Still, the study by the National Institute of Standards and Technology concluded that no amount of fireproofing could have saved the buildings.

Poor evacuation procedures, lack of communication and weak staircases cost the lives of civilians and emergency workers at the towers, as workers waited for directions and were slow to leave after the Sept. 11, 2001, attack, the report said.

Only two of the 198 elevators in the towers survived the initial explosions—forcing most survivors to escape down emergency stairwells, which had suffered extensive damage. The report found that building codes lacked requirements sufficient to protect the structure of emergency stairwells.

Had such codes been in place, said S. Shyam Sunder, the lead investigator of the Institute, "there would have been greater opportunity for people to evacuate."

Another federal report issued Tuesday found that the economic impact of the attacks was less than New York officials had originally estimated. After the attacks, State and city officials said the loss of tax revenue could approach $5.8 billion.

But the Government Accountability Office said the loss attributable to the attacks was closer to $2.9 billion and cited the city's recession, which had begun to take a toll before Sept. 11, for the rest of the loss.

The institute's report on the building collapse was long awaited by city officials. The institute based its analysis on extensive interviews with about 1,000 survivors, computer modeling, recovered steel and communications records.

The Institute will use the findings in the 3,000-page report to formulate recommendations—expected for release in September—for changes in national building codes for office towers. A spokesman at the Port Authority of New York & New Jersey, which owned the World Trade Center, said local and State officials will review the recommendations and use them to guide reconstruction at Ground Zero.

"Whatever recommendations are adopted we will follow," said authority spokesman Steve Coleman. "Our engineering department has oversight over the buildings [and] will ensure the codes are followed."

In the past, city safety codes for office buildings often were a sort of informal compromise between safety and commercial imperatives. In 1968, New York City officials drastically reduced the number of required stairwells in skyscrapers, at the request of the real estate industry, to increase the amount of available rental space.

New York was, in fact, fortunate that the attacks took place in the morning, when most people had not yet reached their offices. If the building had been fully occupied, the report found, a full evacuation would have taken four hours and cost 14,000 lives.

The agency interviewed survivors and found that, although most had participated in a fire drill, nearly one-half had never used the stairwells in the buildings before the attacks. In fact, New York City prevents the use of stairwells during fire drills.

"I've never heard of another jurisdiction having such a prohibition," Sunder said.

Staircases in Twin Towers Are Faulted

BY JIM DWYER
The New York Times

APRIL 6, 2005

he staircases in the twin towers—their number, location, and the weak walls around them—emerged as critical factors in the deaths of many of those killed in the Sept. 11 terrorist attack on the World Trade Center, according to a federal safety report released yesterday. The findings will be used to shape federal recommendations for building-code changes across the country.

And after more than two years of intensive research, investigators uncovered what they said was an elementary shortcoming in the trade center towers: neither building had enough staircases to meet any of the major building codes in the country, including New York City's.

For nearly every man and woman on the upper floors of the towers, the lack of intact staircases meant that they could not get out after the planes struck. Clustered in the centers of the buildings, those staircases were encased in lightweight drywall that was immediately destroyed. Sturdier walls around staircases that were remote from each other "might have provided greater opportunities for escape," said the lead investigator, Shyam Sunder.

In a sobering lesson drawn from one of the day's great successes—the escape of nearly everyone below the points of impact, about 14,000 people—the report said that it had taken about twice as long to go down a single flight of stairs as had been projected by the current engineering standards for tall buildings. The buildings were only half full, investigators said, and if the attack had come at a time when they were filled to occupancy, the evacuation would not have been successful. Thousands more people were likely to have been trapped on the stairs, Mr. Sunder said.

The report, issued by the National Institute of Standards and Technology, also formally confirmed what had long been identified as a significant failure on that day: the leaders of New York's Police and Fire Departments did not coordinate their efforts that morning. The investigation suggested that many of the rescuers died because they simply did not know what was happening around them.

"A preponderance of evidence indicates that a lack of timely information sharing and inadequate communications capabilities likely contributed to the loss of emergency responder lives," the report stated. It cited an interview with an unnamed firefighter who told the investigators, "If communications were better, more firefighters would have lived."

The findings were included in a draft final report from the institute, a branch of the United States Commerce Department that was given authority by Congress in 2002 to investigate the towers' collapse, the evacuation and the emergency response.

The findings total some 10,000 pages, of which 3,400 were made public yesterday. The remainder will be released later in the spring, according to Mr. Sunder. The institute will make recommendations on improvements in the areas it studied.

Building-code changes are decided by local governments, generally using model codes developed by technical experts who work with the insurance and real estate industries.

In a presentation yesterday at a Times Square hotel, Mr. Sunder outlined the techniques used to project the sequence of events that led to the collapse of each tower. Although each building was hit by virtually identical planes, the south tower collapsed in 56 minutes and the north tower in 102 minutes.

A combination of common factors shaped the course of events, he said. The planes plunged through the exterior curtain of each building and fragmented as they passed through the building, with parts emerging on the other side. The impacts killed hundreds of people instantly. In the north tower, American Airlines Flight 11, moving at 443 miles per hour, took .685 seconds to pass through the building; in the south tower, United Airlines 175, hitting at 542 miles per hour, passed through in .58 seconds.

The impact changed tower structures in two critical ways, Mr. Sunder said. First, of the 47 columns in the core of each building, nine were either severed or badly damaged in the north tower, and 11 in the south tower. Second, the impact dislodged the fireproofing that was sprayed on the floors and the columns. As the fires ignited by the jet fuel burned, the floors were weakened.

The floors played an important role in the structures, because they connected the exterior supports—the pinstripe columns that gave the towers their distinctive appearance—to the columns hidden in the cores of the buildings. As the unprotected

floors were weakened by fire, the exterior columns bowed inwards, the investigators reported. In the north tower, a photograph showed they had moved 55 inches off center a few minutes before the collapse; in the south tower, they were 20 inches off center. As those columns became unstable, the building load shifted, but the instability was too great and the cascade of collapse began.

Much of the jet fuel burned outside the buildings in a fireball, but enough remained inside to ignite the office furnishings and building contents.

In its early phases, the investigation by the institute raised serious questions about the adequacy of the original fireproofing applied to the steel in the towers, and Mr. Sunder said those concerns remained. But, he said, in the areas where the fires were most severe, the amount of fireproofing that originally had been applied was "moot" because whatever had been there was knocked off by the planes.

Hundreds of people were trapped above the impact, on floors where there was no immediate damage. This made escape routes an important part of the agency's study.

During the design of the trade center, the Port Authority of New York and New Jersey had decided to use a new version of the city building code that did not require as many staircases as the earlier edition. Instead of six staircases, including a specially reinforced fire escape, the trade center had three stairs in each tower. The investigators determined, though, that even the liberalized code required a fourth staircase, to accommodate the more than 1,000 people expected in the restaurant at the top of the north tower and at the observation deck atop the south tower.

As an interstate agency, the Port Authority is not bound by local building codes, but it had publicly pledged to "meet or exceed" the city code in building the trade center. However, the institute investigators determined that the Port Authority had not supplied enough staircases.

"Once you go over 1,000 people on a floor, you need to have a fourth stairway," said Richard W. Bukowski, a senior engineer with the institute. A spokesman for the Port Authority said its engineers believe that the findings are mistaken. New York City building officials who reviewed the trade center plans, both in the 1960's and after the 1993 terrorist bombing, had not raised any questions about the missing staircase.

Glenn Corbett, a professor at John Jay College of Criminal Justice and an adviser to the institute investigation, said he had asked about the exits for the restaurant and the observation deck. "Imagine what a staircase in the right spot might have done for people that day," Mr. Corbett said.

One of the documents included in yesterday's report showed that the Port Authority was eager to cut down on the amount of space devoted to stairs.

"The tower core should be redesigned to eliminate the fire towers and to take advantage of the more lenient provisions regarding exit stairs," wrote Malcolm P. Levy, the Port Authority's chief planning engineer, who is now deceased.

In the impact area of the north tower, the three staircases were about 70 feet apart and were destroyed immediately.

In the south tower, the plane hit on floors where the three staircases were about 200 feet apart, and one of them survived at least partially intact.

3-Year Federal Study of 9/11 Urges Rules for Safer Towers

BY JIM DWYER AND ERIC LIPTON
The New York Times

JUNE 22, 2005

After an exhaustive, three-year study of the collapse of the World Trade Center, a federal panel will call for major changes in the planning, construction and operation of skyscrapers to help people survive not only terrorist attacks but also accidental or natural calamities, according to officials and draft documents.

The recommendations, to be made public tomorrow, include a call for a fundamental change in evacuation strategies for tall buildings: that everyone should have a way out in an emergency, replacing the current standard of providing evacuation capacity for a few floors near a fire or emergency. The panel also called for sturdier elevators and stairways, and found that current standards for testing fireproofing of steel for tall buildings are flawed.

Taken together, the recommendations, by the National Institute of Standards and Technology, are likely to open an intense national debate over the costs of such changes and whether lessons for other skyscrapers can reasonably be drawn from the extraordinary events of Sept. 11.

The agency's proposals are not binding, but are meant to influence the policies of cities and states across the country. Many of them have become public in draft form during the three-year inquiry and have prompted fierce lobbying or objections from prominent engineers, building industry professionals, and the Port Authority of New York and New Jersey, which built the trade center. While the agency has revised certain aspects of its findings on what precisely happened at the trade center, the package of recommendations makes it clear that the agency has essentially held firm on its emphatic and demanding safety agenda for the next generation of tall buildings in America.

S. Shyam Sunder, the engineer who oversaw the inquiry for the agency, said the investigators worked to identify issues of "safety for the vast majority of buildings" in fires, earthquakes, power losses and sudden hurricanes. The costs of the changes are unknown, but structural engineers suggested they would add two to five percent to development costs of ordinary buildings.

The study disclosed that critical design benchmarks and code standards used in the construction of the trade center—the time it takes to walk down stairs, the distance separating stairways, and the fire-resistance tests—turned out to have little relationship to the experiences or needs of people inside the towers. These findings, Dr. Sunder said, have broad application to buildings everywhere.

The investigation also found that most building codes do not recognize that people on high floors are isolated and easily cut off from help during an emergency.

The inquiry, conducted by more than 200 technical experts and contractors working for the agency, amounts to a 10,000-page autopsy of the trade center collapse. The report includes 25 pages of recommendations, which will be released for the first time as a full set in New York tomorrow.

"The whole purpose of the investigation was to make building occupants and first responders safer in future disasters and to learn whatever we could from what happened on 9/11," Dr. Sunder said. "The recommendations will be reasonable and achievable."

In the United States, building codes are generally adopted by local and State governments that use models developed by private groups like the National Fire Protection Association, established by the insurance industry, and the International Building Code Council, an organization of government construction regulators. Those two groups have set up committees to evaluate the recommendations.

"Will all the recommendations be accommodated verbatim in building codes? I think the answer is no," said Mohammed M. Ettouney, a principal at Weidlinger Associates, a New York-based structural engineering firm that is doing the security-related design work on the Freedom Tower planned for ground zero. "But it will act as a lightning rod for a debate that will now really get under way."

The trade center towers, where 2,749 people died in the Sept. 11 attack, were only one-third occupied that morning. If the buildings had been full, it is likely that 12,000 more people would have died because of limited evacuation capacity, the investigation found.

Already, a proposal for wider exits—making it possible for people to leave faster but reducing the amount of rentable space—has been rejected by one major code-writing organization.

Others have suggested that it is folly to think different rules might have forestalled the collapses.

"They are leading the public down the wrong path," said Jon Magnusson, whose Seattle-based structural engineering firm, Magnusson Klemencic Associates, is the descendant of the company that designed the twin towers. "They are saying we are going to fix the codes in order to deal with Sept. 11th. The physics say that you can't do that."

Dr. Sunder says that is a mistaken reading of the investigation. The agency, he said, does not suggest that buildings should be able to stand up to airplane impacts. "It is more cost effective to keep terrorists away from airplanes, and airplanes away from buildings," he said.

The trade center was built by the Port Authority, which is not subject to any building codes. Despite promises by the Port Authority to "meet or exceed" the New York City code, the federal investigation found that the trade center had fewer exit staircases than required and that the Port Authority never tested the fire resistance of the floors. It also found no evidence that a rigorous engineering study supported the authority's repeated public assertion that the towers could stand up to the impact of a fully loaded commercial airliner.

In recent presentations, Dr. Sunder suggested that agencies that are exempt from building codes, such as the Port Authority, should have an independent party certify their compliance with codes, rather than simply deciding for themselves.

The three-year, $16 million federal investigation was broken into two primary parts. Using computers to reconstruct the attack, engineers found that when the towers were struck, they redistributed load to surviving columns. Once the fire weakened those remaining, extremely stressed columns, whose fireproofing had been knocked off by the planes, the structures collapsed, the report says.

That research found no flaw in the design of the towers that was a critical factor in the collapse, Dr. Sunder said.

As the computer reconstruction of the towers proceeded, others worked on a second inquiry: identifying weaknesses in building codes.

For example, investigators determined that if the towers had been fully occupied, it would have taken about four hours for survivors to exit, more than twice the time either tower stood and twice as long as planners had estimated. That led to the call for changes in evacuation planning.

At least some elevators in tall buildings should be built with more robust shaft walls and with electrical systems that will not fail if exposed to water, the report says, so that they can be used to evacuate people who cannot descend long distances and to take firefighters to high floors.

The investigation also raised hard questions about the usefulness of a century-old furnace test that measures the fire resistance of structural components. Last summer, the National Institute of Standards and Technology arranged a furnace test of a 17-foot piece of steel and concrete floor, the standard requirement at the time that the towers were erected. The floor passed the test. However, the tower floors were built not with 17-foot lengths of floor, but with 35- and 60-foot lengths. When a 35-foot length was tested in the furnace, the floor failed the fire-rating requirement.

The recommendations also say that tall buildings should be designed to prevent "progressive collapse," avoiding a cascade of failures that can bring down a tower in seconds.

The study found that sprinklers, which can replace or reduce other fire-protection systems, should have a redundant water supply or power backups, to avoid being knocked out with one blow. Requirements for how well spray-on fireproofing should adhere to the steel columns also must be clarified, Dr. Sunder said.

The debate over integrating the proposals into building codes and practices will undoubtedly be intense. Mr. Magnusson serves on the special eight-member committee set up by the National Fire Protection Association, along with Sally Regenhard, Chairwoman of the Skyscraper Safety Campaign, who is one of the Nation's most vocal advocates for tougher building codes. She and Monica Gabrielle, a co-founder of the skyscraper campaign, lobbied Congress to finance the agency's investigation and have demanded that the institute not dilute its findings.

"We have to restore the public's perception of safety in skyscrapers," said Ms. Regenhard, whose son, a probationary firefighter, was killed in the attack.

The International Building Code Council moved last year to require that towers taller than about 40 stories have three hours' worth of fireproofing on structural elements, instead of two hours, but rejected proposals that would require wider stairwells and reinforced concrete or masonry walls in buildings over 25 stories.

The National Fire Protection Association, meanwhile, is expected to act in August to require stairwells that serve 2,000 or more people to be a foot wider than currently mandated, an official at the organization said.

CORRECTION: A front-page article on Wednesday about a federal study calling for major changes in skyscraper construction for safety in light of the destruction of the World Trade Center misstated the name of an organization of construction regulators. It is the International Code Council, not the International Building Code Council.

9/11 Firefighters Told of Isolation Amid Disaster

BY JIM DWYER AND MICHELLE O'DONNELL
The New York Times

SEPTEMBER 9, 2005

The firefighters had 29 minutes to get out of the World Trade Center or die. Inside the north tower, though, almost none of them realized how urgent it had become to leave.

They had no idea that less than 200 feet away, the south tower had already collapsed in a life-crushing, earth-shaking heap. Nor did the firefighters know that their commanders on the street, and police helicopter pilots in the sky, were warning that the north tower was on the edge of the same fate.

Until last month, the extent of their isolation from critical information in the final 29 minutes had officially been a secret. For three and a half years, Mayor Michael R. Bloomberg refused to release the Fire Department's oral histories of Sept. 11, 2001. Under court order, however, 12,000 pages were made public in August.

On close review, those accounts give a bleaker version of events than either Mayor Bloomberg or former Mayor Rudolph W. Giuliani presented to the 9/11 Commission. Both had said that many of the firefighters who perished in the north tower realized the terrible danger of the moment but chose to stay in the building to rescue civilians.

They made no mention of what one oral history after another starkly relates: that firefighters in the building said they were "clueless" and knew "absolutely nothing" about the reality of the gathering crisis.

In stairwells or resting on floors, they could not see what had happened or hear clearly stated warnings. Even after the south tower fell, when few civilians remained in the lower floors of the north tower, throngs of firefighters lingered in the lobby and near the 19th floor as time ran down, the survivors said.

"That's the hard thing about it, knowing that there were so many other people still left in that lobby that could have got out," Firefighter Hugh Mettham of Ladder Company 18 said.

Although no official summary specifies where the 343 firefighters died in the rescue effort, a review by *The New York Times* of eyewitness accounts, dispatch records and federal reports suggests that about 200 perished in the north tower or at its foot.

Of 58 firefighters who escaped the building and gave oral histories, only four said they knew the south tower had already fallen. Just three said they had heard radio warnings that the north tower was also in danger of collapse. And some who had heard orders to evacuate debated whether they were meant for civilians or firefighters.

'Not in My Wildest Dream'

"Not in my wildest dream did I think those towers were coming down," said David Sandvik of Ladder 110.

The point made by both Mr. Giuliani and Mr. Bloomberg to the 9/11 Commission—that firefighters died because they delayed their own departures while trying to save the lives of civilians and other firefighters—is, in one sense, fully corroborated by the oral histories.

Even so, measured against the waves of details in those accounts, those valiant last-minute efforts explain just a fraction of the firefighter deaths in the north tower, a small vivid thread running through the broader fabric of the day.

No one in the Fire Department has tried to use the oral histories to reconstruct the events that led to its human losses that day. Although more than 500 interviews were conducted, just about 10 percent of them involved people who had been inside the north tower. (No firefighters in the south tower, which fell first, are known to have survived its collapse.) Many who escaped from the north tower did not give histories. Few follow-up questions were asked of those who did.

The ragged character of the records does not yield a clear explanation for the isolation of the rescuers within the building, and whether it was because of radio failure, a loss of command and control or flaws in the Fire Department's management structure. Some firefighters described receiving a radio message to evacuate; others used strong language to characterize the communications gear as useless.

Despite their spottiness, the oral histories fill out incomplete chapters in the sprawling chronicle of what happened in New York that morning, much of which took place far beyond the sight of television cameras and their global audience.

Firefighters wondered aloud how they could have attacked a fire reached at the end of a four-hour climb. They marveled at the decency of office workers coming down the stairs, at the bellowing, dust-coated chief on the sidewalk who herded the firefighters clear of the collapse zone, at the voices of experience that brooked no hesitation.

The final moments of the department's senior leaders also rise from the histories as a struggle to rescue dozens of firefighters trapped in the Marriott Hotel after the south tower's collapse. As they worked, the north tower crashed down, killing, among others, Chief of Department Peter Ganci, First Deputy Commissioner William Feehan, and Battalion Chiefs Ray Downey and Lawrence Stack.

Precisely 29 minutes earlier, at 9:59 a.m., the fall of the south tower shook the north tower and stopped the slow, muscular tide of rescuers. By then, the north tower firefighters had been on the move for more than an hour. Each carrying about 100 pounds of gear, only a few had climbed much higher than the 30th floor. Some recalled hearing radio messages from individual firefighters who had made it as far as the 40's.

The calamity next door—the collapse of one of the biggest buildings in the world—was heard but not seen; felt but not understood. The staircases had no windows. Radio communication was erratic. Few firefighters even knew a second plane had struck the other building.

From the street, Chief Ganci twice ordered firefighters to evacuate the north tower, according to Chief Albert Turi, but it was not clear who inside, if anyone, heard him. Even Chief Turi, standing a few feet away, said it had not come over his radio.

Still, many decided to leave after hearing a rumor of a partial collapse some floors above them, or because they assumed another plane had hit.

On the 37th floor, Daniel Sterling, of Engine Company 24, had stopped with firefighters from Ladder 5 and Engine 33—who did not survive—when the building rattled. A moment later, Firefighter Sterling said, Chief John Paolillo appeared.

"He thought there was a partial collapse of the 65th floor of our building and that we should drop everything and leave," Firefighter Sterling said.

'Get Up and Go, Go, Go'

A few floors below, around the 30th or 31st floor, Chief Paolillo was spotted again. "He was yelling, 'Leave your equipment and just get up and go, go, go,' like that," Lt. Brian Becker of Engine 28 said. Chief Paolillo died.

The word to leave was passed to the 27th floor, where many firefighters were resting, including Michael Wernick of Ladder 9. "I know that there was no urgency at that point trying to get out of the building," he said.

"Do you think anyone around you was aware that the other building collapsed?" an interviewer asked.

"No," he replied.

One exception was Firefighter John Drumm with Engine 39, who said that on the 22nd floor, he heard a transmission: "Imminent collapse of the north tower. Immediate evacuation."

Then he made a point repeated in nearly every interview: "From what I saw on the way down, very, very few civilians were left."

Firefighter Sterling said, "There was nobody in the staircase on the way down."

Lieutenant Becker said, "There were no civilians to speak of in our stairway. There were a couple of stragglers being helped by somebody or other."

Probationary Firefighter Robert Byrne of Engine 24, working his first fire, reached the 37th floor. "I remember going up the stairs took us over the hour," he said. "Getting down the stairs took maybe 10 minutes, not even."

Also on 37, Capt. John Fischer of Ladder 20 discovered that two of his company had gone up ahead. "He was screaming at them for them to get back down," said Lt. Gregg Hansson of Engine 24, who was with Captain Fischer. "Then he went up to get them." Captain Fischer and his men died in the collapse.

Firefighter William Green of Engine 6 was one of the few who said he knew the other tower had fallen. On the 37th floor, "someone opened the door from the 36th floor and said Two World Trade Center just fell down," he said. Over the radio, he heard "Mayday, evacuate."

Slowed by firefighters entering the staircase below him, he switched sides. "In hindsight, I think that's what saved my life," he said.

He did not dawdle. "Around the fourth floor, I passed this civilian—he might have been 450 pounds," Firefighter Green said. "He was taking baby steps like this. I walked right past him like all the other firemen. I felt like a heel when I'm walking past him, and I'm thinking to myself, what does this guy think of me?"

Yet other chronicles show that a very heavy man in that location was eventually dragged to safety by rescuers who included Firefighter Pat Kelly of Rescue 18. Having helped move the man outside, Firefighter Kelly was the only member of his squad to survive. He did not give an oral history.

Elsewhere, crowds of firefighters lingered.

Lt. William Walsh of Ladder 1 said he heard a Mayday to evacuate when he was around the 19th floor, but did not know that a plane had struck the other building, much less that it had collapsed. As he descended, he saw firefighters who were not moving.

No Rush to Get Out

"They were hanging out in the stairwell and in the occupancy and they were resting," Lieutenant Walsh said. "I told them, 'Didn't you hear the Mayday? Get out.' They were saying, 'Yeah, we'll be right with you, Lou.' They just didn't give it a second thought. They just continued with their rest."

Three court officers reported seeing as many as 100 firefighters resting on the 19th floor minutes before the building fell, but they were not questioned by the Fire Department.

Mayor Bloomberg, in a letter to the 9/11 Commission, wrote: "We know for a fact that many firefighters continued their rescue work despite hearing Maydays and evacuation orders and knowing the south tower had fallen."

Asked to reconcile this statement with the oral histories, the city Law Department cited the accounts of eight firefighters and said that each of them surely had spread the word about the collapse of the other tower. In fact, in six of those oral histories, the firefighters specifically said they did not know the other building had fallen.

In the lobby, just yards from safety, survivors said that uncertainty doomed many firefighters.

John Moribito of Ladder 10 said there were maybe "40 or 50 members that were standing fast in the lobby." Roy Chelsen of Engine 28 said, "There were probably 20 or 30 guys down in the lobby mulling around." The interviewer asked, "They weren't trying to get out?"

"They were just—no, no," Firefighter Chelsen recalled.

His officer, Lieutenant Becker said, "There was chaos in the lobby. It was random people running around. There was no structure. There were no crowds. There was no—no operation of any kind going on, nothing. There was no evacuation."

Firefighters with Ladder 11 and Engine 4 came down together to the lobby, but not all made it out. "Everyone is standing there, waiting to hear what's going to happen next, what's going on," Frank Campagna of Ladder 11 said.

His company left, and a moment later, "it came down on top of us," Firefighter Campagna said. "Four Engine obviously didn't make it out. They were with us the whole time, so I'm assuming they were still in the lobby at that time."

The firefighters of Ladder 9 lingered briefly, and most were clear of the building for less than a minute when it fell. Firefighter Wernick remembered seeing two members of his company in the lobby, Jeffrey Walz and Gerard Baptiste. They did not escape. The funeral for Firefighter Baptiste, whose remains were identified this year, was held on Wednesday.

A Figure Coated in Dust

Over and over, firefighters who had left the building in those final minutes, bewildered by the sudden retreat, the ruined lobby, the near-empty street, mentioned a chief covered in the dust of the first collapse, standing just outside the north tower on West Street.

Some knew his name: Deputy Assistant Chief Albert Turi.

"He was screaming, 'Just keep moving. Don't stop,'" Firefighter Thomas Orlando of Engine 65 recalled, adding, "I still didn't know the south tower collapsed." Chief Turi, he said, "saved an awful lot of people." The chief has since retired.

In blunt speech, free of the mythic glaze that varnished much 9/11 discourse, some firefighters wondered why an endless line of rescuers had been sent to an unquenchable fire that raged 1,000 feet up.

"I think if this building had collapsed an hour later, we would have had a thousand firemen in there," said Firefighter Timothy Marmion of Engine 16, who carried a woman on a stretcher from the staircase to an ambulance.

"If it would have collapsed three hours later," he said, "we would have had 10,000 firemen in those buildings."

Had the buildings not fallen, the gear-laden firefighters would have needed about four hours—almost as long as it takes to fly across the country—to reach workers trapped on the high floors.

"We were just as much victims as everybody that was in the building," Firefighter Derek Brogan of Engine 5 said.

"We didn't have a chance to do anything," he added. "We didn't have a chance to put the fire out, which was really all we were trying to do."

Aron Pilhofer provided computer analysis for this article.

BUILDING SAFETY: Directing the Herd: Crowds and the Science of Evacuation

BY JOHN BOHANNON

Science, Vol. 310, Issue 5746, 219–221
OCTOBER 14, 2005

No skyscrapers are designed to be able to disgorge all their occupants in a dire emergency like the attack on the World Trade Center towers. Can they be made safer?

VIENNA, AUSTRIA—In the hour and 42 minutes that elapsed between the first airplane strike on the World Trade Center (WTC) on 11 September 2001 and the collapse of both towers, more than 2000 people failed to escape. Roughly 500 occupants are believed to have died immediately upon impact, and more than 1500 trapped in upper floors died in the aftermath. The toll might have been far worse, according to studies presented here at the International Conference on Pedestrian and Evacuation Dynamics on 28 to 30 September. Had the same attack come when the towers were at their full capacity of 20,000 people each, says Jason Averill, a fire safety engineer at the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland, the staircases would have quickly grid-locked, resulting in some 14,000 deaths.

No tall building is designed to be fully evacuated. Instead, regulations typically require that a few floors be emptied, assuming nothing worse than a localized fire. "This has to change," says Shyam Sunder, Deputy Director of NIST's Building and Fire Research Laboratory, "because in the lifetime of a building, there will be situations where you've got to get everyone out."

But getting everyone out of harm's way will require a deeper understanding of the collective behavior of crowds, says Jake Pauls, a veteran building safety consultant now based in Silver Spring, Maryland. Researchers are "just scratching the surface," says Averill, although they have made leaps and bounds over the past few years. Studies presented at the meeting offered a glimpse of how evacuations could be conducted more safely.

Modeling mobs

Until recently, there was little science in emergency planning, says Ed Galea, a fire safety engineer at the University of Greenwich, U.K. That is changing as scientists try to capture the behavior of crowds using computer simulations. A diverse effort is under way to refine these models with real-world data. For example, a team led by Jean Berrou, a computer scientist at the Maia Institute in Monaco, has been secretly filming pedestrians in 10 different cities around the world, analyzing nearly 1000 hours of video to measure different cultural patterns of walking. For example, he says, "pedestrians in London are faster than those in New York."

The goal is to find rules that individual pedestrians unconsciously follow to navigate crowded spaces. "What's amazing is that people don't collide with each other more often on a typical city sidewalk," says Jon Kerridge, a computer scientist at Napier University in Edinburgh, U.K. On a scale of microseconds, people negotiate priority with cues transmitted through body language. "If we can understand how that works," he says, we might learn why certain geometries of corridors and portals work better than others.

The next step is to understand how an emergency changes everything. Researchers use a parameter called drive to define the level of motivation people have to go from A to B. "This is where things get very difficult to model," says Kerridge, "because we're talking about innate, personal factors."

Strange things happen when fear is added to the mix. Take the paradox that the more urgently people want to leave a crowded room with a narrow exit, the longer it takes to get out. That occurs in part because of a breakdown in normal communications. Daniel Parisi and Claudio Dorso, computer scientists at the University of Buenos Aires, Argentina, have found that the optimum exit speed is a fast walk of about 1.38 meters per second.

Such studies reveal that "the fundamental unit of a crowd is not the individual but the cluster," says Kerridge. This is because "the first thing we do in an emergency situation is look to each other for support and information." But that response slows movement dramatically. On a larger scale, people form groups similar to animal herds in which individuals let the crowd do the navigating, often passing right by exits within clear view.

Learning to predict and control these behaviors may save lives—and not just in big buildings. The main killer when people mass is not trampling, as is commonly

thought, but "crowd crush." When two large groups merge or file into a dead end, the density makes it impossible to fall down, says Pauls. But the accumulated pushing creates forces that can bend steel barriers. "The situation is horrible," he says: "Suddenly everything goes quiet as peoples' lungs are compressed. No one realizes what's happening as people die silently." Dangers like these make designing architecture and procedures for evacuation like a tightrope walk, says Pauls: "You have to get people out fast, but safely."

Revisiting 9/11

Armed with these insights, two separate groups have been trying to model the WTC evacuation to see what lessons can be learned. In 2002, the U.S. Congress ordered NIST to investigate the WTC safety and emergency response, and the U.K. government commissioned a team led by Galea, which has paved the way for a larger study called HEED. "This was one of the largest full-scale evacuations of people in modern times," says Galea.

To build a minute-by-minute chronology of the event, the NIST team has conducted more than 1000 interviews with survivors by telephone, and Galea's team is set to do up to 2000 face-to-face interviews next year. One of the most surprising discoveries, says Galea, is the long lag time between the first attack and the start of evacuation. Galea's team found that although 77 percent of survivors began the egress within five minutes of the impact, it took another hour for the next 19 percent to get going, and four percent stayed in their offices for over an hour. "In some cases people were more worried about saving their computers," he says.

Both teams have incorporated these data into a model called EXODUS, designed by Galea. When the NIST team used the model to play out the WTC disaster with full occupancy, it estimated roughly 14,000 deaths, most among those stuck on the stairs. This didn't surprise Pauls.

"Those stairs were not designed to handle a full evacuation," he says. "In fact, no tall building is prepared for it." Sunder says NIST is pushing to include full evacuation for many tall buildings in the next review of U.S. building codes in 2008. "There is a lot of resistance" to requiring full evacuation capability even after the WTC attacks because people "believe that was a one-time-only event," he says. But he notes that a building's typical lifetime is a century; designers should be preparing for other "extreme events" like multi-floor fires, earthquakes, and hurricanes.

Until the existing tall buildings are replaced with a new generation, experts say, improvements will have to come through better emergency procedures and retrofitting. For one, elevators should be made usable during emergencies, says Sunder. WTC tower number 2 emptied far more efficiently than tower 1 because its elevators were available before it was hit by the second plane, the studies found. New elevator systems that include independent power supplies and computers that prevent them from opening on a burning floor will be available within a few years, says Averill. Galea suggests another possible innovation: adding sky bridges to create new escape routes linked to other buildings. His simulation of a WTC evacuation with the towers linked by a bridge was far more efficient.

Evacuation experts say they are continuing to look at all kinds of evacuation backups, even far-out ones. For example, a pole system that can be attached to the outside of buildings is being tested. By strapping into a vest attached to the pole, people could slide down safely using electromagnetic brakes. Another option: People could jump into fabric tubes and bounce their way down to the bottom—although this would likely cause friction burns. Even parachutes have been proposed as a last chance resource.

"But really, the best thing we can do to make these buildings safer," says Pauls, "is to focus on the basics." That means better stairs, elevators, and fire drills.